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by
Jie Tian
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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

MANAGING DYNAMIC RELATIONSHIPS

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This dissertation investigates the role of information in long-term managerial investment decisions. The regulatory environment of financial reporting and auditing dictates how information is communicated and thus has a significant effect on managerial behavior. Standard setters who believe that the goal of financial reporting and auditing is only to maintain accuracy simplify the analysis and overlook the fact that managers are rational economic agents. Enlarging the useful information set, we then investigate the role of unverifiable information in managerial investment decisions. Contract renegotiation is served as a mechanism to make use of newly discovered information, even if it is unverifiable. It is efficient to take timely information into consideration in a long-term contracting relationship.
CHAPTER 1
INTRODUCTION

Financial reports are communications between managers and investors. When investors delegate decision rights to managers, there is a demand for information about managers’ action. At the same time, how information is reported affects managers’ incentives to fulfill their responsibilities, which in turn affects the underlying resource allocation. For example, given the widespread concern for accuracy of financial reports in the post-Sarbanes-Oxley environment, managers respond by abandoning accounting treatment but resorting to real business decisions to manager earnings, as documented in a recent survey paper (Graham, Harvey and Rajgopal [2005]). Managers may delay a profitable project because it requires an immediate injection of fund, which can lower the current earnings. Apparently, the rules on financial reporting and auditing change the preparers’ behavior. Since most business activities in the United States are carried out in investor-owned business enterprises, how the information is measured for financial reporting has a significant impact on the welfare of economy. Measurement itself changes the behavior of the subject that is being measured.

Some issued and proposed FASB statements have been criticized for their dysfunctional effects on resource allocation. For example, critics of Statement No. 8 (replaced by SFAS No.52) contend that the inclusion of gains and losses from translation of foreign currency may force companies to engage in uneconomical hedging transactions. Among all the concerns, the most significant cause may be managers’ incentive structure is preoccupied with short-term financial results. The company’s interim financial information is reviewed by auditors (See PCAOB Auditing Standard No.1). Some even argued that the time for continuous audit
has come, which allows using financial information with audited report in real time (See Searcy and Woodroof [2003]). When investment outcome takes a long time to realize, however, periodic financial reporting and auditing change managers’ incentives in making proper investment decisions. Many of the financial reporting rules or audit procedures seem to ignore the dynamic effect of managers’ decisions. For example, auditors are instructed to make sure all amounts are correctly included (the completeness objective) and transactions are recorded in the period when they actually took place (the cutoff objective) (Arens, Elder, and Beasley 2005). While transactions reflect managers’ long-term perspective in decision making, the related reporting issues should also be carefully addressed. Otherwise, the misaligned managerial incentives will drive the firm to operate at an inefficient level.

This dissertation highlights the economic substance in evaluating rules of financial reporting and auditing. Different accounting settings cannot be understood without considering the effect on managerial actions. Moreover, the unique role played by accruals forces us to understand accounting from a multi-period perspective. The effect from dynamic planning adds more concerns to standard-setting, because the standard-setters are not regulating nature but are rational economic agents.

This concern raises questions about the zealous pursuit in accuracy of financial reports, especially the concept of “neutrality”. Neutrality is defined as “absence in reported information of bias intended to attain a predetermined result or to induce a particular mode of behavior.” (FASB Concepts No. 2) In a setting with symmetric and perfect information, such a bias can be easily removed and each party’s behavior can be costlessly monitored. In other times, reporting standards affect the parties’ incentives to communicate the unobservable information, which in turns affects the parties’ incentives to perform their duties. Reporting
standards are bound to “induce a particular mode of behavior”. A naive view of standard-setting will cause the economy to perform at an inefficient level.

The plan of the study is in the following order. In Chapter 2, I selectively review the historical and contemporary literature. Three lines of literature are explored: first, delegating investment decisions to managers; second, dynamic considerations for standard-setting; third, the audit function.

In Chapter 3, I introduce a single-period model that studies the role of communication and auditing. Even though the model is abstracted from any dynamic effect, it helps answering the following questions: First, why investment decision is delegated and what problems could this cause to investors? Second, what kind of information can investors obtain from financial reports and is communicating the information helpful to solve the problems? Third, for public companies, a related issue with financial reporting is that the reported information is audited, what is the value of auditing?

In Chapter 4, a dynamic model is studied. When there are long lags between the manager’s effort and the project’s final outcome, reported information can be used for other purpose. For example, the manager’s contract is subject to renegotiation. Renegotiation occurs as long as there are mutual gains from revising the contract. The disclosed information will be used in the future when parties start to discuss the manager’s compensation package. Anticipating that, the manager changes his initial motivations.

In Chapter 5, a related problem is how to implement optimal investment policy. Previously we focus on using revelation mechanisms (communication) to motivate the manager. Now we focuses on using observed information to design right incentive structures, even the information is not verifiable. In this chapter, we do not constrain our understanding of managerial investment behavior by reading
financial reports (we are dealing with unverifiable information). We investigate the large library of accounting information.

In Chapter 6, I summarize the main results of the dissertation and provide directions for future research.
2.1 Delegating Decision Rights

Investors hire a manager to make various decisions. It is probably because the manager’s expertise offers him a unique access to some information set. Upon observing and analyzing the acquired information, investors are updated about the state of nature, thus being able to adjust the production plan. Since the collected information is valuable to reduce the risk of future production, these information discovering activities, though costly, should be encouraged.

It appears that the traditional agency theory would suffice to explain the problem, because it shares a similar feature when a conflict of interest exists in agency: the agent has incentive to shirk, because exerting higher effort in gathering information incurs higher disutility, and his effort is not observable to the principal. But the new problem is more delicate because there are two separate decisions need to be made: the decision for information acquisition and for production. Whether to delegate only the information acquisition decision or both to the agent generates a stream of related research questions, particularly when the collected new information is only observable to the agent. For example, the principal might want to delegate the production decision to the agent as well, if it is costly to communicate the agent’s private information to the principal. It seems to be more efficient to hand over the decision right to the better-informed. But being privately informed, the risk averse agent might seek a production level in his own interest other than the risk neutral principal’s. Then there is some spillover effect between motivating information acquisition and motivating production decision. The spillover between the two activities could become so severe that the principal
would find it optimal to explicitly allow some underinvestment or overinvestment in production, in order to motivate the agent more efficiently to acquire information. These concerns are termed induced moral hazard, which highlights the tension between the two control problems. That is why sometimes it is not worthwhile at all to motivate any information acquisition activities, even if the information is useful. I will explore various related settings in the literature. While some let the agent choose his effort in gathering information as mentioned above, others treat the information system as exogenously endowed to the agent. But they are all concerned with how the valuable information should be utilized in decision making.

Before we proceed, let’s introduce some common notations and assumptions in the literature:

- \( x \) = production outcome, with \( x \in X \), where \( X \) represents an interval of the real line or some discrete levels.

- \( \eta \) = the agent’s effort in gathering information, i.e., choosing among different information system.

- \( \pi(\eta) \) = the signal which the agent privately observes, based on the information system he selects. \( \pi \in \Pi \), where \( \Pi \) is a bounded interval on the real line or some discrete levels.

- \( m(\pi) \) = the agent’s report given \( \pi \). \( m(\pi) \in M \), where \( M \) is the acceptable reports set.

- \( e(\pi) \) = the agent’s production effort given \( \pi \).

- \( I(\cdot) \) = the agent’s compensation where \( I(\cdot) \) is piecewise continuous.

- \( U(I) \) = the agent’s utility function with \( U''(I) > 0, U''(I) < 0 \).

- \( C(\cdot) \) = the agent’s cost functions from exerting effort in either gathering information or production. \( C'(\cdot) > 0, C''(\cdot) > 0 \). (The agent’s utility function can be additively or multiplicatively separable in wage and effort)

- \( x - I \) = the principal’s utility function.
\[ f(x|\pi, e) = \text{the posterior probability density of outcomes.} \]

\[ f(\pi) = \text{the prior probability density of the signals.} \]

\[ \overline{H} = \text{the reservation utility of the agent.} \]

\[
\begin{array}{cccccc}
t = 0 & t = 1 & t = 2 & t = 3 & t = 4 \\
\text{Contracting Agent’s effort} & \text{Agent observes signal } \pi(\eta) & \text{Investing effort} & \text{Output} \\
I(x, m(\pi)) & \text{in gathering information, } \eta & e(\pi) & x \\
\end{array}
\]

Figure 2–1. The general timeline

Conroy and Hughes [1987] are among the first who address the problem of how to motivate the agent to acquire information. They include several important assumptions besides other classical assumptions in their moral hazard model: (1) the acquired information by the agent is publicly observable; (2) the principal retains the right to take the productive effort, upon observing the agent’s collected information; and (3) higher effort in gathering information \( \eta \) is preferred because it shifts the expected outcome \( x \) from production to the right in the sense of first-order stochastic dominance. The first assumption puts the extra control problem due to asymmetric information to silence. So the only focus is the moral hazard concern in exerting effort to acquire information. Given that the acquired information is verifiable, it is more efficient to let the principal decide the production level. The second assumption eases the moral hazard concern with respect to productive effort. The third assumption implies that the focus effort \( \eta \) can be ranked in the same way as in conventional agency theory. The three assumptions make their results similar to the conventional agency theory. The conventional agency theory’s focus on motivating the productive effort \( e \) has been shifted to motivating the information gathering effort \( \eta \) only. Their model is distinct from other works in this area in that the agent cannot observe \( \pi \). His effort
can only let him observe a sample outcome $y$, which is not a sufficient statistic of the underlying state $\pi$. The main result is, if and only if the production outcome $x$ is conditionally (on $y$) informative about the agent’s effort $\eta$, the principal is better off by contracting on both the sample outcome $y$ and the production outcome $x$ than on the sample outcome $y$ alone. Since their analysis applies to some outsourcing contracts between the firm and an outsider, for example, market researchers, political pollsters, census takers, and so on, it is a useful extension of agency theory.

Penno [1984] directly addressed the effect of the pre-decision asymmetric information inside the firm, when the agent is delegated to conduct a productive decision. Then the deeper question is whether the agent should be granted such an access to private information prior to action. His model assumes the agent’s private information is exogenously endowed. Although the principal can design the information system only accessible to the agent, the agent is not endogenously motivated to acquire this information. That is, referring to our timeline, the step at $t = 1$ is omitted. The agent’s information is his effort’s marginal effect, indicating the random working environment. For example, the information could be the potential market demand: if the demand is rather sluggish, investing much in marketing activities is useless; the reliability of machinery, which is crucial in deciding the efficiency of any productive effort. Specifically, the effect of the information is perfect substitute for the agent’s effort $f(x|\pi, e) = f(x|\pi e)$: if the agent observes a signal indicating that high output will probably occur, it is not necessary for him to work hard in order to achieve the goal. For that exact reason, the principal might not be willing to let the agent have some superior information than herself. On the other hand, the information can also help the agent reduce

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1 That is, $f(x|y, \eta)$ depends on $\eta$. 
effort when there is almost zero marginal effect for his effort, while increase effort when its marginal effect is high. The paper demonstrates that if the principal can costlessly provide partition on the information set to the agent, a strict Pareto improvement will occur.

The main result is, assuming the optimal effort $e^*$ induced by the optimal contract under symmetric information (no private information is accessible to the agent), and the principal can costlessly design the partition on the agent’s private information set, then there is a partition on $\Pi : [0, \pi]$, such that a strict Pareto improvement will occur. The intuition is as follows. Consider this partition: $\{[0, \epsilon], (\epsilon, \pi)\}$. For an arbitrarily small $\epsilon$, the agent saves on his effort from $e^*$ to 0 if he knew $[0, \epsilon]$ realizes; but his effort upon observing $(\epsilon, \pi)$ increases, which increases the principal’s expected utility. The net effect is to increase expected production. Thus, providing partition to the agent improves the total welfare, even it is only observable to the agent.

A major assumption here is that the principal is able to design the information system, which is a little at odds with the issue that the information is only observable to the agent, not the principal. In another words, the principal can control how much the agent knows, but she cannot observe what the agent knows. It seems that the agent usually has much more broad channels than the principal in order to know the details of production environment. The control problem that the principal faces originates from the agent’s superior knowledge. If the principal can control the agent’s knowledge, the problem is alleviated. Therefore, whether some information asymmetry should be created intentionally in organizations deserves more attention.

Lambert [1986] studied a more sensible setting where the agent needs to exert effort to acquire useful information. Based on observed information, the agent is motivated to make a proper investment decision. If the agent invests,
the project returns (randomly) either a high cash flow $\bar{x}$ or a low cash flow $\underline{x}$.
Rejecting the project will keep the status quo, that is, a constant cash flow $x$ will result, and $\underline{x} < x < \bar{x}$. The cash flow $\tilde{x} \in \{x, \underline{x}, \bar{x}\}$ is observed by both parties.
Three cash flows are used to model the trade-off between motivating the manager to make a proper investment decision and compensating the manager for the risk he bears. A distinct feature of this model from conventional agency theory is that the agent’s effort cannot be ranked in the sense of first-order stochastic dominance. If the contract imposes too little risk on the agent, the agent would not search for information but choose the risky project; if the contract imposes too much risk, the agent would not work either but play safe. The contract design is more delicate. The analysis shows that without communication, both underinvestment and overinvestment may occur. But with communication, the problem of underinvestment can be tamed. This result sheds some light on the role of financial reporting from the stewardship perspective. If financial reporting is to communicate information to investors, it helps adjusting risk level on managers so they would work more diligently.

Lambert [1986] can be seen as an example of Demski and Sappington [1987]. Demski and Sappington [1987] formulated a general model to study the spillover effect between motivating the agent to acquire information and to make a proper decision: planning and implementation. They show that even if implementation creates no disutility to the agent, the implementation activity can be distorted in order to provide the agent with incentives to become informed. While communication can alleviate the induced moral hazard, sometimes communication offers no gain. The result depends on the specific information structures.

Laux [2004] continued to investigate the spillover effects among multiple tasks. Specifically, three tasks are motivated: the agent is motivated to gather information; to make an investment decision based on the observed signal;
and to exert an effort to implement the project. Whether the agent invests is contractible; the other two decisions are not observable. The agent’s effort in gathering information to evaluate the project, $\eta$, is either 0 or 1, with cost $c$ if he works. His implementation effort is $e \in (0, \infty]$, with cost $e$. $x_T = X(e_T)$ is the target chosen by the principal, i.e., $e_T$ is determined endogenously. If the project is undertaken, the outcome is a function of both the project quality and the agent’s implementation effort $x = \theta X(e)$, $\theta \in \{0, 1\}$. The agent’s effort $\eta = 1$ allows him to observe two distinct signals $\pi_g$ or $\pi_b$, which is informative about the project quality $\theta$. It is assumed that the principal induces the agent to invest when $\pi_g$ realizes, and reject the project when $\pi_b$ realizes. The information $\pi_g$ or $\pi_b$ is not observable.

The contract depends on the outcome and investment decision. Since there are only two signals, and a separating equilibrium is assumed. The agent’s private information is fully revealed by his observable investment decision. For the same reason, there is no problem of underinvestment or overinvestment (in contrast with Lambert [1986]). So the only spillover effect in this model is between motivating information acquisition $\eta$ and project implementation $e$.

The paper shows that if the concern of motivating information acquisition dominates the concern of motivating project implementation, the risk imposed on the agent for the purpose of motivating information acquisition is sufficient to motivate him to exert high effort in project implementation. Then any informative measure of the implementation effort is redundant. The study offers another view why firms often disregard some informative performance measures in evaluating their managers.

Another interesting result is that motivating information acquisition is never gratuitous even when spillover between multiple tasks is present inside the firm. Imposing risk to motivate the agent to work diligently in project implementation will not automatically offer the agent enough incentive to acquire information
beforehand. It is always more efficient for the principal to explicitly monitor the agent’s effort in information acquisition. In next chapter, I show an audit of financial reports provides such monitoring to motivate the agent to become informed.

2.2 Dynamic considerations for standard-setting

Standard setters believe the primary role of financial reporting is to facilitate decision making. “Financial reporting should provide information that is useful to present and potential investors and creditors and other users in making rational investment, credit, and similar decisions.” (FASB, Concepts Statement No. 1) Therefore, accurate financial reports may be more useful. Although it is true for a single decision-maker—an information system is preferred to its Blackwell garbling, it is generally not the case when there are multiple players and the game lasts more than one period.2

Kydland and Prescott [1977] investigated various occasions where a policy-maker has to make a decision. Many have argued that, at each point in time, the decision should be made optimal given the current and past situation. But the current actions of economic agents also depend in part on their expectations of future policy changes. A well-known example is patent policy. Given that resources have already been spent on inventive activities, the efficient policy is not to offer patent protection in order to reduce monopoly rents. But we know this decision will ruin the incentives to engage in any inventive activities. This expectation affects agents’ current actions, which in turn affect the policy-maker’s future choice. Convergence does not always occur. Accounting policy-makers, however, do not

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2 In a trading game, for example, if all investors get the same information and make a decision on it, investors may well prefer that information not be provided. See Hirschleifer [1971],
seem to care enough about the economic foundation for standard-setting such as the dynamic effect driven by rational expectation. Accounting policies seem to be short-term oriented. Attentions have been focused on producing accurate and reliable financial reports at any snapshot of time, which is at odds with the going-concern assumption.

Among other early work on dynamic consideration for accounting policies, Christensen, Demski and Frimor [2002] studied accounting policies where contracts are subject to renegotiation. Renegotiation affects dynamic uses of information. The disclosed information will be used in the future when parties start to discuss the agent’s compensation package. Anticipating that, the agent changes his initial motivations. In a two-period moral hazard setting, a perfect accounting system causes the agent’s incentives to collapse as in Fudenberg and Tirole [1990]. The intuition is as follows. Once the agent has exerted effort, it is efficient to provide the agent with complete insurance. Foreseeing that his eventual payment would be independent of the outcome, the agent would then prefer to choose the lowest feasible level of effort. However, other regimes that allow the agent to move output from the first to the second period provide him incentives to work in the first period because the agent’s effort creates reserves that will be rewarded in the second period. The paper examines the effect of different accounting policies on the agent’s first-period effort: perfect accounting, aggregate accounting and conservative accounting. The result emphasizes that policy-makers are not only concerned about making a good choice but also constrained by the fact that players are strategic in making their choices as well.

Gigler and Hemmer [2004] compared two reporting regimes on the information about the agent’s past action, when contract renegotiation is considered. Two performance measures are considered: early-revealed information \( (y) \) and late-revealed information \( (x) \). The late information is publicly observable. But
the early information can either be made public by a transparent regime, or be kept private under an opaque regime. So the principal has to rely on the agent’s self-report on $y$ under an opaque regime. If full commitment is achievable in contracting, transparency is certainly preferred, because it is usually extra costly to induce the agent to report truthfully. But renegotiation makes the problem more subtle. Renegotiation tends to make the contract rely more on the information revealed before renegotiation, because the information revealed after renegotiation becomes less credible. If the agent’s high effort is motivated, the insurance opportunity from using the later-revealed information is lost. The contract does not reference the late information. At the renegotiation stage, the agent’s effort is sunk and the principal’s only goal is to reduce compensation cost by lowering risk premium. She will then offer a full-insurance contract given the information observed before renegotiation. That is, the agent’s incentive can be provided only through a short-term contract: on the early-revealed information $y$ only. This opens a door to an opaque regime, where the agent’s information is kept private before renegotiation and is only revealed at the renegotiation stage. Thus, the later-revealed information can be used. It is used to induce the agent to report his private information truthfully at the renegotiation stage. Since no more renegotiation is allowed afterward, the Revelation Principal applies. Motivating truthful report on the early information $y$ will in turn provide the agent incentive to exert high effort. Therefore, although the early information is kept private, it

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3 There is a minor problem with the constraints listed in the opaque regime. The ex ante truth-telling constraints ($TT^k_o$) should not be imposed, because full commitment is not maintained as required by revelation principal. The ex post truth-telling constraints ($ITT^H_o$ and $ITT^L_o$) are valid because full commitment is achieved at the renegotiation stage. This might change some points stated in the paper. But since the ex post truth-telling constraints will automatically imply the ex ante truth-telling constraints, the equilibrium is not changed.
offers the principal extra incentive to reference the late information. Thus both information can be used in the contract, lowering compensation cost.

Two studies on renegotiation are included here to demonstrate the dynamic concerns. Renegotiation allows the principal to move again based on her observation at some interim stage. Anticipating the principal’s move, the agent revises his current choices. Dynamic concerns are also present in other scenarios. For example, Baiman and Rajan [1995] study a setting with incomplete contracts.

2.3 Auditing

Auditing is an attestation service. To do an audit, there must be some information to be attested. Some communication problems must be present for the auditor to verify. Financial reports are communications. It implies we need to consider at least three parties in order to study auditing questions: investors, the manager and the auditor. The incentive interactions among the three parties give rise to the demand of auditing. On the one hand, it is important to recognize the area of auditing is closely related to the area of financial accounting and certainly cannot be isolated with managerial incentives. On the other hand, we find that in literature it is difficult to endogenize the three parties’ behavior all together.

Antle [1982, 1984] uses a multi-agent model to study the role of communication and auditing. Investors hire a manager to perform duties that affect the outcome of the firm. Investors hire another agent—the auditor—to engage in some investigative action about the manager. The contractible information $\pi$ (e.g., earnings) is observable to the manager only. Therefore, without an auditor, the manager would not have incentives to perform his duties since he can report whatever is in his best interest. The auditor exerts effort to verify the manager’s self-report $\hat{\pi}$, observes some information $A$ and issues a report $\hat{A}$. The manager and the auditor choose their actions simultaneously. The principal’s (investor’s) goal is to design the contracts using both agents’ reports to motivate each other.
If the auditor works and truthfully reveals her observation, her report should be consistent with the manager’s. Likewise, the payment to the manager should be set higher if the auditor’s report confirms his report and the opposite holds if the two reports conflict. The three-player framework is useful to visualize the relation between investors, the manager and the auditor and is also widely used in practice. Nevertheless, the model is not tractable enough to incorporate that side-payments can be transferred from the manager to the auditor. Auditor’s independence is presumed in that the auditor is able to deny self-interested behavior completely. Antle [1982] noted, “Modeling the auditor as a player opens a Pandora’s box of methodological problems.” Again, the model is a good benchmark to embark on auditing issues, but more questions need to be answered. For example, law requires no contingent fees be paid to auditors; with the manager’s report absent, what mechanism can provide the auditor with incentives to work?

Baiman, Evans and Noel [1987] also set up a three-player game but the sequence of events is different. The auditor attests to the manager’s report after it is issued, so the auditor’s report is conditional on the manager’s report. One of the results is that there exists no equilibrium in which the manager reports fully. This is because if the auditor knows the manager’s report is correct, she would not expend effort to audit it. The manager’s misreporting behavior is tolerated only to provide the auditor with incentives to work. For tractability, the manager is modeled to take no productive action and his only job is to report his observation. The purpose of the model is to show the role of auditor as a “utility-maximizing agent”, but the model seems to be too focused on the auditor while overly simplifies the manager’s behavior.

Many other works circumvent the modeling impediment by focusing on the interaction between two parties only, leaving the “unimportant” issues exogenous. Fellingham and Newman [1985] studied an auditor-manager game, where the
manager chooses the effort to reduce the probability of a material error and
the auditor chooses whether to extend audit procedures. The two players move
simultaneously. The focus of the paper is to show the auditor should consider
the audit risk model strategically. The manager’s behavior is influenced by his
conjecture of the auditor’s action and vice versa. Relying on single-person decision
theory, the auditor ended up with incorrect evaluation of audit risk. The model
is highly stylized but it is among the first to point out that a successful audit
relies on a thorough understanding of managerial incentives. In addition, the
paper shows that the auditor may frequently use a randomized strategy. That is,
the manager cannot predict what the auditor will do and he can only guess the
auditor’s strategy probabilistically. Anecdotal evidence shows that many audit
failures are due to pre-determined analytical procedures, because it is easy for the
manager to plan accordingly. Strategic considerations are indispensable to study
auditing issues.

Leaving financial reporting problems unmodeled, Antle and Nalebuff [1991]
focused on the negotiation process between the auditor and manager. Financial
statements should be read as a joint output from the auditor-manager negotiation.
The users only see the final negotiated outcome. Whether conservatism reigns
in the final outcome is unclear even when the auditor starts with a conservative
gesture. The manager has superior information and he only protests understatements.
The paper shows, with a cost-sharing contract designed to maximize joint
auditor-manager surplus, the expected ex post bias is always upward.

Cuccia, Hackenbrack and Nelson [1995] studied the ability of professional
standards to mitigate aggressive reporting. Although the experiment was set in a
tax setting, the issue seems to be more general to all reporting behavior. The paper
shows that practitioners will interpret more liberally a vague professional standard
in order to justify aggressive reporting while interpret the evidence more liberally
when facing a more stringent standard. The results are intuitive to capture the practitioners’ intentions to exploit discretion embedded in professional standards. But why the practitioners always choose to report aggressively is not clear. The practitioners’ incentives (for example, resulted from compensation package) are not explicitly studied.

2.4 Summary

In this chapter, I selectively reviewed the literature in three areas: Delegating decision rights, Dynamic concerns for standard-setting and Auditing. We start with the role of financial reporting, approaching from a management stewardship perspective. (FASB, Concepts Statement No.1) When investors rely on a manager’s expertise and delegate some decisions to the manger, there is a demand for information. Communication is valuable especially when the manager endogenously acquires the information and use it to make a production decision. Apparently, financial reporting and auditing standards that govern the communication process affect managerial decision-making and have profound consequences on underlying resource allocation. Pondering on managerial decision-making, we raise some concerns for periodic financial reporting and auditing. Do we pursue an accurate financial reporting system or a dynamic communication process?

The value of auditing is directly related to the value of financial reporting. The literature reveals the difficulty to incorporate interested parties (investors, the manager and the auditor) endogenously. It also presents us the opportunity to practise the art of modeling. We emphasize on the first-order effects: there must be some reporting problems that auditing can help alleviate (the endogenously-created demand for auditing) and there must be some strategic considerations in auditing. Then another tough choice has to be made. Do we focus on the manager’s strategic considerations or the auditor’s?
CHAPTER 3
THE ONE-PERIOD MODEL

3.1 The Role of Communication

The manager commonly expends effort to investigate profitability before investing in a risky project. Periodic financial reporting allows the manager to communicate the acquired information to the investors so that the investment decision can be monitored.\textsuperscript{1} But the self-reported information may not reflect the true value based on the manager’s observation. For example, R&D expenditures may carry some information about the firm’s future investment opportunities. Although R&D expenditures are all expensed as incurred, classification of R&D expenditures can be problematic. The manager may want to include ordinary operating expenditures in R&D. R&D expenditures can also be classified as the follow-through in an early stage of commercial production so the amount can be capitalized. Due to lack of active markets, classification of R&D expenditure is difficult. Therefore, the auditor’s report, as a reliable (but imperfect) source about the manager’s private information, can be valuable in monitoring the manager’s behavior.

3.1.1 The Model

The risk-neutral principal (investors) owns an option to invest in a risky project. She hires a risk-averse manager to make a decision on whether to invest in the project: $v \in \{0, 1\}$. If the manager invests, $v = 1$, the project returns

\textsuperscript{1} Penno [1984], Lambert [1986], Demski and Sappington [1987] and Mehmut and Reichelstein [1987] have shown that in many cases, communication is strictly valuable when the manager has superior pre-decision information.
(randomly) either a high cash flow $\bar{x}$ or a low cash flow $\underline{x}$. Rejecting the project ($v = 0$) will keep the status quo, i.e., a constant cash flow $x$ will result, and $\underline{x} < x < \bar{x}$. The cash flow $\tilde{x} \in \{\underline{x}, x, \bar{x}\}$ is observed by both parties.\(^2\) The manager can understand more about the risky project by searching for additional information. Let the information be the posterior probability of the high outcome occurring: $\Pr(\bar{x} | \pi_i) = \pi_i$. The manager observes three such signal realizations: $1 > \pi_1 > \pi_2 > \pi_3 > 0$. The prior probabilities of these signals’ occurring are $P_1$, $P_2$ and $P_3$, respectively.\(^3\) Therefore, if the manager does not work, he can only predict the project’s profitability via the expectation of the signals: $m = \sum_{i=1}^{3} P_i \pi_i$. The manager’s effort can be either high or low: $\eta \in \{\eta_H, \eta_L\}$. The personal cost of low effort is normalized to 0, but the manager incurs cost $c > 0$ if he exerts high effort, $\eta_H$. (That is, working hard allows the manager to observe a better information system $\eta_H$.) The manager is assumed to incur no extra cost to invest in the project. Hence, the only moral hazard concern is to motivate the manager to acquire information. As we shall see, the manager’s investment decision affects his decision to acquire information when the two tasks are jointly motivated.

Since risk aversion is a first-order effect and the change in risk aversion is not, I assume constant absolute risk aversion for the manager’s utility function: $U(I, c) = -\exp(-r(I - c))$. $I$ is the manager’s compensation and $c$ is the monetary cost of exerting high effort. Without loss of generality, the manager’s next best employment opportunity is assumed to carry a certainty equivalent of 0, that is, his

\(^2\) As in Lambert [1986], three cash flows are necessary to model the trade-off between motivating the manager to make a proper investment decision and compensating the manager for the risk he bears.

\(^3\) As we shall see, at least three signals are required to characterize the interim communication problem when renegotiation is present.
reservation utility level is $-e^{-r^0} = -1$. Let $\Psi(U)$ be the inverse function, that is, the principal will pay the amount of $I = \Psi(U) = -\frac{1}{r} \ln(-U)$ to the manager.

The optimal investment policy deserves some explanations. I restrict the analysis to the cases where the principal prefers that the manager select the risky project only if $\pi_1$ or $\pi_2$ is observed. That is, if the principal can either observe the manager’s effort or the manager’s collected information (the first-best scenario), this investment policy will return the largest expected cash flow.\(^4\) This assumption is stated as

Condition 1. $\pi_2 \bar{x} + (1 - \pi_2) x > x > \pi_3 \bar{x} + (1 - \pi_3) x$

The principal only wants to avoid the worst scenario $\pi_3$. Let $\pi_1\pi_2|\pi_3$ denote this investment policy. Obviously, this is the first-best investment policy. The rest of this analysis examines how the contract is designed in order to implement the first-best policy and whether the first-best policy is still optimal in various second-best settings.

To capture the idea that the information-discovering activities are pervasive in practice, I further assume that acquiring information is always preferred, that is, high effort $\eta_H$ is always motivated.\(^5\)

Notice the principal can infer perfectly the investment choice from the final outcome ($\bar{x}, x$ or $x$), because the choice renders disjoint outcomes. This does not, however, make our problem disappear. The principal does not know why the project was selected or rejected. Was it because the signal the manager received

\(^4\) Two manager types are induced to invest because there should be some pooling before renegotiation takes place. The details will be clear when renegotiation-proof contracts are introduced.

\(^5\) This assumption can be satisfied when the project is very risky, i.e., $\pi_1 \bar{x} + (1 - \pi_1) x >> x >> \pi_3 \bar{x} + (1 - \pi_3) x$, and the cost to acquire information ($c$) is not too large.
indicated the project is not profitable, or did he simply make the decision without searching for information? The principal does not know, either, whether the manager followed the desired investment policy, because the principal cannot observe the information the manager acted upon.

3.1.2 Contracting with Full Commitment

The direct output of the manager’s effort is information. Auditors, whose stock in trade is their ability to process information, seem to be helpful here. This section shows why the principal is better off imposing an audit. As a benchmark, the principal is assumed to maintain the full commitment power in this section. (*Full commitment* means the principal can credibly promise not to alter the terms of a contract, even if it is common knowledge that mutual gains are available from revising the contract.)

| Principal offers $C_{BM}$ | Manager chooses effort $\eta$ to gather information | Manager observes signal $\pi(\eta)$ | Manager makes investment decision based on $\pi$ | Manager reports $\hat{\pi}$, auditor verifies report, issues $A$ | Outcome realized $\pi, x$ or $x$, Payment made |

Figure 3–1. The timeline in a full commitment setting

The manager’s effort is not publicly observable, nor is the collected information. The manager observes the signal and has the authority to make the investment decision. The Revelation Principle allows us to look for the optimal solution.

---

6 This regime is equivalent to the one in which the principal retains the authority to make the investment decision, because the manager communicates his information and the investment decision is observed. A similar situation can be found in Melumad and Reichelstein [1987].
under a direct revelation mechanism only (Myerson [1979], Harris and Townsend [1981]). The manager’s compensation is contingent on the realized cash flow ($x$) and his report on the received signal ($\pi$). There are five payment levels—$I_1, I_1; I_2, I_2; I_3$—when the investment policy $\pi_1 \pi_2 | \pi_3$ is implemented. Correspondingly, the induced utility levels are $U_1, U_1; U_2, U_2; U_3$. Since the manager’s investment decision is observable, all the other off-equilibrium outcomes can be easily penalized. (For example, if the manager reported $\pi_3$, but invested in the project, the principal would observe $x$ or $\bar{x}$, and the manager is then punished so severely that he would never make that choice.) At the end of this section, I will show that the implemented investment policy is indeed optimal.

The manager is motivated to exert high effort, so his expected utility is

$$EU = e^{rc}[P_1 \pi_1 U_1 + P_1 (1 - \pi_1)U_1 + P_2 \pi_2 U_2 + P_2 (1 - \pi_2)U_2 + P_3 U_3].$$

But if he shirks, his expected utility is based on the expectation of the project’s profitability:

$$m \equiv \sum_{i=1}^{3} P_i \pi_i.$$ The principal’s constrained cost-minimization problem ($P_{BM}^{na}$) is:

$$\min_{U_1, U_1, U_2, U_2, U_3} \sum_{i=1}^{2} P_i [\pi_i \Psi(U_i) + (1 - \pi_i) \Psi(U_i)] + P_3 \Psi(U_3)$$

Subject to:

$$EU \geq -1 \quad (1)$$

$$EU \geq m U_1 + (1 - m) U_1 \quad (2)$$

$$EU \geq m U_2 + (1 - m) U_2 \quad (3)$$

$$EU \geq U_3 \quad (4)$$

$$\pi_1 U_1 + (1 - \pi_1) U_1 \geq \pi_1 U_2 + (1 - \pi_1) U_2 \quad (5)$$

$$\pi_1 U_1 + (1 - \pi_1) U_1 \geq U_3 \quad (6)$$
\[ \pi_2 U_2 + (1 - \pi_2) U_2 \geq \pi_2 U_1 + (1 - \pi_2) U_1 \]  
\[ \pi_2 U_2 + (1 - \pi_2) U_2 \geq U_3 \]  
\[ U_3 \geq \pi_3 U_1 + (1 - \pi_3) U_1 \]  
\[ U_3 \geq \pi_3 U_2 + (1 - \pi_3) U_2 \]

Inequality (1) is the IR constraint; inequalities (2)-(4) are the IC constraints for effort selection. If the manager decides to shirk, he can disguise his behavior by claiming he receives signal \( \pi_1, \pi_2 \) or \( \pi_3 \), but he cannot really observe the signal so he has to rely on \( m \) to evaluate his expected utility. Inequalities (5)-(10) are the IC constraints for each manager type to report his information truthfully after having exerted the effort to acquire that information. Notice that the problem of motivating the manager to invest properly has been replaced with the problem of motivating the manager to report truthfully. This is because the investment decision is observable and thus can be enforced based on the reported information.

**Lemma 1.** Assume no audit is performed. If \( m > \pi_2 \), the optimal contract imposes risk on type \( \pi_1 \) only, that is, \( U_1 > U_1 \) and \( U_2 = U_2 \); if \( m \leq \pi_2 \), the optimal contract may impose risk on types \( \pi_1 \) and \( \pi_2 \), that is, \( U_1 > U_1 \) and \( U_2 \geq U_2 \).

The contract should not only motivate the manager to invest properly, but also motivate him to acquire information. Lemma 1 shows how the manager’s incentives in the two tasks interact. The intuition is similar to Lambert [1986]. When the project is expected to be relatively more profitable, that is, \( m > \pi_2 \), (the mean is above the median.) the manager would always invest if he did not acquire any information. This is because the advocated investment policy \( \pi_1, \pi_2 \) encourages investing at any signal realization better than \( \pi_3 \) but now the expectation \( m \) is already above the cutoff investment level. Thus, the manager’s off-equilibrium behavior (i.e., when he shirks) is to claim he received signal \( \pi_1 \) or \( \pi_2 \), so that he is justified to invest. This means constraints (2) and (3) are binding.
Therefore, the principal has to design a “less attractive” contract to alleviate the manager’s temptation to invest. She equates the contract for the investing type to the non-investing type, that is, type $\pi_2$ receives the same payment as type $\pi_3$, $\overline{U}_2 = \overline{U}_2 = U_3$. Type $\pi_2$ is then indifferent between investing and not investing. Equivalently, he is indifferent between reporting $\pi_2$ and $\pi_3$. The investment policy affects the manager’s incentive to acquire information. The manager’s incentive to invest is set weaker in order to provide him with a stronger incentive to search for information.

The manager’s incentives are different when the prior is opposite, that is, $m \leq \pi_2$ (the mean is below the median.) In this case, if the manager decides to shirk, he is not clear about whether to invest or reject the project because $m$ is between $\pi_2$ and $\pi_3$. Constraints (3) and (4) are binding. If the manager invests without collecting any information, there is a high probability he might be wrong because the project is not very attractive: $m \leq \pi_2$. If the manager rejects the project without collecting any information, his chance of being correct is also slim because he may miss the investment opportunity in two possible events $\pi_1$ and $\pi_2$. Therefore, with less concern to motivate the manager to acquire information, the principal can impose risk on both type $\pi_1$ and type $\pi_2$.

Finally, we need to confirm there is no better investment policy in the second-best setting. The principal can choose to induce investing in the project only when the manager receives the best news and forgo the project otherwise, that is, policy $\pi_1|\pi_2\pi_3$. The contract to implement $\pi_1|\pi_2\pi_3$ consists of four payments $\{\overline{U}_1, \overline{U}_1; U_2; U_3\}$, which can implement policy $\pi_1\pi_2|\pi_3$ because type $\pi_2$ is offered a fixed payment and thus is indifferent between investing and not investing. Investing when signal $\pi_2$ is realized not only increases the expected cash flow as indicated by Condition 1, but also expands the set of variables for contracting ($\overline{U}_2$ and
Thus it is never wise to deviate from policy \( \pi_1 \pi_2 | \pi_3 \). \(^7\)

### 3.2 The Role of Auditing

We now introduce the audit function by assuming the auditor is well motivated by professional standards, and follows the audit rules diligently. The model focuses on the procedure of auditing and its function to discipline the manager’s possibly opportunistic (off-equilibrium) behavior. The auditor samples and tests the transactions and so is prone to errors. The audit technology is summarized using the following conditional probabilities:

**Table 3–1. Audit technology**

<table>
<thead>
<tr>
<th>The manager’s report is true</th>
<th>Approve</th>
<th>Disapprove</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manager’s report is true</td>
<td>(1 - \alpha)</td>
<td>(\alpha)</td>
</tr>
<tr>
<td>The manager’s report is false</td>
<td>(\beta)</td>
<td>(1 - \beta)</td>
</tr>
</tbody>
</table>

The auditor’s report is \( A_T \) if she approves the manager’s treatment and issues \( A_F \) if she does not. \( \alpha \) can be interpreted as a Type I error and \( \beta \) as a Type II error. \(^8\) I assume \( \alpha \in (0, \frac{1}{2}) \) and \( \beta \in (0, \frac{1}{2}) \) so the auditor’s report is informative about the true status of the manager’s information. \(^9\)

**Proposition 1.** Auditing is strictly valuable in a full commitment setting.

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\(^7\) Remember I have assumed it is always preferred to acquire information. Other investment policies \( | \pi_1 \pi_2 \pi_3 \) or \( | \pi_1 \pi_2 \pi_3 | \), i.e., always rejecting the project or always investing in the project, do not require the manager to collect any information to implement the policy.

\(^8\) For simplicity, I assume the audit technology does not vary with the manager’s reporting strategies. For example, the sampling error is \( \beta \) whether the type \( \pi_3 \) manager reports \( \pi_1 \) or \( \pi_2 \). This simplification only reduces the notation and does not qualitatively change the results.

\(^9\) It is common in the literature to model audit technology as a garbling of the manager’s information. For example, Dye [1993] and Antle [1984].
Currently, it is mandatory to audit the annual financial statements for public companies. Without incurring extra costs, the principal cannot be worse off by referencing the contract to the auditor’s report. It is simply because the principal maintains full commitment power, and she always has the option to ignore the auditor’s report when offering the contract at the start of the game. Moreover, in the two-task setting, an audit has strict value. On the one hand, it verifies the manager’s self-report so the contract based thereon forces the manager to report truthfully. Based on the (truthful) information, the desired investment policy can be enforced. On the other hand, the contract that references the auditor’s report provides the manager greater incentive to become informed: if the manager did not work hard to search for information, he possessed no information, so he had to lie all the time; but the auditor detects lying with a positive probability. An effective audit makes the two tasks become more complementary and thus the expected compensation cost is reduced.

### 3.3 Summary

This chapter extends the line of literature where the agent is motivated to generate information before making a decision.\(^\text{10}\) In such situations, the contract has to provide incentives for the agent not only to make a proper decision based on the observed information but also to acquire that information. One of the interesting findings is that the principal at times has to distort the agent’s decision-making incentives in order to provide sufficient incentives for the agent to acquire information. I show that an audit of the acquired information helps align the agent’s incentives in both tasks and therefore is strictly valuable.

\(^{10}\) Other examples include finding out about the probability of winning before tendering the bid and researching the potential investments before choosing portfolios for clients. See Lambert [1986], Demski and Sappington [1987], Laux [2004] and Malcomson [2004].
CHAPTER 4
THE DYNAMIC MODEL

An important issue is how to audit the manager’s acquired information. It may not always be efficient to motivate the manager to report accurately what he knows because of the incentive issues that arise in dynamic employment relationships. When there are long lags between the manager’s effort and the project’s final outcome, the manager’s contract is frequently subject to renegotiation. If the auditor motivates the manager to reveal his information accurately, in equilibrium, the investors would be able to infer perfectly that the manager has exerted effort to acquire information. At the following renegotiation encounter, the contract will be revised to provide more insurance to the risk averse manager, that is, the payments will not vary with the outcome of the project. Foreseeing that the final contract will not depend on the project’s outcome, ex ante, the manager would have less incentive to become informed. Since renegotiation occurs as long as there are mutual gains from recontracting, this trade friction itself can limit the usefulness of accurate financial reports. Unless the auditor’s report is highly informative about the manager’s private information, it is not beneficial for the investors to know the manager’s information fully. Arm’s length relationships may be preferred in the dynamic investment game.

As mentioned previously, full commitment may not be a realistic scenario. There may be several years before the project’s outcome is realized. Throughout the intervening years, parties can always choose to tear up the initial contract and open a new contract, as long as both parties agree to the revision. Renegotiation thus enters our long-term project-investing story naturally.
Renegotiation implies interim optimization. From an *ex ante* perspective, the interim optimization problem may add constraints, because both parties’ *ex post* incentives need to be considered at the renegotiation stage. The amount of information to be revealed before renegotiation affects the interim optimization problem. Recalling the full commitment case (Chapter 3), full information revelation is motivated because the principal offers a contract first and commits herself to the rules about how the information is used. With the extra optimization problem, we now reexamine whether information should also be fully revealed.

The timeline is revised to include the renegotiation encounter:

At the *initial* contracting stage, the principal offers a contract, $C_1$, to the manager, who can either accept or reject the contract. If the manager rejects the contract, the game ends and both get their reservation utility.

After the manager accepts the contract, he chooses effort $\eta$ to collect information. Based on the subsequent signal, the manager makes the investment decision $v$.

The *interim* reporting stage comes before renegotiation takes place, when the manager communicates his information to the public ($\tilde{\pi}_I$)\(^1\) and the auditor verifies the manager’s report ($A$).\(^2\)

At the *renegotiation* stage, the principal offers a new continuation contract, $C_2$, to the manager. If $C_2$ is rejected, $C_1$ is the final contract and determines the manager’s compensation. If $C_2$ is accepted, it becomes the final contract.

---

\(^1\) It is common for the board of directors to observe some information before convening to evaluate the manager’s performance.

\(^2\) To capture the feature of periodic auditing, the auditor issues the report at the *interim* reporting stage.
At the final reporting stage, if the manager has not communicated fully his private information at the interim reporting stage, he can elect to report it now ($\hat{\pi}^F$). The project outcome is realized and the manager is compensated based on whichever contract is in place.\(^3\)

<table>
<thead>
<tr>
<th>Principal offers contract $C_1$</th>
<th>Manager chooses effort $\eta$ to gather information</th>
<th>Manager observes signal $\pi(\eta)$</th>
<th>Manager makes investment decision based on $\pi$</th>
<th>Manager reports $\hat{\pi}^f$, auditor verifies report, issues $A$</th>
<th>Contract renegotiated $\hat{\pi}^F$</th>
<th>Manager reports $\bar{\pi}$ or $x$.</th>
<th>Outcome realized, $\bar{x}$, $\bar{x}$ or $x$.</th>
</tr>
</thead>
</table>

Figure 4–1. Timeline when renegotiation is present

At the renegotiation stage, the principal makes a take-it-or-leave-it offer to the manager.\(^4\) The manager can take the newly offered continuation contract $C_2$ or reject it so the initial contract $C_1$ remains in effect. I will show we can restrict

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\(^3\) I allow two reporting stages to ensure there is no restriction on the timeline. Renegotiation can take place before or after information release.

One may also consider another timeline where the investment decision is made after renegotiation, thus after the interim reporting stage. The alternative timeline does not change the results qualitatively, however. Full information revelation before renegotiation will render a full insurance continuation contract whether the investment decision is made before or after renegotiation, because the investment decision is observable and no further incentive concerns are left at the renegotiation stage. (Details will be clearer after I introduce the renegotiation-proof contract.)

Moreover, the current timeline seems to be more plausible, since the investment decision is delegated to the manager but communication often occurs at year-end.

\(^4\) It is comparatively simple to let the principal (instead of the agent) propose a contract at the renegotiation stage. Since the manager possesses private information, the contract proposal itself can reveal information. More analyses can be found in Maskin and Tirole [1992].
attention to the contracts that are renegotiation proof. A contract is renegotiation proof if, at the renegotiation stage, it minimizes the expected compensation cost while leaving no manager type worse off relative to the initial contract. That is, the contract is optimal from the principal’s perspective, conditional on her conjecture regarding the choices the manager has made. Thus, the principal will not choose to alter it at the renegotiation stage.

The principal chooses a continuation contract based on what she knows: observing the manager’s interim report \( \hat{\pi}^I \) and the auditor’s report \( A \), she updates her belief about the manager’s private information through \( \Pr(\pi|\hat{\pi}^I, A) \). Of course, the posterior probability distribution \( \Pr(\pi|\hat{\pi}^I, A) \) also depends on the principal’s conjecture regarding the manager’s effort \( \eta \) and the disclosure level enforced by the auditor.

Since the investment decision \( (v = 0 \text{ or } 1) \) is sunk and the decision can be perfectly inferred, type \( \pi_1 \) or \( \pi_2 \) cannot be mixed with type \( \pi_3^5 \). The continuation contract takes the following form \( \{(U_{jki}, U_{jki}), (U_{3k})\}_{j \in \{1,2\}, k \in \{T,F\}, i \in \{1,2\}} \). Type \( \pi_1 \) or \( \pi_2 \) manager’s utility levels are specified in the first parenthesis. The payment depends on the interim reports \( (\hat{\pi}^I, A_k) \), the final report \( (\hat{\pi}^F) \) and the realized cash flow \( (\bar{x}, \bar{z}) \). Type \( \pi_3 \) manager’s utility level is specified in the second parenthesis. Since type \( \pi_3 \) is not induced to invest and the investment decision is observable, type \( \pi_3 \) can be identified with certainty after the interim reporting stage. The payment only depends on the manager’s report \( (\hat{\pi}^I, A_k) \) and the auditor’s report \( (A_k) \).

**Definition.** A contract \( C = \{(U_{jki}, U_{jki}), (U_{3k})\}_{j \in \{1,2\}, k \in \{T,F\}, i \in \{1,2\}} \) is renegotiation proof, for distribution \( \Pr(\pi|\hat{\pi}^I, A) \), if it minimizes the expected compensation cost given \( \Pr(\pi|\hat{\pi}^I, A) \):

---

\(^5 I \) will show the policy \( \pi_1 \pi_2 | \pi_3 \) is still optimal in Sections 5 and 6.
For type $\pi_1$ or $\pi_2$, who invested:

$$\sum_{i=1}^{2} \Pr(\pi_i|\hat{\pi}_j, A_k)[\pi_i \Psi(\pi_{jki}) + (1 - \pi_i)\Psi(u_{jki})]$$

among all the contracts $\{(\pi_{jki}, u_{jki})\}_{j \in \{1, 2\}, k \in \{T, F\}, i \in \{1, 2\}}$ that satisfy for any $(\hat{\pi}_j, A_k)$:

$$\pi_i u_{jki} + (1 - \pi_i)u_{jki} \geq \pi_i \bar{u}_{iji} + (1 - \pi_i)\bar{u}_{jki'}; \forall i' \in \{1, 2\} \quad \text{(IIC-}\pi_i, \hat{\pi}_j, A_k)$$

$$\pi_i v_{jki} + (1 - \pi_i)v_{jki} \geq \pi_i \bar{v}_{iji} + (1 - \pi_i)\bar{v}_{jki} \quad \text{(IIR-}\pi_i, \hat{\pi}_j, A_k)$$

For type $\pi_3$, who did not invest:

$$\Psi(u_{3k})$$

among all the contracts $\{(u_{3k})\}$ that satisfy for any $(\hat{\pi}_3, A_k)$:

$$u_{3k} \geq U_{3k} \quad \text{(IIR-}\pi_3, A_k)$$

At the renegotiation stage, the principal chooses among the incentive-compatible contracts that will be accepted by each manager type. The interim incentive compatibility constraints (IIC) restrict the set of contracts to those that induce truthful reporting from the manager, that is, all the private information will be revealed at the final reporting stage. The Revelation Principle is invoked here because the timeline presumes no more renegotiation. Notice there are no IIC constraints for the manager who received signal $\pi_3$, because no asymmetric information problem remains. (IIC constraints are imposed for type $\pi_1$ or $\pi_2$, because entering the renegotiation stage the principal may not be certain about these two types.) The interim individual rationality constraints (IIR) restrict the
possible continuation contracts to the class in which each type is offered a (weak) improvement in expected utility relative to the existing contract $C$. IIR constraints are defined recursively. If none of the contracts lowers the expected compensation cost relative to the existing contract, $C$, the principal has no incentive to offer any renegotiation; hence, the contract $C$ is renegotiation proof.

**Proposition 2.** Suppose an equilibrium exists in which (1) the initial contract is $\tilde{C}$, (2) the final contract is $C^*$ and (3) the manager’s strategy profile is $B = (\eta_H, \pi_1 \pi_2 | \pi_3, \pi^I, \pi^F)$. There then exists an equilibrium in which $C^*$ is the initial as well as the final contract, and the manager’s strategy profile is unaltered.

Therefore, without loss of generality, we only consider renegotiation-proof contracts. Exploiting this representation device, the rest of the analysis shows the optimal disclosure level enforced by an auditor.

At the final reporting stage, any unreported information will be revealed, so the focus is how much information should be disclosed at the interim reporting stage. Since the investment decision is sunk, there are only two reporting rules: 1. The manager is motivated to report completely what he knows, $\{\{\pi_1\}\{\pi_2\}\{\pi_3\}\}$. The auditor examines whether the manager’s report is truthful. This partition is denoted as **full** revelation. 2. The type $\pi_3$ manager is motivated to report truthfully as $\tilde{\pi}_3^I$, but types $\pi_1$ and $\pi_2$ are motivated to report the same as $\tilde{\pi}_1^I$. Thus the principal will know the manager received signal $\pi_3$ when he reports $\tilde{\pi}_3^I$, but will not know the manager’s information for sure when he reports $\tilde{\pi}_1^I$. In this case, the auditor only verifies whether the manager’s investment decision is justified based on his acquired information. That is, the auditor only worries about the misstatements that affect the principal’s perception about the firm’s investment opportunities, and a minor misstatement between $\pi_1$ and $\pi_2$ is tolerable. Denote this partition, $\{\{\pi_1, \pi_2\}\{\pi_3\}\}$, as **partial** revelation.
4.1 Full revelation

If the manager’s information is disclosed before the renegotiation stage, the principal will use the disclosed information to renegotiate the original contract. Foreseeing that, the manager has less incentive to give away his advantage. Consequently, if the principal continues to push for more information, the manager may have less incentive to acquire information.

Intuitively, an audit enforcing full information revelation at the interim stage can be harmful. In fact, the manager never discloses all of his information before renegotiation if there is no auditor to attest to his report.

**Lemma 2.** Without an auditor, information acquisition followed by full information revelation at the interim reporting stage cannot be sustained in equilibrium.

The manager knows that if he reveals all of his information, the story ends there: he has acquired information and invested according to the instructed policy. There is no incentive problem left for the principal to solve at the renegotiation stage. The principal will offer a full insurance contract. But knowing the final contract is a full insurance contract, the manager would prefer the low effort instead. Notice this result is reminiscent of Fudenberg and Tirole [1990]. The difference is that in my scenario the reporting problem is intertwined with the effort problem. The pursuit of truthful reporting completely removes the manager’s incentive to exert effort to acquire information. The reporting requirement pollutes the real production.

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6 The only feasible equilibrium other than implementing the low effort $\eta_L$ is in mixed strategies. This paper assumes high effort is always preferred. I will show later, with the auditor’s report or adequate information rationing, high effort (in pure strategies) is indeed implementable.
Fortunately, we have an auditor. As we shall see next, the manager’s incentive
to acquire information is completely provided by contracting on the auditor’s
report.

Given an auditor and using the renegotiation-proof representation, we
characterize the optimal full revelation contract. Since the manager reports all
his information before renegotiation, no information is left for later reporting, and
the contract only relies on the interim report \((\hat{\pi}^I)\), the auditor’s report \((A)\) and the
project outcome \((\bar{x})\).

### 4.1.1 Continuation Contract with Full Revelation

At the renegotiation stage, the principal offers

\[
C^T = \{(\bar{U}_{jk}, U_{jk}), (U_{3k})\}_{j \in \{1, 2\}, k \in \{T, F\}}
\]

that minimizes:

\[
\pi_j \Psi(\bar{\pi}_{jk}) + (1 - \pi_j) \Psi(u_{jk})
\]

subject to:

\[
\pi_j \bar{u}_{jk} + (1 - \pi_j) u_{jk} \geq \pi_j \bar{U}_{jk} + (1 - \pi_j) U_{jk}
\]

(IIR-\(\pi_j, A_k\))

and:

\[
\Psi(u_{3k})
\]

subject to

\[
u_{3k} \geq U_{3k}
\]

(IIR-\(\pi_3, A_k\))

At the renegotiation stage, six possible events may be observed: \((\hat{\pi}^I_1, A_T)\),
\((\hat{\pi}^I_1, A_F)\), \((\hat{\pi}^I_2, A_T)\), \((\hat{\pi}^I_2, A_F)\), \((\hat{\pi}^I_3, A_T)\) and \((\hat{\pi}^I_3, A_F)\). Note the only constraint in
each information event is one IIR constraint, and there are no IIC constraints. The
principal believes the manager has made the proper strategy choices
\(B^T = (\eta_H,\)
\(\pi_1 \pi_2 | \pi_3, \pi_j^I = \pi_j\), so no incentive problem remains at the renegotiation stage. In the next subsection, I will show that the principal’s beliefs about the manager’s choices are indeed correct.

**Proposition 3.** When the auditor’s report is used to enforce full revelation, payments to the manager do not vary with the final outcome of the project.

### 4.1.2 Ex-Ante Contracts that are Consistent with Full Revelation

At the initial contracting stage, the principal offers a contract \(C_T = \{(U_{jk}, U_{jk}), (U_{3k})\}_{j \in \{1,2\}, k \in \{T,F\}}\) that is renegotiation proof given the principal’s beliefs and the contract induces the manager to choose strategies consistent with the principal’s beliefs \(B_T = (\eta_H, \pi_1 \pi_2 | \pi_3, \pi_j^I = \pi_j)\). The principal’s overall problem \(P_T\), therefore, is:

\[
\begin{align*}
\min_{U_{jk}, U_{jk}, U_{3k}} & \sum_{j=1}^2 P_j \{(1 - \alpha)\pi_j \Psi(U_{jT}) + (1 - \pi_j)\Psi(U_{jF})\} \\
+ & \alpha \pi_j \Psi(U_{jF}) + (1 - \pi_j)\Psi(U_{jF})\} + P_3\{(1 - \alpha)\Psi(U_{3T}) + \alpha\Psi(U_{3F})\}
\end{align*}
\]

Subject to:

\[
EU \geq -1 \tag{11}
\]
\[
EU \geq \beta [mU_{1T} + (1 - m)U_{1T}] + (1 - \beta)[mU_{1F} + (1 - m)U_{1F}] \tag{12}
\]
\[
EU \geq \beta [mU_{2T} + (1 - m)U_{2T}] + (1 - \beta)[mU_{2F} + (1 - m)U_{2F}] \tag{13}
\]
\[
EU \geq \beta U_{3T} + (1 - \beta)U_{3F} \tag{14}
\]
\[
(1 - \alpha)\pi_1 U_{1T} + (1 - \pi_1)U_{1T} \geq \alpha\pi_1 U_{1F} + (1 - \pi_1)U_{1F} \tag{15}
\]
\[ \geq \beta U_{3T} + (1 - \beta)U_{3F} \]  \hspace{1cm} (16)

\[ (1 - \alpha)\left[\pi_2 \bar{U}_{2T} + (1 - \pi_2)\bar{U}_{2T}\right] + \alpha \left[\pi_2 \bar{U}_{2F} + (1 - \pi_2)\bar{U}_{2F}\right] \]

\[ \geq \beta \left[\pi_2 \bar{U}_{1T} + (1 - \pi_2)\bar{U}_{1T}\right] + (1 - \beta)\left[\pi_2 \bar{U}_{1F} + (1 - \pi_2)\bar{U}_{1F}\right] \]  \hspace{1cm} (17)

\[ \geq \beta U_{3T} + (1 - \beta)U_{3F} \]  \hspace{1cm} (18)

\[ (1 - \alpha)U_{3T} + \alpha U_{3F} \]

\[ \geq \beta \left[\pi_3 \bar{U}_{2T} + (1 - \pi_3)\bar{U}_{2T}\right] + (1 - \beta)\left[\pi_3 \bar{U}_{2F} + (1 - \pi_3)\bar{U}_{2F}\right] \]  \hspace{1cm} (19)

\[ \geq \beta \left[\pi_3 \bar{U}_{1T} + (1 - \pi_3)\bar{U}_{1T}\right] + (1 - \beta)\left[\pi_3 \bar{U}_{1F} + (1 - \pi_3)\bar{U}_{1F}\right] \]  \hspace{1cm} (20)

\[ \bar{U}_{1T} = U_{1T} \]  \hspace{1cm} (21)

\[ \bar{U}_{2T} = U_{2T} \]  \hspace{1cm} (22)

\[ \bar{U}_{1F} = U_{1F} \]  \hspace{1cm} (23)

\[ \bar{U}_{2F} = U_{2F} \]  \hspace{1cm} (24)

where

\[ EU = e^{rc}\left\{ \sum_{j=1}^{2} P_j(1 - \alpha)\left[\pi_j \bar{U}_{jT} + (1 - \pi_j)\bar{U}_{jT}\right] \right. \]

\[ + P_j\alpha\left[\pi_j \bar{U}_{jF} + (1 - \pi_j)\bar{U}_{jF}\right] + P_3[(1 - \alpha)U_{3T} + \alpha U_{3F}] \} \]

The ex-ante individual rationality constraint (AIR) is (11). Inequalities (12)-(20) are the ex-ante incentive compatibility constraints (AIC). Among them, (12)-(14) are included to motivate the manager to collect information and (15)-(20) are included to motivate him to report truthfully. Inequalities (21)-(24) are the constraints resulting from renegotiation. Notice that problem \( P_T \) differs from the full commitment case by adding four extra constraints (21)-(24), i.e., the project outcome is not used. The presence of renegotiation makes the contract fail to reference another informative contracting variable. Hence, the principal loses the
opportunity to insure the risk averse manager. Renegotiation reduces the efficiency
of contracting with the agent.\footnote{Notice that investment policy $\pi_1 \pi_2 | \pi_3$ is motivated here. Other policies are not optimal. Since the overall contract does not reference the project outcome, the contract is the same no matter what investment policy is motivated.}

The auditor’s report is issued before renegotiation; thus, the contract that
references the report can provide some short-term commitment. When the
auditor’s report is observed ($A_T$ or $A_F$), the manager’s utility level based on the
auditor’s report is in the bank. The principal cannot lower the manager’s utility
level at the following renegotiation stage. Recalling the full commitment setting,
the auditor’s report is useful to motivate information acquisition and truthtelling.
In the same way, the auditor’s report can be used to induce high effort, even in the
presence of renegotiation.

Renegotiation adds extra constraints; however, and consequently the expected
compensation cost will be higher. Pursuing full revelation before renegotiation also
makes the principal short-sighted: the contract puts all the weight on the auditor’s
report and ignores the potential information content of the investment outcome.
The manager’s incentives are provided completely from the auditor’s report. But
can the auditor live up to such an expectation? The next proposition shows it
depends critically on the audit technology.

**Proposition 4.** When $\alpha, \beta \to 0$, the compensation cost is close to the
first-best case; but when $\alpha, \beta \to 0.5$, motivating high effort becomes infeasible.

Proposition 4 implies that the audit technology determines whether it is
beneficial to reveal the information fully. If the audit errors are close to 0, it is
equivalent to allowing the principal to observe the manager’s information directly.
The control problem becomes trivial, the first-best scenario. But if the audit errors
are large, the auditor’s report is not informative enough to motivate high effort. The decision about the project has to be made without information. If this is the case, the principal can switch to the other reporting rule to motivate the manager.

**4.2 Partial Revelation**

Alternatively, the manager can be induced to reveal his information partially at the interim reporting stage—\{\{\pi_1, \pi_2\}\{\pi_3\}\}—and the remaining information is solicited after renegotiation. Accordingly, the auditor here only verifies whether the received signal falls into the investment region \{\pi_1, \pi_2\} or the non-investment region \{\pi_3\}. The essence of partial revelation can be best illustrated through a benchmark case where no audit is available. I will then show that the original problem \(P^P\) is simply an improved version of the benchmark case. Denote the benchmark case as \(P^P_{na}\).

**4.2.1 Benchmark: No Audit Case \(P^P_{na}\)**

**4.2.1.1 Continuation contracts with partial revelation**

At the renegotiation stage, the principal updates her beliefs about the manager’s type based on his report \(\hat{\pi}_j\). Given the manager’s reporting strategy—both type \(\pi_1\) and type \(\pi_2\) report \(\hat{\pi}_1\), but type \(\pi_3\) reports \(\hat{\pi}_3\)—the principal has

\[
\Pr(\pi_i|\hat{\pi}_1) = \frac{P_i}{P_1 + P_2}, \forall i \in \{1, 2\} \text{ and } \Pr(\pi_3|\hat{\pi}_3) = 1.
\]

The principal offers \(C^P_{na} = \{(\underline{u}_i, \overline{u}_i), (\underline{U}_3)\}_{i \in \{1, 2\}}\) that minimizes

if \(\hat{\pi}_1\) is observed:

\[
\sum_{i=1}^{2} \frac{P_i}{P_1 + P_2} [\pi_i \Psi(\pi_i) + (1 - \pi_i)\Psi(\underline{u}_i)]
\]

subject to

\[
\pi_i \overline{u}_i + (1 - \pi_i)\underline{u}_i \geq \pi_i \overline{u}_{i'} + (1 - \pi_i)\underline{u}_{i'}; \forall i' \in \{1, 2\} \quad \text{(IIC-}\pi_i, \hat{\pi}_1\text{)}
\]

\[
\pi_i \overline{U}_i + (1 - \pi_i)\underline{U}_i \geq \pi_i \overline{U}_{i} + (1 - \pi_i)\underline{U}_{i} \quad \text{(IHR-}\pi_i, \hat{\pi}_1\text{)}
\]
if $\hat{\pi}_3$ is observed:

$$\Psi(u_3)$$

subject to

$$u_3 \geq U_3 \quad \text{(IIR-}\pi_3)$$

Notice the principal offers contract $C_{na}^P$ to induce a truthful report from type $\pi_1$ and type $\pi_2$: IIC-$\pi_i, \hat{\pi}_1'$. This is the only incentive problem for the principal at the renegotiation stage. As we shall see, this incentive problem is essential. Without it, a full insurance contract will result and the manager would not exert high effort (see Lemma 3). But now the principal has to impose risk in order to induce truthful reporting. The risk, from letting payments vary with the final outcome, can be sufficient to motivate the manager to exert high effort.

**Lemma 3.** If $C_{na}^P$ is a renegotiation-proof contract and induces investment policy $\pi_1\pi_2|\pi_3$, the following must hold:

$$\bar{U}_1 > U_1,$$

$$\bar{U}_2 = U_2 = U_2,$$

$$\pi_2\bar{U}_2 + (1 - \pi_2)U_2 = \pi_2\bar{U}_1 + (1 - \pi_2)U_1.$$

The continuation contract insures the low type ($\pi_2$) but imposes risk on the high type ($\pi_1$). This is the main result from Stiglitz’s [1977] insurance-policy-offering problem. The key to this adverse selection problem is that a full insurance contract is not optimal. A pooling contract that involves complete insurance limits the principal’s ability to extract rents from different agent types. Thus the contract (for the high type) always involves risk and varies with the final project outcome.
Lemma 4. Let $C_{na}^P = \{(\bar{U}_i, U_i), (U_3)\}_{i \in \{1, 2\}}$ be a feasible continuation contract satisfying

\[ \bar{U}_1 > U_1, \]
\[ \bar{U}_2 = U_2 = U_2, \]
\[ \pi_2 \bar{U}_2 + (1 - \pi_2)U_2 = \pi_2 \bar{U}_1 + (1 - \pi_2)U_1. \]

$C_{na}^P$ is then renegotiation proof if and only if

\[ \frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1 (1 - \pi_1)} \frac{\Psi'(U_2)}{\Psi'(U_1) - \Psi'(U_1)}. \]

The intuition can be grasped from the following figure.

Figure 4–2. The indifference curve

The slope of the indifference curve for the type $\pi_1$ manager is $-\frac{\pi_1}{1-\pi_1} U''(\bar{I})$, and $-\frac{\pi_2}{1-\pi_2} U''(\bar{I})$ for the type $\pi_2$ manager. Thus type $\pi_1$'s indifference curve is always steeper than type $\pi_2$'s, as type $\pi_2$ with a higher probability of encountering the low outcome values insurance more. It is optimal for the principal to insure the low
type \((\pi_2)\) but impose some risk on the high type \((\pi_1)\) in order to deter the low type from mimicking the high type. Naturally, if the low type’s payment could be set higher—from \(I_2\) to \(\bar{I}_2\)—he will have less incentive to mimic the high type. Thus the risk imposed on the high type can be reduced from \((\bar{I}_1, \bar{L}_1)\) to \((\bar{I}_1, \bar{L}_1)\). By doing so, the principal’s compensation cost may be lowered because the risk premium paid to the high type is reduced, although the payment to the low type is increased. But this alteration leaves some room for the principal to improve the current contract. She keeps altering the payments until the gain from reducing the risk imposed on the high type is balanced off by the loss from increasing the payment to the low type. That is, the principal reduces \(\Psi'(U_1) - \Psi'(U_{1\prime})\) while increasing \(\Psi'(U_2)\) until the inequality in Lemma 4 holds. If the inequality is satisfied, it means no gain remains to be reaped via renegotiation, and the principal has reached the optimum. That is, the contract is renegotiation proof.

### 4.2.1.2 Ex-ante contracts that are consistent with partial revelation

Foreseeing these effects of renegotiation, the principal solves the ex-ante problem \(P_{na}^P\).

\[
\min_{U_i, U_{i\prime}, U_3} \sum_{i=1}^{2} P_i [\pi_i \Psi(U_i) + (1 - \pi_i) \Psi(U_{i\prime})] + P_3 \Psi(U_3)
\]

subject to

\[
EU \geq -1 \tag{25}
\]
\[
EU \geq m\bar{U}_1 + (1 - m)\bar{L}_1 \tag{26}
\]
\[
EU \geq m\bar{U}_2 + (1 - m)\bar{U}_2 \tag{27}
\]
\[
EU \geq U_3 \tag{28}
\]
\[ \pi_1 U_1 + (1 - \pi_1)U_1 \geq U_3 \]
\[ \pi_2 U_2 + (1 - \pi_2)U_2 \geq U_3 \]
\[ U_3 \geq \pi_3 U_1 + (1 - \pi_3)U_1 \]
\[ U_3 \geq \pi_3 U_2 + (1 - \pi_3)U_2 \]
\[ U_2 = \frac{\pi_3 U_2 + (1 - \pi_2)U_2}{\pi_2} = \pi_2 U_2 + (1 - \pi_2)U_1 \]
\[ \frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \frac{\Psi'(U_2)}{\Psi'(U_1) - \Psi'(U_1)} \]

Where \( EU = e^{\sum_{i=1}^{2} P_i[\pi_i U_i + (1 - \pi_i)U_i] + P_3 U_3} \).

Inequality (25) is the AIR constraint. Inequalities (26)-(28) are the AIC constraints for effort selection. Inequalities (29)-(32) are the AIC constraints for investment policy \( \pi_1 \pi_2 \pi_3 \). These \textit{ex ante} constraints make sure that the principal’s \textit{ex post} beliefs at the renegotiation stage are consistent with the agent’s strategies. Notice that the extra constraints resulting from renegotiation are (33)-(35).

**Proposition 5.** When motivating partial revelation without an audit, the optimal renegotiation-proof contract \( C_P \) takes the following form:

when \( m > \pi_2 \),

\[ \pi_1 \pi_2 \mid \pi_3 \text{ is still optimal in the partial revelation case. Implementing policy } \pi_1 \pi_2 \pi_3 \text{ is not optimal. The investing type will be offered with a full insurance contract. The same contract has to be offered to the non-investing types. With a full insurance contract, high effort cannot be motivated ex ante.} \]
\[U_1 = \frac{P_1(1 - \pi_1) + (P_2 + P_3)(1 - \pi_2) - (1 - m)e^{-rc}}{P_3(\pi_2 - \pi_3)}\]
\[U_1 = -\frac{P_1\pi_1 - (P_2 + P_3)\pi_2 + me^{-rc}}{P_3(\pi_2 - \pi_3)}\]
\[U_2 = U_2 = U_3 = -\frac{P_1(\pi_1 - \pi_2) + (m - \pi_2)e^{-rc}}{P_3(\pi_2 - \pi_3)};\]

when \(m \leq \pi_2,\)

\[U_1 = \frac{P_1(1 - \pi_1) + (P_2 + P_3)(1 - \pi_2) - (1 - \pi_2)e^{-rc}}{P_1(\pi_1 - \pi_2)}\]
\[U_1 = -\frac{P_1\pi_1 - (P_2 + P_3)\pi_2 + \pi_2 e^{-rc}}{P_1(\pi_1 - \pi_2)}\]
\[U_2 = U_2 = U_3 = -1,\]

if the renegotiation-proof condition \(\frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \frac{\psi(U_2) - \psi(U_1)}{\psi(U_1) - \psi(U_3)}\) is satisfied.

Taking into account the effect of renegotiation, the manager’s ex ante incentives are as follows. Since no risk is imposed on type \(\pi_2,\) type \(\pi_2\) and type \(\pi_3\) must receive the same payment \(U_2 = U_3\) in order to induce policy \(\pi_1\pi_2|\pi_3.\) From the effect of renegotiation, \(U_2 = \pi_2U_1 + (1 - \pi_2)U_1,\) the manager will implement policy \(\pi_1\pi_2|\pi_3.\) If the prior belief indicates the project is promising \((m > \pi_2);\) however, the manager might want to misreport as \(\pi_1\) in order to avoid searching for information. That is, constraint (26) is binding. Similarly, if the project is not that promising, \((m \leq \pi_2),\) he might reject the project (by claiming \(\pi_3\)) before ever searching for information. That is, constraint (28) is binding.

If the contract specified in Proposition 5 does not satisfy the renegotiation-proof condition, the principal will increase type \(\pi_2\)’s payment and reduce the risk imposed on type \(\pi_1\) (Refer to Figure 1). The reduced risk on type \(\pi_1\) will not be sufficient to motivate the manager to exert high effort. If \(\pi_1\) is close enough to 1, however, the renegotiation-proof condition can be satisfied. With \(\pi_1\)
close to 1, \( U_1, U_1, U_2 \) are all finite terms. Hence the ratio \( \frac{\Psi(U_2)}{\Psi(U_1)} \) in the renegotiation-proof condition is also finite, but the ratio \( \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \) can go unbounded. Thus, contract \( C_{na}^P \) will be able to motivate the high effort. To illustrate the feasibility of this contract, consider the following numerical example. Let \( \pi_1 = .9, \pi_2 = .5, \pi_3 = .1, P_1 = .4, P_2 = .4, P_3 = .2, c = 200 \) and \( r = .0001 \). The optimal contract is \( \overline{I}_1 = 1097.67, \overline{I}_1 = -1341.46, I_2 = I_3 = -196.08 \), and the contract does satisfy the renegotiation-proof condition: \( \frac{P_1}{P_2} = 1 \), and \( \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \frac{\Psi(U_2)}{\Psi(U_1)} = 18.6 \). The total expected compensation is 223.86. (In the remainder of the analysis, I consider the contract \( C_{na}^P \) only when the renegotiation-proof condition can be satisfied.)

4.2.2 The Original Problem \( P^P \)

Now return to the original problem where an audit is available. The audit function at the interim reporting stage is to discern whether the manager’s information is consistent with the reporting rule \( \{\{\pi_1, \pi_2\}\{\pi_3\}\} \). The auditor does not distinguish whether the manager received good news (\( \pi_2 \)) or great news (\( \pi_1 \)). Thus the audit function is in effect designed to monitor the manager’s investment decisions.

**Lemma 5.** An audit is weakly efficient in the partial revelation case.

The principal cannot be hurt by the auditor’s report, although it is issued before renegotiation. This is because the auditor’s report is only a garbling of the manager’s reported information, and the principal cannot obtain more information from observing the auditor’s report. Releasing the auditor’s report does not create an incentive for the principal to further renegotiate the contract. But its release helps the principal monitor the manager’s investment decisions and provides short-term commitment before renegotiation takes place, so the auditor’s report is valuable to motivate the manager to acquire information. (Recall the value of auditing in the full commitment setting. The auditor’s report is informative about
the manager’s effort. If the manager did not acquire any information, he has to lie and the auditor can detect lying with a positive probability.)

4.3 The Optimal Information Flow

Compared with the full revelation case, partial revelation limits the principal’s incentive to renegotiate the contract. Restraining information flow, as a substitute for commitment, can make it easier for the principal to manage the long-term relationship with the manager. Recall that the manager’s incentive to reveal his information fully at the interim reporting stage depends solely on the auditor’s report. The audit technology determines whether to pursue full revelation. Specifically, if the audit accuracy is high, i.e., \( \alpha, \beta \to 0 \), when to reveal the manager’s information is trivial. However, if the audit accuracy is low, i.e., \( \alpha, \beta \to 0.5 \), when to reveal the manager’s information is crucial. Inducing partial revelation can successfully motivate the manager to exert high effort, even if no auditor is present. In this way, the adverse consequence of low audit accuracy can be avoided.

**Proposition 6.** If \( \alpha, \beta \to 0 \), full revelation can be preferred; if \( \alpha, \beta \to 0.5 \), partial revelation is preferred.

Using the same parameter values of the numerical example as in Section 6.1.2, the table below compares the total expected compensation between the two reporting rules.

<table>
<thead>
<tr>
<th>((\alpha, \beta))</th>
<th>(.01, .01)</th>
<th>(.2, .2)</th>
<th>(.3, .1)</th>
<th>(.4, .2)</th>
<th>(.4, .4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>full revelation</td>
<td>200.02</td>
<td>200.89</td>
<td>201.08</td>
<td>203.04</td>
<td>212.09</td>
</tr>
<tr>
<td>partial revelation</td>
<td>204.46</td>
<td>206.38</td>
<td>206.93</td>
<td>209.75</td>
<td>215.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>((\alpha, \beta))</th>
<th>(.4, .45)</th>
<th>(.45, .45)</th>
<th>(.45, .47)</th>
<th>(.47, .47)</th>
<th>(.49, .49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>full revelation</td>
<td>221.43</td>
<td>250.08</td>
<td>278.21</td>
<td>341.28</td>
<td>1647.66</td>
</tr>
<tr>
<td>partial revelation</td>
<td>218.28</td>
<td>220.94</td>
<td>221.86</td>
<td>222.68</td>
<td>223.69</td>
</tr>
</tbody>
</table>
The table shows that full revelation dominates partial revelation when $\alpha$ and $\beta$ are small, but the compensation cost increases dramatically when $\alpha$ and $\beta$ are close to 0.5. The compensation cost from inducing full revelation is sensitive to the audit technology. When audit accuracy is high, it is wise to use the auditor’s report fully, i.e., the auditor is instructed to check all details of the manager’s information. But if the audit accuracy is too low, the compensation cost becomes extremely large; ultimately the auditor’s report becomes useless to provide the manager incentive to choose high effort.

The proof follows directly from Propositions 4 and 5 and Lemma 5.

### 4.4 Summary

Partial revelation can be useful. The acquired information is forward looking and communicating it requires estimation. Daily involvement with the firm’s operations and the expertise to search for information put the manager in a better position to interpret the acquired information than the auditor. The auditor will commonly have difficulty reaching agreements with the manager on the reporting issues. Realizing that the audit accuracy can be low in handling this type of information, the auditor should be motivated to allow the manager to withhold some information. The audit is still useful because it verifies whether the manager’s investment decision is justified by his acquired information. But leaving some information unverified can benefit the long-term contracting relationship in that it allows investors to learn gradually about the manager throughout the project and matches better with the manager’s long-term perspective. Of course, some accounts are easier to verify than others. If the auditor is confident with her audit technology, it is reasonable to enforce full revelation. Again, the auditor’s judgment is required.

Paralleling the auditor’s decision, this result also speaks subtly to the value of earnings management. Auditors are less likely to require adjustment of earnings
management attempts when some information is subject to more discretion. (See Nelson, Elliott, and Tarpley [2002].) Perhaps this is because allowing some information to be kept private can avoid disrupting the manager’s long-term objective. Withholding information arises due to the joint effect of long-term investment plans and audit errors.
In this chapter, we consider a larger set of available information for investment decisions. Useful information is not limited to financial reports. Information that comes to help can vary from a formal managerial accounting system to a walk around the factory. One problem is, some of the information is unverifiable. For instance, in the development of a project, both the principal and the manager commonly observe information before making the next move. But evaluation of the project based on the observed information may be subjective. It is not easy to present such information to a third party without causing ambiguity, so this type of information cannot be used in contracting with the manager.

Under some carefully-designed mechanisms, this type of information can still be useful for decisions even if it is not directly contractible. Demski and Sappington [1991] provide an interesting analysis in which both the principal and agent exert productive effort. The principal observes the agent’s effort (the unverifiable information) and has the option to require the agent to purchase the business at a pre-negotiated price. For example, a retailer usually can discern the quality of a product manufactured by a corporation before supplies effort to market the product, and the corporation has sufficient fund to buy out the retailer. The problem can be solved costlessly by letting the manufacturer buy out the business whenever the product quality is not satisfactory. Baiman and Rajan [1995] study a setting where only the principal can observe the unverifiable information so she is subject to moral hazard concerns when she pays the agent based on the unverifiable information. One clever way to use the unverifiable information with multiple
agents is to allow the principal to allocate discretionary bonus among the agents but the total bonus pool is based on some contractible information.

5.1 The Investment Problem

Returning to our investment problem, we know some times underinvestment or overinvestment may occur. One of the reasons may be the decision-facilitating information is unverifiable. The received signals \( \pi_1, \pi_2 \) or \( \pi_3 \) are difficult to articulate so the contract cannot take each contingency into consideration. With the contract going incomplete, some efficiency is lost when the investment decision is delegated to the manager. (For simplicity, I assume both the principal and manager can observe the information, even it is unverifiable. A more general situation would be, the principal and manager observe different information since they may have their own information sources and may interpret the information differently even when they are reading the report from the same consultant.)

Since the acquired information is not contractible, the principal offers contract \( \{U, \bar{U}, U\} \). The payment depends on \( \bar{x} \in \{\pi, x, \bar{x}\} \) only. To minimize the expected compensation cost, the following program \( (P^{FB}) \) is set up to implement the first-best investment policy \( \pi_1 \pi_2 | \pi_3 \).

\[
\begin{align*}
\min_{U, \bar{U}, U} & \quad [P_1 \pi_1 + P_2 \pi_2] \Psi(\bar{U}) + [P_1 (1 - \pi_1) + P_2 (1 - \pi_2)] \Psi(U) + P_3 \Psi(U_3) \\
\text{Subject to:} & \\
EU & \geq -1 \quad (36) \\
EU & \geq m\bar{U} + (1 - m)\bar{U} \quad (37)
\end{align*}
\]
\[ EU \geq U \]  \hspace{1cm} (38)

\[ \pi_2 U + (1 - \pi_2) U \geq U \]  \hspace{1cm} (39)

\[ U \geq \pi_3 U + (1 - \pi_3) U \]  \hspace{1cm} (40)

where \( EU = e^{\text{rec}}\left\{[P_1 \pi_1 + P_2 \pi_2]U + [P_1 (1 - \pi_1) + P_2 (1 - \pi_2)]U + P_3 U\right\} \).

**Proposition 7.** When \( m > \pi_2 \), implementing \( \pi_1|\pi_2\pi_3 \) is strictly less costly than implementing the first-best policy \( \pi_1|\pi_2|\pi_3 \).

If the first-best policy is implemented, the manager has more incentives to avoid searching information because the expected profitability \( m \) is already above the induced investment level \( \pi_2 \). The project, “on average”, is profitable. The manager’s incentives to search for information are different when implementing the policy \( \pi_1|\pi_2\pi_3 \). The manager cannot tell whether the project is worth investing based only on the expected profitability \( m \). “On average”, the project may or may not be worth investing. Therefore, the risk-averse manager would search for more information to settle the uncertainty. It becomes less costly to motivate the manager to acquire information. If the investment gain is not too large to sacrifice when \( \pi_2 \) is observed,\(^1\) the principal can be better off implementing the “second-best” policy \( \pi_1|\pi_2\pi_3 \).

In order to motivate the manager to acquire information, it is generally beneficial to impose maximal uncertainty so the risk-averse manager is more willing to reduce the risk by acquiring information. Inducing the manager to make an efficient investment decision, however, has to rely on the acquired information. The amount of risk has to match up with the manager’s type, i.e., his information. The risky type (the manager type who observes relatively bad signal \( \pi_2 \)) should be provided more insurance relative to the safe type (\( \pi_1 \)). Therefore, it is difficult to

---

\(^1\) That is, \( P_2[\pi_2 x + (1 - \pi_2) x - x] \) is not too large.
reconcile the conflict in designing the contract. That is, the contract may not be able to provide incentives to acquire information and invest efficiently at the same time.\(^2\)

### 5.2 The Effect of Renegotiation

In order to avoid the “underinvestment” problem, one approach is to set up some revelation mechanism, where the principal and agent report their observation to the judge simultaneously. The judge will then penalize the two if their reports conflict. There exists a Nash equilibrium in which the parties can credibly reveal their private information and based on the report, the optimal investment policy can be implemented.\(^3\)

Nevertheless, presenting evidence to a court seems to be different from sending messages inside a firm. Accounting reports only admits some type of information and is restricted in certain formats. In addition, it is difficult to proceed under the revelation mechanism when parties have different private information.

In this section, we resort to ex post contract renegotiation to implement optimal investment policy, without invoking any report of the unverifiable information. The principal offers to renegotiate the manager’s existing contract after the acquired information is observed but before the manager makes any investment decision. Now the new continuation contract can take into account the

---

\(^2\) Proposition 7 characterizes the problem of underinvestment. Similarly, an overinvestment problem may happen when \( m < \pi_2 \). In that case, implementing \( \pi_1, \pi_2 | \pi_3 \) may be less costly when \( \pi_1 | \pi_2, \pi_3 \) is the first-best policy. The reason is the same: create maximal uncertainty to induce information acquiring activities. But implementing overinvestment policy has to compensate the risk-averse manager for the additional risk. A random cash flow results if investing when \( \pi_2 \) is observed. So the benefit of inducing overinvestment is relatively smaller.

\(^3\) Cremer and McLean [1988] study an auction setting where the seller wants to induce buyers to reveal their imperfectly correlated valuation.
realized information implicitly. The risk level based on the information can be set properly so that the manager’s investment incentives can be straightened out. The following timeline reflects the change in the order of events.

| Principal offers contract $C_1$ | Manager chooses effort $\eta$ to gather information | Unverifiable information $\pi(\eta)$ observed | Contract renegotiated $C_2$ | Investment decision made | Outcome realized, $\overline{\pi}, \underline{x}$ or $x$. Payment made |

Figure 5–1. Timeline when unverifiable information is observed

At the renegotiation stage, the principal offers a new continuation contract to minimize the expected compensation cost given the observed information. Of course, the initial contract provides the manager with the default utility level. The result is similar to the full revelation case in Chapter 4. Since I assume there is no extra cost to implement any investment policy, the principal’s optimal choice is to offer a full insurance contract based on the observed information. Suppose the initial contract $\{\overline{U}^{SB}, \underline{U}^{SB}, U^{SB}\}$ induces the second-best investment policy $\pi_1|\pi_2\pi_3$. At the renegotiation stage, the principal offers a new contract $\{U_1, U_2\}$, where the new offer is $U_1$ when the principal observes $\pi_1$, and is $U_2$ when the principal observes $\pi_2$ or $\pi_3$. Manager types $\pi_2$ and $\pi_3$ are offered the same contract because the initial contract induces both types not to invest thus providing the same utility level. If the principal does not observe any new information at the renegotiation stage, she offers $U_2$ to the manager. Then we have
\[
\pi_1 \underline{U}^{SB} + (1 - \pi_1)\overline{U}^{SB} = U_1 \tag{41}
\]
\[
U^{SB} = U_2 \tag{42}
\]

**Proposition 8.** The renegotiated contract \(\{U_1, U_2\}\) implements the first-best investment policy and induces the manager to acquire information at a lower cost compared with the second-best contract \(\{\overline{U}^{SB}, \underline{U}^{SB}, U^{SB}\}\) where no renegotiation takes place.

The effect of renegotiation is to reduce risk premium. In this case, when there is no more incentive problem for the principal to handle, the risk premium is reduced to zero. With a fixed payment, the manager is completely shielded from any risk resulting from his investment decision. He will implement the first-best investment policy.

In order to motivate the manager to acquire information, the following constraints are binding for the initial contract \(\{\overline{U}^{SB}, \underline{U}^{SB}, U^{SB}\}\):

\[
e^r c \{P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1)\underline{U}^{SB} + (P_2 + P_3)U^{SB}\} \geq -1
\]
\[
e^r c \{P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1)\underline{U}^{SB} + (P_2 + P_3)U^{SB}\} \geq m\overline{U}^{SB} + (1 - m)\underline{U}^{SB}
\]
\[
e^r c \{P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1)\underline{U}^{SB} + (P_2 + P_3)U^{SB}\} \geq U^{SB}
\]

Since the renegotiated contract offers the manager the same utility level, the manager’s ex ante incentives to acquire information are not altered. (These constraints are satisfied when we substitute the renegotiated contract \(\{U_1, U_2\}\) with (41), (42) and \(m\overline{U}^{SB} + (1 - m)\underline{U}^{SB} = U_2. \) The last equation is implied by the binding constraints.) Based on the newly observed information, however, the principal is able to reduce the risk premium by insuring the manager types who are invited to invest. Therefore, the expected compensation cost is strictly lower.

The benefit of renegotiation is, it isolates the spillover effect between acquiring information and making an investment decision. After the manager’s effort is sunk,
the contract is revised to reflect the current situation. The current situation is to induce the manager to make a proper investment decision, so the ex post efficient contract will provide the manager with the right incentives. The incentives are reshuffled to accommodate the current need.

This result can be seen as an application of Hermalin and Katz [1991] in a multi-task setting. Renegotiation occurs and takes advantage of the unverifiable information. In contrast, the compensation cost cannot be reduced to the first-best level as in a conventional moral hazard model. The same as their model, the principal can observe the manager’s effort directly: if the manager works, $\pi_1$, $\pi_2$ or $\pi_3$ can be observed, but if he shirks, no information is observed. But the initial contract sets different default utility levels based on the observed information. Hence, the renegotiation process cannot lower the manager’s default utility directly to the first-best level. Endogenously created information changes the manager’s preference entering the renegotiation stage.

We have studied contract renegotiation in Chapter 4 and 5, but the effects are distinct. Chapter 4 studies a setting where renegotiation is purely a trade friction. When the manager holds private information, how the information is reported affects the following renegotiation process which affects the manager’s incentive in productive actions: acquiring information and making a proper investment decision. Chapter 5 deals with unverifiable but observable information. There are no reporting problems. Renegotiation serves as a mechanism to use the unverifiable information indirectly, thus can be beneficial.

5.3 Summary

There are long-standing concerns about efficient investments. Underinvestment in research and development will slow down the long-term growth of the economy. Failure to pull the plug when the project runs on a losing course can cost the company hugely. These problems occur partially because the manager’s
incentives are not adjusted properly along the project’s duration. Newly discovered information calls for a re-evaluation of the project’s profitability. How to make use of the discovered information is the focus of this chapter, even if the discovered information is unverifiable and thus cannot be used directly in contracting with the manager. Instead of relying on some revelation mechanisms, the principal can renegotiate the existing contract based on the newly discovered information. The ex post efficient contract provides the manager with up-to-date incentives to make a proper investment decision.

One caveat of our model is that the investment cost is simplified to be zero. Therefore, a full insurance contract is resulted to take care of the investment incentives. If the project needs an unobservable fund injection after the contract is renegotiated, then a risky contract will be offered. Maybe it is not beneficial to isolate the two tasks by inserting contract renegotiation in between. Sometimes, the spillover effect may be beneficial. For example, the risk imposed to motivate the manager to acquire information may coincide with the risk to motivate the manager to make a proper investment decision, so it is trivial to consider implementing the investment decision. Sometimes, inducing an efficient investment policy may also automatically motivate the manager to acquire information. The nature of multitasking determines the usefulness of contract renegotiation.
Acquiring information for a risk averse manager is never a trivial task. One might think the imposed risk from motivating another task would naturally force the manager to collect more information. But the contract design is subtle. If the imposed risk on the manager is too small, he will not acquire information, but just invest in the project; if the imposed risk is too high, the manager will not do the work either, but just forgo the project.\footnote{Laux [2004] pointed out that motivating the manager to implement another task cannot automatically provide the manager the right incentive to collect information. It is always necessary to motivate information acquisition explicitly.} This paper shows that auditing, when conducted properly, can help create efficient incentives for the manager to acquire information.

An audit of the manager’s acquired information is beneficial because it aligns the manager’s incentives in acquiring useful information and in making a proper investment decision. But if the board of directors cannot commit not to use the disclosed information to renegotiate the initial contract, an extensive audit may exacerbate the control problem. Therefore, if the audit technology is not highly effective in identifying misstatements, the auditor may only want to verify whether the manager’s report is consistent with his investment decision, but allow the manager to keep the finer details private. This arrangement is beneficial because it also reins in the self-interested behavior coming from the owner’s side. Together with the manager’s behavior, it depicts an interesting balance in equilibrium.
Financial reports contain information that is useful for future decision-making. The consequences of past decisions are also recorded in financial reports. The auditor verifies the reported information thus serves as a monitoring device of managers’ decisions. It is important for the auditor to understand the manager’s dynamic decisions making. The manager’s decision in financial reporting is correlated with his decision in productive actions, which in turn affects the underlying resource allocation. Ex post uses of reported information influence the manager’s ex ante incentives to acquire information and make a proper investment decision. It is also important to recognize the economic consequences of standard setting. The rules on financial reporting and auditing change the preparers’ behavior. Standard-setters are not regulating nature but rational economic agents.

The results echo the line of literature that provides explanations for earnings management based on the effect of renegotiation (a violation of the Revelation Principle’s assumptions).\(^2\) My analysis focuses on how renegotiation affects the manager’s investment behavior when the audited information is endogenously acquired. Audit technology determines how much information is to be disclosed. In contrast, a perfect audit in my model results in a first-best scenario and the manager’s information should be disclosed. The intuition is that the manager’s shirking means no useful information is produced and thus will be detected in the audit. The adverse effect of renegotiation is amplified only when the audit technology is relatively ineffective so using the auditor’s report alone is not informative enough to provide incentives for the agent to work. My analysis emphasizes the subtlety of the audit function and therefore the solution is

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\(^2\) See Demski and Frimor [1999], Christensen, Demski and Frimor [2002], Christensen, Feltham and Sabac [2004] and Gigler and Hemmer [2004].
“interior”—motivating accurate financial reports may or may not be efficient. Auditors’ judgments are the centerpiece.

Some argue that we impose too much responsibility on the auditor. The auditor’s job is to “check whether a reported number is correct”. The auditor does not ask why and how the number is generated. As the auditor assesses audit risk and materiality before performing substantive tests of transactions, however, she is concerned about management. SAB 99 advises the auditor to investigate the manager’s incentives carefully as opposed to setting some mechanic materiality threshold. Accounting firms hire experts to audit R&D contracts because they have superior knowledge to evaluate the manager’s performance. Auditing is not a simple task in that it requires the auditor formulate judgments. The deeper the auditor understands managerial decisions, the easier the auditor reaches a correct conclusion.

Some worry about the auditor’s incentives if she is provided more discretion. That is a valid concern. There is another round of incentive problems. One problem is how the PCAOB evaluates the auditor’s work when their opinion is at odds with the auditor’s judgments. Auditor’s exposure to legal liability forces standard setters to consider simple, rules-based standards that permits less discretion. The audit fees, market competition, etc., all influence the auditor’s behavior. A model with multiple players would be more appropriate to address these questions. But our model provides a salient structure of the audit function. More importantly, we point out the gap in the understanding of financial reporting and auditing. If financial reporting is a sophisticated communication process, auditing should help to serve this goal. We first provide a benchmark where an ideal auditor should perform, then we search for feasible mechanisms to induce to the auditor to perform as we hope. After all, the questions boil down to the trade off between revealing information enforced by an auditor and the resulting
concerns for efficiency. The main message from my study is well reflected here: the optimal auditor’s choice depends on the context that creates the incentive nexus and there is no panacea for all the reporting issues. Auditors are expected to rely on judgments to deliver high-quality work.

Besides revelation mechanisms, there are other mechanisms that make the discovered information useful. Contract renegotiation takes into consideration newly discovered information. Thus the manager’s investment incentives are better aligned with the current situation. In this way, the spillover effect between information acquisition and investment decisions can be isolated. Efficiency is strictly improved. However, the result hinges on the assumption that there is no additional cost to invest in the project. An extension would drop this assumption and examine more about the spillover effect between the two tasks. We might find that interim contract renegotiation can disrupt the synergy between the two tasks.
APPENDIX
THE PROOF

Proof of Lemma 1.

First we identify the binding constraints for each of the two situations: \(m > \pi_2\) or \(m \leq \pi_2\).

A. when \(m > \pi_2\).

In a less restricted problem, where only constraints (1) (2) (3) (8) (10) are present, all the constraints are binding. Then I show the less restricted program is feasible to the original problem.

Let \(\lambda, \mu_1, \mu_2, \mu_3, \mu_4\) represent the Lagrangian multipliers for each constraint. The FOCs provide

\[
\Psi'(U_1) = \lambda e^{rc} + \mu_1 [e^{rc} - \frac{m}{P_1\pi_1}] + \mu_2 e^{rc}
\]

\[
\Psi'(U_2) = \lambda e^{rc} + \mu_1 [e^{rc} - \frac{1-m}{P_2(1-\pi_1)}] + \mu_2 e^{rc}
\]

\[
\Psi'(U_2) = \lambda e^{rc} + \mu_1 e^{rc} + \mu_2 (e^{rc} - \frac{m}{P_2\pi_2}) + \mu_3 \frac{1}{P_2} - \mu_4 \frac{\pi_3}{P_2\pi_2}
\]

\[
\Psi'(U_3) = \lambda e^{rc} + \mu_1 e^{rc} + \mu_2 e^{rc} - \mu_3 \frac{1}{P_3} + \mu_4 \frac{1}{P_3}
\]

Remember \(\Psi(\cdot)\) is the inverse function of \(U(\cdot)\). Since \(U'(\cdot) > 0\) and \(U''(\cdot) < 0\), \(\Psi'(\cdot) = \frac{1}{U'(\cdot)} > 0\) and \(\Psi''(\cdot) = -\frac{1}{[U'(\cdot)]^2} U''(\cdot) > 0\). So the RHS increases in \(U\).

Suppose \(\mu_3 = \mu_4 = 0\). With \(U_3 > \underline{U}_2, \underline{U}_2\), it implies type \(\pi_2\) manager always reports \(\pi_3\). Suppose \(\mu_3 = 0, \mu_4 > 0\), again we have \(U_3 > \underline{U}_2, \underline{U}_2\). Suppose \(\mu_3 > 0, \mu_4 = 0\), two possibilities: a \(\mu_2 > 0\) and b \(\mu_2 = 0\). a implies \(\underline{U}_2 < \underline{U}_2\), because \(\frac{m}{P_2\pi_2} > \frac{1-m}{P_2(1-\pi_2)}\). \(\pi_2 \underline{U}_2 + (1 - \pi_2) \underline{U}_2 < \pi_3 \underline{U}_2 + (1 - \pi_3) \underline{U}_2\), since \(\pi_2 > \pi_3\).

Either constraint (8) or (10) must be violated. b implies \(\underline{U}_2, \underline{U}_2 > U_3\). The type \(\pi_3\) manager will always report \(\pi_2\).
Only \( \mu_3 > 0, \mu_4 > 0 \) is valid. Constraints (8) and (10) are binding: \( \pi_2 U_2 + (1 - \pi_2) U_3 = \pi_3 U_2 + (1 - \pi_3) U_2 = U_3 \). Since \( \pi_2 \neq \pi_3 \), the only solution is \( U_2 = U_3 = U_3 \).

Suppose \( \mu_1 = \mu_2 = 0 \), then we have \( U_2 \neq U_3 \), contradict to the result above.

Suppose \( \mu_1 = 0, \mu_2 > 0 \), then we have \( U_1 = U_1 \). With \( U_2 = U_2 = U_3 \), truthful reporting requires all the payments are equal. Then the manager will not work.

Suppose \( \mu_1 > 0, \mu_2 = 0 \), then we have \( U_2 \neq U_2 \), which contradicts to the derived result \( U_2 = U_2 \).

It is easy to check that the rest of constraints are satisfied with the established binding constraints. Hence, constraints (1) (2) (3) (8) (10) are binding for the original program. The FOCs and \( \frac{m}{P_1 \pi_1} < \frac{1-m}{P_1(1-\pi_1)} \) imply \( U_1 > U_1 \).

B. when \( m \leq \pi_2 \).

Similarly, we can find the binding constraints are (1) (3) (4) (7). Reassign \( \lambda, \mu_1, \mu_2, \mu_3 \) to represent the Lagrangian multipliers for these four constraints. The FOCs from the relaxed problem are:

\[
\Psi'(U_1) = \lambda e^r c + \mu_1 e^r c + \mu_2 e^r c - \mu_3 \frac{\pi_2}{P_1 \pi_1},
\]

\[
\Psi'(U_1) = \lambda e^r c + \mu_1 e^r c + \mu_2 e^r c - \mu_3 \frac{1-\pi_2}{P_1(1-\pi_1)},
\]

\[
\Psi'(U_2) = \lambda e^r c + \mu_1 (e^r c - \frac{m}{P_2 \pi_2}) + \mu_2 e^r c + \mu_3 \frac{1}{P_2},
\]

\[
\Psi'(U_2) = \lambda e^r c + \mu_1 (e^r c - \frac{1-m}{P_2(1-\pi_2)}) + \mu_2 e^r c + \mu_3 \frac{1}{P_2},
\]

\[
\Psi'(U_3) = \lambda e^r c + \mu_1 e^r c + \mu_2 (e^r c - \frac{1}{P_2}).
\]

It is also easy to check that the rest of the constraints are satisfied with the established binding constraints. The FOCs and \( \frac{\pi_2}{P_2 \pi_2} < \frac{1-\pi_2}{P_2(1-\pi_2)} \) imply \( U_1 > U_1 \);

\[
\frac{m}{P_2 \pi_2} \leq \frac{1-m}{P_2(1-\pi_2)} \text{ implies } U_2 \geq U_2. \text{ QED.}
\]

**Proof of Proposition 1**

Auditing expands the set of contracting variables. The problem with no audit is a restricted version of the problem where an audit is available, so the no-audit problem can be written as follows:
Min \sum_{i=1}^{2} P_i \{(1 - \alpha)[\pi_i \Psi(U_{iT})] + (1 - \pi_i)\Psi(U_{iF})] + \\
\alpha[\pi_i \Psi(U_{iF})] + (1 - \pi_i)\Psi(U_{iF})\} + P_3[(1 - \alpha)\Psi(U_{3T}) + \alpha\Psi(U_{3F})]

Subject to:

\begin{align}
EU & \geq -1 & (A1) \\
EU & \geq \beta[mU_{1T} + (1 - m)U_{1T}] + (1 - \beta)[mU_{1F} + (1 - m)U_{1F}] & (A2) \\
EU & \geq \beta[mU_{2T} + (1 - m)U_{2T}] + (1 - \beta)[mU_{2F} + (1 - m)U_{2F}] & (A3) \\
EU & \geq \beta U_{3T} + (1 - \beta)U_{3F} & (A4) \\
(1 - \alpha)[\pi_1 U_{1T} + (1 - \pi_1)U_{1T}] + \alpha[\pi_1 U_{1F} + (1 - \pi_1)U_{1F}] & \geq \beta[\pi_1 U_{2T} + (1 - \pi_1)U_{2T}] + (1 - \beta)[\pi_1 U_{2F} + (1 - \pi_1)U_{2F}] & (A5) \\
& \geq \beta U_{3T} + (1 - \beta)U_{3F} & (A6) \\
(1 - \alpha)[\pi_2 U_{2T} + (1 - \pi_2)U_{2T}] + \alpha[\pi_2 U_{2F} + (1 - \pi_2)U_{2F}] & \geq \beta[\pi_2 U_{1T} + (1 - \pi_2)U_{1T}] + (1 - \beta)[\pi_2 U_{1F} + (1 - \pi_2)U_{1F}] & (A7) \\
& \geq \beta U_{3T} + (1 - \beta)U_{3F} & (A8) \\
(1 - \alpha)U_{3T} + \alpha U_{3F} & \geq \beta[\pi_3 U_{1T} + (1 - \pi_3)U_{1T}] + (1 - \beta)[\pi_3 U_{1F} + (1 - \pi_3)U_{1F}] & (A9) \\
& \geq \beta[\pi_3 U_{2T} + (1 - \pi_3)U_{2T}] + (1 - \beta)[\pi_3 U_{2F} + (1 - \pi_3)U_{2F}] & (A10) \\
U_{iT} &= U_{iF} & (A11) \\
U_{iT} &= U_{iF} & (A12) \\
U_{3T} &= U_{3F} & (A13)
\end{align}
Where

\[ EU = e^{rc} \left\{ \sum_{i=1}^{2} P_i [(1 - \alpha) \pi_i U_{iT} + (1 - \pi_i) U_{IT}] + \alpha (\pi_i U_{iF} + (1 - \pi_i) U_{iF})] + P_3 [(1 - \alpha) U_{3T} + \alpha U_{3F}] \right\} \]

It is clear that auditing cannot increase the expected compensation cost by relaxing constraints (A11)-(A13). To show that auditing can strictly reduce the expected compensation cost, consider an audit that is conducted only when \( \pi_3 \) is reported. That is, given \( U_{iT} = U_{iF} \) and \( U_{iT} = U_{iF} \), I show that the constraint \( U_{3T} = U_{3F} \) is binding.

A. when \( m > \pi_2 \)

I have shown that in the proof of Lemma 1, constraints (A1) (A2) (A3) (A8) (A10) are binding. Let \( \lambda, \mu_1, \mu_2, \mu_3, \mu_4 \) represent the Lagrangian multipliers for these constraints so they are all positive. Let \( \mu_5 \) represent the Lagrangian multiplier for the extra constraint (A13). The FOCs for \( U_{3T} \) and \( U_{3F} \) are

\[ \Psi'(U_{3T}) = \lambda e^{rc} + \mu_1 e^{rc} + \mu_2 e^{rc} - \mu_3 \frac{\beta}{P_3(1 - \alpha)} + \mu_4 \frac{1}{P_3} + \mu_5 \frac{1}{P_3(1 - \alpha)} \]
\[ \Psi'(U_{3F}) = \lambda e^{rc} + \mu_1 e^{rc} + \mu_2 e^{rc} - \mu_3 \frac{1 - \beta}{P_3 \alpha} + \mu_4 \frac{1}{P_3} - \mu_5 \frac{1}{P_3 \alpha} \]

Since \( \lambda, \mu_1, \mu_2, \mu_3, \mu_4 > 0 \), in order for \( U_{3T} = U_{3F} \) to hold, \( \mu_5 \) must be negative because \( \frac{\beta}{1 - \alpha} < \frac{1 - \beta}{\alpha} \). Therefore, constraint \( U_{3T} = U_{3F} \) imposes extra costs to the problem.

The proof for \( m \leq \pi_2 \) is similar.

Since adding more audits will not increase the compensation cost when \( \pi_1 \) and \( \pi_2 \) are reported, auditing is strictly valuable to the principal. QED.

**Proof of Proposition 2.**

Suppose the principal offers \( C_1 = C^* \) at the initial contracting stage and that the manager accepts and chooses strategy profile \( B = (\eta_H, \pi_1, \pi_2, \tilde{\pi}_I, \tilde{\pi}_F) \). If \( C^* \) is not renegotiation proof, there must be another contract, \( \tilde{C} \), which offers every
type of the manager at least the same expected utility as \( C^* \) but leads to a lower compensation cost for the principal. Yet such a contract cannot exist, because \( C^* \) is the final contract and hence optimal at the renegotiation stage. Thus \( C^* \) is renegotiation proof given the manager’s strategy profile. The manager’s strategies remain the same, because his compensation depends only on the final contract. If in equilibrium, the manager chooses \( B \) when \( \hat{C} \) is the initial contract and \( C^* \) is the final contract, then he makes the same choices when \( C^* \) is offered initially. QED.

**Proof of Lemma 2**

Suppose without an auditor, the manager reports truthfully \( \pi_1, \pi_2 \) or \( \pi_3 \) before entering the renegotiation stage. Since the low effort produces no information, the principal realizes the manager has already exerted effort to acquire information. Given the principal’s belief that the manager has worked, made a proper investment decision \( \pi_1 \pi_2 | \pi_3 \), and reported his private information truthfully, a contract \( C = \{ (\bar{U}_1, U_1), (\bar{U}_2, U_2), U_3 \} \) is renegotiation proof if

\[
\bar{U}_j, U_j \in \arg\min_{\pi_j, u_j} \pi_j \Psi(\bar{u}_j) + (1 - \pi_j) \Psi(u_j)
\]

subject to

\[
\pi_j \bar{u}_j + (1 - \pi_j) u_j \geq \pi_j \bar{U}_j + (1 - \pi_j) U_j; \forall j \in \{1, 2\}, \quad (\text{IIR-}\pi_j)
\]

and

\[
U_3 \in \arg\min_{u_3} \Psi(u_3)
\]

subject to

\[
u_3 \geq U_3. \quad (\text{IIR-}\pi_3)
\]
With a single IIR constraint in each information event, the principal’s best strategy is to offer a fixed payment: $U_j = U_j = U_j$. Then the payments should be equal for all the three events in order to induce the manager to report truthfully. We have $U_1 = U_2 = U_3$, i.e., a full insurance contract. But a full insurance contract cannot induce the manager to work, which contradicts the principal’s belief that the manager has worked. QED.

**Proof of Proposition 3.**

The result can be derived directly from the interim optimization program. For 1 type $\pi_1$ or $\pi_2$, at each information event $(\hat{\pi}_I, A_k)$, the principal solves a cost-minimization problem with only one IIR constraint. The principal’s optimal strategy is to offer a fixed payment conditional on each information event, i.e., $U_{1T} = U_{1T}^T; U_{2T} = U_{2T}^T; U_{1F} = U_{1F}^T; U_{2F} = U_{2F}^T$. For 2 type $\pi_3$, there is no room to gain via renegotiation. Since there is only one fixed payment for each information event $(\hat{\pi}_I, A_k)$, $U_{3T}$ and $U_{3F}$ are renegotiation proof. Given each information event, the principal offers a full insurance contract: $C^T = \{(U_{1T}, U_{1F}), (U_{2T}, U_{2F}), (U_{3T}, U_{3F})\}$. QED.

**Proof of Proposition 4.**

Considering the following contract: $\{I_{jT} = c + \epsilon, I_{jF} = 0\}$, where $\epsilon > 0$. For this contract to be feasible for the program, the inequalities (11)-(14) should be satisfied:

\[
e^{rc}(1 - \alpha)(-e^{-r(c+\epsilon)} + \alpha(-e^0)) \geq -1
\]

\[
e^{rc}(1 - \alpha)(-e^{-r(c+\epsilon)} + \alpha(-e^0)) \geq -\beta e^{-r(c+\epsilon)} - (1 - \beta)e^0
\]

Notice that other constraints are satisfied using this contract, since $1 - \alpha > \beta$.

Rewriting the two inequalities, we have

\[
-e^{-rc} \geq \frac{\alpha}{1-\alpha} e^{rc} - \frac{1}{1-\alpha}
\]

\[
-e^{-rc} \geq \frac{\alpha}{1-\alpha-\beta} e^{rc} - \frac{\beta}{1-\alpha-\beta} e^{-rc} - \frac{1-\beta}{1-\alpha-\beta}
\]
Thus, $\epsilon$ should be large enough to satisfy the two inequalities. When $\alpha, \beta \to 0$, the RHS of the two inequalities is close to $-1$ so $\epsilon$ can be reduced close to 0. $\epsilon \to 0$ means the compensation cost becomes $c$ as $\alpha, \beta \to 0$, i.e., the first-best solution becomes feasible in the limit.

When $\alpha, \beta \to 0.5$. First multiply $P_1$, $P_2$, $P_3$ to the inequalities (12)-(14), respectively. Then add the three inequalities together. This rearrangement returns

$$e^{rc}\{P_1[(1 - \alpha)UT + \alpha U_1F] + P_2[(1 - \alpha)UT + \alpha U_2F] + P_3[(1 - \alpha)UT + \alpha U_3F]\}$$

$$\geq P_1[\beta U_1T + (1 - \beta)U_1F] + P_2[\beta U_2T + (1 - \beta)U_2F] + P_3[\beta U_3T + (1 - \beta)U_3F]$$

Substituting the negative exponential utility and rewriting the inequality, we have

$$-e^{-rI_1T}[e^{rc}P_1(1 - \alpha) - P_1\beta] - e^{-rI_2T}[e^{rc}P_2(1 - \alpha) - P_2\beta] - e^{-rI_3T}[e^{rc}P_3(1 - \alpha) - P_3\beta]$$

$$\geq -e^{-rI_1F}[P_1(1 - \beta) - e^{rc}P_1]\alpha - e^{-rI_2F}[P_2(1 - \beta) - e^{rc}P_2]\alpha - e^{-rI_3F}[P_3(1 - \beta) - e^{rc}P_3]\alpha$$

The inequality must hold for the program to be feasible. $e^{rc} > 1$ and $1 - \alpha > \beta$ imply $e^{rc}P_1(1 - \alpha) > P_1\beta$. Thus the LHS is less than 0. The inequality requires the RHS must be less than 0, too. This implies at least one $P_j(1 - \beta) - e^{rc}P_j\alpha$ from the RHS must be greater than 0, i.e., $1 - \beta > e^{rc}\alpha$. But when $\alpha, \beta \to 0.5$, this inequality will be violated. QED.

**Proof of Lemma 3**

The proof is similar to Fudenberg and Tirole [1990], Lemma 2.1. There are four situations concerning the two IIC constraints. Three of them will be eliminated. 1Suppose both constraints are binding. IIC-$\pi_1, \hat{\pi}_1^J$ is binding implies $\frac{\pi_1}{1 - \pi_1}(\overline{u}_1 - \overline{u}_2) = (u_2 - u_1)$, and IIC-$\pi_2, \hat{\pi}_1^I$ is binding implies $\frac{\pi_2}{1 - \pi_2}(\overline{u}_1 - \overline{u}_2) = (u_2 - u_1)$. Since $\pi_1 \neq \pi_2$, it must be $\overline{u}_1 = \overline{u}_2$ and $u_2 = u_1$. That is, the two types receive the
same payments $\bar{u}, u$, a pooling contract. There are three possibilities: a $\bar{u} > u$, b $\bar{u} < u$, or c $\bar{u} = u$. a Suppose $\bar{u} > u$ is offered to both types. Consider the following contract for type $\pi_2$: a single payment to the manager who claims $\pi_2$ and $u_2 = \pi_2\bar{u} + (1 - \pi_2)u$, while keeping the contract unchanged for type $\pi_1$. Then all the constraints are still satisfied, but the compensation cost for type $\pi_2$ is reduced, because $\Psi(u_2) < \pi_2\Psi(\bar{u}) + (1 - \pi_2)\Psi(u)$. Since the compensation cost for type $\pi_1$ is unchanged, the above alteration reduces the total compensation cost. b is similar to a, except a change for type $\pi_1$: a single payment $u_1 = \pi_1\bar{u} + (1 - \pi_1)u$, while keeping the contract unchanged for type $\pi_2$. The expected compensation cost is lowered. c Suppose $\bar{u} = u$ is offered to both types. That is, a full insurance contract is offered and each manager type receives the same utility $U = \bar{U} = U$.

The problem becomes

$$\{U\} \in \arg\min_{\bar{u}, u} \frac{1}{P_1 + P_2} \left\{ [P_1(\pi_1 + \pi_2)\Psi(\bar{u}) + [P_1(1 - \pi_1) + P_2(1 - \pi_2)]\Psi(u) \right\}$$

Subject to:

$$\pi_2\bar{u} + (1 - \pi_2)u \geq U$$
$$\bar{u} = u$$

The first inequality is the IIR constraint for type $\pi_2$. Since $\pi_1 > \pi_2$, $\pi_1\bar{u} + (1 - \pi_1)u \geq \pi_2\bar{u} + (1 - \pi_2)u$, the IIR constraint for type $\pi_1$ is satisfied. Denote $\lambda$ and $\mu$ as the Lagrangian multipliers for the two constraints. I will show $\mu \neq 0$ and thus the extra constraint $\bar{u} = u$ is costly.

The FOCs with respect to $\bar{u}$ and $u$ are

$$\Psi'(\bar{u}) = \frac{\lambda\pi_2 + \mu}{P_1\pi_1 + P_2\pi_2}(P_1 + P_2)$$
$$\Psi'(u) = \frac{\lambda(1 - \pi_2) - \mu}{P_1(1 - \pi_1) + P_2(1 - \pi_2)}(P_1 + P_2).$$
We know $\lambda > 0$, because the principal can always reduce the expected compensation cost by offering $(\bar{u} - \varepsilon, \bar{u} - \varepsilon)$, where $\varepsilon$ is a small positive number, and the IIR constraint will still hold. Suppose $\mu = 0$. In order to satisfy $\bar{u} = u$, $\frac{\pi_2}{P_1 \pi_1 + P_2 \pi_2}$ must be equal to $\frac{1 - \pi_2}{P_1 (1 - \pi_1) + P_2 (1 - \pi_2)}$. But simple algebra returns the former ratio is larger than the latter because of the assumption $\pi_1 > \pi_2$. Hence, $\mu \neq 0$, the constraint $\bar{u} = u$ adds more costs to the principal. Offering a full insurance contract is not optimal.

2Suppose neither constraint is binding. Cost minimization implies a fixed-amount payment to type $\pi_1$ and $\pi_2$, respectively. In order to induce a truthful report, the payments should be equal: $u_1 = u_2$. But a full insurance contract is not optimal.

3Suppose IIC-$\pi_1$ is binding, but IIC-$\pi_2$ is nonbinding. Then the cost minimization subject to the rest of constraints yields $\bar{u}_1 = u_1 = u_1$. Rewriting the two IIC constraints, we have $\pi_2 u_2 + (1 - \pi_2) u_2 > u_1 = \pi_1 u_2 + (1 - \pi_1) u_2$. This implies $u_2 < u_2$. For the contract to be incentive compatible to induce the investment strategy $\pi_1 \pi_2 | \pi_3$, the following inequalities must hold: $\pi_2 u_2 + (1 - \pi_2) u_2 \geq u_3 \geq \pi_3 u_2 + (1 - \pi_3) u_2$. But with $u_2 > u_2$, and $\pi_2 > \pi_3$, the inequality cannot hold.

4If IIC-$\pi_2$ is binding, but IIC-$\pi_1$ is nonbinding. Then the cost minimization subject to the rest of constraints yields $\bar{u}_2 = u_2 = u_2$. Rewriting the two IIC constraints, we have $\pi_1 u_1 + (1 - \pi_1) u_1 > u_2 = \pi_2 u_1 + (1 - \pi_2) u_1$. This implies $\pi_1 > u_1$. QED.

**Proof of Lemma 4**

It is similar to Fudenberg and Tirole [1990], Lemma 2.2.

From Lemma 3, we know the optimal renegotiation-proof contract insures the low type ($\pi_2$), but imposes some risk on the high type ($\pi_1$). But this condition may not be sufficient for the contract to be renegotiation proof. The principal might be able to offer the high type more insurance by increasing the low type’s expected
utility. She keeps doing this until the gain from more insurance for the high type is balanced off by the loss from higher payment to the low type.

Notice it is not beneficial to increase the high type’s expected utility. Keeping the low type’s utility unchanged and maintaining the incentive constraint IIC-$\pi_2$, the principal has to impose more risk on the high type in order to prevent the low type from mimicking (See Figure 1). The principal has to pay the high type more for the increased expected utility level and the increased risk premium. There is no gain for the principal. Thus, the principal’s only strategy is to increase the low type’s utility while keeping the high type’s expected utility constant.

Let $V_2 = U_2 + \epsilon$, where $\epsilon$ is a small positive number. Keeping the contract incentive compatible and the high type’s expected utility constant, we have

$$\pi_2 V_1 + (1 - \pi_2) V_1 = V_2 = U_2 + \epsilon$$
$$\pi_1 V_1 + (1 - \pi_1) V_1 = \pi_1 U_1 + (1 - \pi_1) U_1$$

Then we can solve the new contract for the high type as a function of the existing contract and $\epsilon$:

$$V_1 = U_1 - \frac{1 - \pi_1}{\pi_1 - \pi_2} \epsilon$$
$$V_1 = U_1 + \frac{\pi_1}{\pi_1 - \pi_2} \epsilon$$

Notice the risk on the high type is indeed reduced. Substitute the new contract $(\overline{V}_1, V_1, V_2)$ into the objective function at the renegotiation stage and take the derivative with respect to $\epsilon$. For the contract to be renegotiation proof, this derivative must be nonnegative, i.e.,
\[
\frac{P_1}{P_1 + P_2} \left[ -\pi_1 \frac{1 - \pi_1}{\pi_1 - \pi_2} \Psi'(U_1) + \frac{(1 - \pi_1)\pi_1}{\pi_1 - \pi_2} \Psi'(U_1) \right] + \frac{P_2}{P_1 + P_2} \Psi'(U_2) \geq 0
\]

Rearranging it, we have the inequality \( \frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1 (1 - \pi_1)} \frac{\Psi'(U_2)}{\Psi'(U_1) - \Psi'(U_1)} \). QED.

**Proof of Proposition 5**

Substituting \( \bar{U}_2 = U_2 = U_3 \) into the AIC constraints (30) and (32), we have \( U_2 = U_3 \). Then the overall problem \( \mathcal{P}_{na} \) reduces to

\[
\begin{align*}
\min_{U_1, U_1, U_3} & \quad P_1[\pi_1 \Psi(U_1) + (1 - \pi_1) \Psi(U_1)] + (P_2 + P_3) \Psi(U_3) \\
\text{subject to} & \quad \begin{align*}
EU & \geq -1 \\
EU & \geq m\bar{U}_1 + (1 - m)\bar{U}_1 \\
EU & \geq \bar{U}_3 \\
\pi_1 \bar{U}_1 + (1 - \pi_1) \bar{U}_1 & \geq \bar{U}_3 \\
\bar{U}_3 & \geq \pi_3 \bar{U}_1 + (1 - \pi_3) \bar{U}_1 \\
\bar{U}_3 & = \pi_2 \bar{U}_1 + (1 - \pi_2) \bar{U}_1 \\
\frac{P_1}{P_2} & \leq \frac{\pi_1 - \pi_2}{\pi_1 (1 - \pi_1)} \frac{\Psi'(U_2)}{\Psi'(U_1) - \Psi'(U_1)}
\end{align*}
\end{align*}
\]

Where \( EU = e^r \{ P_1[\pi_1 \bar{U}_1 + (1 - \pi_1) \bar{U}_1] + (P_2 + P_3) \bar{U}_3 \} \).

Since \( \pi_1 > \pi_2 > \pi_3 \), with constraint (34), constraint (29) and (31) are nonbinding. We have two situations:

If \( m > \pi_2, m\bar{U}_1 + (1 - m)\bar{U}_1 > \bar{U}_3 \), constraint (28) is nonbinding. I show the only effort selection constraint (26) must be binding. Let \( \lambda, \mu_1, \mu_2 \) represent the Lagrangian multipliers for the constraint (25) (26) and (34). (For the current
analysis, I only consider when the contract is renegotiation proof, i.e., when constraint (35) is satisfied.)

The FOCs are
\[
\Psi'(U_1) = \lambda e^{rc} + \mu_1[e^{rc} - \frac{m}{P_1(1-\pi_1)}] - \mu_2 \frac{\pi_2}{P_1(1-\pi_1)}
\]
\[
\Psi'(U_1') = \lambda e^{rc} + \mu_1[e^{rc} - \frac{1}{P_1(1-\pi_1)}] - \mu_2 \frac{1-\pi_2}{P_1(1-\pi_1)}
\]
\[
\Psi'(U_3) = \lambda e^{rc} + \mu_1 e^{rc} + \mu_2 \frac{1}{P_2+P_3}
\]

Suppose \( \mu_1 = 0 \). There are three cases. \( a \mu_2 = 0 \) \( b \mu_2 > 0 \) \( c \mu_2 < 0 \).

\( a \mu_1 = 0 \) and \( \mu_2 = 0 \) imply a full insurance contract. \( b \) and \( c \) imply either \( U_1, U_1' < U_3 \) or \( U_1, U_1' > U_3 \). Thus constraint (26) must be binding.

I now show the AIR constraint (25) is also binding. The proof is similar to Fudenberg and Tirole [1990]. Currently, we have two binding constraints, (26) and (34). Obviously, offering rent does not relax the equalities. The only possible benefit of offering rent is to relax the renegotiation-proof constraint:

\[
\frac{P_1}{P_2} \leq \frac{\Psi'(U_2)}{\Psi'(U_1)} \frac{\Psi'(U_1')}{\Psi'(U_1)}
\]

A rent can only influence the inequality through the ratio \( \frac{\Psi'(U_2)}{\Psi'(U_1)} \frac{\Psi'(U_1')}{\Psi'(U_1)} \). If the rent increases the ratio, then the principal might want to offer the manager some rent. Let \( -e^{-rR} \) be the rent with \( R > 0 \). A contract offering rent is \( V_1 = -e^{-r(T_1+R)} = e^{-rR}U_1, V_1' = -e^{-r(T_1+R)} = e^{-rR}U_1' \) and \( V_3 = -e^{-r(T_3+R)} = e^{-rR}U_3 \), where \( U_1, U_1', U_3 \) belong to the contract without rent.

I have assumed the negative exponential utility, \( \Psi'(U) = -\frac{1}{U} \). Substitute the function into the ratio, \[
\frac{\Psi'(U_2)}{\Psi'(U_1)} \frac{\Psi'(U_1')}{\Psi'(U_1)} = \frac{-\frac{1}{P_1} e^{rR}}{-\frac{1}{P_2} e^{rR} + \frac{1}{P_2} e^{rR}} = \frac{-\frac{1}{P_1}}{-\frac{1}{P_2} + \frac{1}{P_2}}
\]

Thus offering rent does not relax the renegotiation-proof condition. The AIR constraint (25) must be binding.

Therefore, we can solve three equations (25), (26) and (34) for three unknowns. This completes the proof for the first part of Proposition 5.

If \( m \leq \pi_2, mU_1 + (1 - m)U_1 \leq U_3 \), constraint (26) is nonbinding. Similarly, we have three equations (25), (28) and (34) for three unknowns. This completes the proof for the second part. QED.
Proof of Lemma 5.

The problem with an audit can be solved in a similar way to the benchmark case, except that the dimension of contracting variables is enlarged. At the renegotiation stage, the principal offers $C^p = \{(\overline{U}_{1ki}, \underline{U}_{1ki}), (U_{3k})\}_{k \in \{T, F\}, i \in \{1, 2\}}$ to minimize:

1. If $\hat{\pi}_1^I$ and $A_k^I$ are observed:

$$\sum_{i=1}^{2} \frac{P_i}{P_1 + P_2} \left[ \pi_i \Psi(\overline{u}_{1ki}) + (1 - \pi_i) \Psi(\underline{u}_{1ki}) \right]$$

subject to

$$\pi_i \overline{u}_{1ki} + (1 - \pi_i) \underline{u}_{1ki} \geq \pi_i \overline{u}_{1ki'} + (1 - \pi_i) \underline{u}_{1ki'}; \forall i' \in \{1, 2\} \quad \text{(IIC-}\pi_i, \hat{\pi}_1^I, A_k^I\text{)}$$

$$\pi_i \overline{u}_{1ki} + (1 - \pi_i) \underline{u}_{1ki} \geq \pi_i \overline{U}_{1ki} + (1 - \pi_i) \underline{U}_{1ki} \quad \text{(IIR-}\pi_i, \hat{\pi}_1^I, A_k^I\text{)}$$

2. If $\hat{\pi}_3^I$ and $A_k^I$ are observed:

$$\Psi(u_{3k})$$

subject to

$$u_{3k} \geq U_{3k} \quad \text{(IIR-}\pi_3, A_k^I\text{)}$$

From Lemmas 3 and 4, contract $C^p$ takes the following form:

$$\overline{U}_{1k1} > \underline{U}_{1k1}$$

$$\overline{U}_{1k2} = \underline{U}_{1k2} = U_{1k2}$$

$$\pi_2 \overline{U}_{1k2} + (1 - \pi_2) \underline{U}_{1k2} = \pi_2 \overline{U}_{1k1} + (1 - \pi_2) \underline{U}_{1k1},$$
and $C^P$ is renegotiation proof if and only if the following inequality is satisfied:

$$\frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \frac{\Psi'(U_{1k2})}{\Psi'(U_{1k1}) - \Psi'(U_{1k1})}, \forall k \in \{T, F\}.$$ 

The overall problem $P^P$ is:

$$\min_{U_{1k1}, U_{1k2}, U_{3k}} \sum_{i=1}^{2} P_i (1 - \alpha) \left[ \pi_i \Psi(U_{1Ti}) + (1 - \pi_i) \Psi(U_{1Fi}) \right] + P_3 (1 - \alpha) \Psi(U_{3T}) + \alpha \Psi(U_{3F})$$ 

Subject to:

$$EU \geq -1$$

$$EU \geq \beta \left[ m U_{1T1} + (1 - m) U_{1T1} \right] + (1 - \beta) \left[ m U_{1F1} + (1 - m) U_{1F1} \right]$$

$$EU \geq \beta \left[ m U_{1T2} + (1 - m) U_{1T2} \right] + (1 - \beta) \left[ m U_{1F2} + (1 - m) U_{1F2} \right]$$

$$EU \geq \beta U_{3T} + (1 - \beta) U_{3F}$$

$$(1 - \alpha) \left[ \pi_1 U_{1T1} + (1 - \pi_1) U_{1T1} \right] + \alpha \left[ \pi_1 U_{1F1} + (1 - \pi_1) U_{1F1} \right]$$

$$\geq \beta U_{3T} + (1 - \beta) U_{3F}$$

$$(1 - \alpha) \left[ \pi_2 U_{1T2} + (1 - \pi_2) U_{1T2} \right] + \alpha \left[ \pi_2 U_{1F2} + (1 - \pi_2) U_{1F2} \right]$$

$$\geq \beta U_{3T} + (1 - \beta) U_{3F}$$

$$(1 - \alpha) U_{3T} + \alpha U_{3F}$$

$$\geq \beta \left[ \pi_3 U_{1T1} + (1 - \pi_3) U_{1T1} \right] + (1 - \beta) \left[ \pi_3 U_{1F1} + (1 - \pi_3) U_{1F1} \right]$$

$$\geq \beta \left[ \pi_3 U_{1T2} + (1 - \pi_3) U_{1T2} \right] + (1 - \beta) \left[ \pi_3 U_{1F2} + (1 - \pi_3) U_{1F2} \right]$$

$U_{1k2} = U_{1k2}$

$$\pi_2 U_{1k2} + (1 - \pi_2) U_{1k2} = \pi_2 U_{1k1} + (1 - \pi_2) U_{1k1}$$

$$\frac{P_1}{P_2} \leq \frac{\pi_1 - \pi_2}{\pi_1(1 - \pi_1)} \frac{\Psi'(U_{1k2})}{\Psi'(U_{1k1}) - \Psi'(U_{1k1})}$$

Where
\[ EU = e^{rc} \left\{ \sum_{i=1}^{2} P_i (1 - \alpha) [\pi_i U_{1Ti} + (1 - \pi_i)U_{1Ti}] + P_i \alpha [\pi_i U_{1Fi} + (1 - \pi_i)U_{1Fi}] \right\} + P_3 [(1 - \alpha)U_{3T} + \alpha U_{3F}] \]
It turns out the contract that implements the first-best policy \( \pi_1 \pi_2 \pi_3 \) is feasible to induce the policy \( \pi_1 \pi_2 \pi_3 \), since \( \pi_2 \overline{U} + (1 - \pi_2) \overline{U} = U, \, m \overline{U} + (1 - m) \overline{U} > U \) and then \( e^c \{ P_1 \pi_1 \overline{U} + P_1 (1 - \pi_1) \overline{U} + (P_2 + P_3) U \} \geq U \). The expected compensation cost to implement the first-best policy is \( [P_1 \pi_1 + P_2 \pi_2] \Psi(\overline{U}) + [P_1 (1 - \pi_1) + P_2 (1 - \pi_2)] \Psi(\overline{U}) + P_3 \Psi(U_3) \), which is higher than \( P_1 \pi_1 \Psi(\overline{U}) + P_3 \Psi(U_3) \), because \( \pi_2 \Psi(\overline{U}) + (1 - \pi_2) \Psi(\overline{U}) > \Psi(U) \) from Jensen’s Inequality. Since the contract that implements the first-best policy is only feasible but may not be optimal to implement policy \( \pi_1 \pi_2 \pi_3 \), the expected compensation cost to implement policy \( \pi_1 \pi_2 \pi_3 \) is strictly lower than the one that implements the first-best policy.

QED.

Proof of Proposition 8.

The manager is offered a fixed payment no matter what signal he receives. Therefore, he is indifferent between investing and not investing. Implementing the first-best investment policy is trivial.

From Proposition 7, we know the binding constraints for the second-best contract \( \{ \overline{U}^{SB}, \overline{U}^{SB}, U^{SB} \} \) are

\[
e^c \{ P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1) \overline{U}^{SB} + (P_2 + P_3) U^{SB} \} \geq -1
\]
\[
e^c \{ P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1) \overline{U}^{SB} + (P_2 + P_3) U^{SB} \} \geq m \overline{U}^{SB} + (1 - m) \overline{U}^{SB}
\]
\[
e^c \{ P_1 \pi_1 \overline{U}^{SB} + P_1 (1 - \pi_1) \overline{U}^{SB} + (P_2 + P_3) U^{SB} \} \geq U^{SB}
\]

These constraints imply \( m \overline{U}^{SB} + (1 - m) \overline{U}^{SB} = U^{SB} \). Substitute \( \pi_1 \overline{U}^{SB} + (1 - \pi_1) \overline{U}^{SB} \) with \( U_1 \), \( U^{SB} \) with \( U_2 \), and \( m \overline{U}^{SB} + (1 - m) \overline{U}^{SB} \) with \( U_2 \), we find the constraints still hold. Therefore, the manager’s incentives to acquire information are unchanged. But with \( \pi_1 \overline{U}^{SB} + (1 - \pi_1) \overline{U}^{SB} = U_1 \), we have \( \pi_1 \Psi(U^{SB}) + (1 - \pi_1) \Psi(U^{SB}) > \Psi(U_1) \). Therefore, the expected compensation cost with renegotiation, \( P_1 \Psi(U_1) + (P_2 + P_3) \Psi(U_2) \), is lower than the expected compensation cost without renegotiation, \( P_1 \pi_1 \Psi(U^{SB}) + P_1 (1 - \pi_1) \Psi(U^{SB}) + (P_2 + P_3) \Psi(U^{SB}) \).

QED.
REFERENCES


BIOGRAPHICAL SKETCH

Jie Tian, nicknamed Joyce, was born on May 21, 1976, in Beijing, China. Her parents, Shilin Tian and Xulin Cao, were both engineers. After graduating from the Experimental Middle School of Beijing, she entered Renmin University of China to study international economics. She earned her bachelor’s degree in economics in August, 1998. Soon after the graduation ceremony, she came to the United States to study statistics at University of Nevada, Reno. She received her Master of Science degree in August, 2000. She joined the Ph.D. program of Fisher School of Accounting at the University of Florida and she is expected to receive a PhD degree in 2006.