Subjective Performance Feedback, Employee Turnover and Renegotiation-Proof Contracts

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Abstract

Feedback provision and salary administration are usually two indispensable purposes of conducting performance evaluations. However, the real role that performance feedback plays is affected by the availability of other appraisals that reveal information about the causes of performance. We develop a two-stage principal-agent model where, at the end of the first stage, the principal can choose to evaluate the interim performance, or the first-stage agent’s ability that was previously unknown to any party, or both, and use the results to determine whether the original agent is rehired in the second stage, as well as the compensation. We find that the presence of an ability appraisal undermines the principal’s credibility in the subjective evaluation of interim performance, and prohibits a renegotiation-proof contract from being written contingent upon subjective performance feedback.

1 Introduction

Appraising performance and providing feedback is regarded as an essential managerial activity. While the common view suggests that performance feedback has an impact on employees’ motivation and self-esteem, many studies on how it works present conflicting evidence. For instance, Ilgen and Davis (2000, p.561) claim that "negative performance feedback is a dilemma," because they find that subsequent to a failure, some people give up, yet others make a commitment to working harder. One explanation of this "dilemma," which is provided by management scholars

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(e.g., Dugan 1989), is that an employee’s reaction to performance feedback depends on how he understands its causes. When hard working yields poor performance, an employee intends to doubt his own capacity for the job, resulting in lower morale.\(^1\) However, morale is not necessarily damaged by negative sign of performance feedback, if information is revealed about specific factors that account for the review outcome. Particularly, an employee, when being aware that an earlier failure is attributed to bad luck instead of low ability, would not lose confidence for a next attempt.

By recognizing that the feedback role and the incentive effect of performance evaluation are reliant on the availability of other information, we intend to examine the optimal design of midterm reviews. In fact, supplemental information that influences the understanding of the reasons for the outcome in performance evaluation may be provided in certain appraisals, such as investigation of the employee’s capacity or of the environment in which workplace tasks were undertaken. Those appraisals might be adopted in conjunction with performance evaluation, particularly if the manager’s aims include employee turnover, goal adjustment or organizational intervention (besides salary administration). For example, when an employee is considered for promotion or dismissal, besides documentation of past performance, his personal traits, such as technical skill, leadership ability, or team-working quality, may be examined by the human resource officer. In a procurement setting, when contract renewal is requested, the buyer may not only rate the supplier’s performance of previous year, but also evaluate his delivery capacity. In the setting of project control, the manager usually measures whether each milestone is achieved; if a failure occurs, she may further check the reasons, and base her decision making (such as an employee replacement or goal adjustment) on available investigations.

Therefore, we consider a model where the principal is contemplating a project that contains two stages of independent tasks. To undertake the two tasks, either the same agent is hired, or separate agents are hired, depending on the principal’s decision made at the end of the first stage. The agent will affect the output of each stage through exerting effort. However, the marginal product of effort is determined by the agent’s suitability for the project; in short, we refer to the underlying productivity-related factors as "ability." We assume that the ability level

\(^1\)More precisely, two key factors that establish this statement are the employee’s initial uncertainty about own ability, and complementarity between ability and effort.
is either high or low, but is unknown to both the principal and the agent *ex ante.* Moreover, it is assumed that while both parties are risk neutral, the agent is subject to limited liability, a reasonable assumption in many applications.

Two types of midterm evaluations are considered in our model. After the first-stage task is completed, the principal may conduct an interim performance evaluation (IPE). The interim performance embodies the first-stage agent's effort, his ability, and random factors, so the IPE result is a mixture of these information. Meanwhile, the principal may opt for an ability appraisal that reveals the ability level of the first-stage agent with greater precision than an IPE implies.

We assume that before the project begins, the principal can commit *up front* to certain types of midterm evaluations, because the appraisals typically require specific accounting techniques that take time to implement. However, we assume that the principal cannot commit *ex ante* to a rule of agent turnover; subsequent to midterm evaluations and dependent on the information gathered, the principal will update the belief about the first-stage agent's ability, and replace him with a new agent if she perceives it profitable to do so at that time.3

In a similar two-stage principal-agent model, Crémer (1995) investigates whether the principal gains from committing to undertake an "ability appraisal" at the end of the first stage, implicitly assuming that the interim performance is always revealed and contractable. He finds that conducting an ability appraisal facilitates the implementation of an efficient agent replacement, improving the expected productivity in the second stage; on the other hand, it disables the principal’s commitment to fire the high-ability agent subsequent to poor interim performance, worsening the agency problem in the first stage. By contrast, our paper assumes that conducting an IPE is at principal’s discretion; when it is not chosen, the interim performance is not revealed, and no contract can be written on it. Albeit such difference, we find that if the IPE can provide an *objective* (i.e., verifiable and publicly observable) signal on the interim performance, the principal always finds it profitable to conduct such an IPE, while the trade-off for adding an ability appraisal is very similar to that identified by Crémer.

Our analysis further departs from that in Crémer (1995) by considering the *subjective* IPE.

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2In our model, uncertainty about the marginal product of effort is justified by match-specific reasons or by the agent’s suitability for the job. This assumption is also commonly made in the principal-agent literature (see, e.g., Jovanovic 1979; Harris and Holmström 1982; Kaya 2010).

3Without loss of generality, we refer to the principal as "she," and refer to the agent as "he."
that generates an unverifiable signal for the principal alone. The widespread use of performance feedback systems\(^4\) justifies the assumption that the principal may have private information about the agent’s performance. Moreover, as Prendergast (1999) observes, rewards and promotions are usually contingent on subjective measures of performance. Therefore, an adverse selection problem may arise when the principal reports the IPE outcome. Our model predicts that the presence of an ability appraisal undermines the principal’s credibility of conveying subjective feedback on interim performance. Specifically, if an ability appraisal was chosen that perfectly reveals the agent’s ability, the principal cannot honestly implement any renegotiation-proof contract that is contingent on the subjective IPE signal.

To illustrate the intuition, we consider a situation where both a subjective IPE and an ability appraisal are conducted at the end of the first stage. Note that the marginal product of the agent’s effort in the second stage relies on his ability rather than on previous performance, given task independence across stages. Thus, under a renegotiation-proof contract, the principal’s decision of the agent replacement is made contingent only upon the outcome of the ability appraisal; moreover, the agent’s estimation of own productivity in the second stage is not affected by the IPE result. Suppose that in the ability appraisal an agent was confirmed to have high ability, and hence rehired. When receiving negative feedback in the IPE, this agent would not blame his own ability; instead, he may attribute the earlier failure to being "unlucky" (given that he did not shirk). In this sense, even though the principal under-reports the first-stage performance of a high-ability agent, it would not damage his morale (i.e., belief in the productivity of continuation effort). On the other hand, under-reporting the interim performance may save labor costs for the principal, because a good IPE result may lead to reward for the first-stage effort. To signal her honesty, the principal should motivate the agent with a payment scheme that does not vary across the IPE results.

However, if the principal commits to not appraising the agent’s ability, the credibility of feedback transmission in the subjective IPE is enhanced. Suppose that the principal observes a good IPE signal. In the absence of an ability appraisal, a good IPE signal informs the principal not only that the agent was performing well in the first stage but also that he is more likely

\(^4\)By surveying 400 organizations worldwide, Aberdeen group (2010) reports that 91% of employers use performance feedback systems.
to be of high ability than an outside agent is. If the principal cheats by providing a bad IPE outcome, the agent may attribute such feedback in part to low ability, hence his morale is harmed. Moreover, a renegotiation-proof contract should dictate that the original agent is rehired if a good IPE result is reported and he is fired if a bad result is reported. Therefore, cheating in this case also misleads the agent replacement, reducing the expected productivity in the second stage.

Given the subjectivity of the IPE, the optimal design of midterm reviews corresponds to evaluation of either the interim performance or the first-stage agent’s ability, but not evaluation of both. Our results suggest that if the first-stage agency problem is the main concern, committing to conduct an IPE is better; however, if the second-stage agency problem is the main concern, committing to conduct an ability appraisal is better. The intuition is as follows. The IPE provides an additional measurement for the first-stage success, so a contract written on it will save the incentive cost of inducing the according effort. The ability appraisal generates a signal for instructing an efficient replacement of agent, so it enhances the expected productivity and lowers the incentive cost in the second stage. We also extend the analysis by relaxing several assumptions, such as effort independence across stages, and generalize our findings.

**Related literature** This paper belongs to the nascent and growing literature on IPEs. A number of studies concern the interplay between performance feedback and incentives in two-stage principal-agent models (see, e.g., Lizzeri, Meyer and Persico 2002; Ray 2007; Ederer 2010; Manso 2011; Chen and Chiu 2012). They investigate a similar question — whether the principal gains from conducting an IPE — with different specifications of effort interdependence and contract enforcement. By contrast, the core issue we analyze is whether the presence of an ability appraisal will add or distract from the efficacy of contracting with a subjective IPE. Moreover, our analysis differs from the greater body of literature in our consideration of heterogeneity in

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5Ray (2007) finds that the IPE enhances efficiency by providing the option to end a project with early low returns. His results rely on the assumptions that production is indivisible and that efforts across stages are perfect substitutes. Lizzeri, Meyer, and Persico (2002) and Manso (2011) examine whether the principal should tell the agent about the IPE outcome. These studies engage the key assumption that the IPE outcome is verifiable at the end and can be used in contracting. However, Chen and Chiu (2012) impose a different assumption: a contract made contingent upon the IPE outcome is enforceable if and only if performance feedback is revealed. We follow Chen and Chiu (2012) by maintaining this assumption.
agent productivity, and of occurrence of agent replacement subsequent to midterm reviews.\textsuperscript{6} These distinct assumptions also explain a different setting that our study focuses on.

Another strand of related literature is the studies on the contracting problem associated with subjective performance evaluation. These papers are motivated by the phenomenon that the principal is inclined to renege on the subjective pay that was promised to award the agent upon good performance. MacLeod (2003) and Levin (2003) find that, in order to provide proper incentives for the principal to report truthfully and for the agent to perform well, mutual punishment takes place when bad performance is achieved.\textsuperscript{7} However, destruction of joint surplus in the equilibrium path renders the resulting contracts to be not renegotiation-proof. By presenting a different model where the agent’s ability is assumed to be unknown \textit{ex ante}, our paper shows that the aforementioned reneging problem of the principal can be mitigated, if subjective performance evaluation provides \textit{informative} feedback about the agent’s productivity in the next period and determines his turnover. Particularly, in the absence of other assessments (e.g., an ability appraisal), a renegotiation-proof contract can be written on the basis of a subjective IPE.

Recognizing that the principal may gain from strategic ignorance in a contacting environment is not without precedent in the literature (e.g., Crémer 1995; Dewatripont and Maskin 1995; Riordon 1990; Sappington 1986; Nosal 2006; Kaya 2010). A particularly relevant study is that of Crémer (1995), who shows that by keeping uninformed about an agent’s ability, in the renegotiation phase the principal can commit to a firing rule that may be more desirable from an \textit{ex ante} point of view. However, we show that neglecting the information about the agent’s ability not only gives rise to the benefit identified by Crémer, but also strengthens the principal’s honesty in the provision of performance feedback, making a renegotiation-proof contract that is contingent on \textit{subjective} interim performance feasible.

Another relevant paper is Taylor and Yildirim (2011), who study a model in which an eval-

\textsuperscript{6}A few papers consider heterogeneity in the agent’s ability when studying the principal’s choice of the interim information disclosure policy. Ederer (2010) shows in a dynamic tournament model that full disclosure of interim performance will spur the agent’s effort in the first period, because the agent wants to signal high ability to discourage his opponents from competition in the second period. Hansen (2012) examines how the IPE affects the incentive of an agent (whose ability is unknown by any party) in a career concern model.

\textsuperscript{7}For example, Levin (2003) suggests that the repeated interaction between the employer and the employee should be terminated when the performance falls below a threshold. MacLeod (2003) indicates that in order to prevent the principal from reneging on subjective payments, the agent should impose on the principal some type of socially wasteful cost, such as quitting the job or reducing the morale, when bad performance is reported. Fuchs (2007) considers infrequent performance evaluations in repeated interactions, but indicates that commitment to termination is a necessary method for implementing the contract.
uator wants to judge and select good projects, but cannot commit ex ante to an acceptance criterion before the agent invests to enhance the project quality. They find that blind review, where the agent’s identity (or ability) is not observable by the evaluator, provides better incentives for the agent in project preparation but reduces the precision of project selection. In a two-stage principal-agent model, we analyze a similar mode of "blind review" at the interim stage, and find that choosing it balances providing incentives in the pre-evaluation stage against maintaining productivity in the post-evaluation stage.\(^8\)

The remainder of this paper proceeds as follows. Section 2 lays out the basic model. Section 3 analyzes the regimes without an IPE. Section 4 studies the regimes with an objective IPE and assesses their value. Sections 5 analyzes the regimes with a subjective IPE in the same way, and assesses their value. Section 6 deals with a number of extensions and provides additional discussion. Section 7 presents our concluding remarks.

2 The model

A principal is contemplating a project that contains two stages of sequential tasks. For each task, the principal needs to hire an agent to undertake it. In labor market, agents differ in ability or suitability for a given project. To simplify the analysis, we assume that all agents are either of type \(\theta\) or of type \(\overline{\theta}\). For an agent who is newly hired in the project, his type is unknown to any party ex ante. The prior probability that the agent is of type \(\overline{\theta}\) is given by \(p \in (0, 1)\), and this is common knowledge.

In Stage 1, an agent is hired, and he can choose an unobservable effort \(e_1 \in \{0, 1\}\) at a cost \(c_1e_1\), where \(c_1 > 0\). At the end of this stage, an interim product is generated, with either high quality or low quality. In Stage 2, the original agent is rehired or replaced by a new agent, depending on the principal’s decision. The Stage-2 agent chooses another unobservable effort \(e_2 \in \{0, 1\}\) at a cost \(c_2e_2\), where \(c_2 > 0\). At the end of this stage, a final product is generated, with either high quality or low quality.

Though the cost of exerting effort is the same for all types of agents, the marginal product

\(^8\)In contrast with Taylor and Yildirim (2011), we consider this issue in a contracting setting where transfers between parties are allowed. Other significant difference includes that in our model the agent’s ability is unknown to any party ex ante, while in theirs the agent is privately informed about his own ability.
of effort relies on their types. Following Crémer (1995), we assume that the type-θ agent’s effort can enhance the success probability of each task, while the type-θ agent’s effort always has a productivity of zero. In particular, if the Stage-1 task is undertaken by a type-θ agent, the interim product generated is of high quality with probability \( r_0 + r_1 e_1 < 1 \), and is of low quality with the remaining probability, where \( r_0, r_1 \in (0, 1) \). However, if this task is undertaken by a type-θ agent, the interim product generated is of low quality with probability 1. On the other hand, the quality of final product depends on several factors:

- If the Stage-2 task is undertaken by a type-θ agent, regardless of his effort choice \( e_2 \), the final product is of high quality with probability \( t_0 \) (resp., \( t'_0 \)) and of low quality with the remaining probability, conditional on a high-quality (resp., low-quality) interim product, where \( t_0, t'_0 \in (0, 1) \).

- If the Stage-2 task is undertaken by a type-θ agent, given his effort choice \( e_2 \), the final product is of high quality with probability \( t_0 + t_1 e_2 < 1 \) (resp., \( t'_0 + t_1 e_2 < 1 \)) and of low quality with the remaining probability, conditional on a high-quality (resp., low-quality) interim product, where \( t_1 \in (0, 1) \).

We assume that \( t_0 > t'_0 \), in accord with the definition of a high-quality interim product. We further note that for any type of agent, the marginal product of Stage-2 effort is independent of the state of interim product, so there is no interdependence between the efforts across stages. (The case of effort complementarity and substitutability will be studied in Section 6.1.) Up to now, our model shares many similarities with that in Crémer (1995). Particularly, the Stage-1 production described here is the same as his, and we maintain his assumption that efforts across stages are independent. The only difference introduced in our model is that a high-quality interim product means a high default success probability in Stage 2.

At the end of Stage 2, the quality of final product is observable and verifiable. We assume that the principal gains a positive value, \( B > 0 \), from the project if the final product is of high quality; otherwise, she gains zero. In our model, the interim product is assumed to be an input

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9 More generally, we can assume that if a type-θ agent was hired in Stage 1, the interim product generated is of high quality with probability \( r_0' + r'_1 e_1 \) where \( r_0' < r_0 \) and \( r'_1 < r_1 \). This alternative assumption complicates our analysis and obscures the comparison between our results and Crémer’s (1995), but no new insights are added.

10 By contrast, Crémer (1995) assumes that the Stage-2 production is just a repeat of that in Stage 1, and that there is fundamentally no physical link between the two stages.
of Stage-2 production, and does not generate a separate benefit for the principal. Accordingly, we may call the project a success when the final product is of high quality, and call it a failure otherwise. Both the principal and the agent are risk neutral. The agent’s reservation utility is zero. As well, the agent has no wealth and is subject to limited liability. So the payment transferred from the principal to the agent should be positive in any state.

At the end of Stage 1, two kinds of midterm evaluations, if scheduled, may take place. First, although not immediately observable, the interim product’s quality can be learnt through an IPE. The IPE will inform the principal of a signal $\sigma$, which equals to $h$ if the interim product is of high quality and equals to $l$ otherwise. (For simplicity, we assume that the evaluation process contains no noise.) Subsequent to an IPE, the performance feedback, $m$, is provided to the agent by the principal. We distinguish two formations of the IPE: it may be objective so that the IPE outcome, $\sigma$, is publicly observable and verifiable — and as a result the performance feedback, $m$, coincides with $\sigma$; it may be subjective so that $\sigma$ is unverifiable and known by the principal alone — and $m$ can be manipulated to differ from $\sigma$. Without loss of generality, for both types of IPEs, we assume that a set of all possible messages that the principal may communicate equals $\{h, l\}$.

Second, at the end of Stage 1, the principal can conduct an ability appraisal, which generates a signal $\theta \in \Theta$ that perfectly reveals the type of Stage-1 agent. We assume that the signal $\theta$ is verifiable and publicly observable.\footnote{We focus on the analysis of an "objective" ability appraisal, because the main purpose of this paper is to investigate how revealing information about agent’s ability affects the feedback transmission in the subjective IPE. If an ability appraisal provides a "subjective" signal to the principal, this case is studied in Section 6.4.}

To simplify the analysis, we assume that the costs of conducting the IPE and the ability appraisal are equal to 0 if the principal has chosen them before the Stage-1 task is undertaken, and are equal to $+\infty$ otherwise. This assumption makes sense, because efficient monitoring often requires specific accounting techniques for which the implementation takes time.

To distinguish the regimes that involve various midterm evaluations, we adopt the taxonomy presented in Table 1. For example, if the principal commits to conducting both the ability appraisal and the IPE at the end of Stage 1, we call the corresponding mechanism "dual-review regime," which appears in the right bottom box. For another example, the mechanism in which only the IPE takes place and the ability appraisal is absent is called "performance-review
To summarize, the timing of this game is described as follows.

1.0 The principal determines whether to conduct an IPE and an ability appraisal after the Stage-1 production.

1.1 The principal offers a contract to an agent, whose ability is unknown.

1.2 The agent chooses the level of effort in the Stage-1 production.

1.3 The interim product is generated with certain quality.

1.4 The principal decides whether or not to propose a new contract to the agent, who decides whether or not to accept it.

1.5 The IPE or the ability appraisal will take place, if the principal has chosen it at time 1.0.

2.0 If the contract in force requires it, the Stage-1 agent is fired, and a new agent is hired.

2.1 The agent chooses the level of effort in the Stage-2 production.

2.2 The final product is generated and agents are rewarded according to the terms of contracts.

Before ending this section, Two comments are in order. First, we allow the principal not only to choose an ability appraisal, as considered by Crémer (1995), but also to choose an IPE.
Note that without an IPE conducted by the principal, no contract that is based on the interim product’s quality is enforceable. This assumption of contractibility shares similarity with that in Chen and Chiu (2012), and is supported by the fact that the interim product is an input of the second-stage production and usually transient. Consequently, if both the IPE and the ability appraisal are absent, the feasible contract is written on the quality of the final product alone. However, if any midterm evaluation takes place, the contract terms are enriched: (i) a replacement of agents is conditional on the ability signal \( \theta \) or the performance feedback \( m \); (ii) the payments can vary, contingent upon \( \theta \) or \( m \). Second, among all possible contracts signed at time 1.0, we consider only the renegotiation-proof contracts. More precisely, if the contract is renegotiation-proof, the principal and the agent will not find it mutually beneficial to renegotiate to a new contract at time 1.4.13

3 The regimes without an IPE

In the absence of an IPE, it is worth considering two types of regimes, depending on whether the principal chooses the ability appraisal or does not.

3.1 The no-review regime

Suppose that the principal commits to not conducting any midterm evaluations. In this situation, because no information is gathered at the end of Stage 1, the principal would not replace the agent then. Moreover, the payment transferred from the principal to the agent is contingent on the verifiable nature of the final product. The corresponding contract is defined as follows.

Definition 1 The no-review contract contains a duple \((w, b)\), where \(w\) is a wage that must be paid out, and \(b\) is a bonus paid out if the final product is of high quality. The agent’s limited

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12 Projects fitting our model can be found in many industries, such as construction and software development. The potential safety problems of bridges under construction or possible bugs in an unfinished software package are not easily discovered unless the project manager undertakes interim checkups.

13 It is easy to see that the best renegotiation-proof contract is not dominated by a contract in which renegotiation takes place. Moreover, according to Crémer (1995, p.282), “the only renegotiation-proofness constraint that binds is the constraint bearing on the decision to fire the agent.”

14 There are two reasons. First, at the end of Stage 1, the principal is indifferent to the choice between firing the current agent and hiring a new one, because their productivity is the same in expectation. Second, the bonus used for incentivizing the Stage-1 effort also incentivizes the Stage-2 effort. So retaining the same agent for Stage 2 weakly dominates replacing him with a new one.
liability dictates that\footnote{We assume that \( w \) is paid out along with \( b \) (if rewarded) at the very end. In this case, \( b \) may be negative as long as \( w + b \) is not negative. An alternative assumption is that \( w \) is paid out earlier, at the end of Stage 1, such that \( b \) is not allowed to be negative. But the two assumptions do not lead to any different results, because under our current assumption \( b \) is never negative when optimality is achieved.}

\[ w \geq 0 \quad \text{and} \quad b + w \geq 0. \quad (1) \]

When deciding on effort levels in Stage 1 and Stage 2, the agent does not know his own type. He will choose \( e_1 = 1 \) rather than \( e_1 = 0 \), if and only if

\[ \Pr_1 (t_0 - t_0') b \geq c_1. \quad (2) \]

Note that only the effort of a type-\( \theta \) agent (occupying a portion \( p \) in population) increases the probability of generating a high-quality interim product (by the amount of \( r_1 \)); if the interim product is of high quality rather than of low quality, the final success is achieved with a greater probability (i.e., \( t_0 - t_0' \)). So the left-hand side (LHS) of (2) calculates the agent’s extra gains in choosing \( e_1 = 1 \), and its right-hand side (RHS) represents the cost of his effort.

Likewise, the agent, when deciding on the Stage-2 effort, is still unaware of his type. He continues to choose \( e_2 = 1 \) rather than \( e_2 = 0 \), if and only if the expected gains more than compensate for the effort cost, that is

\[ pt_1 b \geq c_2. \quad (3) \]

If the principal finds it profitable to induce high levels of efforts in both stages, \( e_1 = e_2 = 1 \), her gains in expected benefit should overwhelm the increase in expected payment to the agent, which in turn requires that the project value, \( B \), is large enough. To simplify our analysis and avoid tedious case distinction, we make the following assumption.

**A1** \( B \geq \overline{B} \), where \( \overline{B} \) is defined as the minimal level of \( B \) that satisfies the following two inequalities:

\[ \Pr_1 (t_0 - t_0') B \geq \psi (1) \max \left\{ \frac{c_1}{\Pr_1 (t_0 - t_0') \overline{p} t_1}, \frac{c_2}{p t_1} \right\} - \psi (0) \frac{c_2}{p t_1}, \quad (4) \]

and

\[ pt_1 B \geq \psi (1) \frac{c_2}{p t_1}, \quad (5) \]
where the function $\psi(e_1)$ represents the probability of final success, given the Stage-1 effort choice $e_1$, and takes the form

$$\psi(e_1) = p \left[ (r_0 + r_1 e_1) t_0 + (1 - r_0 - r_1 e_1) t'_0 + t_1 \right] + (1 - p) t'_0.$$ 

This assumption insures that the principal is willing to induce $e_1 = e_2 = 1$ not only under the no-review regime, but also under all the other regimes. Given A1, the optimal no-review contract is characterized by

$$w = 0; \quad b = \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\}. \quad (6)$$

3.2 The ability-review regime

Consider the regime in which the midterm review only contains an ability appraisal. Given assumption A1, the principal would like to induce high levels of efforts in both stages. At the end of Stage 1, if the original agent is found to be of type $\theta$, the principal would not fire him under the renegotiation-proof contract. In more detail, when the principal rehires this agent in Stage 2, the sum of their continuation payoffs is

$$S^r \equiv \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] B - c_2. \quad (7)$$

Because a type-$\theta$ agent was hired in Stage 1, the interim product is of high quality with probability $(r_0 + r_1)$, and is of low quality with the remaining probability. The term $(r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0$ calculates the default success probability in Stage 2. Moreover, rehiring this agent in Stage 2 and inducing him to choose $e_2 = 1$ enhance the success probability by $t_1$. So the first term of (7) computes the expected benefit of rehiring the type-$\theta$ agent, while its second term represents the agent’s cost of choosing $e_2 = 1$. However, when the principal hires a new agent as a replacement, the sum of payoffs of the principal and the old agent is

$$S^f \equiv \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + pt_1 \right] \left( B - \frac{c_2}{pt_1} \right). \quad (8)$$
In this case, with probability $p$, the new agent is of type $\theta$. Therefore, the success probability enhanced by his effort is expected to be $pt_1$. Meanwhile, in order to induce the new agent to choose $e_2 = 1$, the principal awards him a contract that contains a bonus $b'$ paid upon final success. $b'$ solves (3) with equality, so $b' = \frac{c_2}{pt_1}$.

It is evident that $S^\tau > S^\ell$, suggesting that rehiring a type-$\theta$ agent in Stage 2 is better than firing him. If the original contract states the opposite, renegotiation would occur and both parties can be made better off by sharing the increase in total surplus.

On the other hand, the Stage-1 agent, if found to be of type $\theta$ in the ability appraisal, would be replaced. Consequently, the continuation payoff of the principal is

$$\Pi' \equiv (t_0' + pt_1)(B - \frac{c_2}{pt_1}).$$

(9)

If a type-$\theta$ agent was hired in Stage 1, the interim product is certain to have low quality, so the default success probability in Stage 2 is $t_0'$. A new agent will be hired in Stage 2, whose effort is expected to increase the success probability by $pt_1$; meanwhile, an appropriate bonus, $b' = \frac{c_2}{pt_1}$, is used by the principal to induce him to choose $e_2 = 1$.

Thus, under the ability-review regime, the renegotiation-proof contract is defined as follows.

**Definition 2** The ability-review contract states that

(i) If the Stage-1 agent is found to be of type $\theta$, he is fired and paid a wage $w'_f$; meanwhile, a new agent is hired in Stage 2, and will be paid a bonus $b' = \frac{c_2}{pt_1}$ upon final success.

(ii) If the Stage-1 agent is found to be of type $\theta$, he will be rehired in Stage 2 and paid conditional on the final product’s quality; the payments to the type-$\theta$ agent are represented by $(w, b)$, where $w$ is a wage paid regardless of final outcome and $b$ is a bonus paid upon final success, and they satisfy (1).

Given assumption A1, the principal’s profit-maximization problem under the ability-review regime is as follows:

$$\max_{w'_f, w, b} p \left\{ [(r_0 + r_1) t_0 + (1 - r_0 - r_1) t_0' + t_1] (B - b) - w \right\} + (1 - p) \left( \Pi' - w'_f \right),$$

where the first and second terms calculate the payoffs of the principal, when the agent hired
in Stage 1 is of type $\theta$ and type $\theta$, respectively. A type-$\theta$ agent, if hired in Stage 1, is totally unproductive, so rewarding him in any state does not have any incentive effect. Setting $w^f = 0$ is optimal for the principal. The bonus $b$ that is paid to the type-$\theta$ agent upon final success can provide effective incentives in Stage 1, so the principal can set $b$ to induce $e_1 = 1$ and to satisfy the Incentive Compatible (IC) constraint, (2). Moreover, in order to induce the rehired (type-$\theta$) agent to choose $e_2 = 1$, $b$ needs to satisfy the following IC constraint imposed in Stage 2.

$$t_1 b \geq c_2.$$  \hfill (10)

It is routine to solve the optimal ability-review contract as follows:

$$w^f = w = 0; \quad b = \max \left\{ \frac{c_1}{pr_1 (t_0 - t_0')}, \frac{c_2}{t_1} \right\}. $$  \hfill (11)

By comparing the ability-review regime with the no-review regime, we obtain the following proposition. All proof is relegated in the Appendix.

**Proposition 1** The optimal ability-review contract generates a higher level of profit for the principal than does the optimal no-review contract.

If the IPE is not scheduled, conducting an ability appraisal will enhance the payoff of the principal. The underlying reasons are three-fold: (i) conducting an ability appraisal facilitates an efficient replacement of agent, and thereby improves the expected productivity in Stage 2; (ii) the cost of inducing $e_2 = 1$ is reduced under the ability-review regime, because the rehired agent’s morale (or estimation of own productivity) is boosted by the good outcome of the ability appraisal; (iii) the expected cost of inducing $e_1 = 1$ is also reduced under the ability-review regime, because now the bonus $b$ is paid only to the productive (type-$\theta$) agent upon final success.

## 4 The regimes with an objective IPE

When the principal commits to do an IPE, there are two regimes worth considering: (i) the regime that contains an IPE alone, and (ii) the regime that contains both an IPE and an ability
appraisal. Because the outcome of an objective IPE is observable and verifiable, we abstract away the truth-telling problem of the principal when providing performance feedback.

4.1 The performance-review regime

Consider the situation where the IPE is conducted and the ability appraisal is absent. It is clear that, at the end of Stage 1, the agent will be fired if and only if the IPE reveals a low signal \((\sigma = l)\). Intuitively, a low IPE signal not only indicates that the interim product is of low quality, but also implies that the Stage-1 agent is less likely to be of type \(\theta\) than previously thought. By applying Bayes’ rule, the probability of facing a type-\(\theta\) agent conditional on a low IPE signal is computed as follows.

\[
\mu = \Pr(\theta = \theta | \sigma = l) = \frac{p (1 - r_0 - r_1)}{p (1 - r_0 - r_1) + (1 - p)}.
\]

We find that \(\mu\) drops below the prior \(p\). In this circumstance, hiring a new agent who is of type \(\bar{\theta}\) with probability \(p\) generates a higher level of total surplus than does rehiring the old agent. On the other hand, if a high signal is found in the IPE \((\sigma = h)\), the Stage-1 agent is of type \(\bar{\theta}\) for certain (because it is assumed that the type-\(\bar{\theta}\) agent can not produce a high-quality interim product). Thus, under the performance-review regime, the renegotiation-proof contract is defined as follows.

**Definition 3** The performance-review contract states that

(i) If the IPE reveals \(\sigma = h\), the Stage-1 agent is rehired in Stage 2.

(ii) If the IPE reveals \(\sigma = l\), the Stage-1 agent is fired; meanwhile, a new agent is hired in Stage 2, and will be paid a bonus \(b' = \frac{c_2}{pt_1}\) upon final success.

(iii) The payments to the Stage-1 agent are contingent not only on the final product’s quality, but also on the IPE result: they are represented by a quadruple \((w_h, w_l, b_h, b_l)\), where, given the performance feedback \(m\), \(w_m\) is the wage paid out regardless of final outcome, and \(b_m\) is the additional bonus paid out if the final product is of high quality. The limited liability constraints

\[\text{We can consider an alternative payment scheme} (w_h, w_l, b_h) \text{ with } b_l \text{ missing. But the contract described by Definition 3 is more complete, because it allows the payment to be made to the Stage-1 agent in the situation where he is fired at the interim stage but the final success is achieved.}\]
dictate that:

\[ w_h, w_l \geq 0; \quad b_h + w_h \geq 0; \quad \text{and} \quad b_l + w_l \geq 0. \quad (13) \]

Given assumption A1, the principal always wants to induce high levels of efforts in both stages, and her profit-maximization problem under the performance-review regime is as follows:

\[
\max_{w_h, w_l, b_h, b_l} \quad p (r_0 + r_1) \left[ (t_0 + t_1) (B - b_h) - w_h \right] \\
+ \left[ 1 - p (r_0 + r_1) \right] \left[ \Pi' - (t_0' + pt_1) b_l - w_l \right],
\]

where the first and second terms calculate the payoffs of the principal, when the IPE reveals \( \sigma = h \) and \( \sigma = l \), respectively. The principal sets \((w_h, w_l, b_h, b_l)\) to induce \( e_1 = 1 \); the according IC constraint is

\[ pr_1 \left[ (t_0 + t_1) b_h - (t_0' + pt_1) b_l \right] + pr_1 \left( w_h - w_l \right) \geq c_1 + pr_1 c_2. \quad (14) \]

If the Stage-1 agent chooses \( e_1 = 1 \) rather than \( e_1 = 0 \), a high-quality interim product will be generated with a larger probability, \( pr_1 \). Therefore, the LHS of (14) calculates the increase in salary due to choosing \( e_1 = 1 \), while its RHS computes the increase in effort costs.

Moreover, subsequent to a high IPE signal, if the rehired agent is willing to choose \( e_2 = 1 \), the bonus \( b_h \) should fulfill

\[ t_1 b_h \geq c_2. \quad (15) \]

Through computation, the optimal performance-review contract may be characterized by

\[
\begin{align*}
  w_h &= w_l = b_l = 0; \\
  b_h &= \max \left\{ \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)}, \frac{c_2}{t_1} \right\}.
\end{align*}
\]

According to this contract, the Stage-1 agent is rewarded, only when the IPE reveals a high signal \( h \) and the final success is achieved. Two remarks should be included here. First, if the IPE reveals a low signal \( l \), the Stage-1 agent will be fired and end up with zero payment, because any increase in those payments \((w_l, b_l)\) dilutes his incentive in Stage 1. Second, \( w_h \) is equally as
cost-effective as \( b_h \) for inducing Stage-1 effort, so if (14) is binding, any contract that satisfies
\[ w_l = b_l = 0, b_h \in \left[ \frac{c_2}{t_1}, \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)} \right] \] and \( w_h = \frac{c_1 + pr_1 c_2}{pr_1} - (t_0 + t_1) b_h \) is outcome equivalent and is also optimal.

4.2 The dual-review regime

According to our model setup, the agent’s productivity in Stage 2 is reliant on his type, but is irrelevant to the interim performance given effort independence across stages. Therefore, under the dual-review regime, the efficient decision of agent replacement is made contingent upon the information revealed in the ability appraisal. Specifically, the renegotiation-proof contract is defined as follows.

**Definition 4** The dual-review contract states that

(i) If the Stage-1 agent is found to be of type \( \theta_1 \), he is fired and paid a wage \( w^f \); meanwhile, a new agent is hired in Stage 2, and will be paid a bonus \( b' = \frac{c_2}{pr_1} \) upon final success.

(ii) If the Stage-1 agent is found to be of type \( \theta_2 \), he will be retained for Stage 2 and paid conditional on both the IPE result and the final product’s quality. The payments to him are represented by \((w_h, w_l, b_h, b_l)\), where, given the performance feedback \( m \), \( w_m \) is the wage paid out regardless of final outcome and \( b_m \) is the bonus paid upon final success, and they satisfy (13).

Given assumption A1, the principal’s profit-maximization problem under the dual-review regime is as follows.

\[
\max_{w_h, w_l, b_h, b_l, w^f} \left[ p (r_0 + r_1) [(t_0 + t_1) (B - b_h) - w_h] + p (1 - r_0 - r_1) [(t'_0 + t_1) (B - b_l) - w_l] + (1 - p) \left( \Pi' - w^f \right) \right],
\]

where the first two terms calculate the principal’s payoff if a type-\( \theta_1 \) agent was hired in Stage 1 and the last term calculates the principal’s payoff if a type-\( \theta_2 \) agent was hired in Stage 1. The following IC constraint guarantees that the agent will provide high effort in Stage 1.

\[ pr_1 [(t_0 + t_1) b_h - (t'_0 + t_1) b_l] + pr_1 (w_h - w_l) \geq c_1. \quad (17) \]
The following IC constraints guarantee that the rehired (type-$\theta$) agent will provide high effort in Stage 2, subsequent to either a high or low IPE result.

$$b_h, b_l \geq \frac{c_2}{t_1} \tag{18}$$

Through computation, the optimal dual-review contract may be characterized by:

$$w^f = w_h = w_l = 0; \tag{19}$$

$$b_l = \frac{c_2}{t_1}; \quad b_h = \max \left\{ \frac{c_1}{pr_1(t_0 + t_1)} + \frac{(t_0' + t_1) c_2}{(t_0 + t_1) t_1}, \frac{c_2}{t_1} \right\}.$$

Under the dual-review regime, bonuses $b_l$ and $b_h$ are paid only to the type-$\theta$ agent upon final success. In particular, a positive $b_l$ induces him to choose $e_2 = 1$ subsequent to a low IPE signal. On the other hand, a sufficiently large $b_h$ induces not only $e_2 = 1$ subsequent to a high IPE signal but also $e_1 = 1$. Note that the agent’s incentive in Stage 1 is diluted because he anticipates gaining a positive rent even following an unfavorable interim outcome. Thus, by comparing with the optimal performance-review contract described by (16), the optimal dual-review contract is characterized by a larger $b_h$, indicating a higher cost of incentivizing $e_1 = 1$ under the latter contract. Nevertheless, we obtain the following result.

**Proposition 2** Suppose that the IPE is objective. The optimal dual-review contracts generate a higher level of profit for the principal than does the optimal ability-review contract.

Because conducting an ability appraisal has already provided sufficient information for making an efficient turnover decision, adding an objective IPE would not further enhance the Stage-2 productivity. However, the IPE creates a measure of interim product’s quality, which can be used in contracting to reduce the cost of inducing Stage-1 effort. For illustration, let note that the dual-review contract, if fulfilling $b_h = b_l$ and $w_h = w_l$, collapses into the ability-review contract. However, the cost of inducing $e_1 = 1$ can be further reduced by increasing $b_h$ alone, while keeping $b_l$ satisfying the Stage-2 IC constraint (18). This explains the relative advantage of the

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17 $w_h$ is equally as cost-effective as $b_h$ in providing incentive in Stage 1, so in case that (17) is binding, any contract that satisfies $w^f = w_l = 0, b_l = \frac{c_2}{t_1}, b_h = \left[ \frac{c_1}{pr_1(t_0 + t_1)} + \frac{(t_0' + t_1) c_2}{(t_0 + t_1) t_1} \right]$ and $w_h = \frac{c_1}{pr_1} + \frac{(t_0' + t_1) c_2}{t_1} - (t_0 + t_1) b_h$ is outcome equivalent and is also optimal.
dual-review contract in providing incentives in Stage 1.

4.3 The optimal regime

In Propositions 1 and 2 we have shown that, if the IPE is objective, the dual-review regime payoff dominates the ability-review regime, which, in turn, payoff dominates the no-review regime. Thus, to find out the principal’s optimal regime, we just need to compare her payoffs under the performance-review regime and the dual-review regime. In other words, the principal will choose an objective IPE as a certainty, while the question boils down to whether she gains from conducting an ability appraisal. This is exactly the same question investigated by Crémer (1995), and our analysis brings a similar result.

Proposition 3 Suppose that the IPE is objective.

(i) Under the optimal regime, the principal at least chooses an IPE.

(ii) There exist cutoffs $\alpha$ and $R$: When $c_1 \geq \alpha c_2$ and $(r_0 + r_1) \geq R$, there exists a cutoff $\beta^O$, such that the principal chooses the performance-review regime if $B \leq \beta^O$, and chooses the dual-review regime if $B > \beta^O$. When $c_1 < \alpha c_2$ or $(r_0 + r_1) < R$, the principal always chooses the dual-review regime.

By assuming that the interim performance is always revealed and contractable, Crémer (1995) focuses on the comparison between the performance-review regime and the dual-review regime. Our Proposition 3 generalizes Crémer’s Proposition 1 by showing that even though the interim performance is unknown without an IPE conducted by the principal, the aforementioned comparison is without loss of generality given that the IPE is objective.

When an objective IPE has been chosen, the trade-off for adding an ability appraisal is between an increase in the Stage-2 productivity and a reduction in the Stage-1 incentive. In particular, under the performance-review regime, the Stage-1 agent who is of type $\theta$ may be replaced by a type-$\theta$ agent in Stage 2, resulting in a revenue loss; a larger project value, $B$, inflates such a revenue loss, which in turn favors the dual-review regime. However, under the dual-review regime, the type-$\theta$ agent is insulated from harsh punishment (e.g., being fired) following an unfavorable interim outcome, so the incentive in Stage 1 is diluted; an increase in $c_1$ relative to $c_2$ exacerbates this problem, which in turn favors the performance-review regime.
Notice that Crémer (1995) assumes that the Stage-2 production is a repeat of Stage-1 production, so in his model $c_1 = c_2$ and $r_1 = t_1$. However, we assume that these parameters are, in general, variant. Hence, the results on comparative statics are enriched. For example, we find that, by comparing with the performance-review regime, the dual-review regime is dis-favored by a higher $r_1$, but favored by a higher $t_1$. Note that the relative advantage of the dual-review regime arises from using the result of the ability appraisal in making the decision of agent replacement. If $r_1$ is sufficiently large (e.g., close to $1 - r_0$), the outcome of the IPE is as accurate for informing about the agent’s type as is the outcome of the ability appraisal, hence the relative advantage of the dual-review regime becomes tenuous. However, if $t_1$ increases, a wrong replacement of agent leads to a larger reduction in the Stage-2 productivity, hence the performance-review regime becomes less profitable than the dual-review regime.

5 The regimes with a subjective IPE

According to Gibbs (1991), performance feedback systems are pervasive in modern organizations. This phenomenon implies that the IPE may first reveal information about the interim product’s quality to the principal, and then the principal communicates performance feedback to the agent. Moreover, in our model, the interim product is an input of Stage-2 production. Consequently, the IPE signal may be transient, and preserving evidence of it for the purpose of contract enforcement may be impossible. This justifies our study of a subjective IPE. Given that the IPE outcome is the principal’s private information, an adverse selection problem may arise. Nevertheless, we focus on the contracts with the full-revealing property defined as follows:

- A contract is said to satisfy the full-revealing property if the message $m$ announced by the principal is consistent with the true signal $\sigma$ learned in the subjective IPE.

Therefore, the new contracting problem is constrained by additional "truth-telling" conditions. We first revisit the dual-review regime.
5.1 The dual-review regime

Suppose that the principal conducts both an ability appraisal and a subjective IPE at the end of Stage 1. Under the dual-review regime, the contract, if satisfying the renegotiation proofness and full-revealing property, is described by Definition 4. In particular, the decision of agent replacement depends on the outcome of the ability appraisal alone.

We first consider the situation where the Stage-1 agent is found to be of type $\overline{\theta}$ in the ability appraisal. This agent will be rehired regardless of the IPE signal. However, the payment to him may be contingent upon the feedback $m$ provided by the principal in the IPE. In contrast with previous analysis, the IPE is now subjective, such that the principal can manipulate the feedback provision. The principal, finding $\sigma = h$ in the IPE, will communicate a true message $m = h$ to the agent, if

$$(t_0 + t_1)(B - bh) - wh \geq (t_0 + t_1)(B - bl) - wl. \quad (20)$$

No matter what the feedback $m$ the principal provides, the project will be completed by the original agent who is of type $\overline{\theta}$, so the success probability always equals to $(t_0 + t_1)$. The only difference is in regard to the payments. If $m = h$ is revealed to the agent in the feedback session, $wh$ is paid immediately and $bh$ will be paid conditional on final success. Likewise, $wl$ and $bl$ are used if $m = l$ is announced. Therefore, (20) insures that the principal gains more by reporting $m = h$ truthfully.

Likewise, the principal, finding $\sigma = l$ in the IPE, is willing to truthfully report $m = l$, if

$$(t'_0 + t_1)(B - bl) - wl \geq (t'_0 + t_1)(B - bh) - wh. \quad (21)$$

Then consider the situation where the Stage-1 agent is found to be of type $\overline{\theta}$ in the ability appraisal. The original agent will be replaced in Stage 2. Moreover, according to our model setup, the interim product is certain to have low quality, and both the principal and the agent should be aware. So either the principal is unable to cheat, or the feedback $m$ provided by her does not matter, in this situation.

Under a subjective IPE, the principal’s problem of solving the optimal dual-review contract
is the same as that depicted in Section 4.2, except for adding the two truth-telling constraints, (20) and (21). Through computation, we obtain Proposition 4 that stands in contrast with Proposition 2.

**Proposition 4** Suppose that the IPE is subjective. The optimal dual-review contracts generate the same profit for the principal as does the optimal ability-review contract.

If the IPE outcome is not directly observed by the agent, the principal can hide it, and hence commits to a payment scheme that does not vary with performance feedback. This strategy ensures that the principal achieves a payoff under the dual-review regime that is not lower than under the ability-review regime.

In fact, Proposition 4 conveys a message beyond the above analysis. The IPE signal informs about the quality of interim product, and setting variant payments contingent upon it may save the cost of inducing Stage-1 effort. As demonstrated by the dual-review contract that is characterized by (19), when the IPE is objective and the Stage-1 IC constraint (17) is binding, the principal may use a high bonus \( b_h \) relative to \( b_l \), gaining a larger profit than under the optimal ability-review contract. However, if the same contract is signed for a subjective IPE and (17) is still binding, the principal intends to cheat when receiving \( \sigma = h \), because announcing \( m = l \) avoids paying the relatively high bonus \( b_h \) but does not affect the expected benefit in the continuation game. To insure the principal’s honesty, \( b_l \) should be increased to match with \( b_h \).\(^{18}\) Hence, the optimal dual-review contracts that satisfy the full-revealing property are payoff-equivalent to the optimal ability-review contract.\(^{19}\)

To understand Proposition 4 properly, two assumptions that drive this equivalence result deserve to be stressed. First, the ability appraisal reveals a more accurate signal about the agent’s type than the IPE does. Second, given effort independence across stages, the agent’s productivity in Stage 2, and his morale as well, is not affected by the interim performance. These assumptions have two important implications: (i) performance feedback is irrelevant to the principal’s decision of agent turnover under the dual-review regime, and (ii) the feedback role

---

\(^{18}\) Although the principal can increase either \( b_l \) or \( w_l \) to commit to truth telling, in the proof of Proposition 4, we have shown that increasing \( b_l \) is more cost-effective than increasing \( w_l \).

\(^{19}\) Similar to characterizing the optimal dual-review contracts under an objective IPE, multiple solutions may exist under a subjective IPE. The underlying reason is that using \( w_h \) is equally as cost-effective for inducing \( e_1 = 1 \) as using \( b_h \) is. In the Appendix, we have shown that Proposition 4 is unaffected by this concern.
of an IPE is completely eliminated in the presence of an ability appraisal. Consequently, the well recognized problem with subjective pay emerges: as long as the labor cost of the principal varies across subjective performance measures, she has a motive to cheat. To signal her honesty, the principal may disregard the difference of some contingencies informed by subjective evaluation when designing a compensation scheme for the agent. Many previous studies on subjective performance evaluation (e.g., MacLeod 2003; Levin 2003), which emphasize its role of salary administration and ignore its role of feedback provision, find similar results.\footnote{In the models presented by MacLeod (2003) and Levin (2003), there is no uncertainty about the agent’s ability, and the outcome of subjective performance evaluation does not convey information about the agent’s productivity in the future. Therefore, they find that to ensure the principal’s honesty in reporting the agent’s performance, the principal’s labor cost should not vary across subjective performance measures. It is also worth noting that the resulting mechanism involves no balance between the expenditure of principal and the payment to agent. For example, the principal can promise to reward the agent after good performance, and to give the bonus away to a third party after bad performance.}

Before ending this subsection, two remarks are in order. First, in Sections 6.1 and 6.2, we relax the two aforementioned assumptions, separately, and generalize the findings. In Section 6.3, we have further discussion on the feedback role of subjective performance evaluations. Second, our analysis of the subjective IPE is restricted to the contracts satisfying the full-revealing property. Accordingly, a separating equilibrium occurs in the interim information disclosure. However, in the pooling equilibrium where the performance feedback provided by principal is randomized and uninformative, the dual-review contract collapses into the ability-review contract. We can also show that in a semi-separating equilibrium where the principal is allowed to adopt a mixed strategy in reporting the IPE result, Proposition 4 still holds.\footnote{A technical note for proving this claim is available from the authors. The intuition is that the principal’s payoff in the semi-separating equilibrium is between that in the separating equilibrium and that in the pooling equilibrium, and all these payoffs are equivalent to that under the optimal ability-review contract.}

\section{5.2 The performance-review regime}

Consider the situation where the midterm review only contains a subjective IPE. In this case, the IPE outcome is useful not only for determining the agent’s compensation, but also for instructing the agent turnover. Under the performance-review regime, the contract, if satisfying the renegotiation proofness and full-revealing property, is described by Definition 3.\footnote{Restricting analysis to the contracts satisfying the full-revealing property is without loss of generality. If the contract under the performance-review regime is renegotiation-proof, it calls for replacement of agent subsequent to a low IPE signal. So implementing the contract requires a separating equilibrium occurring in the interim information disclosure. It is easy to show that other contracts that do not satisfy the full-revealing property but satisfy the renegotiation proofness cannot perform better than the contract depicted in Definition 3.} In par-
particular, the firing rule is contingent on performance feedback: the Stage-1 agent will be rehired in Stage 2 if the feedback \( m = h \) is provided, but will be fired if \( m = l \) is provided.

To guarantee that the principal truthfully reports \( m = h \) when she observes \( \sigma = h \) in the IPE, the following inequality should be satisfied.

\[
(t_0 + t_1) (B - b_h) - w_h \geq (t_0 + pt_1) \left( B - \frac{c_2}{pt_1} - b_l \right) - w_l.
\] (22)

The LHS of (22) calculates the principal’s payoff if the truth has been told. When the IPE reveals \( \sigma = h \), it informs the principal not only that the interim product generated is of high quality but also that the Stage-1 agent hired is of type \( \theta \). Providing the feedback \( m = h \) to this agent leads to retaining him for Stage 2, so the success probability is \( (t_0 + t_1 e_2) \); meanwhile, the wage \( w_h \) is paid immediately, and the bonus \( b_h \) will be paid upon final success, inducing him to choose \( e_2 = 1 \). However, if the principal tells lies by providing the feedback \( m = l \), the corresponding payments to the original agent are \( w_l \) and \( b_l \); meanwhile, a new agent is hired to replace him. The new agent, who will be paid a bonus \( b' = \frac{c_2}{pt_1} \) upon final success, chooses \( e_2 = 1 \), hence the probability of final success is \( (t_0 + pt_1) \). The principal’s payoff in the case of cheating is calculated by the RHS of (22).

Likewise, when the principal receives \( \sigma = l \) in the IPE, she is willing to truthfully report \( m = l \), if

\[
(t'_0 + pt_1) \left( B - \frac{c_2}{pt_1} - b_l \right) - w_l \geq (t'_0 + \mu t_1) (B - b_h) - w_h,
\] (23)

where \( \mu \) is defined in (12), denoting the principal’s belief that the Stage-1 agent is of type \( \theta \) upon receiving a low IPE signal (\( \sigma = l \)). Recall that \( \mu \leq p \). It implies that cheating by claiming \( m = h \) in this situation results in a rehiring of the original agent who is less likely to be of high ability than an outside agent is, and hence lowers the expected productivity in Stage 2. However, providing the false feedback \( m = h \) deludes the rehired agent into possessing a more optimistic belief on ability, so the labor cost of inducing Stage-2 effort may be saved.\(^{23}\)

Under a subjective IPE, the principal’s problem of solving the optimal performance-review contract is the same as that depicted in Section 4.1, except for facing the two truth-telling

\(^{23}\)More precisely, if \( m = h \) is announced, the Stage-1 agent believes that he is of type \( \theta \), and hence a bonus \( b_h = c_2/t_1 \) is sufficient for inducing him to choose high effort in Stage 2. However, if \( m = l \) is announced, a new agent is hired as a replacement, who will demand a bonus \( b' = c_2/(pt_1) \) for working hard in Stage 2.
It is worth noting that as the project value $B$ goes larger, both (22) and (23) are less likely to be binding. Intuitively, the principal, if cheating in the IPE, will lose a certain amount of expected revenue under the performance-review regime, because false performance feedback leads to an incorrect replacement of the agent. After characterizing the optimal contract, we obtain the following proposition.

**Proposition 5** Suppose that the IPE is subjective.

(i) The performance-review contract is implementable if and only if

$$t_1 B \geq \frac{1}{(1-p)p} \left( \frac{1}{r_1} c_1 - \frac{t_0 c_2}{t_1} \right).$$

(ii) Suppose that (24) holds. The optimal performance-review contract under a subjective IPE is implemented at the same cost as its counterpart under an objective IPE, if

$$\left( p - \mu \right) t_1 B \geq \left[ \left( \frac{1}{p} - 1 \right) t_0 + \left( 1 - \mu \right) t_1 \right] \frac{c_2}{t_1} - \max \left\{ \left( \frac{c_1}{pr_1} - \frac{t_0 c_2}{t_1} \right), 0 \right\};$$

otherwise, the cost of the former contract is strictly higher than the cost of the latter contract, but is decreasing in $B$.

Part (i) of Proposition 5 indicates that for a performance-review contract to be implementable under the subjective IPE, it requires that the project value $B$ is greater than a threshold that is related to $c_1$ and $c_2$. Intuitively, if $c_1$ is large relative to $c_2$, the Stage-1 IC constraint (14) tends to be binding, and the principal would use a large $b_h$ or $w_h$ to induce $e_1 = 1$; however, as dictated by the truth-telling constraint (22), $b_h$ and $w_h$ should be sufficiently small in order to insure the principal’s honesty upon observing a high IPE signal. These two opposite forces may drive the implementation of a performance-review contract to be infeasible. Nevertheless, such a conflict can be reconciled by an increase in $B$, which relaxes (22) but does not affect (14).

Part (ii) states that if the IPE is subjective rather than objective, the implementation cost of the optimal performance-review contract does not necessarily increase. (25) summarizes the two scenarios where this argument holds true. First, if $B$ is greater than a threshold, both

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24 (24) guarantees that (14) and (22) can hold simultaneously. The proof of Proposition 5 also discusses other conditions that need to be satisfied, but they are satisfied given assumption A1.
the truth-telling constraints, (22) and (23), are unbinding, and for this reason, the optimal performance-review contracts under either objective or subjective IPE are solved subject to the same set of constraints. Second, if $c_1$ is sufficiently large relative to $c_2$ such that the Stage-1 IC constraint (14) is binding, the optimal performance-review contract is still implemented at the same cost under the subjective IPE as that under the objective IPE, even though certain truth-telling constraint, (23), is binding.\footnote{As shown in the Appendix, if the IPE is objective and (14) is binding, there exist multiple choices for the optimal performance-review contracts, because increasing $w_h$ is equally as cost-effective as increasing $b_h$ for relaxing (14). If the IPE turns to be subjective but (14) is still binding, imposing additional truth-telling constraints confines the principal’s optimal choice to one of multiple choices under the objective IPE, while the cost of implementation does not increase.}

Proposition 5, in combination with Proposition 4, suggests that given a subjective IPE, there exist circumstances where an extra cost is incurred to "signal" the principal’s honesty under the dual-review regime, but such a cost may be avoidable under the performance-review regime. The underlying reasons are two-fold. First, in the absence of an ability appraisal, performance feedback is indicative of the agent’s productive type, and also determines his turnover, hence cheating may result in a revenue loss for the principal. This explains that a larger project value weakens the principal’s cheating motive under the performance-review regime, while such effect does not appear under the dual-review regime. Second, recall that under the dual-review regime, when $c_1$ is sufficiently large relative to $c_2$, the Stage-1 IC constraint (17) is binding, and the principal is tempted to claim a low IPE result in order to renege on the subjective pay that was promised for rewarding a high IPE result. Under the performance-review regime, though such an under-reporting/reneging motive still exists on the principal’s part when the Stage-1 IC constraint (14) is binding, it is offset by an overstating motive, because now communicating a high IPE result to the agent can boost his self-assessment of ability and lowers the incentive cost in Stage 2.

5.3 The optimal regime

The following proposition characterizes the principal’s optimal regime when a subjective IPE is available (but is not necessarily chosen). Before it, we define the project value $B$ that satisfies (24) with equality as $\beta^{imp}$. 

...
Proposition 6 Suppose that the IPE is subjective.

(i) Under the optimal regime, the principal chooses either an ability appraisal or an IPE, but does not choose both of them.

(ii) Suppose that $c_1$ is sufficiently large relative to $c_2$.
   - When $r_0 + r_1 \geq \frac{(t_0-t_0^0)-(t_0^1+t_1)}{(t_0-t_0^0)}$, there exists a threshold $\beta^S \in (\beta^{imp}, +\infty)$ such that the principal is able to, and does, implement the performance-review regime if $\beta^{imp} < B \leq \beta^S$, and implements the ability-review regime otherwise.
   - When $r_0 + r_1 < \frac{(t_0-t_0^0)-(t_0^1+t_1)}{(t_0-t_0^0)}$, the principal implements the ability-review regime.

Part (i) of Proposition 6 immediately follows from Proposition 4: In the presence of an ability appraisal, conducting a subjective IPE can not enhance the principal’s payoff. Notice that we have ignored the cost of conducting an IPE; a small increase in such a cost will render the dual-review regime to be strictly dominated by the ability-review regime. So when finding the principal’s optimal regime, it is without loss of generality to compare the performance-review regime with the ability-review regime.

In Part (ii), before doing the comparison, we impose a sufficiently high ratio of $c_1/c_2$. This assumption ensures that our analysis is non-trivial. When $c_1$ is small relative to $c_2$, the ability-review regime would dominate the performance-review regime, because the relative advantage of adopting the latter regime arises only when the Stage-1 IC constraints are binding under these regimes. Moreover, this assumption guarantees that (25) is satisfied, so we can avoid tedious case distinction when calculating the cost of the optimal performance-review contract.

Figure 1 illustrates how the subjective nature of the IPE influences the optimal design of midterm reviews. Panel a depicts the principal’s optimal regime in case that an objective IPE is allowed, while Panel b depicts her optimal regime in case that a subjective IPE is allowed. In both panels, the horizontal axis denotes the principal’s valuation of final success, $B$, and the vertical axis denotes the agent’s cost of Stage-1 effort, $c_1$. The shaded region depicts the set of $(B, c_1)$ in which the principal prefers the performance-review regime to other regimes. (We assume that $(r_0 + r_1)$ is sufficiently large so that the shaded region appears in both panels.) Outside the shaded region, the principal will choose the dual-review regime if the available IPE is objective, but will choose the ability-review regime if the available IPE is subjective.

28
In Panel a, the shaded region where the performance-review regime is chosen is bounded right by $B = \beta^O$. Intuitively, being unaware of the result of an ability appraisal and relying on the outcome of an IPE, the principal may replace a type-$\theta$ agent with a type-$\theta$ agent at the interim stage, causing a revenue loss. An increase in $B$ enlarges such a revenue loss and hence disfavors the performance-review regime. In Panel b, the shaded region is bounded right by $B = \beta^S$, due to the same reason as in Panel a; moreover, it is bounded left by $B = \beta^{imp}$, because a very small $B$ may cause the performance-review contract to be not implementable under a subjective IPE. In both panels, the shaded region appears, only when $c_1$ is large enough relative to $c_2$. Because the relative advantage of using the performance-review regime results from saving the cost of inducing Stage-1 effort, the desirability of choosing it hinges on whether the incentive-provision problem in Stage 1 is sufficiently important (e.g., the cost ratio $c_1/c_2$ is sufficiently high).

Note that the cutoff $\beta^O$ in the objective IPE case increases in $c_1$ when $c_1$ is small, but it does not change with $c_1$ when $c_1$ is greater than a threshold. On the other hand, the cutoff $\beta^S$ in the subjective IPE case always increases in $c_1$. The underlying reason is as follows. If the IPE is objective, the two candidates for the optimal regime both involve an IPE, hence the principal can use similar payment instruments contingent on the IPE result (e.g., $b_h$ or $w_h$) to deter the agent’s shirking in Stage 1. If $c_1$ is sufficiently large such that the Stage-1 IC constraints are binding under both the performance-review regime and the dual-review regime, a further increase in $c_1$ would not inflate the costs saved by using one regime relative to the other.\footnote{Under the dual-review regime, the Stage-1 IC constraint is more likely to be binding than that under the performance-review regime. So if $c_1$ is in the intermediate range in which only the Stage-1 IC constraint under the dual-review regime is binding, an increase in $c_1$ inflates the cost saved by using the performance-review regime.} However, if the IPE is subjective, the presence of an ability appraisal makes the principal unable to reward the agent contingent on the IPE result. To provide incentives in Stage 1, the cost-effective instruments $b_h$ or $w_h$, which are used under the performance-review regime, are unavailable under any other regimes, such as the ability-review regime. This explains that an increase in $c_1$ always enhances
the relative advantage of adopting the performance-review regime given a subjective IPE.

6 Extensions and discussion

6.1 Effort interdependence

In the previous analysis, we have assumed that the effort of the type-$\theta$ agent does not enhance the success probability in any stage, and that the effort of the type-$\vartheta$ agent increases a fixed amount of success probability in Stage 2 regardless of the Stage-1 outcome. While the former assumption is made to simplify the analysis, the latter assumption ensures that efforts across stages are independent.

However, it is worthwhile to study a more general model. An agent’s efforts across stages may share certain complementarity (or substitutability); in other words, the Stage-2 effort will become more (less) productive given a higher level of effort invested in Stage 1. To incorporate this feature, we need to slightly adapt the model presented in Section 2. We continue to maintain the assumption that the efforts of the type-$\theta$ agent are totally unproductive. As for the type-$\vartheta$ agent, in Stage 1 his effort still increases the probability of generating a high-quality interim product by an amount of $r_1$, but in Stage 2 the impact of his effort depends on the interim product’s quality: if this agent works upon a high-quality interim product and chooses the effort level $e_2$, the final success probability is $(t_0 + t_1 e_2)$; if he works upon a low-quality interim product, the final success probability turns out to be $(t_0' + t_1' e_2)$. We still assume that $t_0 \geq t_0'$, in accord with the definition of a high-quality interim product. However, $t_1$ can differ from $t_1'$:

(i) if $t_1 = t_1'$, it implies that efforts across stages are independent;
(ii) if $t_1 < t_1'$, it implies that efforts across stages are substitutable;
(iii) if $t_1 > t_1'$, it implies that efforts across stages are complementary.

In any case, we assume that $t_0 + t_1 \geq t_0' + t_1'$ to justify the need of a high level of Stage-1 effort. While our previous analysis focused on case (i), this subsection will study the latter two cases. Given effort substitutability or complementarity, a question immediately arises as to whether or not the presence of an ability appraisal undermines the feasibility of contracting on a subjective IPE. Our analysis is still restricted to the contracts that satisfy the full-revealing property.
Proposition 7 Suppose that the IPE is subjective.

(i) Consider the case where efforts across the stages are substitutes, i.e., \( t_1 < t'_1 \). The optimal ability-review contract weakly dominates the optimal dual-review contract (with the strict dominance holding when \( c_1 < \frac{pr_1(t_0+t_1-t'_0-t'_1)}{t_1}c_2 \)).

(ii) Consider the case where efforts across the stages are complements, i.e., \( t_1 > t'_1 \). If \( c_1 \) is sufficiently small relative to \( c_2 \) and

\[
(t_0 + t_1 - t'_0 - t'_1) \left( (r_0 + r_1) + (1 - r_0 - r_1) \frac{t'_1}{t_1} \right) + t'_1 t_1 < t_0,
\]

the optimal dual-review contract dominates the optimal ability-review contract; otherwise, the latter contract dominates the former contract.

If the ability appraisal was chosen that perfectly reveals the agent’s type, the IPE result is irrelevant to the principal’s decision of agent replacement. However, given effort interdependence, performance feedback may affect the rehired agent’s estimation of own productivity in Stage 2, and his morale as well. Therefore, the principal possesses a different motive when reporting her findings in the subjective IPE.

In case of effort substitutability, a good interim outcome means that the continuation effort of type-\( \theta \) agent is less productive, so reporting a high IPE signal to him will undermine morale. For this reason, under the dual-review regime, the principal has an even stronger motive to cheat when being aware of facing a type-\( \theta \) agent and observing a signal \( \sigma = h \) in the IPE: not only does under-reporting the performance by announcing \( m = l \) renege on the reward that was promised for inducing \( e_1 = 1 \), but it also saves the cost of inducing \( e_2 = 1 \). In order to refrain from cheating, the principal needs to increase the payments contingent upon a low IPE result, \( l \). Consequently, the optimal dual-review contract that satisfies the full-revealing property is characterized by \( w_l = w_h = 0 \) and \( b_l = b_h \), which is implemented at a cost that is not lower than the optimal ability-review contract.27

Consider, next, the case of effort complementarity. Now that a good interim outcome implies

\[
\text{If } c_1/c_2 \text{ is so low that the Stage-2 IC constraints are binding under both the dual-review contract and the ability-review contract, the former contract is characterized by bonuses } b_h = b_l = \frac{2c_2}{(c_0+c_1)t_1+(1-r_0-r_1)t_1} \text{, while the latter contract is characterized by a bonus } b = \frac{2c_2}{(c_0+c_1)t_1+(1-r_0-r_1)t_1}. \text{ It is easy to verify that } b_h = b_l > b, \text{ indicating that the optimal dual-review contract is implemented at a larger cost. However, if } c_1/c_2 \text{ is high, we have } b_h = b_l = b, \text{ indicating that the two aforementioned contracts are implemented at the same costs.}
\]

27
higher productivity of the type $\theta$ agent in the subsequent stage, reporting a high IPE signal to him boosts morale. Under the dual-review regime, when the ability appraisal confirms the Stage-1 agent of type $\theta$, it is less likely that the principal will under-report the interim performance to him, because doing so, though reneging on the subjective pay promised for rewarding the Stage-1 success, undermines this agent’s morale and inflates the incentive cost in Stage 2. Particularly, we find that the optimal dual-review contract can perform strictly better than the optimal ability-review contract, if the Stage-2 incentive-provision problem becomes sufficiently important (e.g., the cost ratio $c_1/c_2$ is sufficiently low) and the inequality (26) holds. This result shares certain similarities with Proposition 6 in Chen and Chiu (2012), but the difference is that they analyze the principal’s profitability of conducting a subjective IPE when there is no uncertainty about the agent’s ability and the same course of effort is intended in the post-evaluation stage.

6.2 The ability appraisal is noisy

In our model, it is assumed that the ability appraisal generates a more accurate signal about the agent’s type than the IPE does. Consequently, conducting an ability appraisal renders the IPE result useless in the principal’s decision of agent turnover. This is also a key assumption that underlies Proposition 4. However, another possibility is that given an ability appraisal in place, the IPE signal provides incremental information about the agent’s type. To analyze this case, we abandon the assumption that the ability appraisal perfectly reveals the agent’s type; instead, we assume that the ability appraisal generates a signal $\delta$, which

- equals $\delta_0$ with probability $q \in (1/2, 1)$ and equals $\delta$ with probability $(1 - q)$, if the agent is of type $\theta$;

- equals $\bar{\delta}$ with probability $q$ and equals $\delta$ with probability $(1 - q)$, if the agent is of type $\theta^*$.

So $q$ is a new parameter that captures the precision of the ability appraisal. We further obtain the following proposition.

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28 Inequality (26) is less likely to be satisfied, if $t_0/t_1$ is higher or if $t_0/t_1$ is lower. Intuitively, if the ratio $t_0/t_1$ becomes larger relative to the ratio $t_0/t_1$, it implies that the rent paid to the agent subsequent to $\sigma = l$ becomes larger relative to the counterpart paid subsequent to $\sigma = h$; the principal’s overstating motive is strengthened, so more money is burnt to ensure a truthful report.
Proposition 8 Suppose that the IPE is subjective, and that the ability appraisal is noisy as modeled in this subsection.

(i) If \( q < \frac{1}{2r_0 - r_1} \), the principal’s optimal choice is the performance-review regime.

(ii) If \( \frac{1}{2r_0 - r_1} \leq q < 1 \), there exists a parameter region where the principal’s optimal choice is the dual-review regime.

Result (i) concerns with the situation where the ability appraisal is so noisy that it reveals a less accurate signal about the agent’s type than the IPE does. In this setting, the principal can maximize the expected productivity of the agent hired in Stage 2, by making the firing decision contingent only on the IPE result: the Stage-1 agent is fired if the IPE reveals a low signal (\( \sigma = l \)), and is rehired otherwise. For this reason, conducting an IPE not only provides an additional measurement of interim performance that facilitates motivating Stage-1 effort, but also yields sufficient information for making an efficient replacement of Stage-2 agent. So the principal will only choose an IPE under her optimal regime.

Result (ii) concerns with the situation where the ability appraisal is precise enough but not perfect, such that the efficient replacement of agent is reliant on the results of both an IPE and an ability appraisal: the Stage-1 agent is fired if the IPE reveals \( \sigma = l \) and the ability appraisal reveals \( \delta = \delta_1 \), and is rehired otherwise. It is evident that the dual-review regime achieves the largest probability of final success, so it dominates all other regimes if the project value \( B \) is sufficiently large.\(^{29}\)

Another dose of realism is that not only the ability appraisal but also the IPE contain noises. Rather than studying such a full model, we conjecture that (i) if the ability appraisal provides sufficient information for making an efficient firing decision, the dual-review regime is weakly dominated by the ability-review regime given the subjectivity of the IPE (e.g., Proposition 4 holds); (ii) if the IPE provides sufficient information for making an efficient firing decision, the performance-review regime dominates all other regimes (e.g., Result (i) of Proposition 8 holds); (iii) if the efficient firing rule relies on the results of both an ability appraisal and an IPE, under the optimal regime, the principal may choose an IPE, or an ability appraisal, or both of them, depending on the parameters (e.g., Result (ii) of Proposition 8 holds).

\(^{29}\)In the proof of Proposition 8, we also show that the implementation cost of the optimal dual-review contract under the subjective IPE is weakly decreasing in \( B \).
6.3 The feedback role of subjective performance evaluations

As the literature on subjective performance evaluations (e.g., Levin 2003; MacLeod 2003) indicates, to prevent moral hazard from arising for the agent and adverse selection from occurring for the principal, subsequent to low performance destruction of mutual benefit (such as termination of the continuation relationship) is necessary. The difficulty is to determine how this can be implemented if a renegotiation of the contract is unavoidable.

By assuming that the agent’s ability is unknown at the start and that a replacement of the agent is allowed subsequent to midterm reviews, we find that if only an IPE is conducted, there exist renegotiation-proof contracts in which the principal fires the first-stage agent once a low IPE signal is detected, because this IPE result indicates that the original agent is less likely to be of high ability than an outside agent is. However, if both an IPE and an ability appraisal are conducted, the principal cannot commit to do so, because in the presence of an ability appraisal, the IPE result no longer affects the principal’s judgement of the agent’s ability, neither does it influence the agent’s assessment of future productivity given effort independence. Summarizing the analysis, we find that preserving the feedback role of subjective performance evaluation is essential for proposing a renegotiation-proof contract on it.

An empirical implication of this result is that to make subjective performance evaluation function well, the managers may use the performance appraisal data for multiple personnel decisions, including salary increases, recommendations for promotion, transfers, and training programs, as well as for employee development and performance feedback. The prevalence of multiple uses of performance appraisal is well documented by management scholars (e.g., Huber 1983; Jacob, Kafry and Zedeck 1980; Landy and Farr 1983). Moreover, the empirical research of Cleveland et al. (1989) shows that most of managers, when being asked why to conduct a performance evaluation, choose a variety of purposes; in particular, salary administration and performance feedback were cited by 69% and 53% of the survey respondents, with a high correlation. Similar findings have been obtained in other empirical studies (e.g., Rendero 1980), supporting that designing incentive schemes and providing informative feedback are usually two indispensable purposes of conducting performance evaluations.
6.4 The ability appraisal is subjective

Previously, we assumed that the ability appraisal reveals a signal that is publicly observable and verifiable. This assumption is not unrealistic, especially when the ability appraisal is conducted by a third party or an outside rater. However, in other settings, assessing the agent’s capacity is subjective, in the sense that it provides a private and unverifiable signal to the principal alone. In this subsection, we extend the analysis to study this case.

Consider the ability-review contract that is described by Definition 2. When the principal finds that the outcome of the ability appraisal is \( \theta = \theta_0 \), she will truthfully report it to the agent, if

\[
\left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t_1' + t_1 \right] (B - b) - w
\geq \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t_1' + pt_1 \right] \left( B - \frac{c_2}{pt_1} \right) - w'.
\]

The LHS of (27) calculates the principal’s payoff upon informing the agent of type \( \theta_0 \) and rehiring him in Stage 2, and its RHS calculates the principal’s payoff when she cheats by claiming that the agent is of type \( \theta_0 \) and then bringing in a new agent as a replacement. Moreover, we find that the optimal ability-review contract that is solved without truth-telling constraints, and that is characterized by (11), does not necessarily violate (27), if the extra benefit of retaining the type-\( \theta_0 \) agent for Stage 2 is not fully offset by the increase in payments due to the rehiring. Otherwise, (27) tends to be binding. In the latter case, the principal will set a sufficiently large \( w' \) (i.e., the wage paid to the type-\( \theta_0 \) agent) to refrain from cheating when observing \( \theta = \theta_0 \). We define \( w' \) that solves (27) with equality as \( w' \).

Likewise, the principal will tell the truth when finding \( \theta = \theta_0 \) in the ability appraisal, if

\[
\left( t_0' + pt_1 \right) \left( B - \frac{c_2}{pt_1} \right) - w' \geq t_0' (B - b) - w.
\]

When the principal observes \( \theta = \theta_0 \), cheating leads to a rehiring of a low-ability agent, who is totally unproductive. The RHS of (28) computes the principal’s payoff of cheating. However, given that \( w' \) is not very large, a truthful report and an agent replacement are more profitable in this situation, with the principal’s payoff calculated in the LHS of (28).
We then characterize the optimal ability-review contract that satisfies the full-revealing property in the following proposition.

**Proposition 9** Suppose that the ability appraisal is subjective.

(i) The ability-review contract is implementable if and only if

\[
\frac{[(r_0 + r_1) (t_0 - t'_0) + t_1]}{pr_1 (t_0 - t'_0)} c_1 < t_1 B + \frac{(r_0 + r_1) (t_0 - t'_0)}{pt_1} c_2. \tag{29}
\]

(ii) Suppose that (29) holds. The optimal ability-review contract is characterized by

\[
w^f = \max \{w', 0\}; \quad w = 0; \tag{30}
\]

\[
b = \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{t_1} \right\}.
\]

Such a contract dominates the optimal no-review contract.

Result (i) clarifies the condition under which the ability-review contract is implementable. Intuitively, though being aware of facing a high-ability agent, the principal may not find it profitable to rehire him, if the bonus \(b\) that will be paid to him upon final success is too high; replacing this agent by misreporting his type allows significant savings in labor costs. So truth telling imposes an upper bound for \(b\).\(^{30}\) On the other hand, inducing high effort in Stage 1 requires a sufficiently large bonus \(b\), which may be more than enough for motivating the rehired agent to work hard in Stage 2. Accordingly, the ability-review contract is implementable with full-revealing property, if the project value \(B\) is sufficiently large such that the truth-telling constraints (27) and (28) are relaxed, or if the cost ratio \(c_1/c_2\) is sufficiently low such that the Stage-1 agency problem is not serious. Result (ii) indicates that the optimal ability-review contract, if implementable, yields a larger profit than the optimal no-review contract.

Finally, we have several comments on the principal’s optimal regime if the ability appraisal and the IPE are both subjective. First, the dual-review regime cannot outperform the ability-review regime, because under the former regime, the truth-telling constraints, (20) and (21), are still imposed to insure the principal’s honesty in the subjective IPE, prohibiting a payment

\(^{30}\)To satisfy (27), \(b\) cannot be greater than a threshold that increases in the choice of \(w^f\). However, (28) imposes an upper bound for \(w^f\). So the two truth-telling constraints together set an upper bound for the choice of \(b\).
from being made contingent on the IPE signal. Second, a region of parameters emerges in which neither the performance-review contract nor the ability-review contract is implementable (e.g., neither (24) nor (29) is satisfied). In this case, the optimal regime contains no midterm evaluation, and the optimal contract is contingent only upon the final product’s quality.

7 Conclusions

Revealing information about the agent’s capacity or about the circumstances under which the agent performs a task helps to attribute performance feedback to a specific cause. However, it may bring forth two negative effects: first, as Crémer (1995) finds, it disables the principal from adopting rules such as "whatever the reasons, if the result is not up to par I will fire you;" second, we further show that if the measurement of the "par" is subjective, the principal cannot credibly use a payment scheme that is contingent on the "par" to motivate the agent, because revelation of the attributing factors undermines the principal’s honesty in feedback transmission.

Given that subjective performance evaluations are endemic to many significant situations, our theoretical findings throw light on the evaluation and contract design in practice. Following the convention in project management (Meredith and Mantel 1995), most real-life projects can be clumped into two categories. For the project that appears easy (or incurs a small labor cost) at an early stage but becomes tougher (or incurs a large labor cost) at a later stage, it is more desirable to appraise the agent’s capacity and use the resulting information for interim interventions; conversely, for the project that experiences many challenges at the start but becomes routine in the remaining work, it is more desirable to review only the interim performance and to reward the agent contingent upon it.

Moreover, our story may demonstrate the advantage of arm’s length relationship when subjective pay is used. As Riordan (1990) indicates, under vertical integration, the owner has better information about the supplier’s performance, but cannot commit to a payment contingent upon it, because the owner is tempted to manipulate the accounts. While lack of objective measure of performance potentially leads to the adverse selection problem on the principal’s side, our analysis shows that easy access to information about the causes of performance exacerbates this...
problem. If we accept the postulate that information is less freely available across organizational boundaries than within organizations, arm’s length relationship may facilitate contracting with subjective performance measures.
References


Appendix: Proofs

Proof of Proposition 1

Proof. The principal’s profit under the optimal no-review contract is denoted by $\Pi^N$ and calculated as follows.

$$\Pi^N = \left\{ p \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] + (1 - p) t'_0 \right\} \times \left[ B - \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\} \right].$$

The principal’s profit under the optimal ability-review contract is denoted by $\Pi^A$ and calculated as follows.

$$\Pi^A = p \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] \times \left[ B - \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\} \right] + (1 - p) \Pi'.$$

Thus,

$$\Pi^A - \Pi^N = p \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] \times \left[ \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\} - \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\} \right]$$

$$+ (1 - p) \left[ pt_1 B - c_2 + t'_0 \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{pt_1} \right\} - t'_0 \frac{c_2}{pt_1} \right].$$

In the RHS of above equality, the first term is positive; the second term is also positive because $pt_1 B > c_2$ according to assumption A1. So it is evident that $\Pi^A - \Pi^N > 0$. ■
Proof of Proposition 2

**Proof.** The principal’s profit under the optimal dual-review contract is denoted by $\Pi^D$ and calculated as follows.

\[
\Pi^D = p (r_0 + r_1) (t_0 + t_1) \left[ B - \max \left\{ \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0' + t_1')}{(t_0 + t_1) \ t_1}, \frac{c_2}{t_1} \right\} \right] + p (1 - r_0 - r_1) (t_0' + t_1) \left( B - \frac{c_2}{t_1} \right) + (1 - p) \Pi',
\]

and the principal’s payoff under the optimal ability-review contract is $\Pi^A$ calculated in (32), so

\[
\Pi^D - \Pi^A = p (r_0 + r_1) (t_0 + t_1) \times \left[ \max \left\{ \frac{c_1}{pr_1 (t_0 - t_0')}, \frac{c_2}{t_1} \right\} - \max \left\{ \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0' + t_1')}{(t_0 + t_1) \ t_1}, \frac{c_2}{t_1} \right\} \right] + p (1 - r_0 - r_1) (t_0' + t_1) \left[ \max \left\{ \frac{c_1}{pr_1 (t_0 - t_0')}, \frac{c_2}{t_1} \right\} - \frac{c_2}{t_1} \right].
\]

Note that $\max \left\{ \frac{c_1}{pr_1 (t_0 - t_0')}, \frac{c_2}{t_1} \right\} \geq \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0' + t_1')}{(t_0 + t_1) \ t_1}$ because (i) if $\frac{c_1}{pr_1 (t_0 - t_0')} \geq \frac{c_2}{t_1}$ then $\frac{c_1}{pr_1 (t_0 - t_0')} \geq \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0' + t_1')}{(t_0 + t_1) \ t_1}$, and (ii) if $\frac{c_1}{pr_1 (t_0 - t_0')} < \frac{c_2}{t_1}$ then $\frac{c_2}{t_1} > \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0' + t_1')}{(t_0 + t_1) \ t_1}$.

Hence, both the first term and the second term in the RHS of (34) are positive. It holds true that $\Pi^D - \Pi^A \geq 0$. ■

Proof of Proposition 3

**Proof.** Part (i) directly follows from Propositions 1 and 2.

Part (ii): The principal’s payoff under the optimal performance-review contract is denoted by $\Pi^P$ and calculated as follows.

\[
\Pi^P = p (r_0 + r_1) (t_0 + t_1) \left[ B - \max \left\{ \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)} \frac{c_2}{t_1} \right\} \right] + [1 - p (r_0 + r_1)] \Pi',
\]

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and the principal’s payoff under the optimal dual-review contract is $\Pi_D$ calculated in (33). Thus,

$$\Pi_D - \Pi_P = p(r_0 + r_1)(t_0 + t_1)$$

$$\times \left[ \max \left\{ \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)}, \frac{c_2}{t_1} \right\} - \max \left\{ \frac{c_1}{pr_1 (t_0 + t_1)} + \frac{(t_0 + t_1) c_2}{(t_0 + t_1) t_1}, \frac{c_2}{t_1} \right\} \right]$$

$$+ (1 - p)(1 - r_0 - r_1) \frac{t_0 c_2}{t_1} + p(1 - r_0 - r_1)(1 - p)t_1 B.$$

It is evident that $(\Pi_D - \Pi_P)$ is increasing in $B$, but is weakly decreasing in $c_1$. $(\Pi_D - \Pi_P)$ is further computed in the following three cases.

1. If $c_1 < \frac{pr_1 (t_0 - t_0')}{t_1} c_2$,

$$\Pi_D - \Pi_P = p(1 - r_0 - r_1)(1 - p)t_1 B + (1 - p)(1 - r_0 - r_1) \frac{t_0 c_2}{t_1} \geq 0.$$

2. If $\frac{pr_1 (t_0 - t_0')}{t_1} c_2 \leq c_1 < \frac{pr_1 t_0}{t_1} c_2$,

$$\Pi_D - \Pi_P = p(1 - r_0 - r_1)(1 - p)t_1 B$$

$$+ p(r_0 + r_1) \left( \frac{t_0 - t_0'}{t_1} c_2 - \frac{c_1}{pr_1} \right) + (1 - p)(1 - r_0 - r_1) \frac{t_0 c_2}{t_1}.$$

3. If $c_1 \geq \frac{pr_1 t_0}{t_1} c_2$,

$$\Pi_D - \Pi_P = p(1 - r_0 - r_1)(1 - p)t_1 B - \left[ p + (r_0 + r_1) - 1 \right] \frac{t_0 c_2}{t_1}.$$

Regarding $(\Pi_D - \Pi_P)$ calculated above, we have Claims 1, 2 and 3.

**Claim 1** Suppose that $c_1 \geq \frac{pr_1 t_0}{t_1} c_2$ and that $B = \overline{B}$. There exists a cutoff $R \in (0, 1)$ such that $\Pi_D - \Pi_P \leq 0$ if and only if $r_0 + r_1 \geq R$.

To prove Claim 1, first, we find that in case that $(r_0 + r_1) \rightarrow 0$,

$$\Pi_D - \Pi_P = p(1 - p)t_1 B + (1 - p) \frac{t_0 c_2}{t_1} \geq 0.$$
Second, in case that \((r_0 + r_1) \to 1\),
\[
\Pi^D - \Pi^P = -p t'_0 c_2 \leq 0.
\]

We further find that if \(c_1 \geq \frac{pr_{10}}{t_0} c_2\), \((\Pi^D - \Pi^P)\) is monotonously decreasing in \((r_0 + r_1)\).

Applying the intermediate value theorem, Claim 1 is immediate.

**Claim 2** Suppose that \(c_1 \geq \frac{pr_{10}}{t_0} c_2\) and \(r_0 + r_1 \geq R\). There exists a cutoff \(\beta^O > B\) such that \((\Pi^D - \Pi^P) \leq 0\) if and only if \(B \leq \beta^O\).

Given Claim 1 and the fact that \((\Pi^D - \Pi^P)\) is increasing in \(B\), Claim 2 is proved.

**Claim 3** There exists a cutoff \(\alpha > 0\): (i) if \(c_1 < \alpha c_2\), it always holds true that \((\Pi^D - \Pi^P) > 0\); (ii) if \(c_1 \geq \alpha c_2\), the sign of \((\Pi^D - \Pi^P)\) depends on other parameters, such as \(B\) and \((r_0 + r_1)\).

Claim 3 follows from Claims 1,2 and the fact that \((\Pi^D - \Pi^P)\) is weakly decreasing in \(c_1\).

Therefore, Claims 1,2,3 lead to Part (ii) of Proposition 3. ■

**Proof of Proposition 4**

**Proof.** First, we prove the following claim.

**Claim 4** Suppose that the IPE is subjective. The optimal dual-review contracts are characterized by \(b_l \geq b_h\) and \(w_h \geq w_l = 0\).

By rearranging (20) and (21), we find that
\[
(t_0 + t_1) (b_l - b_h) \geq w_h - w_l \geq (t'_0 + t_1) (b_l - b_h),
\]
so if (20) and (21) hold simultaneously, it requires that \(b_l \geq b_h\) and \(w_h \geq w_l\) because \((t_0 + t_1) \geq (t'_0 + t_1)\).

Then we prove \(w_l = 0\). Between the two truth-telling constraints, we find that (20) is more likely to be binding. In other words, the principal is more likely to cheat when receiving \(\sigma = h\). The reason is that, according to the optimal dual-review contracts characterized by
(19) or footnote 17 under the objective IPE, if (17) is binding, the principal may set a high \( b_h \) (relative to \( b_l \)) or a positive \( w_h \) to induce \( c_1 = 1 \); in this case, announcing \( l \) instead of \( h \) saves the implementation cost of contract, while not reducing the expected benefit. The principal can increase either \( w_l \) or \( b_l \) to commit to truth telling, but analysis shows that increasing \( b_l \) is more cost-effective than increasing \( w_l \). To be more concrete, (20) is unaffected if increasing \( b_l \) by one unit and reducing \( w_l \) by \( (t_0 + t_1) \), but the implementation cost is reduced by

\[
p(1 - r_0 - r_1) \left[ (t_0 + t_1) - (t_0' + t_1) \right] \geq 0.
\]

Thus, to prevent cheating, the principal will increase \( b_l \) alone, while keeping \( w_l = 0 \). Claim 4 is proved.

We find that if the Stage-1 IC constraint, (17), is not binding, the contract characterized by (19) satisfies (20) and (21), and is hence applicable under a subjective IPE. Moreover, it is easily verified that this contract is payoff equivalent to the optimal ability-review contract that is characterized by (11).

However, if the Stage-1 IC constraint, (17), is binding, the contract characterized by (19) dictates that \( b_h \geq b_l \), which violates Claim 4 and suggests the bindingness of some truth-telling constraints under a subjective IPE. When characterizing the optimal contract in this case, we find that there are multiple solutions, because using \( w_h \) and using \( b_h \) are equally cost-effective to relax (17). We categorize all possible solutions into two groups:

(i) If the principal sets \( w_h = 0 \), the two truth-telling constraints, (20) and (21), dictate that \( b_h = b_l \) and \( w_l = 0 \). So the optimal dual-review contract is characterized by

\[
\begin{align*}
w^f & = w_h = w_l = 0; \\
b_h & = b_l = \frac{c_1}{pr_1(t_0 - t_0')}. 
\end{align*}
\]

This contract is payoff equivalent to the optimal ability-review contract that is characterized by (11).

(ii) If the principal sets a positive \( w_h \), the optimal choice of \( w_h \) should satisfy (17) with equality.
Given $w_l = 0$,

$$w_h = \frac{c_1}{pr_1} - \left[(t_0 + t_1) b_h - (t'_0 + t_1) b_l\right]. \quad (37)$$

Moreover, $b_l$ should satisfy (20) with equality (by substituting $w_l = 0$).

$$b_l = \frac{1}{t_0 + t_1} w_h + b_h. \quad (38)$$

Substituting $w_h$ into (38) by using (37), we find that

$$b_l = \frac{1}{t_0 + t_1} \frac{c_1}{pr_1} + \frac{t'_0 + t_1}{t_0 + t_1} b_l;$$

with some rearrangement, it is equivalent to

$$b_l = \frac{c_3}{pr_1 (t_0 - t'_0)}. \quad (39)$$

Substituting $b_l$ into (37) by using (39), we find that

$$w_h = \frac{t_0 + t_1}{t_0 - t'_0} \frac{c_1}{pr_1} - (t_0 + t_1) b_h. \quad (40)$$

By using (39) and (40), we calculate the implementation cost of this contract.

$$p (r_0 + r_1) \left[(t_0 + t_1) b_h + w_h\right] + p (1 - r_0 - r_1) \left[(t'_0 + t_1) b_l + w_l\right]$$

$$= p (r_0 + r_1) (t_0 + t_1) \frac{c_1}{pr_1 (t_0 - t'_0)} + p (1 - r_0 - r_1) (t'_0 + t_1) \frac{c_1}{pr_1 (t_0 - t'_0)},$$

which is equivalent to the implementation cost of the contract characterized by (36), as well as that of the optimal ability-review contract characterized by (11). Note that these contracts always generate the same expected benefit for the principal. Thus, we complete the proof.

$\blacksquare$
Proof of Proposition 5

**Proof.** First, we claim that under the optimal performance-review contract, \( w_l = b_l = 0 \). The reason is that, an increase in \( w_l \) or \( b_l \) dilutes the incentive in Stage 1, and also triggers the truth-telling constraint, (23), more likely to be binding.

Second, we can represent the choices of \((b_h, w_h)\) in a diagram (see Figure 2). The horizontal axis denotes \( b_h \) and the vertical axis denotes \( w_h \). (22) is satisfied if and only if \((b_h, w_h)\) is below or on the \( h \) line. (23) is satisfied if and only if \((b_h, w_h)\) is above or on the \( l \) line. The Stage-1 IC constraint, (14), is satisfied if and only if \((b_h, w_h)\) is above or on the \( IC_1 \) line. The Stage-2 IC constraint, (15), is satisfied if and only if \((b_h, w_h)\) is on the right side of or on the \( IC_2 \) line.

We note that the \( IC_1 \) line is parallel to the \( h \) line and the iso-cost curves. Moreover, the \( l \) line has a flatter slope than the aforementioned lines. The shaded region depicts the set of feasible solutions satisfying all these constraints, and one can verify that the optimal choice of \((b_h, w_h)\) is the dotted point within the shaded region.

Figure 2 about here

The two panels in Figure 2 depict the two cases: Panel a illustrates the case in which the \( h \) line has a larger horizontal intercept than the \( l \) line, while Panel b illustrates the case in which the \( l \) line has a larger horizontal intercept than the \( h \) line. In any case, we can show that the \( h \) line always has a larger vertical intercept than the \( l \) line, because

\[
(1 - p) t_1 B + (t_0 + pt_1) \frac{c_2}{pt_1} \geq -(p - \mu) t_1 B + (t'_0 + pt_1) \frac{c_2}{pt_1},
\]

where the LHS calculates the vertical intercept of \( h \) line and the RHS calculates the vertical intercept of \( l \) line.

Part (i): to guarantee the existence of a solution, we should find the condition under which the shaded region appears. In Panel a, if a shaded region appears, the horizontal intercepts of \( IC_1 \) line and \( IC_2 \) line should be smaller than the horizontal intercept of \( h \) line. The according
conditions are
\[\frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)} \leq \frac{(1 - p) t_1 B + (t_0 + pt_1) \frac{c_2}{pr_1}}{(t_0 + t_1)},\] 
and
\[\frac{c_2}{t_1} \leq \frac{(1 - p) t_1 B + (t_0 + pt_1) \frac{c_2}{pr_1}}{(t_0 + t_1)}.\] 

Obviously, (42) is self-satisfied, while (41) is re-written as (24).

In Panel b, if a shaded region appears, it requires that both \(IC_1\) line and \(IC_2\) line are on the left side of the intersection point of \(h\) line and \(l\) line. The according conditions are (41) and
\[\frac{c_2}{t_1} \leq \frac{(1 - \mu) t_1 B + (t_0 - t'_0) \frac{c_2}{pr_1}}{(t_0 + t_1) - (t'_0 + \mu t_1)}.\] 

With some rearrangement, (43) is equivalent to
\[t_1 B \geq \left[ t_1 - \frac{(1 - p) (t_0 - t'_0)}{p (1 - \mu)} \right] \frac{c_2}{t_1}.\] 

We can verify that (44) is satisfied given assumption A1.

To sum up, the additional condition that is required for ensuring the existence of solution is (24).

Part (ii): Given that the shaded region exists, characterizing the optimal choice of \((b_h, w_h)\) is to pick up the dotted point within the shaded region.

First, we calculate the intersection point of the \(l\) line with the \(IC_1\) line.
\[b_h = \frac{(p - \mu) t_1 B + \frac{1}{pr_1} c_1 - \frac{t'_0}{pr_1} c_2}{(t_0 + t_1) - (t'_0 + \mu t_1)},\]
\[w_h = \frac{1}{pr_1} c_1 + c_2 - (t_0 + t_1) b_h.\]

Second, if the above intersection point is on the right side of \(IC_2\) line, i.e.,
\[\frac{(p - \mu) t_1 B + \frac{1}{pr_1} c_1 - \frac{t'_0}{pr_1} c_2}{(t_0 + t_1) - (t'_0 + \mu t_1)} \geq \frac{c_2}{t_1}.\]
and the horizontal intercept of $IC_1$ line is larger than that of $IC_2$ line, i.e.,

$$\frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)} \geq \frac{c_2}{t_1}, \quad (46)$$

then the Stage-1 IC constraint (14) is binding and the Stage-2 IC constraint (15) is not binding. (45) is re-written as

$$(p - \mu) t_1 B \geq \left[ \left( \frac{1}{p} - 1 \right) t_0' + (1 - \mu) t_1 + t_0 \right] \frac{c_2}{t_1} - \frac{c_1}{pr_1}, \quad (47)$$

and (46) is re-written as

$$c_1 \geq \frac{pr_1 t_0}{t_1} c_2. \quad (48)$$

Thus, if both (47) and (48) hold, the optimal choice of $(b_h, w_h)$ fulfills

$$b_h = \min \left\{ \frac{(p - \mu) t_1 B + \frac{1}{pr_1} c_1 - \frac{c_2}{pr_1} c_2}{(t_0 + t_1) - (t_0' + \mu t_1)} \cdot \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)} \right\}, \quad (49)$$

$$w_h = \max \left\{ \frac{1}{pr_1} c_1 + c_2 - (t_0 + t_1) b_h, 0 \right\}. \quad (50)$$

Third, if either (47) or (48) is not satisfied, the Stage-1 IC constraint (14) is not binding and the Stage-2 IC constraint (15) is binding. In this case, the optimal contract fulfills

$$b_h = \frac{c_2}{t_1}, \quad (50)$$

$$w_h = \max \left\{ \left[ \left( \frac{1}{p} - 1 \right) t_0' + (1 - \mu) t_1 \right] \frac{c_2}{t_1} - (p - \mu) t_1 B, 0 \right\}. \quad (50)$$

We then prove a sequence of claims.

**Claim 5** If both (47) and (48) hold, the implementation cost of the optimal performance-review contract under the subjective IPE is the same as that under the objective IPE.

If both (47) and (48) hold, the implementation cost of the optimal performance-review contract under the subjective IPE is calculated by using (49). On the other hand, given (48) holding, the optimal performance-review contract under the objective IPE is characterized by
\( w_h = w_l = b_l = 0 \) and \( b_h = \frac{c_1 + p r_1 c_2}{p r_1 (t_0 + t_1)} \) according to (16). We can verify that these two contracts are implemented at the same costs.

For easy check, let note that in Figure 2, the optimal choices of \((b_h, w_h)\) under both the subjective IPE and the objective IPE are located on the same \(IC_1\) line. Because the \(IC_1\) line is parallel to iso-cost curves, any point located on the \(IC_1\) line generates the same costs.

**Claim 6** Suppose that (48) is not satisfied. The implementation cost of the optimal performance-review contract under the subjective IPE is the same as that under the objective IPE if

\[
(p - \mu) t_1 B \geq \left[ \left( \frac{1}{p} - 1 \right) t'_0 + (1 - \mu) t_1 \right] \frac{c_2}{t_1} \tag{51}
\]

otherwise, the former cost is strictly greater than the latter cost, but is decreasing in \(B\).

When (48) is not satisfied, the optimal performance-review contract under the objective IPE is characterized by \(w_h = w_l = b_l = 0\) and \(b_h = \frac{c_2}{t_1}\). On the other hand, the optimal performance-review contract under the subjective IPE is characterized by (50); the optimal choice of \((b_h, w_h)\) that is represented by the dotted point in Figure 2 is located on the \(IC_2\) line. There are two cases for consideration:

(i) If (51) is satisfied, the dotted point is the intersection of \(IC_2\) line and the horizontal axis such that \(w_h = 0\). In this case, the implementation cost of the optimal performance-review contract under the subjective IPE is equivalent to that under the objective IPE.

(ii) If (51) is not satisfied, the dotted point is the intersection of \(IC_2\) line and the \(l\) line such that \(w_h > 0\). In this case, the implementation cost of the optimal performance-review contract under the subjective IPE is greater than that under the objective IPE. Moreover, the former cost is decreasing in \(B\), because \(w_h\) is the only argument in the contract that is is decreasing \(B\).

By summarizing Claims 5 and 6, we find the implementation cost of the optimal performance-review contract under the subjective IPE is equivalent to that under the objective IPE, if either of the following two scenarios occurs: (i) both (47) and (48) hold; or (ii) (48) does not hold, but (51) holds. These two sets of conditions can be summarized by a single inequality (25).
Proof of Proposition 6

Proof. Part (i) directly follows from Propositions 1 and 4.

Part (ii): The principal’s payoff under the optimal ability-review contract is \( \Pi^A \) calculated in (32). Suppose that \( c_1 \) is sufficiently large relative to \( c_2 \) such that (25) is satisfied. The principal’s payoff under the optimal performance-review contract still equals to \( \Pi^P \) that is calculated in (35). Thus, \( \Pi^P \geq \Pi^A \), if

\[
p(r_0 + r_1)(t_0 + t_1) \left[ B - \max \left\{ \frac{c_1 + pr_1c_2}{pr_1(t_0 + t_1)}, \frac{c_2}{t_1} \right\} \right] + p(1 - r_0 - r_1) \Pi' \\
\geq p \left[ (r_0 + r_1)t_0 + (1 - r_0 - r_1)t_0' + t_1 \right] \left[ B - \max \left\{ \frac{c_1}{pr_1(t_0 - t_0')}, \frac{c_2}{t_1} \right\} \right].
\]

The above inequality is adapted into

\[
(1 - r_0 - r_1)(1 - p)t_1B \leq [(r_0 + r_1)t_0 + (1 - r_0 - r_1)t_0' + t_1] \\
\times \max \left\{ \frac{c_1}{pr_1(t_0 - t_0')}, \frac{c_2}{t_1} \right\} - (r_0 + r_1)(t_0 + t_1) \times \max \left\{ \frac{c_1 + pr_1c_2}{pr_1(t_0 + t_1)}, \frac{c_2}{t_1} \right\} \\
- (1 - r_0 - r_1)(t_0' + pt_1) \frac{c_2}{pt_1}.
\]

Regarding (52), we have the following claim.

Claim 7 Suppose that \( B = \overline{B} \). There exists a cutoff \( \alpha' \) such that (52) holds if \( c_1 \geq \alpha'c_2 \), and (52) does not hold if \( c_1 < \alpha'c_2 \).

Claim 7 is true due to the following facts.

(i) When \( c_1 \) is close to 0, the RHS of (52) is negative, while its LHS is positive, so (52) does not hold.

(ii) The RHS of (52) does not change with \( c_1 \) if \( c_1 \leq \frac{pr_1(t_0 - t_0')c_2}{t_1} \) but is strictly increasing in \( c_1 \) if \( c_1 > \frac{pr_1(t_0 - t_0')c_2}{t_1} \). Hence, we can find such a cutoff \( \alpha' \) as defined in the claim.

Moreover, to guarantee that the performance-review contract is implementable, it further requires that (24) holds. We define the value of \( B \) solving (52) with equality as \( \beta^S \), and the value of \( B \) solving (24) with equality as \( \beta^{imp} \). Thus, the principal is able to and does implement

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the performance-review contract, if and only if $\beta^{imp} < B \leq \beta^S$ and $\beta^S \geq \beta^{imp}$. In particular, we find that $\beta^S \geq \beta^{imp}$, if and only if

\[
\begin{align*}
&\left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] \times \max \left\{ \frac{c_1}{pr_1 (t_0 - t'_0)}, \frac{c_2}{t_1} \right\} \\
&- (r_0 + r_1) (t_0 + t_1) \times \max \left\{ \frac{c_1 + pr_1 c_2}{pr_1 (t_0 + t_1)}, \frac{c_2}{t_1} \right\} - (1 - r_0 - r_1) (t'_0 + pt_1) \frac{c_2}{pt_1} \\
&\geq (1 - r_0 - r_1) \frac{1}{p} \left( \frac{1}{r_1 c_1 - \frac{t_0}{t_1 c_2}} \right). 
\end{align*}
\]  

By analyzing (53), we further obtain the following claim.

**Claim 8** Suppose that $c_1 \geq \frac{pr_1 t_0}{t_1 c_2}$, $\beta^S \geq \beta^{imp}$ if and only if $r_0 + r_1 \geq \frac{(t_0 - t'_0) - (t'_0 + t_1)}{(t_0 - t'_0)}$.

Claim 8 is true due to the following facts.

(i) Both the LHS and RHS of (53) are increasing in $c_1$.

(ii) For a very small $c_1$ (e.g., $c_1 \to 0$), (53) always holds, because

\[
\begin{align*}
\text{LHS} &= \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] \frac{c_2}{t_1} \\
&- (r_0 + r_1) (t_0 + t_1) \frac{c_2}{t_1} - (1 - r_0 - r_1) (t'_0 + pt_1) \frac{c_2}{pt_1} \\
&= -(1 - r_0 - r_1) \frac{1}{p} (1 - p) \frac{t'_0}{t_1 c_2} \geq -(1 - r_0 - r_1) \frac{1}{p} \frac{t_0}{t_1 c_2} = \text{RHS}.
\end{align*}
\]

(iii) For a sufficiently large $c_1$ (e.g., $c_1 \geq \frac{pr_1 t_0}{t_1 c_2}$), (53) still holds, if and only if the LHS of (53) increases in $c_1$ at a greater rate than its RHS does. The according condition is

\[
\begin{align*}
\frac{\partial \text{LHS}}{\partial c_1} &= \left[ (r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1 \right] \frac{c_2}{(t_0 - t'_0)} - (r_0 + r_1) \frac{1}{pr_1} \\
&\geq (1 - r_0 - r_1) \frac{1}{pr_1} = \frac{\partial \text{RHS}}{\partial c_1},
\end{align*}
\]

that is,

\[
(t'_0 + t_1) \geq (1 - r_0 - r_1) (t_0 - t'_0),
\]

which is adapted into $r_0 + r_1 \geq \frac{(t_0 - t'_0) - (t'_0 + t_1)}{(t_0 - t'_0)}$.

By summarizing all the above, Claim 8 is proved.
Given Claims 7, 8 and the above analysis, Part (ii) of Proposition 6 is established.

**Proof of Proposition 7**

**Proof.** Before discussing the specific case of task interdependence, we first prove Claims 9 and 10.

**Claim 9** Suppose that the IPE is subjective. No matter whether $t_1 < t_1'$ or $t_1 > t_1'$, the optimal dual-review contract is characterized by $b_l \geq b_h$ and $w_l = 0$.

Under the dual-review regime, the principal’s problem is as follows.

$$\begin{align*}
\max_{w_h, w_l, b_h, b_l, w_f} & \quad p (r_0 + r_1) \left[ (t_0 + t_1) (B - b_h) - w_h \right] \\
& + p (1 - r_0 - r_1) \left[ (t_0' + t_1') (B - b_l) - w_l \right] + (1 - p) \left( \Pi' - w_f \right),
\end{align*}$$

subject to the following IC constraints facing the agent,

$$\begin{align*}
pr_1 \left[ (t_0 + t_1) b_h - (t_0' + t_1') b_l \right] + pr_1 (w_h - w_l) & \geq c_1, \\
& \tag{55}
\end{align*}$$

and

$$b_h \geq \frac{c_2}{t_1} \text{ and } b_l \geq \frac{c_2}{t_1'},$$

$$\tag{56}$$

moreover, the following two truth-telling constraints should be satisfied.

$$\begin{align*}
(t_0 + t_1) (b_l - b_h) & \geq w_h - w_l, \\
w_h - w_l & \geq (t_0' + t_1') (b_l - b_h). \\
& \tag{57}
\end{align*}$$

If (57) and (58) hold simultaneously, it requires that $b_l \geq b_h$ because $(t_0 + t_1) \geq (t_0' + t_1')$.

Moreover, $w_l = 0$ due to the following facts: (i) it is evident that making $w_l$ positive cannot relax any IC constraints; a positive $w_l$ may be useful only if (57) is binding. (ii) However, to relax (57), using $w_l$ is less cost-effective than using $b_l$: increasing $b_l$ by one unit and reducing $w_l$.
by \((t_0 + t_1)\) don’t affect (57), but it will save the cost of the principal by the amount of

\[ p(1 - r_0 - r_1) \left[ (t_0 + t_1) - (t'_0 + t'_1) \right] \geq 0. \]

So the proof of Claim 9 is completed.

**Claim 10** No matter whether \(t_1 < t'_1\) or \(t_1 > t'_1\), the optimal ability-review contract is characterized by \(w = w^J = 0\) and

\[
\begin{align*}
    b &= \begin{cases} 
    \left( \frac{c_2}{(r_0 + r_1)t_1 + (1 - r_0 - r_1)t'_1} \right), & \text{if } c_1 \leq \frac{p_{r_1}(t_0 + t_1 - t'_0 - t'_1)}{(r_0 + r_1)t_1 + (1 - r_0 - r_1)t'_1}c_2; \\
    \frac{c_1}{p_{r_1}(t_0 + t_1 - t'_0 - t'_1)}, & \text{if } c_1 > \frac{p_{r_1}(t_0 + t_1 - t'_0 - t'_1)}{(r_0 + r_1)t_1 + (1 - r_0 - r_1)t'_1}c_2. 
    \end{cases}
\end{align*}
\]

(59)

Under the ability-review regime, the principal’s problem is as follows.

\[
\max_{w^J, w, b} \left\{ \left[ (r_0 + r_1) (t_0 + t_1) + (1 - r_0 - r_1) (t'_0 + t'_1) \right] (B - b) - w \right\} + (1 - p) \left( \Pi' - w^J \right),
\]

subject to the following IC constraints facing the agent,

\[
p_{r_1}(t_0 + t_1 - t'_0 - t'_1) b \geq c_1,
\]

and

\[
\left[ (r_0 + r_1)t_1 + (1 - r_0 - r_1)t'_1 \right] b \geq c_2.
\]

It is routine to solve this problem and obtain Claim 10.

In what follows, we compare the optimal dual-review contract with the optimal ability-review contract by considering effort substitutability and effort complementarity, respectively.

Part (i): Suppose that \(t_1 < t'_1\).

1. Consider the case that \(c_1 \leq \frac{p_{r_1}(t_0 + t_1 - t'_0 - t'_1)}{r_1}c_2\). In this case, the Stage-2 IC constraints,
are binding under the dual-review regime. Due to $\frac{c_2}{t_1} > \frac{c_2}{t_1}$ and according to Claim 9, the optimal dual-review contract is characterized by

$$b_h = b_l = \frac{c_2}{t_1},$$
$$w_h = w_l = 0.$$  

It is evident that this contract is implemented at a strictly higher cost than the optimal ability-review contract characterized by Claim 10.

2. Consider the case that $c_1 > \frac{pr_1}{p_1} \left( t_0 + t_1 - t_0' - t_1' \right) c_2$. In this case, the Stage-1 IC constraints, (55), is binding under the dual-review regime. Given $w_l = 0$, $w_h$ is chosen to satisfy (55) with equality.

$$w_h = \frac{c_1}{pr_1} + \left[ (t_0' + t_1') b_l - (t_0 + t_1) b_h \right]. \tag{60}$$

Between the two truth-telling constraints, (57) is more likely to be binding, because the binding IC constraint (55) requires that $w_h$ and $b_h$ should be large relative to $w_l$ and $b_l$.

By making use of (60) and substituting $w_h$ into (57), we find that

$$(t_0 + t_1) (b_l - b_h) = \frac{c_1}{pr_1} + \left[ (t_0' + t_1') b_l - (t_0 + t_1) b_h \right].$$

With some rearrangement, we find that

$$b_l = \frac{c_1}{pr_1(t_0 + t_1 - t_0' - t_1')} \tag{61}.$$  

By making use of (61) and substituting $b_l$ into (60), we find that

$$w_h = \frac{(t_0 + t_1) c_1}{pr_1(t_0 + t_1 - t_0' - t_1')} - (t_0 + t_1) b_h. \tag{62}$$

By using (61) and (62), we could calculate the implementation cost of this optimal dual-review contract, which is equivalent to that of the optimal ability-review contract characterized by Claim 10.
To summarize the above two cases, Figure 3 illustrates the comparison between the implementation cost of the optimal dual-review contract and that of the optimal ability-review contract. Because these two contracts generate the same expected benefit for the principal, it is clear that the optimal ability-review contract weakly dominates the optimal dual-review contract, with strict dominance holding when \( c_1 < \frac{pr_1(t_0+t_1-t'_0-t'_1)}{t_1}c_2 \).

Figure 3 about here

Part (ii): Suppose that \( t_1 > t'_1 \).

1. Consider the case that \( c_1 \leq \frac{pr_1(t_0+t_1-t'_0-t'_1)}{t_1}c_2 \). In this case, the Stage-2 IC constraints, (56), are binding under the dual-review regime; moreover, due to \( \frac{c_2}{t_1} < \frac{c_2}{t'_1} \), (58) is the binding truth-telling constraint. In the dual-review contract, a positive \( w_h \) is chosen to satisfy (58) with equality. (Increasing \( b_h \) to relax (58) is less cost-effective than increasing \( w_h \).) Therefore, the optimal dual-review contract is characterized by

\[
\begin{align*}
  b_h &= \frac{c_2}{t_1}, \quad b_l = \frac{c_2}{t'_1}; \\
  w_h &= (t'_0 + t'_1) \left( \frac{c_2}{t'_1} - \frac{c_2}{t_1} \right), \quad w_l = 0.
\end{align*}
\]

The implementation cost of this dual-review contract is

\[
\begin{align*}
p (r_0 + r_1) [(t_0 + t_1) b_h + w_h] &+ p (1 - r_0 - r_1) [(t'_0 + t'_1) b_l + w_l] \\
= &\ p (r_0 + r_1) \left[ (t_0 + t_1) \frac{c_2}{t_1} + (t'_0 + t'_1) \left( \frac{c_2}{t'_1} - \frac{c_2}{t_1} \right) \right] \\
&+ p (1 - r_0 - r_1) \ (t'_0 + t'_1) \frac{c_2}{t'_1} \\
= &\ p (r_0 + r_1) (t_0 + t_1 - t'_0 - t'_1) \frac{c_2}{t_1} + p (t'_0 + t'_1) \frac{c_2}{t'_1}.
\end{align*}
\]

On the other hand, the implementation cost of the optimal ability-review contract is

\[
\begin{align*}
p \left[ (r_0 + r_1) (t_0 + t_1) + (1 - r_0 - r_1) (t'_0 + t'_1) \right] x b \\
= &\ \ p \left[ (r_0 + r_1) (t_0 + t_1) + (1 - r_0 - r_1) (t'_0 + t'_1) \right] c_2 \ .
\end{align*}
\]

57
Thus, in this case, the optimal dual-review contract is implemented at a lower cost than
the optimal ability-review contract, if and only if

\[ p (r_0 + r_1) (t_0 + t_1 - t_0' - t_1') \frac{c_2}{t_1'} + p (t_0' + t_1') \frac{c_2}{t_1'} < p \left[ (r_0 + r_1) (t_0 + t_1) + (1 - r_0 - r_1) (t_0' + t_1') \right] \frac{c_2}{(r_0 + r_1) t_1 + (1 - r_0 - r_1) t_1'} . \]

With some adaptation, the above inequality is rewritten as (26).

2. Consider the case that \( \frac{pr_1(t_0+t_1-t_0'-t_1')}{t_1} c_2 < c_1 \leq \frac{pr_1(t_0+t_1-t_0'-t_1')}{t_1} c_2 \). In this case, under the dual-review regime, the Stage-1 IC constraint, (55), is binding, while the binding truth-telling constraint is still (58). The optimal dual-review contract is characterized by

\[ b_h = \frac{c_1}{pr_1(t_0 + t_1 - t_0' - t_1')}, \quad b_l = \frac{c_2}{t_1'}, \]

\[ w_h = \left( t_0' + t_1' \right) \left( \frac{c_2}{t_1'} - b_h \right), \quad w_l = 0. \]

3. Consider the case that \( c_1 > \frac{pr_1(t_0+t_1-t_0'-t_1')}{t_1} c_2 \). In this case, under the dual-review regime, the Stage-1 IC constraint, (55), is binding, while the binding truth-telling constraint is (57). The optimal dual-review contract is characterized in the same way as in Case 2 of Part (i) of this proof. So its implementation cost is equivalent to that of the optimal ability-review contract.

To summarize the above three cases, Figure 4 illustrates the comparison between the im-
plementation cost of the optimal dual-review contract and that of the optimal ability-review
contract. In Figure 4, Panel a illustrates the case where (26) is satisfied, and Panel b illustrates
the case where (26) is not satisfied. Hence, Part (ii) of Proposition 7 is established.
Proof of Proposition 8

Proof. First we have Claim 11 regarding the dual-review regime.

Claim 11 Suppose that the ability appraisal is noisy as modeled in Section 6.2. The renegotiation-proof contract signed under the dual-review regime satisfies the following properties.

(i) Suppose that \( q < \frac{1}{2 - r_0 - r_1} \). The Stage-1 agent is fired if the IPE reveals \( \sigma = l \), and is rehired otherwise.

(ii) Suppose that \( q \geq \frac{1}{2 - r_0 - r_1} \). The Stage-1 agent is fired if the ability appraisal reveals \( \delta = \delta \) and the IPE reveals \( \sigma = l \), and is rehired otherwise.

According to our model setup, if the IPE reveals \( \sigma = h \), the Stage-1 agent is certain to be of type \( \overline{\theta} \), so the principal will rehire him in Stage 2. On the other hand, if the IPE reveals \( \sigma = l \), the probability that the Stage-1 agent is of type \( \overline{\theta} \) is conditional on the signal \( \delta \) revealed in the ability appraisal, and is calculated as follows.

\[
\mu = \Pr(\theta = \overline{\theta} | \delta = \delta, \sigma = l) = \frac{pq(1 - r_0 - r_1)}{pq(1 - r_0 - r_1) + (1 - p)(1 - q)};
\]

\[
\mu = \Pr(\theta = \overline{\theta} | \delta = \delta, \sigma = l) = \frac{p(1 - q)(1 - r_0 - r_1)}{p(1 - q)(1 - r_0 - r_1) + (1 - p)q}.
\]

Because \( \frac{q}{(1 - q)(1 - r_0 - r_1)} > 1 \),

\[
\mu = \frac{p}{p + (1 - p)\frac{q}{(1 - q)(1 - r_0 - r_1)}} < p,
\]

which implies that when receiving \( \delta = \delta \) in the ability appraisal and \( \sigma = l \) in the IPE, the principal will fire Stage-1 agent. However, when receiving \( \delta = \overline{\delta} \) and \( \sigma = l \), the principal will rehire Stage-1 agent, if and only if \( \overline{\mu} \geq p \), i.e.,

\[
q \geq \frac{1}{2 - r_0 - r_1}.
\]

To summarize the above analysis, Claim 11 is established.
Under the dual-review regime, we denote the payments made to the agent as \((w_h, b_h, w_l, b_l)\) when the ability appraisal reveals \(\delta = \overline{\delta}\), and denote the payments as \((w_h, b_h, w_l, b_l)\) when the ability appraisal reveals \(\delta = \underline{\delta}\). Given the performance feedback \(m\), \(w_m\) or \(w_m\) is the wage paid out regardless of final outcome, and \(b_m\) or \(b_m\) is the bonus paid upon final success. In what follows, we discuss the two cases mentioned in Claim 11, separately.

Case (i): Suppose that \(q < \frac{1}{2 - r_0 - r_1}\). First, it is easy to verify that Proposition 1 still holds given a noisy ability appraisal: the optimal ability-review contract dominates the optimal no-review contract. The proof is omitted.

Second, if \(q < \frac{1}{2 - r_0 - r_1}\), the optimal performance-review contract dominates the optimal ability-review contract. The underlying reason is as follows. Previously, the relative advantage of adopting the ability-review contract arises only when the ability appraisal provides a more precise signal for instructing the agent replacement than does the IPE. However, if the ability appraisal is very noisy, i.e., \(q < \frac{1}{2 - r_0 - r_1}\), the efficient replacement of agent is contingent only upon the IPE result.

Third, we prove the following claim.

**Claim 12** Suppose that the IPE is subjective, and that \(q < \frac{1}{2 - r_0 - r_1}\). The optimal performance-review contract weakly dominates the optimal dual-review contract.

First consider the dual-review contract. The following IC constraints ensure that the agent provides high efforts in Stages 1 and 2, respectively.

\[
pr_1 \left[ (t_0 + t_1) \left( q b_h + (1-q) b_l \right) - (t'_0 + pt_1) \left( q b_l + (1-q) b_h \right) \right] + pr_1 \left[ \left( q w_h + (1-q) w_l \right) - \left( q w_l + (1-q) w_h \right) \right] - pr_1 c_2 \geq c_1. \tag{63}
\]

\[
\frac{b_h}{t_1} \geq \frac{c_2}{t_1}, \quad b_h \geq \frac{c_2}{t_1}. \tag{64}
\]
The following truth-telling constraints insure the principal’s truthful report in the subjective IPE.

\[(t_0 + t_1)(B - \overline{b_h}) - w_h \geq (t_0 + pt_1)(B - \frac{c_2}{pt_1} - \overline{b_l}) - \overline{w_l}, \quad \text{(Truth } \delta - h)\]

\[(t_0 + t_1)(B - b_h) - w_h \geq (t_0 + pt_1)(B - \frac{c_2}{pt_1} - \overline{b_l}) - \overline{w_l}, \quad \text{(Truth } \hat{\delta} - h)\]

\[\Big(t'_0 + pt_1\Big) \left(B - \frac{c_2}{pt_1} - \overline{b_l}\right) - \overline{w_l} \geq \Big(t'_0 + pt_1\Big) \left(B - \overline{b_h}\right) - \overline{w_l}, \quad \text{(Truth } \bar{\delta} - l)\]

\[\Big(t'_0 + pt_1\Big) \left(B - \frac{c_2}{pt_1} - \overline{b_l}\right) - w_l \geq \Big(t'_0 + pt_1\Big) \left(B - b_h\right) - w_l, \quad \text{(Truth } \hat{\delta} - l)\]

Given any payment scheme \((\overline{w_h}, \overline{b_h}, \overline{w_l}, \overline{b_l}, w_h, b_h, w_l, b_l)\) that satisfies all the above constraints under the dual-review contract, we can construct a performance-review contract as follows.

\[w_h = q\overline{w_h} + (1 - q)w_h,\]
\[w_l = q\overline{w_l} + (1 - q)w_l,\]
\[b_h = q\overline{b_h} + (1 - q)b_h,\]
\[b_l = q\overline{b_l} + (1 - q)b_l.\]

We can verify that the above constructed performance-review contract \((w_h, w_l, b_h, b_l)\) satisfies all the constraints, (14), (15), (22), (23), and that this contract generates the same level of cost and revenue as the original dual-review contract. It implies that for the optimal dual-review contract, we can find a corresponding performance-review contract that yields the same profit as it. However, given any performance-review contract, we cannot always find an equally profitable dual-review contract, because there are more truth-telling constraints imposed when solving the latter contract than when solving the former contract. To sum up, the optimal performance-review contract should yield a profit that is not lower than the optimal dual-review contract. Thus, Claim 12 is proved.

Summarizing the analysis of Case (i), Part (i) of Proposition 8 is established.
Case (ii): Suppose that $q \geq \frac{1}{2-r_0-r_1}$. Here we prove the following claim.

**Claim 13** Suppose that $q \geq \frac{1}{2-r_0-r_1}$. There exists a threshold $\beta^*$ such that the optimal dual-review contract dominates all other contracts if $B > \beta^*$.

First consider the dual-review contract. To induce high efforts in both stages, besides (63) and (64), the following IC constraint should be satisfied.

$$\bar{b}_l \geq \frac{c_2}{\mu t_1}$$

(65)

The following truth-telling constraints insure the principal’s truthful report in the subjective IPE.

$$(t_0 + t_1) (B - \bar{b}_h) - w_h \geq (t_0 + t_1) (B - \bar{b}_l) - w_l, \quad \text{(Truth } \delta - h)$$

$$(t_0 + t_1) (B - \bar{b}_h) - w_h \geq (t_0 + pt_1) \left( B - \frac{c_2}{\mu t_1} - b_l \right) - w_l, \quad \text{(Truth } \delta - h)$$

$$(t'_0 + \mu t_1) (B - \bar{b}_h) - w_l \geq (t'_0 + \mu t_1) (B - \bar{b}_l) - w_h, \quad \text{(Truth } \delta - l)$$

$$(t_0 + pt_1) \left( B - \frac{c_2}{\mu t_1} - b_l \right) - w_l \geq (t'_0 + \mu t_1) (B - b_h) - w_h. \quad \text{(Truth } \delta - l)$$

On the one hand, the dual-review contract achieves a higher level of expected benefit than all other contracts, because the efficient firing rule is contingent on the results of both the IPE and the ability appraisal. By using the dual-review contract rather than other contracts, the net gains in expected benefit are increasing in $B$. On the other hand, the implementation cost of the optimal dual-review contract is weakly decreasing in $B$, because an increase in $B$ relaxes its truth-telling constraints (Truth $\delta - h$) and (Truth $\delta - l$), while not affecting the other two truth-telling constraints (Truth $\bar{\delta} - h$) and (Truth $\bar{\delta} - l$). So if $B$ is sufficiently large, the dual-review regime is the principal’s optimal choice. Thus, Claim 13 is proved, and also Part (ii) of Proposition 8 is established. ■

**Proof of Proposition 9**

**Proof.** The principal’s problem is similar as that described in Section 3.2, except adding the truth-telling constraints (27) and (28). It is evident that the principal would set $w = 0$. We
can represent the choices of \((b, w^f)\) in a diagram (see Figure 5). The horizontal axis denotes \(b\) and the vertical axis denotes \(w^f\). (27) is satisfied if and only if \((b, w^f)\) is above or on the \(\overline{\theta}\) line. (28) is satisfied if and only if \((b, w^f)\) is below or on the \(\underline{\theta}\) line. The Stage-1 IC constraint, (2), is satisfied if and only if \((b, w^f)\) is on the right side of or on the \(IC_1\) line. The Stage-2 IC constraint, (10), is satisfied if and only if \((b, w^f)\) is on the right side of or on the \(IC_2\) line.

Figure 5 about here

Part (i): It is evident that the horizontal intercept of line \(\overline{\theta}\) is greater than that of line \(\underline{\theta}\). Moreover, the slope of line \(\overline{\theta}\) is greater than that of line \(\underline{\theta}\). To ensure that there is a region of \((b, w^f)\) satisfying all the constraints, it is essential to check whether the lines \(IC_1\) and \(IC_2\) are on the left side of the intersection point between line \(\overline{\theta}\) and line \(\overline{\theta}\). The corresponding conditions are

\[
\frac{t_1B + (r_0 + r_1) (t_0 - t'_0) \frac{c_2}{pt_1}}{[(r_0 + r_1) (t_0 - t'_0) + t_1]} \geq \frac{c_2}{t_1},
\]
and

\[
\frac{t_1B + (r_0 + r_1) (t_0 - t'_0) \frac{c_2}{pt_1}}{[(r_0 + r_1) (t_0 - t'_0) + t_1]} \geq \frac{c_1}{pr_1 (t_0 - t'_0)}.
\]

We further find that (66) is satisfied given assumption \(A_1\), while (67) is re-written as (29). So given assumption \(A_1\), (29) guarantees the existence of a solution.

Part (ii): computing the optimal solution of \((b, w^f)\) is routine. If

\[
\frac{[(r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1]}{pr_1 (t_0 - t'_0)} \frac{c_1}{pt_1} > (1 - p) t_1B + \left[(r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + pt_1\right] \frac{c_2}{pt_1},
\]

the optimal choice of \(w^f\) satisfies

\[
w^f = w^f' \equiv \left[(r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + t_1\right] \frac{c_1}{pr_1 (t_0 - t'_0)} - (1 - p) t_1B - \left[(r_0 + r_1) t_0 + (1 - r_0 - r_1) t'_0 + pt_1\right] \frac{c_2}{pt_1}.
\]
and the optimal choice of $b$ satisfies

$$b = \frac{c_1}{pr_1 (t_0 - t'_0)}. \quad (70)$$

If (68) does not hold, the optimal contract is characterized by $w = 0$ and $b = \max \left\{ \frac{c_2}{pr_1 (t_0 - t'_0)}, \frac{c_1}{pr_1 (t_0 - t'_0)} \right\}$.

We compare the optimal ability-review contract with the optimal no-review contract, and find that if the latter contract dominates the former contract, it requires that (68) holds and $\Pi^A < \Pi^N$. By making use of (6), (69) and (70), $\Pi^A < \Pi^N$ is rewritten as

$$(1 - p) (\Pi' - w') < (1 - p) t'_0 \left( B - \frac{c_1}{pr_1 (t_0 - t'_0)} \right).$$

Substituting $\Pi'$ and $w'$ into the above inequality, it is rearranged into

$$\left[ \frac{(r_0 + r_1) (t_0 - t'_0) + t_1}{pr_1 (t_0 - t'_0)} \right] c_1 > t_1 B + \frac{(r_0 + r_1) (t_0 - t'_0)}{pt_1} c_2. \quad (71)$$

(71) contradicts with (29), so the optimal no-review contract can not dominate the optimal ability-review contract when the latter contract is implementable. \[\blacksquare\]
Panel a: the optimal regime in case of an objective IPE

Panel b: the optimal regime in case of a subjective IPE

Figure 1: the optimal regime for the principal
Figure 2: solving the optimal performance-review contract under a subjective IPE
Figure 3: the case of substitute efforts
Figure 4: the case of complementary efforts
Figure 5: solving the optimal ability-review contract when the ability appraisal is subjective.