

Setbacks Big and Small*

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Abstract

We study the optimal incentive contract for a time-to-build project subject to both major and minor setbacks. Setbacks are flaws in the project, discovered (not caused) by the agent, and the size is privately observed by him. The agent can exploit this informational advantage to hide being behind schedule, generating persistent private information. We show that the optimal contract is governed by a family of “no-postponed-setback” constraints that imply a weakly higher likelihood of termination following larger reported setbacks. These constraints provide a straightforward organizing principle for the optimal contract and clarify how continuation utility is rationed across histories. Our analysis complements the all-or-nothing environment we studied in *Setbacks, Shutdowns, and Overruns* (Econometrica, 2024) and offers tractable tools for settings in which effort incentives interact with persistent private information.

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1 Introduction

In previous work [Feng, Taylor, Westerfield, and Zhang \(2024\)](#) (FTWZ), we study a dynamic moral-hazard problem in which a principal hires an agent to work on a project that is subject to random setbacks. The key innovation is that setbacks are discoveries that occur in the process of work, as opposed to being a result of indolence, and the agent requires incentives to both work and report bad news. In that baseline model, setbacks are *total*: whenever one occurs, the state of progress is knocked all the way back to zero. This assumption is convenient because it keeps the agent’s private information low-dimensional and allows us to characterize the optimal contract in continuous time. Essentially, the agent’s persistent private information is reset after each reported setback. At the same time, this assumption is clearly extreme. In many applications—drug development, software projects, engineering design—setbacks are often *partial*: a bug or flaw may require rework, but it typically does not erase all accumulated progress. In this note, we generalize the notion of bad news to total and partial setbacks, giving the agent more scope for misreporting and bad acts.

We show, in a transparent discrete-time setting, how partial setbacks can be handled in a tractable way and how doing so changes (or, as it turns out, largely does *not* change) the structure of the optimal contract. We consider the simplest environment that generates genuinely new issues: a project that requires two units of progress to complete and that is subject to both major and minor setbacks when the agent works at the intermediate stage. A major setback wipes out all progress; a minor setback leaves the project at the intermediate stage. Relative to our earlier work with only total setbacks, this simple modification creates additional persistent private information: the principal’s belief about the state can be wrong in two distinct ways (the agent can be either “behind” or “ahead” of schedule), and partial setbacks make it easier for the agent to hide being behind.

To keep the problem tractable, we restrict attention to Markovian contracts in which the agent’s continuation utility depends only on the true state of progress and the principal’s belief about progress. There are three stages: no progress (stage 0), partial progress (stage 1), and completion (stage 2). Within this class, which involves consideration of eight incentive constraints, we solve for the optimal contract, characterize the retention probabilities after reported setbacks and the prize for completion, and show that the key constraints that bind take a particularly intuitive form.

The main findings are summarized as follows.

- (i) Under an optimal contract, the principal commits to random termination after reported setbacks and a prize upon successful completion.
- (ii) Partial setbacks change the *space of deviations* but not the central logic of the contract. The new incentive problems—in particular, the temptation to postpone reporting a major setback at stage 1 or to hide being behind schedule at stage 0—are handled by two natural no-postponed-setback conditions at the two stages.
- (iii) In an optimal contract, the retention probability is decreasing in the severity of the reported problem: the agent is retained with highest probability after a stage-0 setback, with an intermediate probability after a minor stage-1 setback, and with the lowest probability after a major stage-1 setback. This gives a simple, testable comparative statics prediction about how principals should respond to good and bad news in milestone-based projects.
- (iv) The optimal initial promised utility must be at least what the agent could obtain by shirking and delivering nothing. When the completed project payoff is modest, the principal chooses the “toughest” contract with this minimum level of initial utility and the strictest incentive compatible retention probabilities after reports of setbacks. When the project payoff is large, the principal optimally softens the contract by increasing retention probabilities and promising the agent more utility, but the qualitative structure of incentives remains unchanged.

Taken together, these results suggest that the core economics of optimal contracts in the context studied in FTWZ are robust to the presence of partial breakdowns. Even though partial setbacks generate more persistent private information, the optimal contract can still be expressed in terms of a pair of simple no-postponed-setback constraints that discipline the agent’s reporting behavior. The discrete analysis offered here, therefore, both justifies and complements the continuous-time formulation in our earlier work.

Additionally, this note contributes to a growing literature on optimal deadlines in dynamic agency. [Green and Taylor \(2016\)](#) study a multistage innovative project that advances through Poisson breakthroughs, where the agent privately observes the first breakthrough and can divert resources for private benefit. Their optimal contract

features a soft deadline, but in a “mirror-image” environment: progress is irreversible and the agent ultimately faces smooth stochastic termination at a constant rate for *not* reporting good news. By contrast, in our setting the project is a designed production process subject to setbacks of different sizes rather than innovative discoveries, and the agent faces discrete randomization between extension and shutdown for *reporting* bad news, with a termination probability that rises with the maturity of the project and the severity of the reported problem. Related deadline-based contracts with a single privately observed transition appear in Madsen (2022), who studies an expert advisor managing a project of uncertain scope; in Mayer (2022), who analyzes a project that survives only if it avoids a privately observed failure shock; and in Curello and Sinander (2025), who examine optimal screening for technological breakthroughs. Relative to these contributions, our note focuses on projects that may experience many (possibly partial) setbacks without ever rendering completion infeasible, and shows how the interaction between incremental progress and repeated setbacks shapes the optimal use of soft deadlines and late-stage randomization.

2 Model

A principal (she) contracts with an agent (he) to manage a project. Both parties are risk neutral with no discounting, but the agent has limited liability.

The project requires total progress $\bar{X} = 2$ to be completed, upon which the principal receives R . The project starts at $X_0 = 0$. If the agent shirks, progress stays constant with $X_{t+1} = X_t$, and the agent receives a private benefit b . Setbacks are *discovered* while working. If the agent works in state $X_t = 0$, then a setback occurs with probability λ that results in $X_{t+1} = 0$. With the complementary probability $1 - \lambda$, progress advances and $X_{t+1} = 1$. At $X_t = 1$, work can generate discovery of a major or minor setback:

- (i) With probability $\lambda\alpha$, a *major* setback occurs and $X_{t+1} = 0$
- (ii) With probability $\lambda(1 - \alpha)$, a *minor* setback occurs and $X_{t+1} = 1$
- (iii) With the remaining probability, $(1 - \lambda)$, progress advances, completing the project.

Purely for ease of exposition, project completion is assumed to be publicly observable. In Proposition 2 we show that this assumption is without loss because the

agent has no incentive to hide project completion under the optimal contract. We restrict attention to Markovian contracts in which the agent's continuation utility is a function of progress X_t and the principal's belief $\hat{X}_t$ about progress. The reason is that the existence of partial setbacks, even in this simple setting, generates more persistent private information than allowing for only total setbacks. By concentrating on Markovian mechanisms, it is possible to account for the additional persistent private information by keeping track of the agent's continuation utility when the principal's beliefs are incorrect, which can happen in only two ways in this setting, as discussed below.

Accordingly, let $\hat{X}_t \in \{0, 1\}$ denote the principal's belief about the state. Let p_0 be the probability of retaining the agent (i.e., not firing him) after a reported setback when $\hat{X}_t = 0$. Let $\bar{p}_1$ and $\underline{p}_1$ be the respective probabilities of retaining the agent after a reported major and minor setback when $\hat{X}_t = 1$. Let K be the reward to the agent upon project completion. We write $W_{X,\hat{X}} \in \{W_{0,0}, W_{0,1}, W_{1,0}, W_{1,1}\}$ for the agent's continuation utility when the true state of the project is X but the principal believes it is $\hat{X}$; e.g., $W_{0,1}$ is the agent's expected utility from acting optimally when he has no progress in hand, but the principal believes that he does.

3 The Agent's Problem

3.1 Promise Keeping

On the path with effort and truth-telling, the agent's continuation utility evolves as follows:

$$W_{0,0} = (1 - \lambda)W_{1,1} + \lambda p_0 W_{0,0} \tag{1}$$

and

$$W_{1,1} = (1 - \lambda)K + \lambda \alpha \bar{p}_1 W_{0,0} + \lambda (1 - \alpha) \underline{p}_1 W_{1,1} \tag{2}$$

Solving these gives

$$W_{0,0} = \frac{(1 - \lambda)^2 K}{D(p_0, \underline{p}_1, \bar{p}_1)} \tag{3}$$

and

$$W_{1,1} = \frac{(1 - \lambda p_0)(1 - \lambda)K}{D(p_0, \underline{p}_1, \bar{p}_1)}, \quad (4)$$

where

$$D(p_0, \underline{p}_1, \bar{p}_1) \equiv (1 - \lambda p_0)(1 - \lambda(1 - \alpha)\underline{p}_1) - (1 - \lambda)\lambda\alpha\bar{p}_1. \quad (5)$$

3.2 Off-Path Payoffs

An important consideration is the agent's optimal course of action when the principal's belief about the state is wrong. First suppose the agent is behind schedule so that the state is $(0, 1)$. Here the agent chooses between shirking and working and on what to report contingent on the realized outcome:

$$W_{0,1} = \max \left\{ b + \max\{\underline{p}_1 W_{0,1}, \bar{p}_1 W_{0,0}\}, (1 - \lambda) \max\{\underline{p}_1 W_{1,1}, \bar{p}_1 W_{1,0}\} + \lambda \max\{\underline{p}_1 W_{0,1}, \bar{p}_1 W_{0,0}\} \right\}. \quad (6)$$

The first term in the outer braces corresponds to shirking, yielding the agent private benefit b . After shirking he must decide whether to report a minor setback with retention probability $\underline{p}_1$ and the same state $(0,1)$ conditional on being retained or a major setback with retention probability $\bar{p}_1$ and state $(0,0)$ conditional on being retained. The second term in the outer braces corresponds to working. With probability $1 - \lambda$ the project progresses to intermediate state $X = 1$, but since the principal already believed $\hat{X} = 1$, the agent must make an excuse for why completion did not obtain; i.e., report either a minor setback (putting him on schedule at $(1, 1)$ if retained) or a major setback (putting him ahead of schedule at $(1, 0)$ if retained). With probability λ working results in a setback so that $X = 0$, and the agent is in the same reporting situation as if he had shirked in state $(0, 1)$.

Next, consider the state $(1, 0)$ in which the agent is ahead of schedule. Here he cannot work, since project completion will reveal that he falsely reported a setback at some point in the past. Hence the agent shirks and then decides between reporting progress (putting him on schedule at $(1, 1)$) or reports a setback with retention

probability p_0 and the same state $(1, 0)$ conditional on being retained.

$$W_{1,0} = b + \max\{W_{1,1}, p_0 W_{1,0}\}. \quad (7)$$

3.3 Incentive Compatibility

We have the following eight incentive constraints:

1. From $X_t = 0$, shirking and reporting a false setback must not benefit the agent

$$W_{0,0} \geq b + p_0 W_{0,0} \quad (\text{IC1})$$

2. From $X_t = 0$, shirking and reporting false progress must not benefit the agent

$$W_{0,0} \geq b + W_{0,1} \quad (\text{IC2})$$

3. From $X_t = 1$, shirking and reporting a false minor setback must not benefit the agent

$$W_{1,1} \geq b + \underline{p}_1 W_{1,1} \quad (\text{IC3})$$

4. From $X_t = 1$, shirking and reporting a false major setback must not benefit the agent

$$W_{1,1} \geq b + \bar{p}_1 W_{1,0} \quad (\text{IC4})$$

5. If a setback occurs at $X_t = 0$, the agent should report it immediately

$$p_0 W_{0,0} \geq W_{0,1} \quad (\text{IC5})$$

6. The agent truthfully reports a minor setback.

$$\underline{p}_1 W_{1,1} \geq \bar{p}_1 W_{1,0} \quad (\text{IC6})$$

7. The agent truthfully reports a major setback.

$$\bar{p}_1 W_{0,0} \geq \underline{p}_1 W_{0,1} \quad (\text{IC7})$$

8. At $X = 0$, the agent does not shirk twice, report progress twice (completion), and fail to deliver the project.

$$W_{0,0} \geq 2b \quad (\text{IC8})$$

We can immediately simplify some of these incentive constraints:

Lemma 1 *The incentive constraints simplify as follows:*

(i) (IC2) and (IC4) are redundant.

(ii) The agent is retained with (weakly) higher probability when he reports a minor setback rather than a major one: $\bar{p}_1 \leq \underline{p}_1$.

(iii)

$$W_{0,1} = \max \left\{ \underbrace{b + \bar{p}_1 W_{0,0}}_{\text{shirk}}, \underbrace{(1 - \lambda) \underline{p}_1 W_{1,1} + \lambda \bar{p}_1 W_{0,0}}_{\text{work}} \right\}. \quad (\text{W01})$$

We will want to refer to the elements in the maximization in (W01) separately. Thus we have two new constraints that are weaker than the maximization condition:

$$W_{0,1} \geq b + \bar{p}_1 W_{0,0} \quad (\text{W01a})$$

$$W_{0,1} \geq (1 - \lambda) \underline{p}_1 W_{1,1} + \lambda \bar{p}_1 W_{0,0} \quad (\text{W01b})$$

4 The Principal's Problem

Now looking at the principal's on-path value, we have

$$F_0 = (1 - \lambda) F_1 + \lambda p_0 F_0 - c \quad (8)$$

$$F_1 = (1 - \lambda)(R - K) + \lambda \alpha \bar{p}_1 F_0 + \lambda(1 - \alpha) \underline{p}_1 F_1 - c \quad (9)$$

Combining, we have

$$F_0 = \frac{1}{D(p_0, \underline{p}_1, \bar{p}_1)} \left((1 - \lambda)^2 (R - K) - c(1 - \lambda) - c[1 - \lambda(1 - \alpha)\underline{p}_1] \right). \quad (10)$$

The principal's problem is to maximize this expression with respect to the choice variables $\{p_0, \underline{p}_1, \bar{p}_1, K, W_{0,0}, W_{1,1}\}$ subject to the two promise-keeping equality constraints and the seven remaining inequality incentive constraints. Note that we can use (3) to substitute K out of the problem and (1) to substitute $W_{1,1}$ out. We are then left to choose $(p_0, \underline{p}_1, \bar{p}_1, W_{0,0})$ to maximize

$$F_0 = \frac{1}{D(p_0, \underline{p}_1, \bar{p}_1)} \left((1 - \lambda)^2 R - c(1 - \lambda) - c[1 - \lambda(1 - \alpha)\underline{p}_1] \right) - W_{0,0} \quad (\text{F0})$$

subject to the incentive constraints. Observe that the objective is increasing in all three probabilities and decreasing in $W_{0,0}$. Indeed, ignoring the constraints and setting all three retention probabilities to 1 and $W_{0,0}$ to 0 yields the principal's first-best payoff

$$F_0^{\text{FB}} = R - \frac{c[2(1 - \lambda) + \alpha\lambda]}{(1 - \lambda)^2}. \quad (11)$$

We solve the principal's problem to show that the constraints (IC1), (IC5), and (IC7) must hold with equality and that (IC8) holds with inequality in an optimal contract. This leaves a single degree of freedom, either $W_{0,0}$ or p_0 , yielding our main result:

Proposition 1 *Under an optimal contract the following must hold: $W_{0,0} = \frac{b}{1-p_0} \geq 2b$, $p_0 \geq \frac{1}{2}$, $\underline{p}_1 = 2 - \frac{1}{p_0}$, $\bar{p}_1 = 2p_0 - 1$, and $W_{0,1} = b + \bar{p}_1 W_{0,0}$.*

Observe that the reward for completion is recovered by substituting these values into (3) using (5):

$$K = \frac{[1 - \lambda(1 - \alpha\underline{p}_1)](1 - \lambda p_0) - (1 - \lambda)\lambda\alpha p_0 \underline{p}_1}{(1 - \lambda)^2} \cdot \frac{b}{1 - p_0} \quad (12)$$

5 Discussion

Simple algebra reveals the following relationships.

- Toughest Contract: $p_0 = \frac{1}{2}$, $\underline{p}_1 = \bar{p}_1 = 0$, and $W_{0,0} = 2b$.
- Softest Contract: $p_0 = 1$, $\underline{p}_1 = \bar{p}_1 = 1$, and $W_{0,0} = \infty$.
- Interior Contract: $p_0 \in (\frac{1}{2}, 1)$, $p_0 > \underline{p}_1 > \bar{p}_1 > 0$.

The softest contract obviously cannot be optimal because if the agent is never fired for reporting stage-0 setbacks, then he must be promised an infinite payoff in order to deter shirking and falsely claiming setbacks forever. For an interior contract, the probability of retention is highest for a stage-0 setback, lower for a minor stage-1 setback, and lowest for a stage-1 major setback as accords with intuition.

It is useful to interpret these objects in light of FTWZ. There, because all setbacks are total, the key incentive problem is to prevent the agent from *postponing* the report of a setback in order to collect private benefits for a few extra periods before absence of project completion forces him to report one. For late-stage setbacks, the optimal contract solves this by putting the agent on a short leash: after a reported setback the agent is retained only with some probability, and the promised continuation utility is just large enough to make it better to report a setback immediately than to delay.

Partial setbacks enrich the agent's deviation set in two ways. First, when the project is actually at stage 0 but the principal believes it is at stage 1, the agent may try to pretend that progress is on track by temporarily withholding news of a setback. Second, when the project is at stage 1 and a major setback occurs, the agent can try to downplay it as a minor setback and hope to repair the damage later. Proposition 1 shows that both problems are handled by a pair of tightly related conditions:

- at $X = 0$, the agent must prefer to report setbacks as they happen rather than string the principal along (IC5);
- at $X = 1$, the agent must prefer to report a major setback as such rather than relabel it as a minor one and then delay further bad news (IC7).

Thus the crucial incentive constraints in this setting are “no postponed setbacks” at $X = 0$ and “no postponed *major* setbacks” at $X = 1$. These are natural discrete counterparts of the *No Postponed Setbacks* condition in FTWZ. Importantly, once these two constraints are enforced, the other deviations—for example, misreporting minor setbacks or hiding completion—are either ruled out automatically or bounded by the same no-postponement logic.

From the principal's perspective, the single choice variable p_0 plays a central role. It determines both the initial promised utility, $W_{0,0} = b/(1-p_0)$, and the entire pattern of retention probabilities $(p_0, \underline{p}_1, \bar{p}_1) = (p_0, 2 - 1/p_0, 2p_0 - 1)$. When p_0 is close to $1/2$, the agent starts with very little promised utility and faces an aggressive short-leash policy: any reported stage-1 setback leads to certain termination, so partial setbacks are effectively ignored. As p_0 increases, the principal softens the contract. The agent is retained more often after early setbacks, his promised utility rises, and partial setbacks begin to matter: minor setbacks are treated more leniently than major ones, reflecting their informational content about the agent's effort.

Using Proposition 1 to substitute for $\underline{p}_1$, $\bar{p}_1$, and $W_{0,0}$, the principal's problem is to choose $p_0^* = \arg \max_{p_0} F(p_0)$, where

$$F_0(p_0) = \frac{R(1-\lambda)^2 - c(1-\lambda) - c[1-\lambda(1-\alpha)(2-1/p_0)]}{(1-\lambda p_0)[1-\lambda(1-\alpha)(2-1/p_0)] - \lambda(1-\lambda)\alpha(2p_0-1)} - \frac{b}{1-p_0}. \quad (13)$$

Consider the toughest contract. Plugging $p_0 = \frac{1}{2}$ in (13) yields the payoff

$$F^{\text{SL}} = 2\lambda \left(\frac{R(1-\lambda)^2}{1-(1-\lambda)^2} - \frac{c+b}{\lambda} \right). \quad (14)$$

The contract can be implemented by giving the agent a time budget of $\bar{X} = 2$ and initial utility $2b$. If the agent reports a setback at the end of stage 0, when his continuation utility is b , then with probability $p_0 = \frac{1}{2}$ he gets an extension (continuation utility of $2b$) and with probability $\frac{1}{2}$ the project is canceled (continuation utility of 0). If the agent reports a setback of either kind at the end of stage 1, when his continuation utility is 0, then the project is canceled for sure. Because of this feature, the possibility of partial setbacks is irrelevant under the toughest contract.

In fact, this contract can exhibit a kink at $W_{0,0} = 2b$ (or, equivalently $p_0 = \frac{1}{2}$) because the contract is only incentive compatible if $W_{0,0} \geq 2b$. If the agent is required to start with some initial level of utility $\bar{W} < 2b$, then he must be immediately randomly terminated so that his post-randomization survival utility is at least $2b$. There is a range of parameters that generate both $F_0(W_{0,0} = 2b) > 0$ and $F'_0(W_{0,0} = 2b) < 0$, indicating that the principal's value is maximized by providing $W_{0,0} = 2b$.

However, if b is sufficiently small or R is sufficiently large, then the toughest contract will not be optimal. Instead, the principal will implement an interior solution

with $p_0^* \in (\frac{1}{2}, 1)$ and initial utility of $\frac{b}{1-p_0^*} > 2b$.

Figure 1 below illustrates some examples of the objective function (13) and the optimal choices p_0^* . When the project payoff R is small relative to the cost of effort c and the private benefit b , it is optimal to keep the agent on the toughest possible contract, with $p_0 = \frac{1}{2}$ and $W_{0,0} = 2b$. In this case, partial setbacks are so unimportant that the principal optimally ignores them. When R is large, the principal is willing to grant more insurance against early bad news, raising p_0 and promising the agent more utility. The comparative statics are therefore intuitive: the more valuable the project, the more forgiving the optimal contract, but in all cases the core no-postponed-setback logic remains in place.

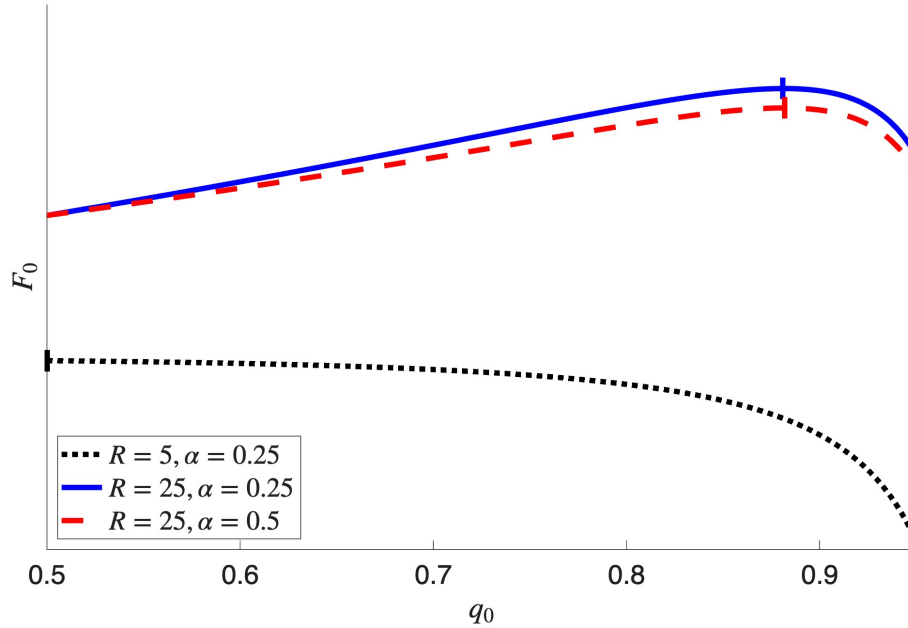


Figure 1: This figure illustrates several examples of the objective function (13) and the optimal choice p_0^* , indicated by the vertical markers on each line. The common parameters are: $c = 1$, $b = 0.5$, $\lambda = 0.5$.

In general, the optimal incentive scheme is broadly similar to the one derived in FTWZ. The incentive constraints that do the work here are (IC5) and (IC7), which correspond to “report setbacks at zero immediately” and “report major setbacks at $X = 1$ instead of minor ones”. In contrast, (IC1) is akin to a participation condition – the agent’s initial utility must correspond to what he could get by shirking and falsely reporting stage-0 setbacks until fired. The other constraints are either slack

or bound by (IC5) and (IC7).

In fact, (IC7) is itself a type of no-postponed setback constraint. To see this, suppose that the agent is behind schedule (the true state is 0 but principal believes it is 1). Then, treating (W01a) as binding implies that it is optimal for the agent to shirk and then report a major setback. Substituting (W01a) into the right side of (IC7) gives

$$\bar{p}_1 W_{0,0} \geq \underline{p}_1 (b + \bar{p}_1 W_{0,0}). \quad (15)$$

which requires that it is better for the agent to truthfully report a major setback immediately than to report a minor setback, and – upon survival – shirk, and then report a major setback. Thus (IC7) prevents the agent from postponing the reporting a major setback, and is labeled a “No Postponed Major Setbacks” condition. Hence, the critical incentive constraints in this setting are no-postponed setbacks at $X = 0$ (IC5) and no-postponed major setbacks at $X = 1$ (IC7).

6 Hidden Completion

Proposition 1 also implies that our model is robust to whether completion is publicly observable. We can show that, as long as completion is verifiable, i.e., the agent can hide, but not fake, completion, our results remain intact. Formally:

Proposition 2 *Suppose completion is verifiable to the principal but observable only to the agent. Then if completion is achieved, the agent will reveal that to the principal immediately under the optimal contract. All properties of the optimal contract derived in Proposition 1 remain intact.*

7 Conclusion

This note takes a deliberate step beyond the “all-or-nothing” setback structure of FTWZ by introducing partial setbacks into an otherwise stripped-down version of the model. Allowing both major and minor setbacks makes it easier for the agent to hide being behind schedule and creates additional persistent private information about the state of the project. In principle, this could make the optimal contract highly history-dependent and opaque. Instead, we show that within a natural class

of Markovian contracts, the optimal scheme remains remarkably parsimonious: the agent’s continuation utility can be summarized by a small set of state variables $W_{X,\hat{X}}$, and the contract is governed by a pair of no-postponed-setback constraints that mirror the central *No Postponed Setbacks* condition in the continuous-time model of FTWZ.

When the project payoff R is modest, the agent is kept on a tight leash. He is terminated with high probability after early bad news, and partial setbacks are effectively ignored. When the project is very valuable, the optimal contract becomes more forgiving in an intuitive way: the agent is retained more often after early setbacks, and minor setbacks are treated more leniently than major ones, reflecting their weaker informational content about shirking. The key discipline on the agent’s behavior is the prohibition on postponing bad news. Once we ensure that the agent never wants to delay reporting setbacks—neither at stage 0 nor for major setbacks at stage 1—the remaining incentive constraints fall into place automatically.

The basic model presented here expands the existing literature on optimal project management to a richer environment in which projects progress through multiple stages and face setbacks of varying severity. It shows that partial setbacks need not overturn the basic economics of optimal project governance: the principal still relies on a combination of promised continuation utility and random termination to induce effort and prompt revelation of bad news. At the same time, the “no-postponed-setback” constraints that organize the contract parallel the discipline that emerges in the all-or-nothing environment of FTWZ, suggesting that the core logic of short-leash project management is robust and providing useful guidance for future studies of persistent private information in dynamic agency.

Appendix

Proof of Lemma 1. Plugging (IC5) into (IC1) implies (IC2). Plugging (IC6) into (IC3) implies (IC4).

To derive the value of $W_{1,0}$, observe that (7) can be written as

$$W_{1,0} = \max \left\{ b + W_{1,1}, \frac{b}{1 - p_0} \right\} \quad (16)$$

and (IC1) can be written as $W_{0,0} \geq \frac{b}{1 - p_0}$. (1) implies $b + W_{1,1} > W_{0,0}$, which implies $b + W_{1,1} > \frac{b}{1 - p_0}$, so taking the maximum in (16) shows

$$W_{1,0} = b + W_{1,1} \quad (W10)$$

Plugging that value for $W_{1,0}$ into (IC6) yields $\bar{p}_1 \leq \underline{p}_1$.

We can resolve the interior maximizations in (6) with (respectively) (IC7), (IC6), and (IC7). ■

Proof of Proposition 1. The principal's problem is to maximize (F0) subject to (IC1)–(IC8) and (W01).

First, we disregard the constraints (IC2) and (IC4), which are redundant by Lemma 1. We then relax the problem by ignoring (IC3), (IC6), and (W01b) and verify later that they are indeed satisfied. This leaves us with (IC1), (IC5), (IC7), (IC8), and (W01a). To proceed, we relax the problem using (W01a) to replace (IC5) and (IC7) with

$$p_0 W_{0,0} - b - \bar{p}_1 W_{0,0} \geq 0 \quad (IC5a)$$

$$\bar{p}_1 W_{0,0} - \underline{p}_1 b - \underline{p}_1 \bar{p}_1 W_{0,0} \geq 0 \quad (IC7a)$$

We will also re-write (IC1) as $W_{0,0} - \frac{b}{1 - p_0} \geq 0$ and (IC8) as $W_{0,0} - 2b \geq 0$.

Thus our relaxed problem is to maximize (F0) subject to (IC1), (IC5a), (IC7a), and (IC8). We will use a lagrangian with multipliers γ_1 , γ_5 , γ_7 , and γ_8 . The first-order conditions with respect to $W_{0,0}$, p_0 , $\underline{p}_1$ and $\bar{p}_1$ are

$$0 = -1 + \gamma_1 + \gamma_8 + \gamma_5 (p_0 - \bar{p}_1) + \gamma_7 (\bar{p}_1 - \underline{p}_1 \bar{p}_1) \quad (17)$$

$$0 = \frac{\partial F_0}{\partial p_0} - \gamma_1 \frac{b}{(1 - p_0)^2} + \gamma_5 W_{0,0} \quad (18)$$

$$0 = \frac{\partial F_0}{\partial \underline{p}_1} - \gamma_7 (b + \bar{p}_1 W_{0,0}) \quad (19)$$

$$0 = \frac{\partial F_0}{\partial \bar{p}_1} - \gamma_5 W_{0,0} + \gamma_7 (W_{0,0} - \underline{p}_1 W_{0,0}) \quad (20)$$

We observe again that the objective (F0) is strictly increasing in all the retention probabilities $\{p_0, \underline{p}_1, \bar{p}_1\}$ in the region in which F_0 is positive. Then (19) implies $\gamma_7 > 0$. Then, $\gamma_7 > 0$ and (20) imply $\gamma_5 > 0$. Then, $\gamma_5 > 0$ and (18) imply $\gamma_1 > 0$. Thus the solution to the relaxed problem has (IC1), (IC5a), (IC7a) binding. Rearranging the binding constraints and applying (IC8) to the value of $W_{0,0}$, we have $\bar{p}_1 = \underline{p}_1 p_0$ and

$$W_{0,0} = \frac{b}{1 - p_0} \quad (21)$$

$$\underline{p}_1 = 2 - \frac{1}{p_0} \quad (22)$$

$$\bar{p}_1 = 2p_0 - 1 \quad (23)$$

$$p_0 \geq \frac{1}{2}. \quad (24)$$

We now check to see if this is indeed a solution to the original problem, i.e. if all the original constraints are met. This means checking constraints (IC3), (IC6), and the maximization in (W01) which we temporarily ignored above. From (1), $(1 - \lambda)W_{1,1} = (1 - \lambda p_0)W_{0,0}$. Plugging this into the second element of (W01) yields

$$\underline{p}_1(1 - \lambda p_0)W_{0,0} + \lambda \bar{p}_1 W_{0,0} = W_{0,0} \left[\underline{p}_1 - \lambda \bar{p}_1 + \lambda \bar{p}_1 \right] = W_{0,0} \underline{p}_1 \quad (25)$$

Therefore, the maximization condition in (W01) is met (the first element is greater) if $b + \bar{p}_1 W_{0,0} \geq W_{0,0} \underline{p}_1$. Plugging in the values of $W_{0,0}$, $\underline{p}_1$ and $\bar{p}_1$ in terms of p_0 yields $p_0 \geq 2 - \frac{1}{p_0}$, which is true for $p_0 \geq \frac{1}{2}$.

Meanwhile, (IC3) is

$$\frac{1 - \lambda p_0}{1 - \lambda} W_{0,0} = W_{1,1} \geq \frac{b}{1 - \underline{p}_1} = \frac{b}{\frac{1}{p_0} - 1} = p_0 W_{0,0} \quad (26)$$

Since $1 - \lambda p_0 > (1 - \lambda)p_0$, this is met.

Finally, (IC6) is

$$W_{1,1} \geq \frac{\bar{p}_1}{\underline{p}_1} W_{1,0} = p_0 W_{1,0} = p_0(b + W_{1,1}) \Leftrightarrow W_{1,1} \geq p_0 \frac{b}{1 - p_0} = p_0 W_{0,0} \quad (27)$$

where the last equality on the left side follows from (W10) and the final statement that $W_{1,1} \geq p_0 W_{0,0}$ follows from the verification of (IC3). ■

Proof of Proposition 2.

Allowing the agent to hide a completed project requires additional incentive compatibility constraints. The first set concerns the possibility that the agent does not misreport a completed project. The second is that the agent prefers to shirk when

already ahead, i.e. $W_{1,0} = b + W_{1,1}$ instead of completing the project and lying about it.

Suppose the agent has completed the project but chooses not to report that to the principal. Then, he must either report a minor setback, which yields utility $W_{2,1}$ if he survives randomization with probability $\underline{p}_1$, or he reports a major setback, which yields utility $W_{2,0}$ if he survives randomization with probability $\bar{p}_1$. Then, the agent prefers to report completion immediately if

$$W_{2,2} \geq \max \left\{ \underline{p}_1 W_{2,1}, \bar{p}_1 W_{2,0} \right\} = \max_{\underline{p}_1} \{W_{2,1}, p_0 W_{2,0}\} \quad (\text{IC9})$$

because $\bar{p}_1 = p_0 \underline{p}_1$ from Proposition 1. Meanwhile, if the true state is 2 but the principal believes the state is 0, the agent can shirk for one period and report either progress or a setback (and be subject to randomization), implying that

$$W_{2,0} = b + \max \{W_{2,1}, p_0 W_{2,0}\} \quad (28)$$

Similarly, if the true state is 2 but the principal believes the state is 1, the agent can shirk for one period and report either completion, a minor setback, or a major setback (and be subject to the respective randomizations), implying that

$$W_{2,1} = b + \max \left\{ W_{2,2}, \underline{p}_1 W_{2,1}, \bar{p}_1 W_{2,0} \right\} \quad (29)$$

Suppose (IC9) is violated, then (29) can be simplified to

$$W_{2,1} = b + \max \left\{ \underline{p}_1 W_{2,1}, \bar{p}_1 W_{2,0} \right\} = b + \max_{\underline{p}_1} \{W_{2,1}, p_0 W_{2,0}\} \quad (30)$$

If $W_{2,1} \geq p_0 W_{2,0}$, then (30) implies $W_{2,1} = b + \underline{p}_1 W_{2,1} = \frac{p_0 b}{1-p_0}$ given the value of $\underline{p}_1$ from Proposition 1. In addition, (28) implies $W_{2,0} = b + W_{2,1} = \frac{b}{1-p_0}$. Meanwhile, if $W_{2,1} \leq p_0 W_{2,0}$, then (28) implies $W_{2,0} = b + p_0 W_{2,0} = \frac{b}{1-p_0}$, and (30) implies $W_{2,1} = b + \bar{p}_1 W_{2,0} = \frac{p_0 b}{1-p_0}$. In either case, we have $W_{2,1} = p_0 W_{2,0} = \frac{p_0 b}{1-p_0}$. The RHS of (IC9) becomes $\underline{p}_1 p_0 W_{2,0}$ and we require $W_{2,2} < \underline{p}_1 p_0 W_{2,0}$ for (IC9) to be violated. Since $W_{2,2}$ is also the prize K for completing the project, we can use K from (3) and substitute in D from (5) to obtain the necessary condition to violate (IC9):

$$(1 - \lambda p_0)(1 - \lambda(1 - \alpha)\underline{p}_1) - (1 - \lambda)\lambda\alpha\bar{p}_1 - (1 - \lambda)^2 \underline{p}_1 p_0 < 0 \quad (31)$$

Substituting in the values of $\underline{p}_1$ and $\bar{p}_1$ from Proposition 1, we see that (31) becomes $1 - \frac{\lambda}{2} < 0$ when $p_0 = 1/2$, while it becomes $0 < 0$ for $p_0 = 1$, both of which are impossible. Since the derivative of the LHS with respect to p_0 is negative, (31) is never satisfied. Thus (IC9) is satisfied under the contract in Proposition 1.

Finally, we verify that (IC6) still holds. In the results of Proposition 1, we showed that the agent preferred to shirk when ahead, i.e. $W_{1,0} = b + W_{1,1}$, and we used that

to show (IC6) was valid as a consequence. However, the agent could not work because the project would be revealed as completed too early. With hidden completion, the agent prefers to work while ahead, so $W_{1,0}$ has a greater value, but (IC6) still holds.

The agent prefers to work at $W_{1,0}$ if

$$b + W_{1,1} \leq (1 - \lambda) \max\{W_{2,1}, p_0 W_{2,0}\} + \lambda(1 - \alpha) \max\{W_{1,1}, p_0 W_{1,0}\} + \alpha \lambda \max\{W_{0,1}, p_0 W_{0,0}\} \quad (32)$$

Using (IC5) and (IC6) resolves the last two maximizations. In addition, with (IC9), we have that (29) becomes $W_{2,1} = b + W_{2,2}$ and that (28) becomes $W_{2,0} = b + \max\{b + W_{2,2}, p_0 W_{2,0}\}$. If we had $W_{2,0} = b + p_0 W_{2,0}$, then $W_{2,0} = \frac{b}{1-p_0} = W_{0,0}$ and we would require $b + W_{2,2} < p_0 W_{0,0}$, which violates (IC9). Thus we have

$$b + W_{1,1} \leq (1 - \lambda)(b + W_{2,2}) + \lambda(1 - \alpha)W_{1,1} + \alpha \lambda p_0 W_{0,0} \quad (33)$$

Using $W_{1,1} = \frac{1-\lambda p_0}{1-\lambda} W_{0,0}$, then (3) and (5) to substitute out $W_{2,2}$, and finally $W_{0,0} = \frac{b}{1-p_0}$, we can write (33) entirely as a function of parameters and p_0 . We can verify that the inequality is met and that

$$W_{1,0} = \frac{b(\lambda + 2p_0 - \alpha\lambda - 3\lambda p_0 + \lambda p_0^2 - p_0^2 + 2\alpha\lambda p_0 - \alpha\lambda p_0^2)}{p_0(1 - \lambda)(1 - p_0)} \quad (34)$$

Considering (IC6), and using $W_{1,1} = \frac{1-\lambda p_0}{1-\lambda} W_{0,0}$ and $W_{0,0} = \frac{b}{1-p_0}$, we require

$$\frac{1 - \lambda p_0}{1 - \lambda} \frac{b}{1 - p_0} = \frac{1 - \lambda p_0}{1 - \lambda} W_{0,0} = W_{1,1} \geq \frac{\bar{p}_1}{\underline{p}_1} W_{1,0} = p_0 W_{1,0} \quad (35)$$

which is met using $W_{1,0}$ from (34). Thus (IC6) is satisfied under the given contract. ■

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