Timing of Verification Procedures: Monitoring versus Auditing

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Abstract

In an agency model this paper studies the strategic effect of differences in timing of verification. A principal may choose between two equally efficient verification procedures: monitoring and auditing. Under auditing the principal receives additional private information. Because auditing exacerbates the tension between incentives for effort and verification, monitoring is superior if 1) verification costs are low such that a high verification intensity is desirable, or if 2) steep incentives structures are costly to implement due to bounded transfers or risk averseness.

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1 Introduction

One of the main internal problems of an organization is the existence of moral hazard. When an employee’s effort or action cannot be observed, his renumeration cannot be linked to his actual effort decision and room for moral hazard exists. As is well known, problems of moral hazard place a cost on the organization. Organizations will therefore have reasons to reduce the scope for moral hazard and obtain more accurate information about the unobservable effort decision through costly verification procedures (e.g. Townsend (1979)). Many aspects of such verification procedures will lie in the hands of the organization itself. It must decide what kind of information it wants to acquire, when to acquire it, and how to use it.\footnote{Hence, this paper is related to the “accounting method choice” literature in accounting, which investigates how organizations choose among competing methods of accounting, e.g. Watts (1979) and Holthausen and Leftwich (1983). According to Holthausen (1990) there exist three competing theories towards accounting choice: opportunistic behavior of management, efficient contracting and informational aspects. This paper takes the efficient contracting perspective that the choice is driven by efficient contracting.}

The purpose of this paper is to look into the “when” of information acquisition, i.e., its timing.\footnote{Already the original work on moral hazard of Holmstrom (1979) and Shavell (1979) considered the question of how to use available information. Maskin and Riley (1985) and Khalil and Lawarree (1995) address the first question of what kind of information the principal should gather.}

More specifically, in a standard agency setting this paper studies two alternative procedures of verification that I call monitoring and auditing. The difference between the two procedures is that monitoring takes place \textit{while} the agent chooses his action, while auditing occurs \textit{after} he has taken his action. This difference in timing has a strategic consequence, because after the agent’s decision the principal receives supplementary information about his actual behavior. Hence, with auditing the principal’s decision to verify is taken on the basis of additional information that is not available under monitoring. It is this informational wedge that influences the principal’s optimal verification procedure.

To focus on the effects which are due to this difference in timing I assume that monitoring and auditing concern the verification of identical variables and that both procedures are equally efficient. This modeling allows for two different interpretations. First, the difference between monitoring and auditing may regard the exact
point in time at which the decision to evaluate evidence is taken. For instance, the principal may decide to observe the agent with video cameras. Monitoring would then mean that the principal follows the agent’s behavior “live” on a video screen. Auditing, on the other hand, would mean that the principal collects the recordings and decides about reviewing them on the basis of some additional information that comes available after the agent has completed his tasks, e.g. the success of the project the agent worked on. Second, the physical character of different procedures of verification may lead to a natural difference in timing. For instance, direct supervision of an agent necessarily implies monitoring, whereas checking the agent’s reports about his actions involves auditing.

Clearly, if the principal can fully commit herself to the implementation of a specific verification strategy, she can never be worse off under auditing. With auditing she can achieve any outcome under monitoring by simply mimicking the monitoring strategy, i.e., disregarding all intermediate information. The mimicking-strategy, however, requires that the principal’s verification strategy is verifiable such that her commitment to disregard additional information is credible. When such contractual commitment is not feasible, the weak optimality result of auditing may be overturned.

Indeed, if the principal cannot commit to a verification strategy contractually, the principal’s verification behavior becomes a strategic variable that is chosen sequentially rational. A non-commitment to verification seems reasonable if the effectiveness of verification depends on an unobservable scrutinizing effort by the principal. A second reason may be due to the difficulty of committing to random verification. As is well known (e.g. Mookherjee and Png (1989)), optimal verification procedures often require a random use of verification. Yet, agents and outside courts may find it hard to verify whether the principal did indeed apply the correct random behavior as stipulated by some contract. This seems the most realistic reason why the assumption of non-verifiable verification makes sense: Many real life contracts do stipulate the possibility that the agent is being verified, but do not determine the actual frequency. Such contracts conform to the contractibility assumption in this

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3This argument is also used in Khalil (1997).
4In many countries employers are, by law, only allowed to use stochastic verification procedures if they inform the employee explicitly about the possibility of verification in advance.
paper. I.e., the principal binds herself contractually to a verification procedure, but its actual use is left at the principal’s discretion.

The intuition behind the non-trivial trade-off between monitoring and auditing is the existence of a natural tension between incentives to the agent to work and to the principal to verify. To induce high effort from an agent it is well known that the principal must reward him when there is evidence that he worked. Such a payment structure, however, implies that the principal has less incentives to verify when she has some indication that the agent worked. Hence, it becomes more difficult for the principal to verify with a high intensity, if her decision to verify is based on additional information. The difference between monitoring and auditing is exactly this additional information and the tension between incentives is therefore more severe under auditing than under monitoring.

For two reasons the difficulties in inducing high verification intensities under auditing may render it suboptimal. First, if verification costs are low such that a high verification intensity is desirable, monitoring is optimal, because, for the aforementioned reason, a high intensity is cheaper to implement under monitoring. Second, since auditing implies a lower verification intensity, the incentive structure to the agent to induce working must be steeper. If transfers are bounded or the agent is risk averse, the steeper incentive structure may be impossible or too costly to implement. Also in this case, monitoring is superior. On the other hand, for relatively high costs of verification and a risk neutral agent with unbounded transfers, auditing is optimal, because it allows the principal to use a more selective form of verification.

The rest of the paper is organized as follows. In the next section we present a simple model of verification. Section 3 derives the optimal contract under monitoring and Section 4 analyzes the case of auditing. Section 5 compares the optimal contracts and derives conditions under which monitoring is superior to auditing. Section 6 concludes.

2 The Model

Consider a risk neutral principal who has a project that is run by a risk neutral agent. The agent chooses to work $w$ or shirk $s$. If the agent works, the project
is always successful.\footnote{Qualitative results remain unchanged when the probability of success is smaller but close to one. The assumption increases tractability and eases the exposition.} With shirking the project is only successful with probability $1 - p$. A successful project yields the principal a payoff of $y$. An unsuccessful project is worthless. Hence, the productive gain when the agent works is $\Delta y \equiv (1 - p)y$. If the agent works he incurs a disutility of $e$. Shirking is costless to the agent. The difference $\Delta y - e$ measures therefore the potential social gain of working versus shirking. To have a non-trivial problem, we assume that this gain is strictly positive, i.e., $\Delta y > e$.

The agent’s decision and the success of the project are not verifiable. Instead, the principal may, at a personal cost $c < e$, verify the agent’s action to detect shirking. That is, there exists a verifiable signal $\sigma \in \{w, s\}$ about the agent’s action whose informative content depends on a verification effort of the principal. The principal’s effort is binary; she either verifies actively and incurs the cost $c$ or she does not verify. Active verification reveals a shirking agent perfectly. If the principal does not verify actively, she cannot detect shirking and the signal $\sigma$ always reports $\sigma = w$.

The principal and agent write a contract $t$ that stipulates transfers from the principal to the agent. Since only the signal $\sigma$ about the action is verifiable, a general contract of transfers is simply a combination $(t_w, t_s)$. The agent is protected by a limited liability of zero. The maximum transfer that the principal can promise is also bounded by $\bar{t} \geq e$.\footnote{Clearly, if $\bar{t} < e$, the agent cannot be compensated for his effort cost $e$.} Hence, a feasible contract requires $t_w, t_s \in [0, \bar{t}]$. Due to the simple contractual structure the difference $\Delta t \equiv t_w - t_s$ is a straightforward measure of the steepness of the agent’s incentive structure. Limited liability implies that the steepness of the incentive structure is at most $\bar{t}$. Finally, the agent’s outside option is zero.

Before offering a contract to the agent the principal commits to one of the two verification procedures auditing or monitoring. If the principal adopts monitoring, she chooses her verification effort before knowing the agent’s action and the timing is as follows:

1. Principal offers a contract.
2. Agent decides whether to accept the contract.
3. Agent and principal decide simultaneously about action and verification effort respectively.

Hence, under monitoring the agent and principal play a simple simultaneous move game. In contrast, the principal and the agent play a sequential game under auditing. The agent chooses first his action, after which the principal observes the output. Only then she chooses whether to verify:

1. Principal offers a contract.
2. Agent decides whether to accept the contract.
3. Agent chooses his action.
4. Principal observes the output and chooses verification effort.

The game with auditing is more complicated, in that the principal takes her decision under asymmetric information. Hence, whereas with monitoring we may solve the subgame in stage 3 as a straightforward Nash equilibrium, the appropriate equilibrium concept in the game with auditing is Perfect Bayesian Equilibrium.

3 Monitoring

First suppose the principal uses monitoring as her procedure of verification. Clearly, if the principal does not monitor actively, the agent will shirk, since without verification his renumeration is independent of his actual action. Hence, if the principal wants to induce the agent to work, she must verify actively. Indeed, if the principal monitors with probability $\gamma$ the agent receives a net utility of $\gamma t_w + (1 - \gamma) t_w - e$ if he works. Shirking on the other hand, yields the agent $\gamma t_s + (1 - \gamma) t_w$. Hence, the agent has a weak incentive to work if

$$\Delta t \geq e / \gamma.$$  \hspace{1cm} (1)

The inequality represents the agent’s incentive constraint. It shows that the required steepness of the incentive structure, $\Delta t$, is inversely related to the principal’s monitoring intensity $\gamma$. Indeed, if $\gamma$ approaches zero, the required wedge $\Delta t$ goes to infinity. It reflects the observation that at least some active verification has to occur to induce the agent to work.
An inducement of working requires active verification by the principal. Yet, because verification is not contractible, the contract \((t_w, t_s)\) must give the principal genuine incentives to monitor. Given that the agent works, the principal pays \(t_w + c\) if she decides to monitor. If she, on the other hand, does not verify, she pays \(t_w\). Hence, given that the agent worked, the principal will not monitor. Consequently, there is no equilibrium in which the agent works with probability one.

Now suppose the agent chooses to work with a probability \(\alpha\) less than one. This requires that the agent is indifferent between working and shirking. That is, the agent’s incentive constraint (1) must hold in equality:

\[
\Delta t = \frac{e}{\gamma}.
\]  

(2)

If the principal monitors, she expects to pay \(\alpha t_w + (1 - \alpha) t_s + c\), whereas she pays \(t_w\) if she does not monitor. Hence, the principal has an incentive to monitor if

\[
\Delta t \geq \frac{c}{1 - \alpha}.
\]  

(3)

Inequality (3) represents the principal’s incentive constraint to monitor actively. It confirms the former observation that the principal cannot be given incentives to monitor if the agent works with probability one, as the required wedge \(\Delta t\) goes to infinity when \(\alpha\) goes to one. Furthermore, combining the constraint with the incentive constraint (2) of the agent reveals that the minimum steepness of incentives to induce working is \(\Delta t = e\) and induces the agent to work with probability \(1 - c/e\), while the principal monitors with probability one.

The incentive constraints (2) and (3) describe the implementation restrictions due to asymmetric information. In addition to these constraints, the contract must ensure participation of the agent. That is, ensure the agent a non-negative utility. Yet, because the agent is protected by a limited liability of zero and shirking is costless, any admissible contract yields the agent a non-negative payoff if he chooses to shirk. Hence, any incentive compatible contract that satisfies limited liability ensures the agent at least his reservation utility of zero. Hence, one may disregard the agent’s individual rationality constraint and it follows that the optimal contract

\[\text{7Throughout the paper we assume that optimal contracts induce a strictly positive working intensity } \alpha.\]
is the solution to the following problem

\[
P1 : \max_{t_w, t_s, \gamma, \alpha} V_p = (\alpha + (1 - \alpha)p)y - \alpha t_w - (1 - \alpha)[\gamma t_s + (1 - \gamma)t_w] - \gamma c
\]

s.t. \( (1 - \gamma)(\Delta t - c/(1 - \alpha)) = 0 \) (4)

(2) and (3),

where the constraint (4) guarantees that the principal is indifferent about monitoring, if she monitors with a probability less than one.

**Proposition 1** Under monitoring the optimal contract is \((t_w, t_s) = (t_w^*, 0)\) and yields the principal \(V_1^*\). It induces the agent to work with probability \(\alpha = 1 - c/t_w^*\) and the principal to monitor with probability \(\gamma = e/t_w^*\), where

\[
t_w^* = \begin{cases} 
  e & \text{if } c < e^2/\Delta y \\
  \sqrt{c\Delta y} & \text{if } c \in [e^2/\Delta y, \bar{t}^2/\Delta y] \\
  \bar{t} & \text{if } c > \bar{t}^2/\Delta y
\end{cases}
\]

\[
V_1^* = \begin{cases} 
  y - e - c\Delta y/e & \text{if } c < e^2/\Delta y \\
  y - 2\sqrt{c\Delta y} & \text{if } c \in [e^2/\Delta y, \bar{t}^2/\Delta y] \\
  y - \bar{t} - c\Delta y/\bar{t} & \text{if } c > \bar{t}^2/\Delta y
\end{cases}
\]

The proposition shows that the maximum punishment principle holds. That is, it is optimal to set \(t_s\) to its minimum of zero. An intuitive result as the transfer \(t_s\) is only paid, when it is verified that the project failed and the agent shirked. On the other hand, the optimal level of \(t_w\) depends on the cost of verification \(c\). If monitoring costs are relatively small, the principal chooses \(t_w\) such that she monitors with probability 1. For larger monitoring costs it is optimal for the principal to monitor with a probability less than one. Since \(t_w^*\) is increasing in \(c\), the monitoring intensity is decreasing in the cost of verification \(c\). This intuitive feature of the optimal contract will play an important role when comparing monitoring to auditing. Finally, the maximum allowable transfer \(\bar{t}\) restricts the principal only if it is relatively small.

## 4 Auditing

Now suppose the principal chooses auditing as her procedure of verification. In this case the principal decides about active verification after observing the project’s outcome. Hence, she may audit failed and successful projects with different intensities. Suppose the principal audits successful project with probability \(\gamma_s\) and
failures with probability \( \gamma_f \). To induce the agent to work with positive probability, the decision to work must yield the agent at least as much as shirking. Given the principal’s auditing intensities \( \gamma_f \) and \( \gamma_s \), the agent receives a utility of \( p(\gamma_s t_s + (1 - \gamma_s) t_w) + (1 - p)(\gamma_f t_s + (1 - \gamma_f) t_w) \) when he shirks. Working, on the other hand, yields a net utility of \( t_w - e \). Hence, the agent has a weak incentive to work if

\[
\Delta t \geq \frac{e}{\gamma_s p + \gamma_f (1 - p)}. \tag{5}
\]

Constraint (5) represents the agent’s incentive constraint under auditing. It shows that at least some auditing must take place, if the agent is to work with positive probability.

Like in the previous section, the principal’s auditing behavior is guided by the contract \( t \) and, in addition, her belief about the agent’s behavior. More precisely, given that the principal believes that the agent worked with probability \( \omega \), she has a weak incentive to audit if

\[
\omega t_w + (1 - \omega) t_s + c \leq t_w.
\]

The principal’s belief \( \omega \) depends on the outcome of the project. If the principal observes a failure, this can only have come, because the agent shirked. Hence, \( \omega_f = 0 \) and the principal has a (weak) incentive to audit a failed project, if

\[
\Delta t \geq c. \tag{6}
\]

On the other hand, if the principal observes a successful project, the agent either worked or shirked, but was lucky. Given that the agent works with probability \( \alpha \) the probability that the agent worked follows from Bayes’ rule:

\[
\omega_s = \frac{\alpha}{\alpha + (1 - \alpha)p}.
\]

Consequently, the principal has a (weak) incentive to audit after observing a successful project if,

\[
\Delta t \geq c \left(1 + \frac{\alpha}{(1 - \alpha)p}\right). \tag{7}
\]
Effectively, constraint (6) and (7) imply that the principal may choose between two basic auditing strategies. Either she only audits failed projects, or she audits both successful and failed projects. Quite intuitively, the principal cannot induce herself to audit only successful project, because constraint (7) is stricter than (6). Hence, an exclusive auditing of failed projects requires less costly incentives than if the principal is to audit also successful projects. Moreover, the constraints show that, in equilibrium, the auditing intensities $\gamma_f$ and $\gamma_s$ are interdependent. If the principal audits successful projects with a positive probability, then she must audit failed project with probability one. Alternatively, if the principal audits failed projects with a probability less than one, she does not audit successful projects.

We may use the interdependence to simplify the agent’s incentive constraint (5). If the principal audits failed projects with a probability less than one ($\gamma_f < 1$), she does not audit successful projects ($\gamma_s = 0$) and the agent’s incentive constraint (5) reduces to

$$\Delta t \geq \frac{e}{\gamma_f(1 - p)}.$$ \hspace{1cm} (8)

In contrast, if the principal audits successful projects with a probability $\gamma_s > 0$, the principal audits failed project with certainty, i.e., $\gamma_f = 1$. Moreover, it requires that inequality (7) must be satisfied such that $\alpha < 1$. That is, if in equilibrium the principal audits also successful projects, the agent has to shirk with positive probability and must, therefore, be indifferent between working and shirking. Consequently, the incentive constraint (5) rewrites as

$$\Delta t = \frac{e}{1 - (1 - \gamma_s)p}.$$ \hspace{1cm} (9)

Whether the principal chooses a contract that induces her to audit only failed projects or also successful projects depends on which type of contract yields the highest utility. The optimal contract under the exclusive auditing of failed projects is the solution to the following problem.\(^8\)

\[ P2 : \max_{t_w, t_s, \gamma_f, \alpha} V_2 = (\alpha + (1 - \alpha)p)(y - t_w) - (1 - \alpha)(1 - p)(\gamma_f t_s + (1 - \gamma_f)t_w + c\gamma_f) \]

\[
\begin{align*}
s.t. & \quad (1 - \gamma_f)[\Delta t - c] = 0; \quad (1 - \alpha)[\Delta t - e/(\gamma_f(1 - p))] = 0 \quad (10) \\
& \quad (6) \text{ and } (8),
\end{align*}
\]

\(^8\)Again any incentive compatible contract satisfying limited liability is automatically individually rational to the agent.
where the constraints in (10) guarantee that the principal or agent is indifferent if she or he uses a mixed strategy.

In contrast, the optimal contract that induces the principal to audit both successful and failed projects is the solution to the following problem:

\[ P3 : \max_{t_w,t_s,\gamma_s,\alpha} V_3 = (\alpha + (1 - \alpha)p)y - \alpha(t_w + \gamma_sc) - (1 - \alpha)p((1 - \gamma_s)t_w + \gamma_st_s + \gamma_sc) \]
\[ - (1 - \alpha)(1 - p)(t_s + c) \]
\[ \text{s.t.} \quad (1 - \gamma_s)[c(1 + \alpha/(p(1 - \alpha))] = 0 \]
\[ (7) \text{ and } (9), \]

where equality (11) guarantees that the principal is indifferent about auditing a successful project if she is to audit such projects with a probability less than one.

In the remainder of this section we solve the two problems and state the optimal contracts.

**Proposition 2** An optimal contract that induces the principal to audit only failed projects exists only if \( \bar{t} \geq e/(1 - p) \). It exhibits \( t_w^* = e/(1 - p) \) and \( t_s^* = 0 \) and induces the principal to audit failed projects with probability one and the agent to work with probability one. It yields the principal \( V_2^* = y - e/(1 - p) \).

The proposition shows that a contract which induces the principal to audit only failed projects may not exist. This observation follows directly from the agent’s incentive constraint (8). Indeed, given that the principal audits only failed projects, the agent’s shirking is identified only if the project fails. Hence, under an exclusive auditing of failed project, the detection probability of shirking is at most \( 1 - p \). This reveals the disadvantage that an exclusive auditing of failed projects leads necessarily to a low detection probability and therefore requires high powered incentives for the agent. Such high powered incentives are possible only if the maximum allowable payment \( \bar{t} \) is large enough. Only in this case an optimal contract exists. It induces the agent to work with probability one and the principal to audit failed projects with probability one.
Before we derive the optimal contract that induces the principal to audit also successful projects define
\[ \hat{t}_{wf} \equiv \frac{(1-p)c + \sqrt{(1-p)c(e+py)}}{p}. \]

**Proposition 3** The optimal contract that induces the principal to audit failed and successful projects is \((t_w, t_s) = (t^*_w, 0)\). It yields the principal \(V^*_3\) and induces the agent to work with probability \(\alpha = p(t_w) - c/[p(t_w - c) - c]\) and the principal to audit failed project with probability one and successful projects with probability \(\gamma_f = 1 - [t_w + e]/(twp)\) where
\[
t^*_w = \begin{cases} \min\{\hat{t}_{wf}, e/(1-p), \bar{t}\} & \text{if } \hat{t}_{wf} \geq e. \\ e & \text{if } \hat{t}_{wf} < e \end{cases}
\]
and
\[
V^*_3 = \begin{cases} \frac{\bar{t}p(y-\bar{t})-c^2(1-p)}{(1-p)c+\bar{t}p} & \text{if } \hat{t}_{wf} > \bar{t} \text{ and } \bar{t} < e/(1-p) \\ \frac{ep(y(1-p)-e) - c^2(1-p)^3}{(1-p)^2c+ep} & \text{if } \hat{t}_{wf} > e/(1-p) \text{ and } \bar{t} \geq e/(1-p) \\ \frac{y - \frac{2(1-p)c-2\sqrt{(1-p)c+py))}{p}}{ep(y-e) - c^2(1-p)} & \text{if } \hat{t}_{wf} \in [e, \bar{t}] \\ \frac{ep(y-e) - c^2(1-p)}{(1-p)c+ep} & \text{if } \hat{t}_{wf} < e. \end{cases}
\]

The proposition shows that the optimal contract that gives the principal incentives to audit both failed and successful projects has more in common with the optimal contract under monitoring than with the first type of contract under auditing. First, the contract exists for any \(\bar{t} \geq e\). Second, the verification probability in equilibrium is decreasing in the cost of verification \(c\). Under this type of contract the principal is also able to induce verification with certainty when she sets \((t_w, t_s) = (e, 0)\). In the next section we compare the contracts more thoroughly.

## 5 Monitoring versus Auditing

In the previous two sections we derived the optimal contracts under monitoring and auditing. In this section we compare the three different types of contracts. Comparing the optimal contract under monitoring to the optimal contract that gives the principal incentives to audit both failed and successful projects yields the following result.
Proposition 4 \textit{It holds $V_1^* \geq V_3^*$}. 

The proposition establishes the superiority of monitoring over an auditing of failed and successful projects. The intuition behind the proposition may be gained from comparing the incentive constraints of the principal under the two forms of verification. Specifically, the constraint (2) is weaker than the constraint (9) and implies that the inducement of a working intensity $\alpha$ requires lower powered incentives under monitoring. Since the maximum punishment principle holds this implies that for a given working intensity $\alpha$ the principal must, under the auditing from failed and successful project, pay the agent more than under monitoring.

Because for $\bar{t} < e/(1-p)$ the only contract that induces the agent to work induces the principal to audit failed and successful project the proposition has a straightforward corollary.

Corollary 1 \textit{Monitoring is strictly better than auditing if $\bar{t} < e/(1-p)$}. 

Hence, if the maximum payment $\bar{t}$ is relatively low, the principal prefers monitoring over auditing. The corollary follows directly due to exogenously bounded transfers. Yet, the result should be interpreted in a broader way. The upshot of the corollary is that if auditing is to be better than monitoring then, according to Proposition 4, only with a contract that induces an exclusive auditing from failed projects. But if such contracts are to induce the agent to work, then it requires a steeper incentive scheme than under monitoring. Hence, auditing can only be better than monitoring if the implementation of steep incentives is not too costly. Limited transfers are an extreme, but convenient way of introducing a cost to steeper incentives. It renders the cost of a steep incentive structure infinitely costly. Yet, since a steeper incentive structure implies more risk, steeper incentive structures would also be costly if the agent is risk averse. That is, if transfers are unlimited but the agent is rather risk averse then auditing is inferior to monitoring, because the cost of compensating the agent for his increased risk will outweigh the gain from a selective auditing of failed projects. Indeed, one may see boundedness of transfers as a rather extreme type of risk averseness. Instead of assuming that wages cannot exceed $\bar{t}$, one may assume that the agent has a utility of $u(t) = \min\{t, \bar{t}\}$ for positive transfers $t \geq 0$. That is, the agent is risk neutral in the interval $[0, \bar{t}]$ and infinitely risk averse for wages exceeding $\bar{t}$ and 0.
Proposition 5 Suppose the maximum transfer is unbounded then monitoring is superior to auditing if

\[ c < \min \left\{ \frac{e^2p}{(1-p)^2y}, \frac{e^2}{4(1-p)^3y} \right\}. \]

The proposition shows that if the cost of verification is relatively small the principal is better off under monitoring than auditing. Indeed, with small costs of verification the principal wants to verify relatively often. Yet, under an exclusive auditing of failed projects the auditing intensity is at most \(1 - p\). Hence, high auditing intensities require that the principal audits also successful projects. Yet, according to Proposition 4 these contracts yield the principal less than the optimal contract under monitoring.

Proposition 6 Auditing does strictly better than monitoring if \(\bar{t} \geq e/(1 - p)\) and

\[ c > \max \left\{ \frac{e^2p}{(1-p)^2y}, \frac{e^2}{4(1-p)^3y} \right\}. \]

This proposition is the counterpart of Proposition 5. It states that if the cost of verification is relatively high and steep incentives are possible, the principal’s optimal verification strategy is to use auditing and audit only failed projects. Higher costs of verification make verification a less attractive option and renders a selective auditing of failed projects optimal. Hence, if such a selective verification is possible, that is, if \(\bar{t} \geq e/(1 - p)\), then auditing is optimal.

6 Conclusion and Final Remarks

This paper studied the strategic effect of a difference in the timing of verification. It showed that when the principal’s verification behavior is non-contractible, monitoring may be optimal, as for two reasons the additional information received under auditing may hurt the principal. First, the additional information makes it more difficult to verify with a high intensity. Hence, if verification costs are low such that
a high verification intensity is in principle attractive, it may be optimal for the principal to refrain from obtaining the extra information and use monitoring rather than auditing. It follows that auditing can only be optimal if a low verification intensity is required. Yet, a second disadvantage of auditing is that it requires steeper incentives for the agent. Hence, if the implementation of steep incentives is, due to bounded transfers, not possible, or, due to risk aversion, costly to implement, monitoring may again turn out to be optimal. Ultimately, the optimality of monitoring is due to a natural tension between the principal’s incentives to verify and the incentives for the agent which auditing exacerbates. Indeed, by switching to monitoring as her procedure of verification the principal relaxes the tension. Hence, monitoring may be seen as a commitment device not to act on the additional information.

The paper assumed that the additional information that the principal receives under auditing is the agent’s actual output. This is a convenient modeling assumption. Yet, the paper’s results hold for other informative signals. As soon as the additional information is informative about the agent’s action, it worsens the tension between the two incentives. Hence, preventing oneself from receiving the information, i.e., choosing monitoring rather than auditing, may be an optimal strategy for the principal.

Since the difference between monitoring and auditing is only the additional information, our results also shed light on the value of information to the principal. More precisely, only if verification costs are low and steep incentives are not too costly to implement the information has a positive value to the principal. In this case, the difference $V_2^* - V_1^*$ expresses the value of information and represents the principal’s maximum willingness to pay for the information.

7 Appendix

Proof of Proposition 1

Proof: We solve problem P1 by disregarding (4), as the solution of the relaxed problem automatically satisfies the constraint. Substitution of (2) yields the simplified problem

$$\max_{t_s, \gamma, \alpha} V = (\alpha + (1 - \alpha)p)y - t_s - (1 - (1 - \alpha)\gamma)e/\gamma - \gamma c$$
s.t. \[ \alpha \geq 1 - c\gamma/e \]

with \( t_w = t_s + e/\gamma \). Since the constraint is independent of \( t_s \) and the objective constraint is decreasing in \( t_s \), optimality requires \( t_s = 0 \). Moreover, assuming that the remaining constraint is not binding leads to a contradiction: If it does not bind, the objective function is linear in \( \alpha \), and, since, by assumption, \( \alpha > 0 \) is optimal, linearity implies that \( \alpha = 1 \) is optimal. Yet, this violates the constraint. Consequently, the maximization problem can be reduced to

\[
\max_{t_w} y - t_w - \frac{(1-p)yc}{t_w},
\]

which is concave in \( t_w \) as the 2nd derivative w.r.t. \( t_w \) is \(-2(1-p)cy/t_w^3\). Hence, the first order condition is sufficient and yields

\[
\hat{t}_w = \sqrt{(1-p)cy}.
\]

If \( \hat{t}_w > \bar{t} \) then optimally \( t_w^* = \bar{t} \). Otherwise, \( t_w^* = \max\{e, \hat{t}_w\} \). Note: \( \hat{t}_w \geq e \iff (1-p)cy \geq e^2 \). Finally note that since inequality (3) is binding at the optimum, the constraint (4) is automatically satisfied and there is no loss of generality in disregarding it.

Q.E.D.

**Proof of Proposition 2**

Proof: From (8), \( \gamma_f \leq 1 \), and \( t_s \geq 0 \) it follows that \( t_w \geq e/(1-p) \). But since \( t_w \leq \bar{t} \), a necessary condition for the existence of a contract that induces the agent to work is \( \bar{t} \geq e/(1-p) \).

Therefore suppose \( \bar{t} \geq e/(1-p) \) then constraint (10) implies that either \( \alpha = 1 \) or (8) is binding. First suppose (8) is slack such that \( \alpha = 1 \). The maximization problem reduces then to

\[
\max_{t_w, t_s} y - t_w
\]

and yields \( t_w = 0 \) as an optimum. Yet, for any \( t_s \geq 0 \) this violates (8). Consequently, (8) must be binding at the optimum, which implies that (10) is automatically satisfied and may be disregarded. Substitution of a binding (8) reduces the maximization problem to

\[
\max_{t_s, \alpha} (\alpha + (1 - \alpha)p)(y - e/(1-p) - t_s) - (1 - \alpha)(1-p)(t_s + c)
\]
the objective function is linearly decreasing in \( t_s \) and linearly increasing in \( \alpha \). Hence \( \alpha = 1 \) and \( t_s = 0 \) is optimal such that \( t_w^* = e/(1-p) \) and \( V_2^* = y - e/(1-p) \). Hence, \( \bar{t} \geq e/(1-p) \) is sufficient for existence.

Q.E.D.

**Proof of Proposition 3**

Proof: We solve problem P3 by first assuming that (11) is satisfied. Substitution of the solution of (9) with respect to \( t_w \) yields

\[
V_3 = (\alpha + (1-\alpha)p)y - c(1-(1-\alpha)(1-\gamma_p)p - \alpha(1-\gamma_p)) - \frac{(\alpha + (1-\gamma_p)(1-\alpha)p)c}{1 - (1-\gamma_p)p} - t_s,
\]

and shows that \( V_3 \) is decreasing in \( t_s \). Hence, optimality requires \( t_s = 0 \). Moreover, since \( V_3 \) is linear in \( \alpha \) and, by assumption, \( \alpha > 0 \) is optimal, it follows that (7) must bind at the optimum. This implies that (11) is automatically satisfied. Hence, our starting assumption that (11) is satisfied was without loss of generality. A substitution of the solution of (9) with respect to \( \gamma_p \) and the solution of (7) with respect to \( \alpha \) simplifies the problem to

\[
\max_{t_w \in [e, \min\{e/(1-p), \bar{t}\}]} V_3(t_w) = \frac{pt_w(y - t_w) - c^2(1-p)}{pt_w + (1-p)c},
\]

where the domain restriction \( t_w \in [e, e/(1-p)] \) guarantees that \( \gamma \in [0, 1] \). The first order condition is

\[
\hat{t}_3 = \frac{\sqrt{(1-p)c(c + py) - (1-p)c}}{p}.
\]

Since the 2nd derivative w.r.t. \( t_w \) at \( \hat{t}_3 \) is \(-2p/\sqrt{(1-p)c(c + py)} < 0 \) the first order condition is sufficient if it satisfies the domain restrictions. I.e., \( t_w^* = \hat{t}_3 \) is optimal if \( \hat{t}_3 \in [e, \min\{e/(1-p), \bar{t}\}] \). Now if \( \hat{t}_3 < e \) then \( t_w^* = e \) is optimal. On the other hand, if \( \hat{t}_3 > \min\{e/(1-p), \bar{t}\} \) then optimality requires \( t_w^* = \min\{e/(1-p), \bar{t}\} \). For the principal’s utility it follows

\[
V_3^* = \begin{cases}
\bar{t}_p(y - \bar{t}) - c^2(1-p) \\
\frac{ep(y - \bar{t}) - c^2(1-p)^3}{(1-p)(1-p^2(c + ep))} \\
y - \frac{2\sqrt{(1-p)c(c + py) - 2(1-p)c}}{ep(y - e) - c^2(1-p)^3} \\
\frac{pt_w(y - t_w - c^2(1-p))}{(1-p)c + ep} & \text{if } \hat{t}_w > \bar{t} \text{ and } \bar{t} < e/(1-p) \\
\bar{t}_p(y - \bar{t}) - c^2(1-p) & \text{if } \hat{t}_w > e/(1-p) \text{ and } \bar{t} \geq e/(1-p) \\
\frac{ep(y - e) - c^2(1-p)}{(1-p)c + ep} & \text{if } \hat{t}_w \in [e, \min\{e/(1-p), \bar{t}\}] \\
\bar{t}_p(y - \bar{t}) - c^2(1-p) & \text{if } \hat{t}_w < e.
\end{cases}
\]
Proof of Proposition 4

Proof: We must show that \( V_1^* \geq V_3^* \). Since \( \bar{t} \geq e \) it suffices to distinguish between three cases

1) If \( \sqrt{(1 - p)cy} \in [e, \bar{t}] \) then, according to Proposition 1, \( V_1^* = y - 2\sqrt{(1 - p)cy} \). Proposition 3 implies \( V_3^* \leq \bar{V}_3^* \equiv y - 2\sqrt{(1 - p)c(c + py)2(1 - p)c}/p \). It holds

\[
V_1^* - \bar{V}_3^* = \frac{2 \left[ \sqrt{(1 - p)c(c + py)} - (1 - p)c - p\sqrt{(1 - p)cy} \right]}{p} \geq 0.
\]

That the term in the square bracket is non-negative, follows from the following argument:

\[
p^2(c - (1 - p)y)^2 \geq 0 \Rightarrow (c + py + (1 - p)c - p^2y)^2 \geq 4(1 - p)c(c + py)
\]

\[
\Rightarrow c + py + (1 - p)c - p^2y \geq 2\sqrt{(1 - p)c(c + py)} \]

\[
\Rightarrow (1 - p)c \left[ (c + py) + (1 - p)c - 2\sqrt{(1 - p)c(c + py)} \right] \geq (1 - p)c p^2y \]

\[
\Rightarrow \sqrt{(1 - p)c(c + py)} - (1 - p)c \geq p\sqrt{(1 - p)cy}
\]

2) For \( \sqrt{(1 - p)cy} < e \) it holds \( V_1^* = y - e - (1 - p)yc/e \) and \( V_3^* \in \{ V_3(t_w) \mid t_w \in [e, e/(1 - p)] \} \) with \( V_3(t_w) \) as defined by (12). But for any \( t_w \in [e, e/(1 - p)] \) it holds

\[
V_1^* - V_3(t_w) = \frac{p}{t_w - e} \left[ etw - c(1 - p)y + c(1 - p)(e - c) \left[ (1 - p)y - c \right] \right] \geq 0,
\]

where the non-negativity of the first bracketed term follows from \( (1 - p)cy < e^2 < et_w \).

3) If \( \sqrt{(1 - p)cy} > \bar{t} \) then \( V_1^* = y - \bar{t} - (1 - p)cy/\bar{t} \). Due to \( c < e < y(1 - p) \) it holds \( t_{wf} > \sqrt{(1 - p)cy} > \bar{t} \). Therefore, \( t_{wf} \) exceeds \( \bar{t} \) which implies \( V_3^* \leq \bar{V}_3^* = (\bar{t}p(y - \bar{t}) - c^2(1 - p))/((1 - p)c + \bar{t}p) \). It follows that

\[
V_1^* - \bar{V}_3^* = \frac{c(1 - p)(\bar{t} - c)\left[ (1 - p)y - \bar{t} \right]}{\bar{t}(c + p(\bar{t} - c))} > 0.
\]

The inequality holds, because from \( \sqrt{(1 - p)cy} > \bar{t} \) and \( \bar{t} > c \) it follows \( (1 - p)y > \bar{t}^2/c > \bar{t} \).
Proof of Proposition 5

Proof: If the maximum transfer $\bar{t}$ is unbounded, then $V^*_2 = y - e/(1-p)$.

For $(1-p)cy \geq e^2$ it follows that $V^*_1 = y - 2\sqrt{c(1-p)y}$ and $V^*_1 - V^*_2 = e/(1-p) - 2\sqrt{c(1-p)y}$. Hence, due to $c < e^2/[4(1-p)^2y]$ it holds $V^*_1 > V^*_2$.

For $(1-p)cy < e^2$ it follows $V^*_1 = y - e - (1-p)yc/e$ and due to $c < e^2p/[(1-p)^2y]$ it holds $V^*_1 > V^*_2$. 

Q.E.D.

Proof of Proposition 6

Proof: If $\bar{t} \geq e/(1-p)$, then $V^*_2 = y - e/(1-p)$.

For $(1-p)cy \geq \bar{t}^2$ it follows that $V^*_1 = y - \bar{t} - c\Delta y/\bar{t}$ and

$$V^*_2 - V^*_1 = \frac{\bar{t}((1-p)\bar{t} - e) + (1-p)^2yc}{(1-p)\bar{t}}$$

which is positive, due to $\bar{t} \geq e/(1-p)$.

For $(1-p)cy \in (e^2, \bar{t}^2)$ it follows that $V^*_1 = y - 2\sqrt{c(1-p)y}$ and $V^*_1 - V^*_2 = e/(1-p) - 2\sqrt{c(1-p)y}$. Hence, if $c > e^2/[4(1-p)^2y]$ then $V^*_2 > V^*_1$.

For $(1-p)cy < e^2$ it follows $V^*_1 = y - e - (1-p)yc/e$ and due to $c > e^2p/[(1-p)^2y]$ it holds $V^*_2 > V^*_1$.

Q.E.D.

References


