The Impact of Renegotiation and Reporting Systems on Real Option Value

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1. Introduction

The optimal structure of a firm's reporting system depends on context and circumstance (Demski, 1994). In this paper, we construct an Antle and Eppen (1985) style model of capital budgeting, wherein an agent (manager) in a firm has private information about project costs and subsequently seeks resources from the principal (owner). Like Antle, Bogetoft and Stark (1995), the investment opportunity is characterized by two mutually exclusive projects. With two mutually exclusive projects, the option value is defined as the benefit of having a second project available, where the benefit is the increase in expected profits compared to having only one project available. However, different from Antle, Bogetoft and Stark (1995), we assume the principal and agent can renegotiate the contract after the agent reports the cost of the first project. We further assume the principal can not commit to not renegotiate the original contract. Within this setting, we examine the interaction between the level of detail for an internal reporting system and the option value of the investment opportunity.

In our model, the principal's inability to commit affects option value in subtle ways. Our main results are as follows. If the internal reporting system allows the agent to freely report the cost, the principal's inability to commit not to renegotiate the contract nullifies the option value. However, if the principal installs a reporting system that limits the agent's reporting, some of the option value is restored. Communication is thus valuable to the principal, as long as the agent is not provided too much flexibility in his reporting. This result differs from Demski and Frimor (1999), who in a somewhat different context find that with renegotiation opportunities communication makes the principal and the agent (weakly) worse off.

The outline of the paper is as follows. Section 2 provides background. Section 3 describes the basic model. Section 4 provides preliminary results regarding the full information and full commitment settings. Section 5 discusses renegotiation and provides the main results. Section 6 concludes the paper.

2. Background Literature

This brief review presents the work most similar to ours. For an extensive review of the resource allocation literature, see Antle and Fellingham (1997).

Antle and Eppen (1985) present a single-agent, single-period capital budgeting model in which the agent consumes excess funds provided by the principal. The agent knows the cost of production prior to investing in the project. In the model, adverse selection or interim participation constraints prevent the principal from costlessly extracting the agent's private information. The principal sacrifices efficient production in order to reduce the agent's slack.

Antle and Fellingham (1990), Farlee, Fellingham and Young (1996), Fellingham and Young (1990) and Arya, Fellingham and Young (1994) consider the case where the agent sequentially learns the cost of projects but they are not mutually exclusive. They demonstrate that the incentive problem induces an interaction among the project approval decisions even though the projects are independent.

Antle, Bogetoft and Stark (1999) explore a model in which the agent communicates his private information about the cost of several projects. They demonstrate that when projects are mutually exclusive the principal optimally sets a project-specific target. His decision rule is to select the project whose reported cost is farthest below its target. Some positive net present value projects are rejected, as in Antle and Eppen (1985), and further, the one that is chosen does not necessarily have the highest net present value. When projects are not mutually exclusive, they provide conditions under which batch processing strictly dominates independent appraisal. The batch processing approach supports the idea of capital budgeting meetings where agents' reports are compared to decide which to accept. Arya, Glover and Young (1996) demonstrate that when there are multiple agents in correlated environments relative project ranking can be efficient.

Antle and Fellingham (1990) examine the welfare implications of public information that partition the agent's private cost information. They make the case that the effect of information system choice on capital budgeting decisions should be of first-order importance to accountants. Arya, Glover and Sivaramakrishnan (1997) consider the effect of commitment issues when there is a single project available. They demonstrate that when the principal cannot commit but there exists a possibility that the cost exceeds the revenue, the principal optimally coarsens the agent's reporting system. This coarsening of the information system is a costly substitute for commitment. Our result regarding limiting the agent's reporting in order to increase the option value of the investment opportunity in a renegotiation setting conveys a similar message.

3. Model

The model involves two risk neutral parties, a principal and an agent. The principal owns property rights to one of two mutually exclusive projects. The costs of Project *i* is denoted c_i, i = 1, 2. We assume the costs of Project 1 and 2 are independent and have identical common knowledge probability densities, $f(c_i) > 0, \quad c_i \quad C$. Thus, the joint density is $g(c_1, c_2) = f(c_1)\, f(c_2)$. We further assume the revenue from taking either project is one dollar and c_i $C = [0,1]$.[1] These assumptions simplify the notation and allow us to more clearly expose the important aspects of the interaction between the internal accounting system, the principal's limited commitment ability, and the option value of the projects.

We use an indicator variable, P_1 to represent investment in Project 1, where $P_1 = 0$ and $P_1 = 1$ represents rejection and acceptance, respectively. Similarly, P_2 indicates whether investment in Project 2 occurs. Since Projects 1 and 2 are mutually exclusive, we require $P_1 + P_2 \leq 1$.

Figure 1 describes the sequence of events. At Date 0, the principal contracts with the agent to implement investment. At Date 1, the agent alone learns and reports the cost of Project 1. At Date 2, the principal decides whether to invest in Project 1 and, if so, how much to fund. If he decides to invest in Project 1 ($P_1 = 1$), at Date 3 the principal provides funds equal to y_1, he consumes the returns from Project 1, and the game ends. If instead the principal decides to reject Project 1 ($P_1 = 0$), at Date 3 the agent alone learns and reports the cost of Project 2. At Date 4, the principle decides whether to invest in Project 2, and, if so, how much to fund. If he decides to invest in Project 2 ($P_2 = 1$), at Date 5 the principal provides funds equal to y_2, he consumes the returns from Project 2, and the game ends.

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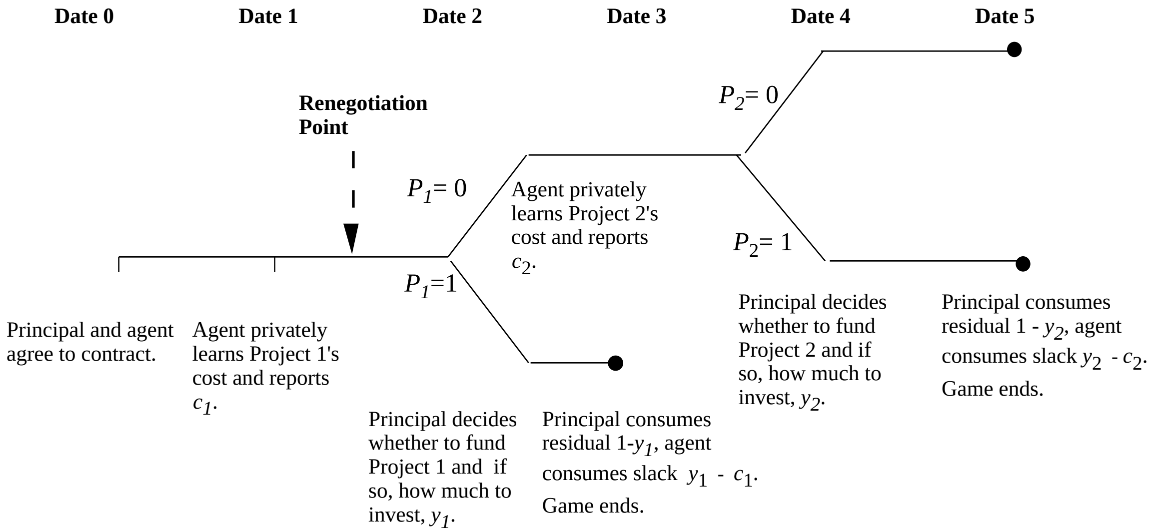
[1] We ignore discounting.

Figure 1
Sequence of Events



Given the sequence of events, the principal can use the agent's reports in several ways. First, he can use the agent's report of c_1 to condition his decision regarding whether to fund Project 1, denoted by $P_1(c_1)$. Second, if he funds Project 1, he can use the report of c_1 to condition his decision regarding how much to transfer to the agent, $y_1(c_1)$. If Project 1 is rejected, the principal can use the agent's reports of c_1 and c_2 to condition his decision of whether to invest in Project 2 or not, denoted by $P_2(c_1, c_2)$. The principal can also use the agent's reports of c_1 and c_2 to condition his decision regarding how much to transfer to the agent for Project 2, $y_2(c_1, c_2)$.

The agent consumes slack, which is the difference between the amount transferred by the principal and the project’s cost. Combined with the agent's ability to privately observe the cost, the agent has the opportunity and motivation to overstate the cost. Because the agent is risk neutral, he reports so as to maximize his expected terminal slack at each point in time.

Our model is similar to Antle et al. (1995) except we specify a renegotiation date immediately following the agent's report of the cost of Project 1, as reflected in Figure 1. We assume if the agent rejects the renegotiated contract, the initial contract remains in place; otherwise the renegotiated contract replaces the original contract. In addition, the principal acts so as to maximize his expected profits after receiving the report of the agent regarding the cost of Project 1. At the time of issuing the first cost report, the agent is aware that the principal cannot commit as to how he will use it.

4. Analysis of Benchmarks

As a first step in measuring the effect of reporting incentives on the option value, we compute the value of the option under two benchmark cases. Under the first benchmark, the principal has symmetric information about Project 1's cost when he decides whether to accept Project 1, and if he rejects Project 1 he subsequently observes Project 2's cost. Under the second benchmark, the principal is informationally disadvantaged regarding Project 1's cost but can commit to not renegotiate the original contract.

4.1 Option Value with Symmetric Information

The principal's problem with the option and with symmetric information about the cost of the projects is to maximize

$\int_{c_1}\int_{c_2}\{P_1(c_1) - y_1(c_1) + P_2(c_1,c_2) - y_2(c_1,c_2)\}\, f(c_2)dc_2\, f(c_1)dc_1$, subject to providing non-negative slack to the agent whenever investment occurs. The proof of Proposition 1 in Antle et al. (1995) can easily be applied to the simpler case. The principal should invest in Project 1 only for a lower interval of costs and otherwise should invest in Project 2. Formally, the complete solution is as follows.

$P_1(c_1) = 1,\ y_1(c_1) = c_1,$ $\quad c_1 \le \int_0^1 c_2 f(c_2)dc_2 = \bar{c}$

$P_1(c_1) = 0,\ y_1(c_1) = 0,\ P_2(c_2) = 1,\ y_2(c_2) = c_2$ $\quad c_1 > \bar{c}$ and all c_2,.

The principal's expected profit is as follows.

$$\int_0^{\bar{c}}(1-c_1)f(c_1)dc_1 + \int_{\bar{c}}^1\int_0^1(1-c_2)f(c_2)dc_2 f(c_1)dc_1$$

$$= \int_0^1(1-c_1)f(c_1)dc_1 + \int_{\bar{c}}^1(c_1-\bar{c})f(c_1)dc_1 \qquad (1)$$

The first term in equation *(1)* is expected profits if there were only one project available, so the second term is the option value, which is positive.

4.2 Option Value with Asymmetric Information – Full Commitment

If the principal could commit to not renegotiate given the agent's report concerning Project 1, the revelation principle would hold at Date 0 (Myerson 1979). Under that situation, any equilibrium allocation of utilities could be replicated by a direct revelation mechanism in which the agent reported his private information truthfully. The mechanism designed by the principal could thus make full revelation of c_1 and c_2 incentive compatible with no loss of generality. In particular, in our setting the principal would be able to costlessly commit to not renegotiate based on information disclosed at that stage.

In this full commitment case, the principal's problem is to choose when to invest in Project 1 or 2 so as to maximize his expected profits, subject to the following constraints. The *ex post* participation (or bankruptcy) constraints (*B*) ensure that the agent will not earn negative slack. The control problem is uninteresting if the *ex post* bankruptcy constraints do not bind; hence we guarantee the bankruptcy constraints bind by assuming the agent's *ex ante* reservation expected utility is zero.

There are two sets of incentive compatibility constraints that describe the agent's reporting behavior. First, (*IC-1*) guarantees the agent receives as much current and expected future slack from reporting the truth about c_1 as for lying. Second, (*IC-2*) guarantees the agent receives as much current slack from reporting the truth about c_2 as from lying. The principal's contracting program under full commitment, denoted (*FC*), is as follows.

Program *FC*:

$$\text{Max} \int_{c_1}\int_{c_2} \{P_1(c_1) - y_1(c_1) + P_2(c_1,c_2) - y_2(c_1,c_2)\} f(c_2)dc_2 f(c_1)dc_1$$

subject to*:*

$$y_1(c_1) - c_1 P_1(c_1) \geq 0 \quad c_1 \qquad (B\text{-}1)$$

$$y_2(c_1,c_2) - c_2 P_2(c_1,c_2) \geq 0 \quad c_2 \qquad (B\text{-}2)$$

$$y_1(c_1) - c_1 P_1(c_1) + \int_{c_2} [y_2(c_1,c_2) - c_2 P_2(c_1,c_2)] f(c_2)dc_2 \qquad (IC\text{-}1)$$

$$\geq y_1(c_1') - c_1 P_1(c_1') + \int_{c_2} [y_2(c_1',c_2) - c_2 P_2(c_1',c_2)] f(c_2)dc_2 \quad c_1, c_1',$$

$$y_2(c_1,c_2) - c_2 P_2(c_1,c_2) \geq y_2(c_1,c_2') - c_2 P_2(c_1,c_2') \quad c_1, c_2, c_2' \qquad (IC\text{-}2)$$

$$P_1(c_1), P_2(c_1,c_2) \quad \{0,1\} \quad c_1, c_2$$

$$P_1(c_1) + P_2(c_1,c_2) \leq 1 \quad c_1, c_2$$

If the agent privately observes c_1, the symmetric information solution violates the agent's incentive compatibility constraints. Because under that solution the principal promises to pay $y_1(c_1) = c_1$, the agent would be strictly better off claiming the cost is $\bar{c}$ for all $c_1 < \bar{c}$.

The following lemmas, due to Antle et al. (1995), characterize the solution to *(FC)* where k_2^F denotes target cost for Project 2 under full commitment.

Lemma 1: Incentive compatibility implies production occurs on Project 2 if and only if $c_2 \leq k_2^F \leq 1$.

Lemma 2: Incentive compatibility implies production occurs on Project 1 if and only if $c_1 \leq k_1^F \leq 1$.

Lemma 3: k_2^F is independent of c_1.

These lemmas imply the optimal contract can be represented parsimoniously by two parameters, a target cost k_1^F for the first project and a target cost k_2^F for the second project where, further, k_2^F is independent of c_1. The principal must pay a "bribe" to get the agent to report the first project's cost truthfully, because the agent can overstate the cost and take his chances on the expected slack forthcoming from the second project. This "bribe" is equal to: $\int_0^{k_2^F} (k_2^F - c_2) f(c_2) dc_2$.

Optimality implies that for all $c_1 \leq k_1^F$, the principal pays $y_1 = k_1^F + \int_0^{k_2^F} (k_2^F - c_2) f(c_2) dc_2$ and $y_2 = k_2^F$. Substituting for y_1 and y_2, the principal's expected profit is as follows.

$$\int_0^{k_1^F} [1 - k_1^F - \int_0^{k_2^F} (k_2^F - c_2) f(c_2) dc_2] f(c_1) dc_1 + \int_{k_1^F}^1 \int_0^{k_2^F} (1 - k_2^F) f(c_2) dc_2 f(c_1) dc_1$$

$$= F(k_1^F)(1 - k_1^F) - F(k_1^F) \int_0^{k_2^F} (k_2^F - c_2) f(c_2) dc_2 + [1 - F(k_1^F)] F(k_2^F)(1 - k_2^F) \quad (2)$$

The first order conditions are as follows.

$$1 - k_1^F - \frac{F(k_1^F)}{f(k_1^F)} - \int_0^{k_2^F} (1 - c_2) f(c_2) dc_2 = 0 \quad (3)$$

$$1 - k_2^F - \frac{F(k_2^F)}{f(k_2^F)} \frac{1}{[1 - F(k_1^F)]} = 0 \quad (4)$$

Both target costs differ from the optimal one-project target cost. Farlee et al. (1995)

demonstrate that with one project (and, hence, no option value) the principal optimally chooses a target cost k^* that satisfies the first order condition in equation *(5)*.

$$1 - k^* - \frac{F(k^*)}{f(k^*)} = 0 \qquad (5)$$

The Observation below states that the option value is positive despite the bribe that must be paid to induce incentive compatibility on the first project's cost.

Observation: Under full commitment, the option value is positive, and the optimal target costs satisfy:

(a) $k_1^F < k^*$

(b) $k_2^F < k^*$.

Proof: The objective function value without the option can be produced by substituting $k_1^F = 0$ and $k_2^F = k^*$ into equation *(2)*. Further substituting these values into *(3)*, the derivative with respect to k_1^F is strictly positive, implying at the margin the objective function can be increased by increasing k_1^F. The remainder of the Observation follows from the first-order equations *(3)* and *(4)*, because $\int_0^{k_1^F}(1-c_2)f(c_2)d(c_2) > 0$ and $\frac{1}{[1-F(k_1^F)]} > 1$. ■

We introduce a numerical example for concreteness. Assume $f(c_i) = 1$, $0 \le c_1 \le 1$. Denote the principal's and agent's expected utility at Date 0 by EU_P and EU_A, respectively. We present the solutions to four scenarios (see Table 1).

The solution under symmetric information with the option is for the principal to accept Project 1 if c_1 is less than or equal to 0.5 and pay c_1. If c_1 exceeds 0.5, he would accept Project 2 and pay c_2 and so EU_P =.625. The solution under symmetric information without the option is to always produce and pay the cost, and so EU_P =.50. The option value is thus 0.125 under symmetric information.

The solution under asymmetric information with the option is for the principal to set k_1^F = .341 and k_2^F = .397, so EU_P =.356 and EU_A =.137. Note, the bribe is equal to 0.079. Without the option, the optimal contract would set k = .5, so EU_P =.250, and EU_A =.125. Comparing EU_P and EU_A in the two settings, we see the option of waiting to produce is valuable to both the principal and the agent under asymmetric information.

It also is useful to compare the symmetric information case with option to the asymmetric information case with option. Suppose the principal set k_1 = 0.5, so he would accept Project 1 with the same probability as with symmetric information. Given this value of k_1, the principal optimally would set k_2 = 1/3 in order to maximize his ex ante expected profit (see equation (4)). However, the resulting ex ante probability distribution of production is far from optimal in the presence of the incentive problem. It is optimal for the principal to move production from the first to the second project by reducing k_1 below 0.5 and increasing k_2 above 1/3. The principal finds shifting production from Project 1 to Project 2 efficient until k_1 = 0.341 and k_2 = 0.397.[2]

[2] We note that without the option the uniform distribution case can be thought of as finding the maximium area rectangle for a fixed perimeter (Antle and Fellingham, 1995; p. 46). The result is the principal's profit when producing (1-k) is equal to the probability the project gets accepted (k), which implies k = 0.5. The same interpretation applies in the option setting. Regarding Project 1, the principal's profit when producing ($1-k_1-k^2_2/2$) minus the principal's opportunity cost of not taking Project 2 ($k_2[1-k_2]$) is equal to the probability Project 1 gets accepted (k_1). Similarly, the principal's probability of getting to Project 2 times the profit from Project 2 ($[1-k_1][1-k_2]$) is equal to the probability Project 2 gets accepted (k_2).

Table 1 - Numerical Example - No Renegotiation Point

	Symmetric Information With Option	Symmetric Information No Option	Asymmetric Information With Option	Asymmetric Information No Option
y_1	c_1	c_1	0.420	0.500
y_2	c_2	not applicable	0.397	not applicable
EUP	0.625	0.500	0.356	0.250
EUA	0.000	0.000	0.137	0.125

5. Optimal Contracts with Renegotiation Encounter

In this section, we analyze the case where the principal cannot commit to not renegotiate the initial contract. There is only one renegotiation point, whereupon we assume the principal can make a take-it-or-leave-it offer. After the contract is renegotiated, we assume the principal can fully commit as to his use of any information subsequently communicated by the agent, i.e., c_2.

We focus without loss of generality on renegotiation-proof contracts, where the initial contract survives renegotiation (Demski and Frimor, 1999). We can take this approach because the principal and agent are fully aware of all possible future contingencies (Hart and Moore, 1988, p. 776).

The contract that survives renegotiation must ensure that, given the report, the principal maximizes his conditional expected utility. We must include interim individual rationality constraints (*IIR*), to ensure that given the report r_1, there exists no other mechanism, (y_1, P_1), that increases the agent's expected utility above what he would obtain if the contract stayed in place. This constraint makes the original contract renegotiation-proof.

The optimal funding and investment decisions under Project 2 is identical to the one-period contracting solution with commitment, where for $c_2 \le k_2^D(r_1)$, the principal invests in Project 2 and transfers $y_2(c_2) = k_2^D(r_1)$; otherwise no investment occurs and $y_2(c_2) = 0$. Given the principal's preferences and independence of c_1 and c_2, k_2^D is independent of r_1 and hence $k_2^D = k^*$, the solution to equation (5).

A renegotiation-proof contract must be one that satisfies (*RNP*) for all r_1, which appears below.

Program *RNP*:

$$\underset{P_1, y_1}{\text{Max}} \; P_1(r_1) - y_1(r_1) + [1 - P_1(r_1)] \int_0^{k^*} (1 - k^*) f(c_2) dc_2$$

subject to:

$$y_1(r_1) - c_1 P_1(r_1) \ge 0 \qquad r_1 \qquad (B)$$

$$y_1(r_1) - c_1 P_1(r_1) + [1 - P_1(r_1)] \int_0^{k^*} (k^* - c_2) f(c_2) dc_2 \qquad (IIR)$$

$$\ge \tilde{y}_1(r_1) - c_1 \tilde{P}_1(r_1) + [1 - \tilde{P}_1(r_1)] \int_0^{k^*} (k^* - c_2) f(c_2) dc_2 \qquad r_1, y, \tilde{y}, P_1, \tilde{P}_1$$

$$P_1(r_1) \quad \{0,1\} \quad r_1$$

We begin the analysis with Proposition 1, which implies that the renegotiation encounter is non-trivial.

Proposition 1: The full commitment solution is not renegotiation-proof.

Proof: The full commitment solution is not renegotiation-proof for two reasons. First, from the Observation, k_2^F is less than the optimal one-period target. The agent as well as the principal would be better off *ex post* with the larger optimal one period target k_2^F. Second, the full commitment solution for k_1^F is also not renegotiation-proof. For some $c_1 \ge k_1^F + \varepsilon$, $\varepsilon > 0$, the principal and agent could mutually benefit by renegotiating the contract. To see this, suppose for ε, close to zero the principal pays the agent $y_1(c_1) = c_1 + \int_0^{k_2^F}(k_2^F - c_2) f(c_2)dc_2 + \delta$, where δ is positive and sufficiently small; the integral is the agent's expected slack under Project 2 if Project 1 is rejected. If he were to honor the full commitment contract, the principal would reject Project 1 and receive expected profits under Project 2 equal to $\int_0^{k_2^F}(1 - k_2^F) f(c_2)dc_2$. Under the proposed renegotiated contract, the principal obtains expected profits as follows.

$$1 - y_1(k_1^F + \varepsilon) = 1 - k_1^F - \varepsilon - \int_0^{k_2^F}(k_2^F - c_2) f(c_2)dc_2 - \delta \qquad (6)$$

$$= \frac{F(k_1^F)}{f(k_1^F)} + \int_0^{k_2^F}(1 - k_2^F) f(c_2)dc_2 - \delta - \varepsilon \qquad (7)$$

We want to show (7) is greater than $\int_0^{k_2^F}(1 - k_2^F) f(c_2)dc_2$, or equivalently,

$\frac{F(k_1^F)}{f(k_1^F)} - \delta - \varepsilon > 0$. This inequality holds for sufficiently small values of ε and δ. ■

To illustrate Proposition 1, reconsider the previous example, where under full commitment k_1^F = .3408, k_2^F = .3973. If c_1 is slightly larger than k_1^F, say c_1 = .4, under the full commitment contract the principal should reject Project 1, receiving expected profits of .3973 (1-.3973) =.2395. The agent's expected slack would be $\int_0^{3973}(.3973 - c_2)dc_2$ = .0789. However, the principal could make a counteroffer of y_1 = .50 and invest in Project 1, so as to receive profits of (1-.50) = .50 > .2395. The agent also would prefer this contract to the original, as it would give him current slack of .10 > .0789.

5.1 Detailed Reporting

In this section, we analyze a *detailed* reporting system wherein the agent's report is unrestricted, that is $r(c_1)$ C. It is useful to introduce notation for the principal's expected profits and agent's expected slack from Project 2, Π_2 and S_2, respectively.

$$\Pi_2 = \int_0^{k*} (1 - k*) f(c_2) dc_2$$

$$S_2 = \int_0^{k*} (k* - c_2) f(c_2) dc_2 .$$

We now solve for the Project 1 reporting and funding decisions. They must be self-enforcing at Date 2, given the Project 2 funding decision. A similar argument to that made in the full commitment case implies Project 1 is funded for all reports consistent with $c_1 \leq k_1^D$.

Lemma 4: Incentive compatibility for the agent implies production occurs on Project 1 if and only if $c_1 \leq k_1^D \leq 1$.

Proof: Assume there exists an interval where for c_1 Project 1 is accepted and for c_1' Project 1 is declined, i.e., $P_1(r(c_1)) = 1$ and $P_1(r(c_1')) = 0$. Then, within the region where Project 1 is accepted, *(IC)* implies: $y_1(r_1) - c_1 \geq y_1(\hat{r}_1) - c_1$. So if the principal offers a contract in which $y_1(r_1) > y_1(\hat{r}_1)$, the agent will in equilibrium claim r_1, and the principal will pay $\hat{y} \equiv y_1(r_1)$ Within the region where Project 1 is rejected, the same argument implies, in equilibrium, the principal pays a constant, $\hat{\hat{y}}$. We next consider across regions incentive compatibility: $\hat{y} - c_1 \geq \hat{\hat{y}} + S_2$ and $\hat{\hat{y}} + S_2 \geq \hat{y} - c_1'$. Therefore, $c_1' > c_1$. ■

Given the agent's reporting strategy, the principal picks a target cost such that the principal invests in Project 1 when $r_1 \leq k_1^D$, otherwise the principal rejects Project 1. The agent will report k_1^D for all $c_1 \leq k_1^D$. Proposition 2 provides a complete characterization of the solution to the principal's problem with renegotiation and detailed reporting.

Proposition 2: An optimal contract with *detailed* reporting has the following properties.

$y_1(r(c_1))$	$= 1 - \Pi_2,$	$c_1 \le k_1^D,$	where $k_1^D = 1 - \Pi_2 - S_2$
	$= 0\ ,$	$c_1 > k_1^D$	
$r(c_1)$	$= 1 - \Pi_2 - S_2,$	$c_1 \le k_1^D$	
	$= 1 - \Pi_2 - S_2 + \varepsilon,$	$c_1 > k_1^D,$	$\varepsilon > 0$
$y_2(c_2)$	$= k_2^D,$	$c_2 \le k^*,$	
	$= 0$	$c_2 > k^*$	

Proof: Suppose there exists an r such that $P_1(r)$=1. Then *(IC)* states the agent will choose r_1 to maximize $y_1(r_1)$-c_1 for all $c_1 \le k_1^D$ (by Lemma 4). Thus, in this region the agent in equilibrium receives y^*. Then *(IC)* further implies y^*-$c_1 \ge S_2$ for $c_1 \le k_1^D$, which in turn implies $y^* \ge k_1^D + S_2$. Further, suppose there exists an r' such that $P_1(r')$=0. Then *(IC)* also implies $y^* - c_1 \le S_2$ for $c_1 > k_1^D$, which in turn implies $y^* \le k_1^D + S_2$. Thus $y^* = k_1^D + S_2$. Substituting y^* into the objective function provides 1- $k_1^D - S_2$ if $P_1(r_1) = 1$ or Π_2 if $P_1(r_1) = 0$. Because the objective function is linear in $P_1(r_1)$, for there to exist a non-trivial region in which Project 1 is accepted we must have $1 - k_1^D - S_2 = \Pi_2$, or

$k_1^D = 1 - \Pi_2 - S_2$. ■

The aspect of the full commitment solution that renders it infeasible with the possibility of renegotiation is that it calls for the principal to turn down Project 1 whenever the agent reports the cost is larger than the Project 1 target cost. During the renegotiation encounter, if the cost is not much larger than k_1^F, the agent could benefit from the fact that *ex post* the principal wishes to invest in Project 1.[3] In order to make the original contract renegotiation-proof, the principal initially sets $y_1 = 1 - \Pi_2$. This in turn

[3] We note that continuity is not necessary for this phenomenon.

requires that k_1^D be sufficiently larger than k_1^F. The reason is with detailed reporting the agent has the ability and can benefit from indicating when the cost is between k_1^F and $1 - \Pi_2 - S_2$. With detailed reporting, the principal's lack of commitment completely destroys the option value of waiting for the second project.

5.2 Coarse Reporting

The nature of the detailed reporting equilibrium suggests that there is a potential benefit from imposing a mechanism in which the agent's reporting is stifled. We analyze a *coarse* reporting system wherein the agent is restricted to reporting $r(c_1) \in \{L, H\}$. The use of only two signals prevents the agent from distinguishing costs within the interval $[k_1^F, 1 - \Pi_2 - S_2]$ from those in the interval $[1 - \Pi_2 - S_2, 1]$.

We naturally assume the reporting system does not change, regardless of whether Project 1 or 2 is undertaken. We show that coarse reporting leads to an equilibrium in which $r(c_1) = L$ is rationally interpreted by the principal to mean $c_1 \leq k_1^C$ and $r(c_1) = H$ to mean $c_1 > k_1^C$, where k_1^C is the course reporting target.

The following Proposition summarizes the optimal solution with coarse reporting.

Proposition 3: An optimal contract with *coarse reporting* has the following properties.

$$
\begin{aligned}
y_1(r(c_1)) &= 1 - \Pi_2 - \frac{F(k_1^C)}{f(k_1^C)}, && c_1 \leq k_1^C && \text{where } k_1^C = 1 - \Pi_2 - S_2 - \frac{F(k_1^C)}{f(k_1^C)} \\
&= 0, && c_1 > k_1^C \\
r(c_1) &= L, && c_1 \leq k_1^C \\
&= H, && c_1 > k_1^C \\
y_2(c_2) &= k_2, && c_2 \leq k^* \\
&= 0 && c_2 > k^*
\end{aligned}
$$

Proof: We first demonstrate the agent rationally will report H if and only if $c_1 > k_1^C$. If c_1

≤ k_1^C, the agent obtains $k_1^C + S_2$ - c_1 if he reports *L* and S_2 if he reports *H*, so he reports *L*. If $c_1 > k_1^C$, $k_1^C + S_2$ - c_1 is less than or equal to S_2, so he reports *H*.

The principal's expected profits *(10)* and first order conditions *(11)* are as follows.

$$\int_0^{k_1^C} (1 - k_1^C - S_2) f(c_1) dc_1 + \int_{k_1^C}^1 \Pi_2 f(c_1) dc_1 \tag{10}$$

$$1 - k_1^C - S_2 - \Pi_2 - \frac{F(k_1^C)}{f(k_1^C)} = 0 \tag{11}$$

When this reporting behavior is anticipated by the principal, he does not wish to renegotiate the contract. If the agent reports *L*, the principal promises to invest in Project 1 and pay $k_1^C + S_2$. The principal receives 1 - ($k_1^C + S_2$), which is equal to $\Pi_2 + \frac{F(k_1^C)}{f(k_1^C)} > \Pi_2$, so the principal will go through with the contract. If the agent reports *H*, the principal knows only $c_1 \geq k_1^C$. Because the cost can be as large as 1, the bankruptcy constraints require that the principal pay $y_1 = 1$, and so his best response clearly is to invest in Project 2 and receive $\Pi_2 > 0$. ■

Further interpreting Proposition 3, the target cost with coarse reporting is less than the target cost with detailed reporting, so coarse reporting restores some of the option value. Coarse reporting does not allow the agent to distinguish between the intervals of medium and high costs. For this reason, with coarse reporting it is crucial that the agent and principal not have further exchanges of communication subsequent to the agent's report of *H*. Expected profits are higher and expected slack is lower with coarse reporting than with detailed reporting. Thus, there is disagreement between the principal and the agent about the reporting system.

The solution under coarse reporting is different from the full commitment solution because with renegotiation, the Project 2 target cost cannot interact with the Project 1 cutoff as it does in the full commitment case. If Project 2 target cost were set equal to the full commitment target cost, or $k_2^C = k_2^F$, then $k_1^C = k_1^F$ and coarse reporting would be a perfect substitute for commitment.

Table 2 below summarizes and compares the full commitment, detailed reporting, and coarse reporting solutions for the numerical example, where $f(c_i) = 1$, $i = 1,2$.

Table 2- Numerical Example

	Asymmetric Information Full Commitment	**Asymmetric Information Detailed Reporting**	**Asymmetric Information Coarse Reporting**
y_1	0.420	3/4	7/16
y_2	0.397	0.5	0.5
EUP	0.356	0.250	0.348
EUA	0.137	0.320	0.174

6. Conclusions

We construct a simple model of capital budgeting, where the investment opportunity consists of two mutually exclusive projects. The option value of the investment opportunity is destroyed if the accounting system grants complete flexibility to the agent when he reports on the cost of Project 1. However, if the agent's report is constrained to be binary, some of the option value is restored. In future work we expect to show that only two signals are optimal and that adding a third signal would result in the detailed reporting solution. Thus, some communication is valuable to the principal if restricted. Our results suggest that the accounting system can interact with the firm's capital budgeting decisions so as to make restricted reporting optimal.

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