Optimal Subjective Contracting with Revision*

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Abstract

We study the optimal contracting problem with subjective evaluation when the principal can ask the agent to revise his work. The possibility of revision benefits the principal by providing the option value of making another attempt at the work. But it also introduces a new type of incentive problem for the principal: She may ask for revision even if it is inefficient to do so. This new incentive issue for the principal also affects the incentive of the agent: He may procrastinate his effort in anticipation of excessive revision. This results in a trilemma: The optimal contract cannot simultaneously provide for efficient revision, efficient effort, and minimal ex-post surplus destruction. The optimal contract will of necessity contain at least one of the following problems: *revision*–the principal asks for excessive revision; *procrastination*—the agent shirks in the early stage; or *punishment*—excessive surplus destruction at low-quality final output.

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1 Introduction

In many business and employment relationships—particularly in industries where the work or service requires creativity—evaluations of the quality of the final output are subjective. From advertising agents to architects, actors to designers, consultants to script writers, all serve clients and bosses who may disagree with them on the quality of their work. Dealing with these disagreements is an important part of contract design because it affects the incentives for the participants in the relationship, and therefore the efficiency of the relationship.

The economic literature on subjective contracting, pioneered by MacLeod (2003), Levin (2003), and Fuchs (2007), has focused on how to reduce disagreement by inducing the principal to tell the truth after the output is realized. The process that generates the output—the back-and-forth between the contracting parties on intermediate versions of output—has not received attention. But this process is a common feature of tasks involving subjective output, and how the process is structured affects not only the quality of the final output but also the time and effort spent on the work. The purpose of this paper is to explore one aspect of this process—that the principal may ask the agent to revise his work until either she is satisfied or the deadline is reached—and study its implications on optimal contract design.

Pop culture is littered with stories of demanding principals asking agents to repeatedly revise their work. James Wong, Hong Kong's preeminent songwriter of the last century, was once pushed to the limit by the director Hark Tsui, who insisted that he rewrite a lyric six times. Pepsi China, according to the urban legend, once asked an advertising company to revise a design 48 times before finally signing off on it. While these may be exceptional examples, it is common for agents to revise their work many times at the request of their clients. According to a recent survey of over 500 practitioners in the advertising industry, agencies on average made four or five revisions before their client are satisfied. Around 10 percent have to revise work more than 10 times before their design is accepted.[1]

The possibility of revision helps improve the quality of final output by providing an option value: It allows agents to make additional attempts at the work if the quality of the existing output is low. But revision also entails costs and introduces new types of inefficiency. First, because the

[1]The original report in Chinese can be retrieved from http://www.roifestival.com/ueditor/upload/file/2021/03/25/1616633036509096102.pdf.

principal does not incur the effort cost of revision, she may therefore ask for revision even if it is socially inefficient to do so. Second, and somewhat paradoxically, if the agent anticipates that the principal will ask for excessive revision, he may choose to put in low levels of effort in the initial stages. This justifies the principal's request for revision and will cause a delay in the completion of the task.

The purpose of this paper is to study how best to design contracts when the quality of the output is subjective and the principal may ask the agent to revise his work. We show that excessive revision may be a necessary feature of an optimal contract, as also may be procrastination. Optimal contracts without these features must entail excessive ex-post surplus destruction when the principal is dissatisfied with the final output.

Formally, we study a two-period model in which an agent privately chooses whether to work or shirk in each period. The production is identical across the two periods: There are three output levels—H(igh), M(iddle), L(ow)—and by working, the agent makes higher levels of output more likely. The principal privately observes the output level. After observing the first-period output, the principal may stop the game and accept it as the final output; or she can ask for revision, in which case the final output is the second-period output. We assume that when the first-period output is M, it is socially efficient to stop. But because the revision requires the agent's and not the principal's effort cost, the principal will ask for revision if doing so requires no additional payment from her.

As in models of subjective evaluation, our model features a two-sided moral hazard problem. Not only may the agent not put in effort, but also the principal may not tell the truth about the output. This two-sided moral hazard problem implies that, as in existing models of subjective evaluation, if the principal reports the final output to be L, it is unclear whether that is because the agent shirked or because the principal misreported. As a consequence, surplus destruction, sometimes referred to as money-burning, must occur following L to provide incentives to both parties. In this case, the agent receives less than what the principal pays out: The difference is destroyed (or given to a third party). If the principal and the agent were to have repeated future interactions, surplus destruction could also take the form of terminating those future interactions even if it would be valuable to continue the relationship.

Different from existing models of subjective evaluation, the possibility of revision introduces a new type of incentive problem for the principal. The principal may misreport not only the second-period output, but also the first-period output (by asking for revision when it is inefficient to do so). Similarly, the agent may shirk not only in the second period, but also in the first period, and this makes revision more likely.

Our main result shows that to induce the agent to put in effort in the first period, either the principal asks for excessive revision or, when the final output is reported to be L, there is excessive surplus destruction, i.e., more surplus is destroyed than is needed to motivate the agent to put in effort in the second period. In other words, the principal is faced with a trilemma of efficient revision, efficient effort, and minimal surplus destruction.

To see why the trilemma arises, recall that the principal will ask for revision when first-period output is M and she does not need to pay extra. In other words, when her payments in the two periods are the same, the principal will ask for revision to gain the option value from continuing. To prevent her from doing so, the principal's payments in the second period must then be higher. But a higher payment in the second period gives the agent stronger incentive to procrastinate. To prevent him from procrastinating, the principal must punish the agent by destroying excessive surplus in the second period (if output is L). In summary, a payment structure that ensures efficient revision will cause procrastination, and to induce efficient effort, excessive surplus destruction is needed. This leads to the trilemma.

We characterize the optimal contract in the presence of the trilemma. Depending on the parameters, the optimal contract takes one of the three possible forms, each of which featuring exactly one type of inefficiency. First, there is the *revision contract*, where the principal asks for excessive revision. Second, there is the *procrastination contract*, where the agent does not work in the first period. Finally, there is the *punishment contract*, where excessive amount of surplus is destroyed when the final output is L. We derive conditions under which each form of contract will arise.

Our main results are extended in a number of directions. We show that, when first-period output can be used in the second period, or when the agent's effort cost of revision is lower, the revision contract is more likely to arise. We also extend the analysis to cases where output or effort is continuous. Under both cases, it is possible for the optimal contract to feature multiple types of inefficiency.

This paper is related to MacLeod (2003), Levin (2003), and Fuchs (2007), who pioneered the study of contracting with subjective evaluation.[2] Their research provides the insight that subjective contracting has the problem of two-sided moral hazard. Several papers have explored how surplus is destroyed in various contexts.[3] Different from these papers, we focus on the principal's moral hazard problem (of asking the agent to make inefficient revision) that precedes rather than follows the realization of the output.

The rest of paper is organized as follows. Section 2 introduces the model. We show how our analysis can be reduced in Section 3. The main results are presented in Section 4. Section 5 discusses extensions of the model and concludes.

2 Model

We start with a simple model to illustrate our main results. The robustness of the results is studied and presented in the discussion section.

2.1 Production Technology

A principal interacts with an agent for two periods: $t \in \{1, 2\}$. Both players are risk-neutral and share a common discount factor δ. At the beginning of period 1, the principal offers a contract stipulating effort choices, payments, and stopping rules, to be specified below. If the agent rejects the contract, both parties receive a payoff of 0 and the game ends.

If the agent accepts the contract, he privately chooses effort $e_1 \in \{0, 1\}$. The cost of effort $c(e_1) = c$ if $e_1 = 1$ and is 0 otherwise. Effort stochastically raises output level $Y \in \{L, M, H\}$, where $L < M < H$. The probability of period 1 output y_1 is given by

$$\Pr(y_1 = Y) = \begin{cases} p_Y & e_1 = 1 \\ q_Y & e_1 = 0 \end{cases},$$

where $p_L/q_L < p_M/q_M < p_H/q_H$, so that effort improves output in the sense that it satisfies the

[2] Also see Bull (1987), MacLeod and Malcomson (1989) and Baker, Gibbons, and Murphy (1994). While these earlier works focus more on dynamic incentives through repeated interaction, this paper is closer to MacLeod (2003), since we also follow the "static output with money-burning" approach.

[3] See, for example, Rajan and Reichelstein (2009), Chan and Zheng (2011), Maestri (2012), Zábojník (2014), Fuchs (2015), Deb, Li, and Mukherjee (2016), Kamphorst and Swank (2018), Letina, Liu, and Netzer (2020) and Cheng (2021).

monotone likelihood ratio property. Under this property, higher output is more indicative of effort; see, for example, Milgrom (1981) for a detailed discussion. For simplicity, we assume the value of L is 0.

Once y_1 is realized, it is privately observed by the principal, who decides to stop or continue the game. If she stops it, the game ends and final output is y_1. If she continues the game to period 2, in which a revision is needed, the agent then chooses his private effort $e_2 \in \{0, 1\}$. The production technology in $t = 2$ is the same as that in $t = 1$. Output y_2, which is the final output, is privately observed by the principal.

In this setup, notice that it is possible for the period 2 output to be worse than that of period 1. This captures situations in which revisions do not always improve the output quality. An alternative setup is to assume that period 2 output is always weakly better. This can happen, for example, when period 1 output can be recalled. We study this setup in the discussion section and show that it strengthens our main result.

2.2 Contract

The contract consists of the agent's effort levels, a stopping rule that decides whether the game ends in period 1, and the associated payments. Let the effort levels be $\mathbf{e} = (e_1, e_2)$ and the stopping rule be $s(y_1) \in \{0, 1\}$, a function that maps period 1 outputs to a binary outcome. The game stops if $s(y_1) = 1$. For the payments, let w be a base wage paid out at the beginning of period 1. Let $B_1(y_1) \geq 0$ be the additional payment from the principal if the game ends in period 1 and $B_2(y_1, y_2) \geq 0$ be her payment if the game ends in period 2. Let $b_1(y_1) \geq 0$ and $b_2(y_1, y_2) \geq 0$ be the corresponding amount the agent receives. We assume that $b_1(y_1) \leq B_1(y_1)$ and $b_2(y_1, y_2) \leq B_2(y_1, y_2)$ to allow for the possibility that some portion of the payment from the principal may be destroyed. Such surplus destruction is a standard feature of contracts with subjective evaluation. It reflects and may take the form of, for example, the termination of future transactions; see, for example, Levin (2003). Note that the payments and stopping rule depend on the principal's private information, and we are implicitly requiring the principal to tell the truth in our setup (and will formally impose the truth-telling constraint in our analysis below). Alternatively, we can allow the principal to send messages based on her private information and let the stopping decision and payments depend on the messages. Doing so does not change the result of the paper, and we do not introduce the messages to save on notation.

If the game ends in period 1, the payoffs for the principal and the agent are

$$\pi_1 = y_1 - w - B_1(y_1); \quad u_1 = w + b_1(y_1) - c(e_1).$$

If it ends in period 2, their payoffs are

$$\pi_2 = -w + \delta(y_2 - B_2(y_1, y_2)); \quad u_2 = w - c(e_1) + \delta(b_2(y_1, y_2) - c(e_2)).$$

To make the analysis interesting, we assume that when $y_1 = M$, it is efficient to stop the game, but the principal prefers to continue it (as long as she does not need to make additional payments). We also assume that it is efficient to put in effort in both periods. Formally, the conditions are stated as follows:

$$\delta\mathbb{E}[y|e=1] > M > \delta(\mathbb{E}[y|e=1] - c);$$

$$(p_H - q_H)H + (p_M - q_M)M + (p_L - q_L)\delta(\mathbb{E}[y|e=1] - c) > c;$$

$$\mathbb{E}[y|e=1] - c - \frac{p_L}{q_L - p_L}c \geq \mathbb{E}[y|e=0].$$

Here, the first condition highlights the tension of stopping the game when $y_1 = M$. The second condition states that effort is efficient in the first period. The last inequality states that it is efficient to put in effort even if surplus destruction is necessary. The $\frac{p_L}{q_L - p_L}c$ is a standard term of surplus destruction, which we will discuss later.

3 Preliminary Analysis

In this section, we carry out the groundwork for characterizing the optimal contract. We set up the principal's maximization problem in Subsection 3.1. Subsection 3.2 describes basic features of the optimal contract.

3.1 Principal's Program

We characterize the optimal contract using the two-step approach a là Grossman and Hart (1983): First, the principal minimizes per expected payments given a fixed effort level and stopping rule, and second, she maximizes her expected payoff over the effort levels and stopping rules. Specifically, for each $\mathbf{e} = (e_1, e_2)$ and $s(y_1)$, the principal first solves the following program (P-1a):

$$\text{(P-1a)} \qquad \min_{w,b_1,b_2,B_1,B_2} w + \mathbb{E}[s(y_1)B_1(y_1) + (1 - s(y_1))\delta B_2(y_1, y_2)|\mathbf{e}]$$

subject to

$$\mathbf{e} \in \arg\max_{\mathbf{e}'=(e_1',e_2')} w + \mathbb{E}[s(y_1)b_1(y_1) - c(e_1') + (1 - s(y_1))\delta(b_2(y_1, y_2) - c(e_2'))|\mathbf{e}'] \tag{ICA}$$

$$w + \mathbb{E}[s(y_1)b_1(y_1) - c(e_1) + (1 - s(y_1))\delta(b_2(y_1, y_2) - c(e_2))|\mathbf{e}] \geq 0 \tag{IRA}$$

$$\begin{aligned} &\mathbb{E}[s(y_1)(y_1 - B_1(y_1)) + (1 - s(y_1))\delta(y_2 - B_2(y_1, y_2))|\mathbf{e}] \\ &\geq \mathbb{E}[s(y_1')(y_1 - B_1(y_1')) + (1 - s(y_1'))\delta(y_2 - B_2(y_1', y_2'))|\mathbf{e}] \end{aligned} , \forall y_1', y_2' \tag{TTP}$$

where the first two conditions represent the agent's incentive compatibility constraint (the agent finds given effort choice his best response) and his individual rationality constraint (the agent is willing to take the contract over his outside option). The last condition requires the principal to truthfully report the output she observes because it is in her best interest. Otherwise, she can always deviate secretly without being detected, since output is her private information.

In the second step, the principal optimizes over possible combinations of effort level $\mathbf{e} = (e_1, e_2)$ and stopping rule $s(y_1)$:

$$\text{(P-1b)} \qquad \max_{e_1,e_2,s(y_1)} -\tilde{w} + \mathbb{E}[s(y_1)(y_1 - \tilde{B}_1) + (1 - s(y_1))\delta(y_2 - \tilde{B}_2)|\mathbf{e}],$$

where $\tilde{w}, \tilde{B}_1$, and $\tilde{B}_2$ are solutions to P-1a.

Notice that we focus on the pure strategy in our analysis. We show in Online Appendix **??** that allowing for random revision rules does not change our main results, since the principal does not take it in any optimal contracts.

3.2 Basic Features of an Optimal Contract

We now describe the features of the optimal contract that are useful for simplifying the main analysis.

Lemma 1. *In an optimal contract, the following holds:*

1. *The principal's payment is independent of the output:* $B_1(y_1) = B_1; B_2(y_1, y_2) = B_2$.
2. *The principal stops at* $y_1 = H$ *and continues at* $y_1 = L$.

Part 1 of this lemma follows directly from the principal's truth-telling constraint and is a standard result in contracting with subjective evaluation (MacLeod, 2003). Part 2 shows that, at the end of period 1, the principal stops at the best output and continues with the worst output. It is intuitive that the principal stops at H, since she has nothing to gain by continuing.

It is less clear why the principal continues at L. When the principal stops at L, the game essentially ends in period 1. Though this type of one-period contract has the advantage of committing the principal not to ask for revision, it is dominated because we can improve the principal's payoff by adding a second-period contract (that is appended after L). Specifically, this second-period contract takes the form of a standard one-period optimal contract (that induces effort and gives the agent an expected payoff of zero). If this contract is added following L in period 2, the agent's incentive is unaffected, since his expected payoff upon each realization of y_1 is unchanged. The principal's payoff is improved, since she gets the agent to put in effort following $y_1 = L$.

The above discussion implies that the principal's payoff is higher when she can ask the agent to revise. In essence, by having the opportunity to ask the agent to revise, the principal gains the option value: If the output is low in period 1 ($y_1 = L$), the agent can have a second attempt.

Lemma 2. *Given* $e_2 = 1$*, there exists an optimal contract that the following hold:*

1. *If the game stops at* $t = 1$*, there is no surplus destruction:* $b_1(y_1) = B_1$.
2. *If the game stops at* $t = 2$*, surplus destruction occurs at the lowest output level in period 2:*

$$b_2(y_1, y_2) = \begin{cases} B_2 & \text{if } y_2 \neq L \\ B_2 - z & \text{if } y_2 = L \end{cases},$$

where $z \geq \underline{z} \equiv \frac{1}{q_L - p_L} c$ *is the amount of surplus destruction.*

Lemma 2 describes the payment the agent receives if the optimal contract requires the agent to put in effort in the second period. Recall that the payments from the principal are independent of output (Lemma 1), so the payment the agent receives must sometimes be smaller than the principal's payment, to induce effort from the agent. Part 1 shows that surplus destruction does not occur if the game ends in period 1. This follows because, rather than ending the game and destroying surplus, the principal is better off asking for a revision if she is unsatisfied with period 1 output.

Part 2 shows that surplus destruction needs to occur only when output is at the lowest level (L) in the second period. This result contains both a familiar and an unfamiliar feature. The familiar feature is that surplus destruction occurs only at the output level that is most informative of shirking. The principal minimizes the expected surplus destruction by punishing the agent only when he is most likely to have shirked.

On the unfamiliar feature, Part 2 shows that, when period 2 output is L, surplus destruction also occurs if period 1 output is M. This is different from the standard feature of optimal subjective contracts, that surplus destruction occurs only when outputs are low in both periods ((L,L)). Punishing only at (L,L) minimizes surplus destruction because the punishment in period 2 can be reused to motivate effort in period 1. In our setting, however, the principal can also motivate effort in period 1 by increasing B_1 and decreasing B_2 (so that the agent gains by finishing the game in period 1). Since adjusting payments does not require surplus destruction, the principal does not need to rely on the reusability of punishment to minimize surplus destruction. Note that punishing only at (L,L) is also optimal, but we choose our contract to simplify the exposition.

Finally, to motivate effort in the second period, surplus destruction has to occur at $y_2 = L$. Notice that $\underline{z} \equiv \frac{1}{q_L - p_L} c$ is the familiar expression of minimal surplus destruction in a one-period model. We therefore say that excessive surplus destruction occurs if $z > \underline{z}$.

4 Main Analysis

In this section, we start with a benchmark analysis of one subclass of the optimal contracts. In Subsection 4.2, we study the full set of optimal contracts.

4.1 A Benchmark Analysis: Punishment Contracts

In this subsection, we analyze contracts where the agent always puts in effort and the principal chooses the efficient revision rule. We denote this subclass of contracts as punishment contracts because punishment (that results in surplus destruction) is the only source of inefficiency in such contracts. By analyzing punishment contracts, we highlight a new incentive cost in subjective contracting when the principal can ask for revision.

Proposition 1. *In any punishment contract, excessive surplus destruction occurs ($z > \underset{\sim}{z}$).*

Proposition 1 shows that to induce both efficient effort from the agent and efficient revision rule from the principal, excessive surplus destruction must occur. In other words, if there is no excessive surplus destruction, then efficient revision and efficient effort cannot hold simultaneously. This is because, when surplus destruction is minimal ($z = \underset{\sim}{z}$), efficient revision requires $B_1 < \delta B_2$, yet efficient effort requires $B_1 \geq \delta B_2$.

To see why efficient revision requires $B_1 < \delta B_2$, notice that by continuing at M, the principal's expected output is higher ($\delta \mathbb{E}[y|e = 1] > M$). Therefore, to make the principal take the efficient revision rule (stop at M), her payment in period 1 must then be lower. That is, $B_1 < \delta B_2$.

The argument for why efficient effort requires $B_1 \geq \delta B_2$ follows from two observations. First, notice that a necessary condition for inducing the agent to put in efficient effort ((1,1)) is that, if the agent only puts in effort once, he must weakly prefer to put it in the first period ((1,0)) rather than in the second period ((0,1)). This is because when $z = \underset{\sim}{z}$, the agent is indifferent between putting in effort or not in period 2, and putting in effort only in period 1 ((1,0)) gives the same payoff as efficient effort ((1,1)). As efficient effort requires the agent to weakly prefer (1,1) over all other choices (including (0,1)), he must also weakly prefers (1,0) over (0,1).

The second observation is that preferring (1,0) to (0,1) requires $B_1 \geq \delta B_2$. This is because under the efficient revision rule, surplus destruction occurs only at (L,L). Since the probability of (L,L) is the same under (1,0) and (0,1), the expected surplus destruction is the same if the agent only puts in effort once. Moreover, when the agent chooses (0,1), his cost of effort is weakly lower than (1,0) because of discounting. Therefore, for the agent to weakly prefer (1,0) over (0,1), the expected bonus he receives in the first period must be weakly higher. That is, $B_1 \geq \delta B_2$.

Together, the two observations imply that efficient effort requires $B_1 \geq \delta B_2$ when the surplus destruction is minimal. Since efficient revision requires $B_1 < \delta B_2$, they cannot coexist. This leads to the following trilemma: It is impossible to have efficient effort, efficient revision, and minimal surplus destruction simultaneously.

Next, we describe the properties of the optimal punishment contract, that is, the punishment contract that maximizes the principal's payoff. Let z_{Pu} be the surplus destruction in the optimal punishment contract and $V \equiv \delta\mathbb{E}[y|e=1] - M$ be the option value of carrying out the revision (without taking into account the effort cost).

Corollary 1. *The following two properties hold:*

1. *Compared to the case without revision, the optimal punishment contract increases the principal's payoff by $p_L M$.*

2. *The excessive surplus destruction $z_{Pu} - \underset{\sim}{z}$ increases in V and c.*

Part 1 shows that under the optimal punishment contract, the expected gain from revision is $p_L M$. To see this, notice that since the revision rule is efficient under the optimal punishment contract, the principal gains only when period 1 output is L, which happens with probability p_L. In addition, when L occurs, the principal's maximal possible gain is M. Otherwise, when period 1 output is M, the principal has an incentive to misreport it as L to get a higher payoff. This violates the principal's truth-telling constraint.

Part 2 shows that the excessive surplus destruction increases both in the option value V and the effort cost c. A higher option value gives the principal stronger incentive to ask for revision, making the principal's truth-telling constraint more difficult to be satisfied. A higher cost of effort gives the agent stronger incentive to procrastinate, i.e., putting in effort only in period 2, making the agent's incentive constraint more difficult to be satisfied. Increases in both V and c, therefore, make the optimal punishment contract less efficient because they require higher levels of excessive surplus destruction to satisfy the incentive constraints. As we will see in the next subsection, it is precisely when they are large that the optimal contract takes other forms.

4.2 Optimal Contracts

In this subsection, we characterize the forms of optimal contracts and describe the conditions under which each form arises. We also discuss the payment structure of different forms of contracts and the performances—final output qualities and task completion time—they induce.

Proposition 2. *The optimal contract takes one of the three forms:*

1. *Revision: The agent puts in effort in period 1, the principal continues at M, and there is minimal surplus destruction.*

2. *Procrastination: The agent does not put in effort in period 1, the principal stops at M, and there is minimal surplus destruction.*

3. *Punishment: The agent puts in effort in period 1, the principal stops at M, and there is excessive surplus destruction.*

Recall the trilemma that it is impossible for an optimal contract to have efficient revision, efficient effort, and minimal surplus destruction simultaneously. Proposition 2 shows that the optimal contract features inefficiency in one of the three dimensions. The inefficiency can occur in the revision dimension, leading the principal to ask for excessive revision. It can occur in the effort dimension, causing the agent not to put in effort in the first period. It can also lead to excessive surplus destruction, as we have shown in Proposition 1. Notice that when the optimal contract takes the form of a revision contract or a procrastination contract, the surplus destruction is minimal.

In principle, the optimal contract can feature multiple types of inefficiency at the same time. Proposition 2 shows that only one type of inefficiency will occur in the optimal contract. This is because when the agent's effort is binary, the principal's payoff is linear in the type of inefficiency the optimal contract induces. When there are multiple levels of effort, there can be more than one type of inefficiency, and it is possible to have both excessive revision and procrastination, which we will discuss in Section 5.

Next, we describe the conditions under which different forms of contracts arise.

Corollary 2. *The following hold:*

1. *For each V, there exists a $c(V)$ such that*

   (a) *Excessive revision will occur as long as $\delta c < c(V)$.*

   (b) *$c(V)$ increases as option value increases.*

2. *There exists a cutoff option value $\underline{V}$ such that when c increases,*

   (a) *If $V \leq \underline{V}$, the optimal contract first moves from excessive revision to excessive punishment, and then to procrastination.*

   (b) *If $V > \underline{V}$, the optimal contract moves directly from excessive revision to procrastination.*

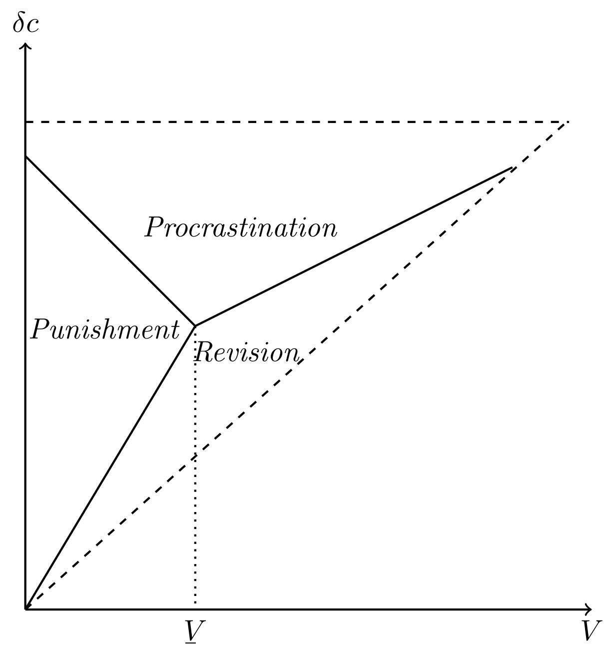

Figure 1: Contract Forms in V and δc Space

The results of Corollary 2 are illustrated in Figure 1. The figure shows that the conditions for the emergence of different optimal contracts can be organized along two dimensions: the option value of revision V and the agent's effort cost c. Recall it is inefficient to continue at M ($\delta(\mathbb{E}[y|e = 1] - c) < M$), so the figure is drawn above the 45-degree line. $\underline{V}$ is the maximum option value under which there are three regions of optimal contracts.

Figure 1 shows that the punishment contract is optimal when both the option value of revision (V) and the agent's cost of effort (c) are low. When V is low, the principal does not have strong incentive to ask for revision. When c is small, the agent does not have strong incentive to procrastinate. In this case, the amount of excessive surplus destruction is small under the punishment contract (as mentioned in Corollary 1). This makes the punishment contract optimal.

Figure 1 also shows that the procrastination contract is optimal when the cost of effort is sufficiently large. The procrastination contract has the direct benefit of saving the effort cost in period 1. In addition, the procrastination has an indirect benefit (relative to the punishment contract) of saving the incentive cost of the agent by eliminating the excessive surplus destruction. When c is larger, both the direct and indirect benefit increase, making the procrastination contract optimal.

Finally, Figure 1 shows that the revision contract can arise when the option value of revision (V) increases. As V increases, it makes the revision contract more attractive by directly increasing the benefit of revision. More importantly, a higher V also means that the principal is more tempted to ask for revision when the period 1 output is L. This implies that the incentive cost of maintaining efficient revision can be so high that the relationship is better off by allowing for excessive revision.

Notice that the option value V increases in the convexity of the production function. As the production function becomes more convex, in the sense that it increases the difference between the average output ($E[y|e=1]$) and middle output (M), the option value becomes higher. This suggests that when the high output is particularly valuable (such as in the case of a blockbuster song or advertisement), excessive revisions are likely to arise.

It is worth noting that both the procrastination contract and the revision contract, when chosen, improve the payoff of the principal relative to the case without revision (because they perform better than the punishment contract). Relative to the punishment contract, revision occurs (and therefore the option value is realized) more frequently in these two forms of contracts. This is clearly the case for the revision contract because revision occurs at M. For the procrastination contract, because the agent does not put in effort in period 1, L is more likely to occur, resulting in more revision.

In the last part of the subsection, we describe the payment structure of different forms of contracts and the performances they induce in terms of final output quality and task completion time.

Corollary 3. *The following hold:*

1. *The payment structure of the optimal contracts satisfies the following:*
   (a) *Revision contract must involve bonus for early completion,* $B_1 - \delta B_2 > 0$.
   (b) *Procrastination and punishment contract must involve compensation for one more attempt,* $B_1 - \delta B_2 < 0$.

2. *The performance of the optimal contracts satisfies the following:*

   (a) *Both the expected output and the probability of high output are highest in the revision contract.*

   (b) *The expected task completion time is longest in the revision contract if and only if $p_H < 1 - q_L$, and is shortest in the punishment contract.*

Part 1 follows from the discussion of Proposition 1. Early bonus comes from the agent's incentive and late compensation comes from the principal's incentive. When $B_1 > \delta B_2$, the principal will ask for excessive revision because by continuing at M, she has a higher expected output and a lower expected payment. One form of early bonus ($B_1 > \delta B_2$) is to set a fixed payment for the project regardless of its completion time ($B_1 = B_2$). Such contracts are commonly observed in creative industries and are therefore suggestive of excessive revision.

To avoid excessive revision, the principal must raise the payment in the second period. This can be implemented by requiring the principal to give the agent an additional payment if revision is needed ($B_1 < B_2$). This type of contracts is also common in practice and may prevent excessive revision. However, it may lead the agent to procrastinate, since it is now more attractive to receive the payment in period 2. If procrastination is costly, the principal must then prevent it by resorting to harsh punishment after low output, possibly through a high probability of terminating the relationship in the future (when our game is part of a long-term relationship).

Part 2 follows from direct calculation. It is natural that when the agent puts in effort in both periods and the principal imposes high standards by continuing at M, the revision contract leads to the highest expected output and highest probability of obtaining high output. Part 2 (a) then suggests that high-quality work is often associated with (possibly too many) revisions. While conducive to high output, the downside of the revision contract is the long time it takes to complete the task. Part 2 (b) shows that expected task completion time for the revision contract is always longer than that of the punishment contract. This follows because, same as the revision contract, the agent also puts in effort, but unlike the revision contract, the principal stops at M. Interestingly, the revision contract can even have a longer expected completion time than the procrastination contract when the probability of high output is low. Both forms of contracts cause delay, albeit for different reasons. Delays occur in procrastination contracts because the agent does not put in effort in period 1, and they occur in revision contracts because the principal is too demanding. Depending on which type of delay is more significant, the revision contract can have either a longer or shorter completion time than the procrastination contract.

5 Discussion and Conclusion

This paper studies optimal subjective contracting with revision. Our model focuses on the possibility that the principal may ask for revision when the output level is her subjective information. This results in a trilemma: The optimal contract cannot simultaneously feature efficient revision, efficient effort, and minimal surplus destruction.

The optimal contract takes one of the three forms: a revision contract in which excessive revision takes place; a procrastination contract in which the agent withholds effort prior to revision; and a punishment contract in which excessive amount of surplus is destroyed ex-post following a low final output. We provide the conditions under which each form of contract will arise and describe the respective payment structure and performance outcomes.

The main results are robust under a number of extensions.[4] Notably, we show that excessive revision is more likely to occur if previous output can be recalled or if the revision cost is lower. First, suppose the principal can turn back to the period 1 output at the end of period 2. One interpretation of this is that the second-period effort is a revision that weakly improves output quality. With output recall, the trilemma remains and the optimal contract takes of the one three forms as in the main model. However, because the final output is weakly higher when output recall is allowed, the principal gains more from revision and is thus more likely to ask for it. An implication of this extension is that in industries where output is tractable and retrievable, more revisions will occur.

We next consider the case when revision entails lower cost to the agent than the initial effort. As in the case of output recall, the trilemma and forms of optimal contracts in the main model remain. However, with a lower revision cost, the revision is less costly to ask, and therefore revision contract is also more likely to be chosen.

In addition, multiple types of inefficiency can occur simultaneously when output is continuous

[4] The details and proofs of the extensions are relegated to Online Appendix **??**.

or effort is continuous. First, suppose output is continuous but effort is still binary. The trilemma still holds, but the optimal contract may involve multiple types of inefficiency. The principal can now use both excessive revision and punishment to motivate the agent, and the optimal contract may involve the combination of both types to minimize the distortion.

Next we allow effort to be continuous while keeping the output discrete. As in the continuous output case, the trilemma remains and multiple types of inefficiency can occur simultaneously. When there are multiple levels of effort, the optimal contract can feature both excessive revision and procrastination. This echoes the self-fulfilling prophecy observed in real lift: If the agent anticipates that the principal will ask for excessive revision, he will strategically withhold effort at first, and this lower level of effort further justifies the principal's request for revision.

Our model is a first step toward studying the revision process in a contracting problem. Economists have not focused extensively on the processes that lead to the final output, but these processes matter greatly for productive efficiency. Casual empiricism suggests that excessive revision is a problem for the economics profession, and possibly for academia in general. Better understanding of the incentives and constraints associated with the revision process has the potential to improve the efficiency of knowledge creation.

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