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# Auditing versus monitoring and the role of commitment

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## Abstract

This paper studies the effect of timing and commitment of verification in a principal-agent relationship with moral hazard. To acquire additional information about the agent's behavior, the principal possesses a costly technology that produces a noisy signal about the agent's effort choice. The precision of this signal is affected by the principal's verification effort. Two verification procedures are discussed: monitoring where the principal verifies the agent's behavior simultaneously with his effort choice and auditing where the principal can condition her verification effort on the realized outcome. As it is well known, the principal prefers to audit the agent's behavior if she can commit to her verification effort at the time of contracting. The main contribution of this paper is to highlight the importance of commitment by the principal to her verification effort. In particular, I show that, when the principal cannot commit to her verification effort ex-ante, the principal strictly prefers monitoring to auditing if the gains from choosing high effort are sufficiently high.

**Keywords** Monitoring · Auditing · Commitment · Double moral hazard

**JEL Classification** D82 · D86 · M42 · M52

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The idea of this paper is based on the second part of my doctoral dissertation, and I thank my supervisor Martin Hellwig for his support and advice as well as the seminar audience at Bonn University in 1987, especially Urs Schweizer. In the 30 years that followed, a number of colleagues have contributed with their comments. For comments during the last period of work on this paper, I thank Stefan Reichelstein, two anonymous referees, and Ralf Ewert, Michael Kopel, Anna Ressi, Ulf Schiller, Georg Schneider, Alfred Wagenhofer and the seminar audience at the University of Basel 2017 and Graz 2017 for helpful comments. All remaining errors are on my side.

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## 1 Introduction

Delegated decision making where an agent (henceforth he) has the responsibility for taking actions in the interests of a principal (henceforth she) in return for some kind of payment, forms the basis of every hierarchical relationship. However, if the agent's behavior cannot be directly observed, the payment cannot be linked to his decision but only to the realized outcome, leading to a moral hazard or incentive problem. A natural remedy to this moral hazard problem then is the acquisition of additional information about the behavior of the agent, as proposed by Alchian and Demsetz (1972) and Jensen and Meckling (1976). If this information acquisition is costless, it is always valuable and should be used in contracting (e.g., Hölmstrom (1979), Shavell (1979), Harris and Raviv (1979)). If, however, information acquisition is costly for the principal, she has to weigh the costs and benefits of the additional information. This trade-off is driven by several aspects of the underlying verification procedure for acquiring information. As in Strausz (2005), I focus on the timing of verification and the principal's verification strategy: should the principal verify the agent's behavior after the agent has exerted his effort contingent on the outcome that realized (auditing), or is it better to verify the agent's behavior simultaneously with his choice of an effort level, that is, independent of the outcome that will be realized (monitoring)? And what is the principal's optimal auditing and monitoring strategy? As an extension of Strausz, this article highlights the principal's ability to commit to her verification strategy for the costs and benefits of the two verification procedures if the realized outcome is verifiable: what is the effect of timing and commitment of verification on the outcome-contingent payment for the agent? And how do timing and commitment influence the behavior of the agent?

The purpose of this paper is to answer these questions in the following generic principal-agent model. The agent who is risk neutral and protected by limited liability, can either adhere to a normal level of effort or exert high effort. A high effort tends to produce higher outcome levels than a normal level of effort, the monotone likelihood ratio condition (MLRC), and the principal prefers that the agent chooses high level. However, without verification, this choice is unobservable by the principal. To induce incentives for choosing high effort, she then offers a monetary outcome-contingent contract, which gives the agent a pre-specified payment as a function of his verifiable performance. In addition to monetary incentives, the principal also has the possibility to verify the agent's behavior either by auditing or by monitoring. In both cases, her verification generates a signal indicating whether the agent chooses a high level of effort. The precision of this signal depends on the principal's verification effort. The higher her effort the better the signal, with decreasing marginal precision. Nevertheless, the signal is still noisy, and there always exists an error in verification independent of the level of verification effort, leading to a misjudgment of the agent's behavior. To focus solely on incentive considerations due to moral hazard concerns, both verification procedures are assumed to be equally efficient and costly for the principal.<sup>1</sup> To study the principal's ability to commit to her

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<sup>1</sup>In reality, of course, there exist several differences between the efficiency of monitoring and auditing. Monitoring, for example, might give the principal the possibility to take corrective actions or to provide

verification effort, I also assume that she can commit herself to a verification procedure at the time of contracting. In practice, this assumption is satisfied when the two verification procedures require the installation of different technologies. Monitoring, for example, might be executed by direct supervision of the agent's behavior, whereas auditing might imply that the principal checks the agent's reports about his actions. Moreover, the assumption that commitment to a verification procedure is possible but not to its actual use is confirmed by many real life contracts where an employer is only allowed to use (stochastic) verification procedures if she informs her employee explicitly about their existence *ex-ante*.<sup>2</sup>

Given the principal can commit to the verification effort at the time of contracting with the agent, the following three results are already known or can be inferred from the literature (see Section 2). First, of course, verification takes place only if its costs are sufficiently small. If that is not the case, the optimal monetary incentive scheme only rewards the agent for the highest possible outcome and the agent, in turn, then chooses the high level of effort. This result relies on the fact that the agent is risk-neutral but has limited liability and the MLRC holds. Under these assumptions the highest outcome is the most informative one and gives the agent the highest incentives to increase his level of effort. And since risk allocation is not an issue, it is optimal for the principal to reward the agent only if this outcome realizes. Second, given that verification costs are sufficiently low and render the acquisition of additional information worthwhile, the principal audits the agent's behavior only in the highest possible outcome level and thereby reduces the agent's reward. Again, this follows from the fact that the agent is risk-neutral and that the agent's incentives to choose high effort are highest if auditing and rewarding take place only in the highest possible outcome, due to the MLRC. Compared to the case without verification, auditing yields a lower reward. This is because monetary incentives and auditing are substitutes for incentivizing the agent. Third, using monitoring as a verification procedure is always inferior to auditing. This observation results from the fact that, under auditing, the principal has additional information on the agent's behavior by conditioning her verification on the outcome actually realized, whereas she has to verify the agent's behavior independent of the outcome under monitoring. This implies that her overall verification costs in case of auditing are smaller than under monitoring.<sup>3</sup>

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additional support to the agent, whereas such activities are not possible under *ex-post* auditing. Moreover, monitoring might be more costly than auditing due to its continuous verification and nearly real-time check of the agent's behavior, whereas auditing might provide less precise information than monitoring would do.

<sup>2</sup>See Strausz (2005) and his Footnote 4.

<sup>3</sup>The superiority of auditing depends crucially on the complexity of the underlying model and on the concavity of the verification technology. To see the first point, suppose, for example, that the outcome would always be highest if the agent chooses high effort. Then auditing as well as monitoring would never occur in other outcome levels, and both would be cost equivalent. To see the second point, consider a verification technology where the principal's verification costs are linear in her effort. Then there exists no solution to the principal's problem, in the auditing as well as in the monitoring case. The reason is simple: For every payment scheme and every verification strategy, the principal always has an incentive to lower her verification effort to increase her profits. In the limit, this reasoning comes as close as it can to the first-best solution. In such a framework, auditing is not superior to monitoring.

The main purpose of the paper is to highlight the importance of the principal's commitment to her verification effort for the optimal verification procedure. So what is different in case she cannot commit to her verification strategy and only to her verification procedure at the time of contracting? First of all, the optimal verification effort under commitment is not optimal under non commitment. In the latter situation, an additional moral hazard problem for the principal comes into play: regardless of whether she verifies the agent's behavior *ex-post* or simultaneously with the agent's choice of an effort level, she must have sufficient incentives to do so. However, the optimal verification effort under commitment does not fulfill this credibility constraint under non commitment. If she announces her plan to verify the agent's behavior and this induces the agent to choose high effort, she has no incentive to actually perform this verification *ex-post*: knowing the agent has chosen high effort, she not only saves verification costs but also pays the agent's reward with a lower probability. Of course, this is foreseen by the agent, who, in turn, has no incentives to choose the high level of effort. As a consequence, the agent cannot be incentivized to take the high level of effort with certainty but only with some positive probability.<sup>4</sup>

To solve this double moral hazard problem, the principal therefore has to adjust the optimal monetary incentive scheme and his verification effort in such a way that her verification becomes credible *ex-post*. This has two implications. First, it requires that the agent's expected reward in case of verification has to be lower than in case of non-verification. Otherwise, the principal has no incentive to verify the agent's behavior. As a consequence, verification is credible *ex-post* only if the principal passes on her verification costs to the agent; that is, he has to bear the principal's verification costs. And second, her marginal benefits from an increase in the precision of the signal have to balance her marginal effort costs from doing so. Due to the concavity of the verification technology, this incentive constraint implies that the marginal reduction of the agent's expected payment and her verification effort are now complements. Since the agent bears the principal's verification costs, an increase in her verification efforts then necessarily implies that the agent receives a lower expected payment.

How should the principal then optimally choose the verification effort and incentive structure under the two verification procedures? Consider first the case of auditing. Three results characterize the optimal solution. First of all, it is never optimal to audit the agent's behavior in only one outcome, since he would then adjust the probability of choosing high effort to a level such that the principal has no incentives to audit. This is beneficial for the agent because he then receives a higher payment. Second, the principal optimally audits the agent's behavior in two outcome levels; in a high one where she believes the agent only chooses the normal level of effort, and in a low one where she believes the agent chooses the high level of effort. Moreover, she rewards the agent in both cases if the audit contradicts her belief: in case of the high outcome, she rewards him if the audit signals high effort, and in case of the low outcome, she rewards the agent although the audit signals only a normal level of effort. This reward structure is necessary to make her auditing *ex post* credible. In

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<sup>4</sup>Whether the principal's inability to commit to her verification strategy actually leads to an additional moral hazard problem depends again crucially on the underlying verification technology; see our discussion in Section 2.

both cases, she benefits because it is more likely that the audit confirms her belief about the agent's behavior so that auditing reduces the expected payment to the agent. And third, the principal's incentive constraint then implies that the agent's rewards and her verification effort are complements in both outcome levels. Since the agent bears the cost of verification, an increase in the principal's auditing effort necessarily implies that she has to compensate the agent with a higher payment.

Monitoring, however, can now be beneficial for the principal compared to auditing for two reasons. First, whereas under auditing the credibility constraint has to be satisfied for every outcome in which the principal wants to verify the agent's behavior, this is no longer true for monitoring. In this case, the principal's incentives to monitor are determined by the entire monetary incentive scheme over all outcomes. Different from auditing, this gives the principal additional options for making her credibility constraint binding. Second, whereas under auditing the principal has to respond after the agent's choice of an effort level, this is not the case for monitoring. Here, the principal acts simultaneously with the agent so that the latter cannot influence the principal's expectation about his behavior via the realized outcome. These two advantages of monitoring have two implications. First, as in the case of commitment, the principal rewards the agent for high effort in the highest outcome so that her verification effort and the agent's payment are now substitutes. Of course, to make verification credible, she then also has to reward the agent for normal effort in the lowest outcome. Since the agent bears the principal's verification cost, this payment and her monitoring effort remain complements for this outcome level. And second, the agent's probability of choosing the high level of effort is higher, as in the case of auditing. This follows directly from the fact that the principal can use the reward in the highest outcome for motivating the agent to choose high effort. In particular, this is beneficial for the principal when the productive gains from high effort are sufficiently high. In this case, she prefers monitoring to auditing.

The paper proceeds as follows: Section 2 reviews the related literature. In Section 3, I set up a principal-agent model with moral hazard, limited liability, and a finite number of possible outcome levels in which the principal has the possibility to choose a verification procedure, either auditing or monitoring. The properties of the principal's optimal verification effort and her optimal monetary incentive devices are discussed in Section 4 for the commitment setting and analyzed in Section 5 for the non commitment setting. Section 6 concludes. The proofs for Section 4 are available upon request to the author; the proofs for Section 5 are collected in the [Appendix](#).

## 2 Related literature

This is not the first paper that considers the principal's ability to commit to her verification effort in a principal-agent framework.

Much of the literature assumes that the principal can commit to her verification effort at the time of contracting and studies the optimal design of her verification under moral hazard (e.g., Evans (1980); Baiman and Demski (1980); Lambert (1985); Kanodia (1985); Dye (1986); Kim and Suh (1992) for auditing and Jost

(1991); Demougin and Fluet (2001) for monitoring).<sup>5,6</sup> To relate my results in the commitment setting with auditing in Section 4 to this literature, note that all articles mentioned above study a principal-agent framework with a risk-averse agent. In such a setting, the principal trades off efficiency and risk allocation to determine the optimal verification strategy and the optimal incentive scheme, whereas in a setting with a risk-neutral agent, she trades off efficiency and rent extraction. It is for this reason that most of the results from prior work differ to those in the present study. Having this in mind, Evans (1980) shows that, if the auditing technology is perfect and deterministic, verification takes place when outcome levels are low, given the agent is risk-averse. Baiman and Demski (1980) show that the outcome region in which the principal audits depends crucially on the agent's risk aversion or risk tolerance, respectively. In particular, the optimal auditing strategy is either "one-tailed" or independent of the outcome that occurs.<sup>7</sup> They assume that auditing is imperfect and generates a signal about the agent's behavior that is independent of the outcome. The model by Lambert (1985) is similar to Baiman and Demski (1980) but assumes that the principal's information from auditing depends on the level of outcome. This assumption implies that an outcome not only provides information about the agent's effort but that the outcome also affects the informativeness of the verification. This effect can lead to a "two-tailed" auditing strategy; that is, a verification occurs only after the outcome is low or high. The article by Dye (1986) generalizes the basic approach by Baiman and Demski (1980) to finite effort levels for the agent and general utility functions. He shows that, if high-effort levels tend to produce higher outcome levels, the optimal auditing probabilities are deterministic, and auditing takes place with certainty if a low outcome level occurs. The same result is derived by Kanodia (1985) in a model similar to Dye (1986), except that he allows the agent to acquire information before taking an action and contracts are pure wage contracts.

An article closely related to the non commitment setting in Section 5 of the present paper is Strausz (2005). He also compares auditing and monitoring and shows that auditing is optimal if the productive gains from high effort are sufficiently high, his Proposition 5. This result is in direct contrast with my result in Section 5, where I show, in Corollary 2, that if the productive gains from high effort are sufficiently high, the principal prefers monitoring to auditing. This inconsistency in results can easily be resolved by comparing the key assumptions of both models and their implications;

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<sup>5</sup>In the accounting literature, auditing is generally viewed as verification of a report provided by the agent about his activities. In these models, the agent's activities are exogenously influenced by some private information relevant for evaluating his performance. In my model, his activities are endogenously driven by the fact that his action choice is not observable by the principal. Given this moral hazard scenario, however, there is no analytical difference whether the principal wants to implement a certainty action by ensuring the agent's incentive compatibility constraint or whether the agent truthfully reports his chosen action by ensuring the agent's truth-telling constraint.

<sup>6</sup>See also Kim (1995), Demougin and Fluet (1998), or Fagart and Sinclair-Desgagné (2007) on the comparison of different verification procedures with respect to their information generated.

<sup>7</sup>An auditing strategy is called "lower-tailed" if auditing takes place only in low outcome levels. Otherwise, if auditing occurs only if the outcome is high, the strategy is called "upper-tailed." In both cases, auditing is "one-tailed."

see my discussion in Section 5.2. In an extension of his basic model, Strausz (2005) then also considers a situation in which the level of outcome is verifiable. He argues that because “the analysis becomes less tractable” in this case, he only confirms the intuition of the basic model without formal proofs. In this extension, he considers a convex outcome space and assumes that the principal can condition her auditing on some additional information such that a higher signal indicates that the agent chooses the higher effort level. This assumption implies that, if the agent randomizes between low and high effort, the principal’s belief that the agent chooses high effort is increasing in the signal. Strausz (2005, p. 101f) then argues that “it is harder for the principal to verify with a high probability under auditing than under monitoring” and that “steeper incentives are required to induce the agent to take a high effort level.” Implicitly, this argumentation rests on the structure of his basic model, in which the auditing probabilities for success and failure were interdependent: since in case of success it is less likely that the agent chose a low effort level, the principal is less likely to save her bonus than in case of a failure. Since the principal does not update her belief about the agent’s behavior under monitoring, auditing in both outcomes requires higher powered incentives than monitoring. However, this argumentation neglects the fact that, in his extended model, the principal can condition her payments on the outcome level. But if she offers an outcome-dependent payment scheme, the auditing probabilities become independent between outcome levels, as in my model, and the principal’s incentives to audit must be given for every outcome in which auditing occurs.

The contribution of the present paper then is to clarify and extend the insights of Strausz (2005) for his extended modelling. I clarify his argumentation by introducing a verification technology where the precision of the generated signal is not perfect. This is important for two reasons. First, the result of Corollary 1 in Strausz – monitoring is strictly better than auditing if the maximal payment is sufficiently low – does not necessary hold if the outcome is contractible and non-verification produces no signal. According to his discussion of Corollary 1, Strausz (2005, p. 99) introduced “a boundedness of transfers as an extreme form of risk aversion.” However, if the agent is risk averse and the verification technology is perfect, the literature review above shows that the optimal auditing probabilities are either zero or one. But then the double moral hazard problem is not an issue for the principal, since she can implement the optimal auditing solution independent of her commitment abilities by offering the agent a high compensation if verification does not occur. And second, the same is true for the result of Proposition 5 in Strausz (2005): monitoring is strictly better than auditing if the costs of verification, relative to the benefits from high effort, are sufficiently low. If the outcome is contractible and the outcome space is compact, the MLRC implies that it is optimal for the principal to use an upper-tailed auditing strategy where she audits with certainty if the outcome level is high. Under commitment this strategy induces the agent to choose the high level of effort with certainty and not with some positive probability. But then the inability to commit to her auditing probabilities is again not necessarily an issue for the principal. If non-verification produces no signal, she can implement her auditing strategy under non commitment by offering the agent a sufficiently high payment in case of non-auditing. Then she always has an incentive to audit, even if her announcement was not binding.



Besides the noisiness of the principal's verification technology in the presence of outcome-contingent contracting, I also extend the insights of Strausz (2005) by introducing a model with a finite number of possible outcome levels greater than two. This extension is fruitful for two reasons. First, it introduces a new force to the comparison of auditing with monitoring. Whereas under auditing the principal has to adjust the agent's payments for every outcome in which she wants to verify his behavior, she has greater flexibility when designing the monetary incentive scheme under monitoring. This advantage of monitoring over auditing in the non commitment setting is not discussed by Strausz (2005). And second, my model is more tractable than the one of Strausz (2005), which allows us to explicitly calculate the optimal monetary incentive scheme and the optimal verification effort under auditing and monitoring and compare them accordingly.

### 3 The model

A principal delegates a task to an agent. The agent is assumed to be risk-neutral and protected by limited liability. He has no wealth, and his reservation utility is given by zero.<sup>8</sup> Under this arrangement, the agent is supposed to take an effort  $e \in \{0, 1\}$  which is not directly verifiable for the principal. The effort  $e = 0$  refers to choosing a normal level of effort, whereas the effort  $e = 1$  refers to choosing a high level of effort. The agent's cost for exerting effort  $e \in \{0, 1\}$  is denoted by  $e \cdot c_H$ , where  $c_H > 0$ . I allow that the agent can also choose a mixed strategy  $\alpha \in [0, 1]$  such that  $\alpha$  denotes the probability for choosing high effort.

His effort choice together with the realization of a random state of nature determines an outcome  $x$ . There is a finite number of possible outcome levels,  $x \in \{x_1, \dots, x_n\}$ , with  $x_1 < \dots < x_n$ . Neither the agent nor the principal can observe the value of the random variable, whereas the outcome is publicly observable and contractible. Effort  $e \in \{0, 1\}$  determines an outcome  $x_i$  with probability  $\pi_i(e) \in (0, 1)$  and  $\sum_{i=1}^n \pi_i(e) = 1$  for  $e \in \{0, 1\}$ . Throughout the paper, it is assumed that the higher level of effort increases the probability of a higher outcome level. This property is modelled using the Monotone Likelihood Ratio Condition (MLRC); that is,

$$\delta_i := \frac{\pi_i(0)}{\pi_i(1)} \quad \text{is decreasing in } i.$$

To receive additional information about the agent's behavior, the principal can decide to verify. She is assumed to be risk-neutral and interested in her net profits  $\Pi$ . That

<sup>8</sup>The assumption that both the lower bound of the agent's compensation and the agent's outside utility equal zero is a standard assumption in most agency models with limited liability and is assumed for simplicity. The assumption implies that the agent's participation constraint is always satisfied, and the agent therefore receives a positive rent. In our context, I used the assumption to clearly formulate the nature of the principal's problem, which is to trade off the agent's rent against her verification costs. The optimal verification level then equalizes the marginal cost of verification and the marginal benefits in terms of rent reduction. In a setup in which the agent's outside utility would be positive and sufficiently large such that the agent's participation constraint is binding, the optimal level of verification is the smallest one that is compatible with zero rent for the agent. See the following footnotes 9, 11 and 15 for how the results change in this case.

is, she maximizes gross profits minus the payment to the agent minus her verification costs. Note that, if she wants to implement  $e = 0$ , there is no incentive problem and she should pay the agent a constant payment of zero in every outcome without verifying his behavior. Therefore the problem is of interest only if the principal wishes to implement  $e = 1$  with some positive probability. Since the focus of our analysis is on the optimality of the principal's verification, it is assumed that she prefers that the agent chooses a high level of effort with certainty, even if she does not verify his behavior. That is, the principal's expected gross benefits when the agent chooses high effort  $e = 1$ , instead of  $e = 0$ , are greater than the agent's additional effort cost  $c_H$ :

$$\sum_{i=1}^n (\pi_i(1) - \pi_i(0)) x_i > c_H.$$

I follow Kim and Suh (1992) and assume that a verification generates an additional, verifiable signal  $y$ , indicating whether the agent has taken  $e = 1$  or  $e = 0$ .<sup>9</sup> In the first case,  $y = H$ ; in the second case,  $y = L$ . A verification is always noisy, but the precision  $p$  of the signal depends on the principal's verification effort  $v$ ; that is,  $p = p(v)$ . The precision then is the probability that the signal indicates  $y = H$  ( $y = L$ ), given the agent chose  $e = 1$  ( $e = 0$ ). In particular, I assume that the precision of the signal is increasing in the level of verification effort,  $p'(v) > 0$ ; that is, she receives a more precise signal about the effort actually chosen by the agent. Moreover, the marginal precision is decreasing in verification effort,  $p''(v) < 0$ , such that the verification technology is strictly concave. The unit cost of verification are represented by  $c > 0$ . Without verification, the principal receives no additional information about the agent's effort choice,  $p(0) = \frac{1}{2}$ , whereas a perfect signal is possible only with an infinite effort,  $p(\infty) = 1$ . Note that this verification technology is symmetric in the sense that

$$p(v) = \Pr(y = H | e = 1; v) = \Pr(y = L | e = 0; v).$$

I consider two different verification procedures, according to the timing of verification, monitoring, and auditing. Under monitoring, the principal chooses a verification effort  $v \geq 0$  simultaneous with the agent's choice of an effort. Hence her verification is independent of the outcome that is realized by the agent's effort. A monitoring strategy then is simply her verification effort  $v$ . Under auditing, the principal can condition her verification effort on the level of outcome, that is,  $v(x)$ . In this case, I denote the verification effort with  $v_i \geq 0$  if she observes outcome  $x_i$ . An auditing strategy  $v(x) = (v_1, \dots, v_n)$  then specifies her verification effort for each possible outcome level  $x_i$ .

<sup>9</sup>The assumption that the principal's verification generates a public signal about the agent's effort might not be given in all situations. Depending on the institutional features of the principal-agent relationship, the generated signal might be not readily observable or verifiable. Hidden cameras or time cards can serve as public signals of the agent's effort, but direct observations or "spot checks" by the principal may be difficult to use as a public signal. This is, for example, the case if the agent's effort has a quality dimension. In those cases, where signals are private significant resources may have to be spent to write contracts contingent upon the signal. A costly third-party certification then may be required to make payments based on the signal, because the principal may not reveal the additional information if it will hurt her; see Strausz (1997).

The monetary incentive scheme the principal offers to the agent is described by a contract  $s = s(x, y)$  with the following interpretation. If outcome  $x$  is realized and verification generates a signal  $y$ , the agent is paid a wage  $s(x, y)$ . Since there are finitely many outcome levels  $x \in \{x_1, \dots, x_n\}$  and only two possible signals  $y \in \{L, H\}$ , I write  $s(x, y) = (s_{1L}, \dots, s_{nL}, s_{1H}, \dots, s_{nH})$ . Of course, if the principal decides not to verify,  $s(x, y) = s(x)$  because the signal reveals nothing about the agent's effort choice. The assumption that the agent has limited liability requires that the agent's payment has to be non-negative,  $s(x, y) \geq 0$ . Moreover, I assume that the principal can always commit to the compensation scheme  $s(x, y)$  at the time of contracting independent of her choice of a verification procedure.

Suppose that the principal chooses an auditing strategy  $v(x)$  and offers a contract  $s(x, y)$ . Then her expected net profits, given the agent chooses a mixed strategy  $\alpha \in [0, 1]$ , is

$$\begin{aligned} & E\Pi(v(x), s(x, y); \alpha) \\ &= \alpha \left( \sum_{i=1}^n \pi_i(1) (x_i - p(v_i) s_{iH} - (1 - p(v_i)) s_{iL} - cv_i) \right) \\ & \quad + (1 - \alpha) \left( \sum_{i=1}^n \pi_i(0) (x_i - p(v_i) s_{iL} - (1 - p(v_i)) s_{iH} - cv_i) \right) \end{aligned}$$

and the agent's expected utility under this contracting then is

$$\begin{aligned} EU(\alpha; s(x, y), v(x)) &= \alpha \left( \sum_{i=1}^n \pi_i(1) (p(v_i) s_{iH} + (1 - p(v_i)) s_{iL}) - c_H \right) \\ & \quad + (1 - \alpha) \left( \sum_{i=1}^n \pi_i(0) (p(v_i) s_{iL} + (1 - p(v_i)) s_{iH}) \right). \end{aligned}$$

Under monitoring, the principal's expected net profit and the agent's expected utility are identical to these expressions under auditing with the additional constraint that  $v_i = v$  for all  $i = 1, \dots, n$ .

In the following, I analyze the principal's optimal compensation scheme and verification procedure and the agent's optimal choice of an effort in two different settings. In the commitment setting, I assume that the principal can commit to her monitoring strategy  $v$  or auditing strategy  $v(x)$ , at the time of contracting; in the non commitment setting, I assume the principal cannot contractually specify her monitoring or auditing strategy. I assume in both settings that the principal can commit to the compensation scheme and to the verification procedure.

## 4 Monitoring and auditing under commitment

When the principal can commit to her monitoring or auditing strategy at the time of contracting, the game between the principal and the agent has five stages.

1. The principal decides on her verification procedure and offers a monetary incentive scheme  $s(x, y) \in [0, \infty]^{2n}$ . If she adopts auditing, she commits to a strategy  $v(x) = (v_1, \dots, v_n) \in [0, \infty]^n$ ; if she chooses monitoring, she commits to verification effort  $v \in [0, \infty]$ .
2. The agent decides whether to accept this arrangement. He accepts if his expected utility is at least equal to zero.<sup>10</sup> Having signed the contract, the agent chooses a mixed strategy  $\alpha \in [0, 1]$  over his effort levels  $e = \{0, 1\}$ . If the principal adopted monitoring, she simultaneously monitors his behavior, as committed to at Stage 1.
3. The effort  $e \in \{0, 1\}$  taken by the agent together with the realization of a random variable results in a verifiable outcome  $x_i$  with probability  $\pi_i(e)$ .
4. If the principal adopted auditing, she audits with an effort  $v_i$  to verify the agent's behavior, as committed to at Stage 1.
5. The agent gets paid according to the contract  $s$ , the realized outcome  $x_i$  and the signal  $y$ . He receives a payment  $s(x_i, H) = s_{iH}$  if the verification indicates that he chose  $e = 1$  and  $s(x_i, L) = s_{iL}$  otherwise.

To analyze the optimal behavior in the commitment setting, suppose that the principal wishes to implement effort  $e = 1$ . I will start our discussion with the benchmark scenario, assuming that her verification costs are sufficiently high such that she only provides monetary incentives  $s(x)$ . I then consider the optimal monitoring and auditing strategies and finally compare both verification procedures.

### 4.1 Benchmark: no verification

Suppose that the principal can use only contract  $s(x) = (s_1, \dots, s_n)$  as an incentive device for implementing  $e = 1$ ; that is, she pays the agent a wage  $s_i \geq 0$  whenever outcome  $x_i$  realizes as a result of his performance. Her problem then is to choose this contract to minimize her expected implementation costs such that the agent accepts contracting and chooses  $e = 1$ . Suppose that  $(s_1^*, s_2^*, \dots, s_{n-1}^*, s_n^*)$  is a solution to this problem (P1) of minimizing

$$\sum_{i=1}^n \pi_i(1)s_i \quad \text{such that} \tag{P1}$$

$$\sum_{i=1}^n \pi_i(1)s_i - c_H \geq \sum_{i=1}^n \pi_i(0)s_i \tag{ICA}$$

$$\sum_{i=1}^n \pi_i(1)s_i - c_H \geq 0. \tag{IRA}$$

<sup>10</sup>The agent always accepts contracting since his reservation utility is zero, and payments are assumed to be non-negative.

The acceptance of the contract, given by the individual rationality constraint (IRA), is always ensured since wages are assumed to be non-negative: as soon as one wage is positive,  $s_i > 0$ , the agent's utility from  $e = 0$  is positive, and the incentive compatibility constraint (ICA), which ensures his compliance with  $e = 1$ , implies that he always has a positive rent in this relationship.

In which outcome levels should the principal reward the agent? Since the agent is risk-neutral, it is not necessary for the principal to insure him against the exogenous risk. Instead, the principal's payments are only driven by incentive consideration. Due to the MLRC, the highest outcome level  $x_n$  is the most informative one and indicates that the agent chose the high level of effort with the highest probability. Hence the greatest incentives to choose high effort are given if the agent receives a reward only when this outcome realizes. To minimize expected payments to the agent, this reward is then adjusted such that he is indifferent between  $e = 1$  and  $e = 0$ ; that is, (ICA) is binding.

**Proposition 1** *If the principal decides not to verify the agent's behavior, the optimal monetary incentive scheme  $(s_1^*, s_2^*, \dots, s_{n-1}^*, s_n^*)$  has the following properties:*

$$s_1^* = \dots = s_{n-1}^* = 0, \text{ and } s_n^* = \frac{c_H}{\pi_n(1)(1 - \delta_n)}.$$

*The agent accepts this contract and chooses  $e^* = 1$ .*

This is a standard result in principal-agent models with risk neutrality and limited liability by the agent; see, for example, Demougin and Fluet (1998). The intuition behind this incentive scheme is straightforward. The principal offers a bonus contract of the "pass or fail" type. Only if the outcome level is most informative about the agent's behavior, he receives a bonus, whereas he receives no payment in all other outcome levels. Note that the bonus contract guarantees the agent a positive rent<sup>11</sup>

$$c_H \frac{\delta_n}{1 - \delta_n}.$$

The optimality of this bonus contract is a direct consequence of the agent's risk neutrality since he has no loss in utility for bearing the risk that the maximal outcome level actually occurs.

## 4.2 Auditing under commitment

Now suppose that verification costs are sufficiently low such that the principal uses a verification procedure as an additional incentive device to reduce the agent's rent.

<sup>11</sup>If the agent's outside option would be higher than this rent, equilibrium contracting would change as follows. Either the principal extends the bonus in the highest outcome level such that (IRA) becomes binding and pays nothing in all other outcomes, as in Macho-Stadler and Pérez-Castrillo (2018). Then (ICA) is not binding. Or the principal pays in addition to the optimal payment scheme in Proposition 1 a non-contingent transfer such that the participation constraint is met. In this case, both (ICA) and (IRA) are binding, as in Demougin and Fluet (2001).

I consider first the case of auditing, that is, the principal offers an incentive scheme  $(s_{1L}, \dots, s_{nL}, s_{1H}, \dots, s_{nH})$  and chooses an auditing strategy  $(v_1, \dots, v_n)$ . Since her auditing strategy is binding, her problem (P2) then is to choose a contract and an auditing strategy to minimize her expected implementation costs such that the agent accepts contracting and chooses high effort.

As in the benchmark scenario without verification, the incentive rationality constraint is always satisfied since at least one payment has to be positive, and the incentive compatibility constraint is binding to save implementation costs. Since auditing effort increases the precision of the signal,  $p(v_i) > \frac{1}{2}$  for  $v_i > 0$ , the error of a misjudgment becomes smaller, and the principal can increase the agent's incentives to choose a high level of effort by setting  $s_{iH} > s_{iL} = 0$ . Due to the MLRC, the agent's incentive to choose high effort are highest if the principal verifies only in the highest outcome  $x_n$  and rewards him only if the signal indicates high effort. In all other outcomes, she pays the agent no reward and does not audit because the corresponding factors are always lower.

**Proposition 2** *If the principal decides for auditing with positive probability, the optimal monetary incentive scheme  $(s_{1L}^*, s_{1H}^*, \dots, s_{nL}^*, s_{nH}^*)$  and auditing strategy  $(v_1^*, \dots, v_n^*)$  have the following properties:*

$$\begin{aligned}
 s_{1L}^* &= \dots = s_{nL}^* = 0, \\
 s_{1H}^* &= \dots = s_{n-1H}^* = 0, s_{nH}^* > 0 \\
 v_1^* &= \dots = v_{n-1}^* = 0, v_n^* > 0 \text{ where} \\
 s_{nH}^* &= \frac{c_H}{\pi_n(1) (p(v_n^*) - \delta_n (1 - p(v_n^*)))} \text{ and} \\
 \frac{c_H}{c} &= \frac{\pi_n(1)^2 (p(v_n^*) - \delta_n (1 - p(v_n^*)))^2}{\pi_n(0) p'(v_n^*)}
 \end{aligned}$$

The agent accepts contracting and chooses  $e^* = 1$ .

Three remarks are worth making. First note that under auditing the principal offers a lower reward in outcome  $x_n$  than in the benchmark scenario; that is,  $s_{nH}^* < s_n^*$ . This result directly follows from the fact that auditing in this outcome increases the precision of the signal,  $p(v_n) > 1 - p(v_n)$ . According to the characterization of the optimal reward  $s_{nH}^*$ , the monetary payment and the auditing effort are substitutes,

$$\frac{\partial s_{nH}^*}{\partial v_n^*} < 0.$$

Second, the characterization of the optimal auditing effort  $v_n^*$  shows that her verification is decreasing in verification costs. In fact, using the envelope theorem, it follows

that  $\partial v_n^*/\partial c < 0$ .<sup>12</sup> In fact, no auditing takes place,  $v_n^* = 0$ , if the verification costs are sufficiently high

$$c \geq 4c_H \frac{\pi_n(0)p'(0)}{\pi_n(1)^2(1-\delta_n)^2} =: c_a.$$

The optimal reward is then given by  $s_{nH}^* = s_n^*/2$  as  $p(0) = 1/2$ . Hence, because no verification gives no signal,  $s_{nH}^* = s_{nL}^*$ , the reward is  $s_n^*$ , as in Proposition 1.

And third, the agent's rent now reads as

$$\frac{\delta_n(1-p(v_n^*))}{p(v_n^*)-\delta_n(1-p(v_n^*))}c_H$$

and is lower than his rent in the benchmark scenario without verification.<sup>13</sup>

### 4.3 Monitoring under commitment

As an alternative verification procedure, I consider now the case in which the principal opts for monitoring. In this scenario, she offers an incentive scheme  $(s_{1L}, \dots, s_{nL}, s_{1H}, \dots, s_{nH})$ , depending on the generated signal, and chooses a verification effort  $v > 0$ . Since her verification effort is binding, the optimal contract and verification effort  $(s_{1L}^*, s_{1H}^*, \dots, s_{nL}^*, s_{nH}^*, v^*)$  minimize her expected implementation costs such that the agent accepts contracting and chooses high effort. Similar to the case of auditing, the principal's problem (P3) leads to the following result.

**Proposition 3** *If the principal decides for monitoring with positive probability, the optimal monetary incentive scheme  $(s_{1L}^*, s_{1H}^*, \dots, s_{nL}^*, s_{nH}^*)$  and monitoring strategy  $v^*$  have the following properties.*

$$\begin{aligned} v^* &> 0, s_{1L}^* = \dots = s_{nL}^* = 0, \\ s_{1H}^* &= \dots = s_{n-1H}^* = 0, s_{nH}^* > 0 \text{ where} \\ s_{nH}^* &= \frac{c_H}{\pi_n(1)(p(v^*)-\delta_n(1-p(v^*)))} \text{ and} \\ \frac{c_H}{c} &= \frac{(p(v^*)-\delta_n(1-p(v^*)))^2}{\delta_n p'(v^*)} \end{aligned}$$

<sup>12</sup>Note that

$$\frac{\partial v_n^*}{\partial c} = - \frac{2c_H(p(v_n^*)-\delta_n(1-p(v_n^*)))p'(v_n^*)^2(1+\delta_n)-(p(v_n^*)-\delta_n(1-p(v_n^*)))p''(v_n^*)}{c^2 p'(v_n^*)^2}$$

Since  $p(v_n^*)-\delta_n(1-p(v_n^*)) > 0$  and  $p''(v_n^*) < 0$ , both terms are positive.

<sup>13</sup>If the agent's outside option would be higher than this rent, equilibrium contracting would change as follows. As in Proposition 2, the agent receives only a payment in the highest outcome level when the signal is favorable. To meet the agent's reservation utility for a fixed verification efforts, the principal then offers in addition to the optimal reward in Proposition 2 a bonus such that the agent's individual reservation constraint becomes binding. Because verification and payment are substitutes, minimizing verification costs then implies that this bonus increases so that the incentive constraint is still binding. If the agent's reservation utility then is so high that her verification effort approaches zero, the principal chooses the optimal reward scheme, as in the benchmark scenario without verification. This reasoning holds for auditing and monitoring.

*The agent accepts contracting and chooses  $e^* = 1$ .*

Compared to the optimal solution under auditing, three remarks are worth making. First, the principal’s effort to verify the agent’s behavior is lower than in case of auditing. This result follows from the fact that her marginal benefits from an increase in the precision of the signal are identical under both verification procedure – she pays the agent in both cases only in the highest outcome level – but her marginal costs are higher under monitoring than under auditing – she verifies his behavior under auditing only in the highest outcome but monitors in all outcome levels. As a consequence, the principal prefers to choose less verification effort under monitoring.

Second, as a direct consequence of the first remark, the critical value  $c_m$  such that the principal solely relies on monetary incentives without verification is lower than in case of auditing,  $c_m < c_a$ . In fact, monitoring will not take place,  $v^* = 0$ , if the unit verification costs are sufficiently high; that is,

$$c > c_m =: 4c_H \frac{\delta_n p'(0)}{(1 - \delta_n)^2} = \pi_n(1)c_a.$$

Third, our first remark above also implies that the principal offers a higher reward  $s_{nH}^*$  in case of monitoring than in case of auditing. This is because monetary incentives and verification effort are substitutes and the incentive constraint has to be satisfied.

**Corollary 1** *The principal never decides for monitoring to verify the agent’s behavior. If the unit verification costs are lower than*

$$c_a = 4c_H \frac{\pi_n(0)p'(0)}{\pi_n(1)^2(1 - \delta_n)^2}$$

*she decides for the optimal auditing strategy and the contract specified in Proposition 2, otherwise for the optimal monetary incentive scheme in Proposition 1.*

This corollary summarizes our finding for the case in which the principal can commit to her verification effort at the time of contracting.

## 5 Monitoring and auditing under non commitment

In the non commitment setting, I assume that the monitoring or auditing strategy announced by the principal at the time of contracting is not binding after the agent has exerted his effort. Thus I deal with the following game in five stages.

1. The principal decides on her verification procedure and offers a monetary incentive scheme  $s(x, y) \in [0, \infty]^{2^n}$ .
2. The agent chooses a mixed strategy  $\alpha \in [0, 1]$  over his effort levels  $e = \{0, 1\}$ , given he accepted contracting. If the principal announced in Stage 1 her intent to monitor, she simultaneously decides about her monitoring strategy and chooses an effort  $v \in [0, \infty]$  to verify the agent’s behavior.



3. The effort  $e \in \{0, 1\}$  taken by the agent together with the realization of a random variable results in a verifiable outcome  $x_i$  with probability  $\pi_i(e)$ .
4. If the principal decided in Stage 1 to audit, she forms a belief  $\mu_i$  about the agent's behavior, given the realized outcome  $x_i$ , and then chooses a verification effort  $v_i \in [0, \infty]$ .
5. The agent gets paid according to the contract  $s(x, y)$  and the signal  $y$ . He receives a payment  $s(x_i, H) = s_{iH}$  if verification indicates that he chose high effort and  $s(x_i, L) = s_{iL}$  otherwise.

The principal in this game faces the following credibility problem with respect to her verification strategy. Suppose that the monetary incentive scheme and a pre-announced verification strategy induce the agent to act in her interests. As verification is costly, the principal can save costs if she does not stick to her announcement to verify. This, of course, will be foreseen by the agent and the principal's pre-announced verification strategy will not be credible *ex-post*. As a consequence, the optimal contracting under commitment is not optimal under non commitment. The principal's inability to commit to her verification strategy then introduces an additional moral hazard problem on the part of the principal. I capture this issue by requiring sequential rationality by the principal with respect to her verification strategy. (1) The principal chooses her verification effort to minimize her expected costs, given the agent's mixed strategy. (2) The agent decides on his mixed strategy, given the principal chooses her verification effort by (1).

### 5.1 Auditing under non commitment

Consider first the case in which the principal chooses an auditing strategy to implement high effort,  $e = 1$ . Then at stage 4 of the game, given an outcome  $x_i$  is realized, her belief about the agent's behavior is  $\mu_i = 1$ , and she chooses an effort level  $v_i$  to minimize expected costs

$$p(v_i)s_{iH} + (1 - p(v_i))s_{iL} + cv_i,$$

with  $v_i \geq 0$ . Optimally, the principal then chooses  $v_i^*$  such that

$$p'(v_i)(s_{iH} - s_{iL}) + c \leq 0.$$

This condition describes the principal's incentive constraint for auditing in outcome  $x_i$ . An immediate consequence from this condition is that, if auditing takes place, the agent's payment in case the signal indicates a normal level of effort has to be higher than for a high effort level; that is,  $s_{iL} > s_{iH}$ . That is, she pays the agent more, if the audit contracts her initial belief. The interpretation of this condition is that the principal rewards the agent for his bad luck: although he implemented effort  $e = 1$ , verification showed a normal effort level. But this can only be possible because of the imprecision of the signal and the corresponding error in judgement. It is for this reason that the principal has to reward the agent, even if auditing indicates that he chose  $e = 0$ , given she wants the agent to choose high effort.

As a consequence, the principal cannot incentivize the agent to choose the high level of effort with certainty if auditing is not binding.<sup>14</sup> Besides the possibility to offer the optimal contract without auditing (see Proposition 1), the principal then has to give up her desire to implement  $e = 1$  with certainty. In this case, she incentivizes the agent to choose some mixed strategy over choosing high or normal effort, such that her overall profit is higher under auditing than in the case without verification. To analyze this possibility, let  $\alpha \in (0, 1)$  be the probability that the agent chooses  $e = 1$ . At stage 4 of the game, the principal forms a belief  $\mu_i$  about the agent's behavior after observing an outcome  $x_i$  and then chooses an auditing effort  $v_i \geq 0$  to minimize expected costs. Updating her a priori probability  $\alpha$  according to Bayes' rule implies that the probability that the agent chooses high effort is given by

$$\mu_i = \frac{\alpha \pi_i(1)}{\alpha \pi_i(1) + (1 - \alpha) \pi_i(0)} = \frac{\alpha}{\alpha + (1 - \alpha) \delta_i}.$$

The principal's expected costs then are given by

$$\begin{aligned} &\mu_i (p(v_i) s_{iH} + (1 - p(v_i)) s_{iL}) + (1 - \mu_i) (p(v_i) s_{iL} + (1 - p(v_i)) s_{iH}) + c v_i \\ &= \mu_i s_{iL} + (1 - \mu_i) s_{iH} + p(v_i) (2\mu_i - 1) (s_{iH} - s_{iL}) + c v_i. \end{aligned}$$

Optimally, the principal chooses  $v_i^{**}$  such that the derivative of her expected costs is non-positive,

$$p'(v_i) (s_{iH} - s_{iL}) (2\mu_i - 1) + c \leq 0.$$

Suppose that auditing takes place,  $v_i > 0$ . Then

$$p'(v_i) = \frac{c}{2 (s_{iH} - s_{iL}) \left( \frac{1}{2} - \mu_i \right)}.$$

Hence, if  $\mu_i > \frac{1}{2}$  and it is more likely that the agent chose the high level of effort, the principal has to offer a higher reward if the signal indicates  $e = 0$  than if the signal indicates  $e = 1$ ,  $s_{iL} > s_{iH}$ .<sup>15</sup> If  $\mu_i < \frac{1}{2}$ , it is more likely that he did not choose the high level of effort, and she offers a higher reward if the signal indicates high instead of normal effort,  $s_{iH} > s_{iL}$ . In both cases, the agent's reward then is higher if the audit contradicts her belief about his behavior. Note also that, by choosing his probability  $\alpha$ , the agent influences the principal's optimal auditing effort  $v_i$  via her updated belief  $\mu_i$ . In particular,  $\mu_i \geq \frac{1}{2}$  is identical to

$$\alpha \geq \frac{\delta_i}{(1 + \delta_i)} = \frac{\pi_i(0)}{\pi_i(1) + \pi_i(0)};$$

that is, the principal only believes that the agent chooses the high level of effort if his actual probability of choosing  $e = 1$  is lower than the conditional probability for this event, and vice versa.

<sup>14</sup>This result is similar to Proposition 1 of Dryminotes (2007, p. 368) for the case of monitoring and in line with the findings by Fudenberg and Tirole (1990) when the principal can not commit to an incentive contract: The lack of commitment destroys the agent's incentives to choose high effort, and, in equilibrium, the agent randomizes over effort levels.

<sup>15</sup>The interpretation of this reward structure resembles the discussion above where the principal pays the agent in case the audit signals a normal level of effort although it is more likely that he chose  $e = 1$ : she rewards the agent for bad luck in the realization of the outcome.

Given the optimal auditing strategy  $(v_1^{**}, \dots, v_n^{**})$  at Stage 2, the agent chooses a probability  $\alpha \in (0, 1)$  to maximize his expected utility. Indifference requires that his expected utility is identical when he chooses the high or the normal level of effort:

$$\begin{aligned} &\sum_{i=1}^n \pi_i(1) (p(v_i^{**}) s_{iH} + (1 - p(v_i^{**})) s_{iL}) - c_H \\ &= \sum_{i=1}^n \pi_i(0) (p(v_i^{**}) s_{iL} + (1 - p(v_i^{**})) s_{iH}) \end{aligned}$$

Since the principal’s optimal auditing strategy in Stage 4 depends on his behavior, he then chooses  $\alpha$  such that

$$\sum_{i=1}^n \pi_i(1) \left( p'(v_i^{**}) \frac{\partial v_i^{**}}{\partial \alpha} (s_{iH} - s_{iL}) (\alpha - (1 - \alpha) \delta_i) \right) = 0.$$

At Stage 1, the principal then offers a monetary incentive scheme to maximize her expected net profits, given the agent’s indifference and her sequential rationality constraint with respect to her auditing efforts. The optimal solution  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**})$  then maximizes the following problem (P4):

$$\alpha \left( \sum_{i=1}^n \pi_i(1) (x_i - p(v_i^{**}) s_{iH} - (1 - p(v_i^{**})) s_{iL} - c v_i^{**}) \right) \tag{P4}$$

$$+ (1 - \alpha) \left( \sum_{i=1}^n \pi_i(0) (x_i - p(v_i^{**}) s_{iL} - (1 - p(v_i^{**})) s_{iH} - c v_i^{**}) \right) \text{ such that}$$

$$\begin{aligned} &\sum_{i=1}^n \pi_i(1) p(v_i^{**}) \left( \left( \left( 1 - \delta_i \frac{1 - p(v_i^{**})}{p(v_i^{**})} \right) s_{iH} \right) \right. \\ &\left. + \left( \frac{1 - p(v_i^{**})}{p(v_i^{**})} - \delta_i \right) s_{iL} \right) = c_H \end{aligned} \tag{ICA4a}$$

$$\sum_{i=1}^n \pi_i(1) \left( p'(v_i^{**}) \frac{\partial v_i^{**}}{\partial \alpha} (s_{iH} - s_{iL}) \right) (\alpha - (1 - \alpha) \delta_i) = 0 \tag{ICA4b}$$

$$p'(v_i^{**}) (s_{iH} - s_{iL}) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) + c \leq 0. \tag{ICP4}$$

**Proposition 4** *If the principal decides for auditing with positive probability, the optimal monetary incentive scheme  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**})$  and the optimal auditing strategy  $(v_1^{**}, \dots, v_n^{**})$  have the following properties: there exist two subsequent outcomes  $x_k$  and  $x_{k-1}$  such that*

$$\begin{aligned} &s_{k-1H}^{**} > 0, s_{iH}^{**} = 0 \text{ for all } i \neq k - 1 \\ &s_{kL}^{**} > 0, s_{iL}^{**} = 0 \text{ for all } i \neq k \\ &v_{k-1}^{**}, v_k^{**} > 0, v_i^{**} = 0 \text{ for all } i \neq k - 1, k \text{ with} \end{aligned}$$

$$s_{k-1H}^{**} = \left( \frac{\alpha + (1 - \alpha) \delta_{k-1}}{(1 - \alpha) \delta_{k-1} - \alpha} \right) \frac{c}{p'(v_{k-1}^{**})} \text{ and}$$

$$s_{kL}^{**} = \left( \frac{\alpha + (1 - \alpha) \delta_k}{\alpha - (1 - \alpha) \delta_k} \right) \frac{c}{p'(v_k^{**})}.$$

In equilibrium, the agent chooses the high level of effort with a probability  $\alpha^{**} \in \left( \frac{\delta_k}{(1+\delta_k)}, \frac{\delta_{k-1}}{(1+\delta_{k-1})} \right)$ .

Several remarks are worth making. First, it is the agent who indirectly bears the cost of verification in both outcomes. In fact, if no verification would take place in outcome  $x_i, i = k - 1, k$ , the agent can expect a reward equal to

$$\frac{1}{2} \pi_i(1) (s_{iH}^{**} + s_{iL}^{**}) (\alpha^{**} + (1 - \alpha^{**}) \delta_i).$$

But if auditing occurs,  $v_i^{**} > 0$ , his expected reward is

$$\begin{aligned} & \alpha^{**} \pi_i(1) (p(v_i^{**}) s_{iH}^{**} + (1 - p(v_i^{**})) s_{iL}^{**}) \\ & + (1 - \alpha^{**}) \pi_i(0) (p(v_i^{**}) s_{iL}^{**} + (1 - p(v_i^{**})) s_{iH}^{**}) \\ & = \frac{1}{2} \pi_i(1) (s_{iH}^{**} + s_{iL}^{**}) (\alpha^{**} + (1 - \alpha^{**}) \delta_i) \\ & + \pi_i(1) (\alpha^{**} - (1 - \alpha^{**}) \delta_i) \left( \left( p(v_i^{**}) - \frac{1}{2} \right) (s_{iH}^{**} - s_{iL}^{**}) \right). \end{aligned}$$

For  $s_{k-1L}^{**} > s_{k-1H}^{**} = 0$  in case  $\mu_i > \frac{1}{2}$ , the second term is negative as  $(\alpha^{**} - (1 - \alpha^{**}) \delta_{k-1}) > 0$ . And for  $s_{kH}^{**} > s_{kL}^{**} = 0$  in case  $\mu_i < \frac{1}{2}$ , this second term is also negative as  $(\alpha^{**} - (1 - \alpha^{**}) \delta_k) < 0$ . Hence, by getting a lower reward in case of auditing, the agent indirectly pays for the verification of his behavior.

Second, it is necessary for the principal to set incentives such that she verifies the agent’s behavior in two outcomes and not only in one. To see this, note that

$$\frac{\partial v_i^{**}}{\partial \mu_i} = \frac{p'(v_i^{**})}{p''(v_i^{**}) \left( \frac{1}{2} - \mu_i \right)}.$$

Hence the principal’s auditing effort decreases in  $\alpha$  if she believes he did not choose the high level of effort, and vice versa. That is,<sup>16</sup>

$$\frac{\partial v_i^{**}}{\partial \alpha} < 0 \text{ for } \mu_i < \frac{1}{2} \text{ and } \frac{\partial v_i^{**}}{\partial \alpha} > 0 \text{ for } \mu_i > \frac{1}{2}.$$

In particular, for  $\mu_i = \frac{1}{2}$ , the principal’s expected costs in outcome  $x_i$  are  $\frac{1}{2} (s_{iH}^{**} + s_{iL}^{**} + 2cv_i^{**})$ , and she would decide not to audit. Now suppose the principal would set positive rewards in only one outcome  $x_i$ . Then the agent would set his optimal effort choice such that  $\alpha^{**} = \delta_i / (1 + \delta_i)$ , implying no verification and

<sup>16</sup>Note that

$$\frac{\partial \mu_i}{\partial \alpha} = \frac{2\delta_i}{(\alpha + (1 - \alpha) \delta_i)^2} > 0.$$

hence a higher expected wage; see our first remark above. But this cannot be optimal for the principal since the optimal contract without verification pays for the highest outcome level and implements  $e = 1$  with certainty. To avoid this behavior of the agent, the principal therefore has to offer monetary incentives for two outcomes such that her auditing efforts are credible in both. In fact, if there exist two outcomes in which the principal has an incentive to audit, the agent never chooses a probability  $\alpha$  such that no auditing will take place in one of these outcomes. This is because the principal's auditing behavior in the other outcome then leads to the highest loss in expected payment. To see this formally, note that the agent chooses his optimal  $\alpha^{**}$  such that his marginal utility is zero:

$$\begin{aligned} & \pi_{k-1}(1)p'(v_{k-1}^{**}) \frac{\partial v_{k-1}^{**}}{\partial \alpha} (\alpha - (1 - \alpha) \delta_{k-1}) s_{k-1H}^{**} \\ & = \pi_k(1)p'(v_k^{**}) \frac{\partial v_k^{**}}{\partial \alpha} (\alpha - (1 - \alpha) \delta_k) s_{kL}^{**}. \end{aligned}$$

Since  $\partial v_{k-1}^{**}/\partial \alpha < 0$  and  $\partial v_k^{**}/\partial \alpha > 0$  it follows that

$$\frac{\delta_k}{(1 + \delta_k)} < \alpha^{**} < \frac{\delta_{k-1}}{(1 + \delta_{k-1})}.$$

Third, under auditing, the principal's auditing efforts and the monetary payments are now complements in both outcomes:

$$\frac{\partial s_{k-1H}^{**}}{\partial v_{k-1}^{**}} > 0 \text{ and } \frac{\partial s_{kL}^{**}}{\partial v_k^{**}} > 0,$$

since  $p''(v) < 0$ . That is, if the principal wants to increase her auditing effort, she necessarily has to pay the agent a higher wage in the lower and in the higher outcome. This observation results directly from the principal's incentive constraint (ICP4) for the outcome levels  $x_{k-1}$  and  $x_k$ . The intuition is as follows. According to our first remark, the agent has to bear the principal's verification costs to make auditing credible. But this implies that the principal has to compensate the agent with a higher payment if she increases her auditing effort. According to our second remark, she rewards the agent in a high outcome level where she believes the agent only chooses normal effort, and in a low outcome level where she believes he chooses high effort and the audit contradicts her belief. But this implies the agent's payment and her auditing effort in both outcome levels are complements. Note that this property differs from our finding in the case of commitment. There an increase in the principal's auditing effort implied a lower payment to the agent, so that both variables were substitutes under commitment. Of course, auditing under non commitment is still beneficial for the principal because the agent's expected reward is lower whenever auditing occurs.<sup>17</sup>

<sup>17</sup>If the agent's outside option would be higher than his rent under non-commitment, equilibrium contracting would change as follows. As in Proposition 4, it is optimal to verify the agent only in the two outcomes. Since the principal's incentive constraint requires that her verification and the agent's payments are complements, the principal already chooses her verification as low as possible in case the agent receives a positive rent. To meet the agent's reservation utility, the principal then pays a non-contingent transfer such that the participation constraint becomes binding. This reasoning holds for monitoring and auditing.

And fourth, when contrasting Proposition 4 to Proposition 1, the agent’s optimal monetary incentive payment scheme is now less extreme. In the non-verification setting, the agent only receives a bonus if the maximal outcome level occurs. In the non commitment setting the agent now gets paid in two subsequent outcome levels in which auditing takes place. But this necessarily implies that these payments are less extreme than the bonus in the non-verification setting, similar to the case of a risk-averse agent (e.g., Baiman and Demski 1980 or Dye 1986).

### 5.2 Monitoring under non commitment

Consider now the case in which the principal uses monitoring as a verification procedure to verify the agent’s behavior. At Stage 2 of the model, the principal then chooses her monitoring effort simultaneously with the agent’s choice of an effort level. Given  $\alpha \in [0, 1]$ , effort  $v$  then minimizes her expected costs

$$\alpha \left( \sum_{i=1}^n \pi_i(1) (p(v) s_{iH} + (1 - p(v))s_{iL}) \right) + (1 - \alpha) \left( \sum_{i=1}^n \pi_i(0) (p(v) s_{iL} + (1 - p(v))s_{iH}) \right) + cv,$$

with  $v \geq 0$ . Optimally, the principal then chooses  $v^{**}$  such that

$$p'(v) \sum_{i=1}^n \pi_i(1) (s_{iH} - s_{iL}) (\alpha - (1 - \alpha) \delta_i) + c \leq 0.$$

Simultaneously, given  $v \geq 0$ , the agent chooses the probability  $\alpha \in [0, 1]$  to maximize his expected utility. Indifference requires that his expected utility is identical when he chooses the high or the normal level of effort,

$$\sum_{i=1}^n \pi_i(1) (p(v) s_{iH} + (1 - p(v))s_{iL}) - c_H = \sum_{i=1}^n \pi_i(0) (p(v) s_{iL} + (1 - p(v))s_{iH}).$$

At Stage 1, the principal then offers a monetary incentive scheme to maximize her expected net profits, taking the optimal decisions  $(v^{**}, \alpha^{**})$  as given. The optimal solution  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**})$  then maximizes the following problem (P5):

$$\alpha^{**} \left( \sum_{i=1}^n \pi_i(1) (x_i - p(v^{**}) s_{iH} - (1 - p(v^{**}))s_{iL}) \right) \tag{P5}$$

$$+ (1 - \alpha^{**}) \left( \sum_{i=1}^n \pi_i(0) (x_i - p(v^{**}) s_{iL} - (1 - p(v^{**}))s_{iH}) \right) - cv^{**} \text{ such that}$$

$$\sum_{i=1}^n \pi_i(1) (s_{iL}^{**} - \delta_i s_{iH}^{**}) + p(v^{**}) \sum_{i=1}^n \pi_i(1) (s_{iH}^{**} - s_{iL}^{**}) (1 + \delta_i) = c_H \tag{ICA5}$$

$$p'(v^{**}) \sum_{i=1}^n \pi_i(1) (s_{iH}^{**} - s_{iL}^{**}) (\alpha^{**} - (1 - \alpha^{**}) \delta_i) + c \leq 0. \tag{ICP5}$$

**Proposition 5** *If the principal decides for monitoring with positive probability, the optimal monetary incentive scheme  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**})$  and the optimal monitoring effort  $v^{**}$  have the following properties.*

$$\begin{aligned}
 & s_{1L}^{**} > 0, s_{iL}^{**} = 0 \text{ for all } i \neq 1 \\
 & s_{nH}^{**} > 0, s_{iH}^{**} = 0 \text{ for all } i \neq n \text{ with} \\
 & s_{1L}^{**} = \frac{\pi_n(1)(\alpha^{**} - (1 - \alpha^{**})\delta_n)s_{nH}^{**} + \frac{c}{p'(v^{**})}}{\pi_1(1)(\alpha^{**} - (1 - \alpha^{**})\delta_1)} \text{ and} \\
 & s_{nH}^{**} = \frac{\pi_1(1)((1 + \delta_1)p(v^{**}) - 1)s_{1L}^{**} + c_H}{\pi_n(1)((1 + \delta_n)p(v^{**}) - \delta_n)}.
 \end{aligned}$$

*In equilibrium, the agent chooses the high level of effort with a probability  $\alpha^{**} > \frac{\delta_1}{(1 + \delta_1)}$ .*

If I compare this result with the one under auditing, several remarks are worth making. First, and similar to the case of auditing under non commitment, monitoring implies that the principal rewards the agent in two different outcome levels – in one outcome for choosing normal effort and in another outcome for choosing high effort. But the reason is different. Whereas under auditing the agent could adjust his behavior to influence the principal’s auditing efforts via her updating of his effort choice, such a reaction is not possible when the agent decides simultaneously with the principal. Under monitoring, the principal takes the agent’s effort choice as given and reacts accordingly, without any further information about the realized outcome and updating of her beliefs. It is this difference that renders payments for two outcomes optimal. Whereas under auditing, paying only in one outcome was not optimal because the agent could then adjust his behavior to avoid any verification, paying in only one outcome under monitoring is not optimal because it requires that the principal expects the agent not to have chosen the high level of effort with a certain probability. To maximize his expected payments, the agent, however, would then choose  $e = 1$  with certainty. But then the principal’s expectations are not consistent. Hence the principal also has to reward the agent for a normal level of effort.

Second, and also different from the case of auditing, the optimal incentive scheme under monitoring does not reward the agent in subsequent outcome levels. Instead, under monitoring he is paid for a high level of effort in the highest outcome if the signal indicates high effort, and he is rewarded for a normal level of effort in the lowest outcome if the signal indicates  $e = 0$ . This difference stems from the fact that to make her monitoring credible, the principal now has greater flexibility when designing her monetary incentive scheme: she can adjust her payments across all outcome levels, whereas this was not possible under auditing where she had to offer appropriate payments for those outcomes where auditing was optimal. To see how the principal optimally uses this flexibility, consider her incentive constraint (ICP5) for making monitoring credible, with positive rewards only in outcome  $x_k$  and  $x_j$  when the signal indicates a normal or a high level of effort,  $s_{kL} > 0$  and  $s_{jH} > 0$ ,

$$p'(v) (\pi_k(1)(\alpha - (1 - \alpha)\delta_k)s_{kL} - \pi_j(1)(\alpha - (1 - \alpha)\delta_j)s_{jH}) = c.$$

If monitoring signals high effort, the payment  $s_{jH}$  should then be granted for the highest possible outcome  $x_n$ . This is beneficial for the principal for two reasons. First, the agent’s incentives for choosing high effort are highest in this case because the MLRC implies that choosing a high instead of a normal level of effort increases the relative likelihood of a better outcome. And second, since she uses the reward in the highest outcome to motivate the agent to choose high effort, her monitoring effort  $v$  and the payment  $s_{nH}$  are now substitutes. Hence, by paying the agent in outcome  $x_n$ , the principal can reduce monitoring effort and therefore verification costs. To make verification credible, the principal then rewards the agent for normal effort in the lowest outcome; that is,  $s_{1L} > 0$ . To see this, consider the payment  $s_{kL}$  in which monitoring signals normal effort. Then this payment should be given for the lowest realized outcome  $x_1$  for the same two reasons. First, it increases the agent’s incentives to choose high effort. This is because the principal’s incentive constraint requires that  $\alpha$  is sufficiently high,  $\alpha > \delta_k / (1 + \delta_k)$ , so the probability that the agent chooses high effort is highest for the lowest outcome level  $x_1$ . And second, since the agent bears the principal’s verification cost, the monitoring effort  $v$  and the payment  $s_{kL}$  remain complements for this outcome level, so that paying the agent in an outcome that is as low as possible again reduces her verification costs.

Note that agent’s probability of choosing the high level of effort is higher as in the case of auditing. This follows directly from the fact that the principal can use the reward in the highest outcome for motivating the agent to choose high effort. In particular, this is beneficial for the principal when the productive gains from high effort are sufficiently high. In this case, she prefers monitoring to auditing.

**Corollary 2** *The agent’s probability for choosing the high level of effort is higher under monitoring than under auditing,  $\alpha_M^{**} > \alpha_A^{**}$ . Hence the principal never decides for auditing to verify the agent’s behavior if her gains from implementing high effort,*

$$\sum_{i=1}^n (\pi_i(1) - \pi_i(0)) x_i,$$

*are sufficiently high. If the unit verification costs are lower than some critical value  $c_m$ , she decides for the optimal monitoring strategy and the contract specified in Proposition 4, otherwise for the optimal monetary incentive scheme in Proposition 1.*

This corollary now comes without surprise. If I compare auditing and monitoring, the latter procedure has two relative advantages: on the one hand, it gives the principal greater flexibility for making her verification effort credible and, on the other, monitoring avoids that the agent influences her expectations about his effort choice as he does under auditing. The corollary then follows from the fact that these differences result in a higher probability for choosing high effort; see Propositions 4 and 5.

Note that Corollary 2 is in direct contrast with Proposition 5 of Strausz (2005). In his “extremely stylized” model, Strausz has three key assumptions. First, if the agent chooses high effort, the outcome of the project run by the agent is always a success, whereas with low effort the outcome is a failure with some positive probability. Second, the outcome of the project is not verifiable. And third, the principal’s



verification effort is binary – she either costly verifies actively and then reveals the agent’s effort perfectly, or she does not verify. Given these assumptions, a feasible contract in Strausz requires that the principal pays the agent a certain bonus for choosing high effort unless verification reveals low effort. Hence she audits failed projects to avoid paying the bonus. More importantly, auditing of failed projects does not take place in equilibrium, since the principal uses auditing only as “a threat to withhold the agent from shirking”; see Strausz (2005, p. 97). To induce him to take high effort, she then pays a sufficiently high bonus so that auditing of successful projects is not necessary. And finally, since a failure occurs only if the agent chooses low effort, she can incentivize the agent to choose high effort with certainty. His Proposition 5 then follows since under monitoring the agent is induced to choose high effort only with a certain probability in equilibrium. This reasoning does not hold in the present paper. First, since outcome is contractible, paying a bonus that is independent of the level of outcome is never optimal. Second, the principal will always make the agent’s payments outcome-contingent so that auditing to avoid paying a bonus is not a reason for verification. Third, auditing by the principal is not a threat but actually takes place in equilibrium. Hence, different from Strausz where the principal’s incentive to audit is strict, she truly faces a double moral hazard problem in my model. And fourth, whereas in Strausz (2005, p. 97) “the principal’s inability to commit does not constrain the equilibrium”, non commitment in my model implies that the agent never chooses high effort with certainty. This last result also implies why in my model monitoring is optimal when the productive gains from high effort are sufficiently high: whereas in Strausz (2005) the agent’s effort is higher under auditing than under monitoring, the reverse is true in my model.

## 6 Conclusion

It is a natural remedy to the moral hazard problem in principal-agent relationships that the principal acquires additional information about the effort choice of the agent and uses this information in contracting. The present paper analyzes the role of commitment to her verification effort at the time of contracting. If commitment is possible, I show that the principal prefers auditing because the additional information on the realized outcome leads to lower verification cost. If commitment is not possible, however, my results demonstrate that the principal may strictly prefer monitoring because this relaxes her credibility constraint and avoids that the agent will influence her expectations about his effort choice.

Of course, if one compares the two verification procedures in the commitment and non commitment setting, the principal always prefers to commit to an auditing strategy rather than to announce a non-binding verification procedure. To resolve her commitment inability, the literature offers two remedies to her commitment problem. She can either delegate her auditing to a third party, (see e.g., Melumad and Mookherjee (1989) or Strausz (1997)), or she can build up a reputation that she sticks to her auditing in situations in which both parties are engaged in an ongoing relationship, (see e.g., Kreps and Wilson (1982)). However, in the absence of reputational effects or if delegation of verification to third parties is not possible, the principal’s

commitment abilities are crucial for her optimal verification procedure. As noted in Section 2 on the related literature, the principal has no commitment problem in a situation in which her optimal verification strategy is a bang-bang solution; that is, the optimal verification probabilities are either zero or one. However, according to Strausz (2005): “the 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.” My characterizations of the optimal strategies under auditing and monitoring in case of non commitment are therefore important in those situations where the principal cannot commit to her verification efforts ex-ante.

My findings also relate the present paper to the economic literature on strategic ignorance and the accounting literature on substitutes for commitment. The literature on strategic ignorance shows that information avoidance may be beneficial for a player because others, knowing that she is uninformed, are influenced in their decision-making, (see, for example, Schelling (1960), Dewatripont and Maskin (1995) or Aghion and Tirole (1997)). The present paper contributes to this stream of literature by pointing out that the principal prefers to ignore the additional information on the realized outcome that is available under auditing and to use monitoring instead, if she cannot commit to her verification strategy. In addition, there is an extensive literature in accounting on institutional features that may alleviate the frictions associated with the principal’s lack of commitment, (see, for example, Demski (1998), Demski and Frimor (1999), or Indjejikian and Nanda (1999)). My analysis adds to this literature by showing that verifying the agent’s behavior early before the outcome is realized provides higher incentives for her verification than when she relies on auditing.

## Appendix

*Proof of Proposition 4* Suppose that  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**}, v_1^{**}, \dots, v_n^{**}, \alpha^{**})$  is a solution of the principal’s maximization problem

$$\begin{aligned} \mathcal{L}_4 = & \sum_{i=1}^n \pi_i(1) (x_i - cv_i) (\alpha + (1 - \alpha) \delta_i) \\ & - \sum_{i=1}^n \pi_i(1) (p(v_i) s_{iH} + (1 - p(v_i)) s_{iL}) + (1 - \alpha) c_H \\ & + \lambda \left( \sum_{i=1}^n \pi_i(1) (p(v_i) s_{iH} + (1 - p(v_i)) s_{iL}) - c_H \right) \\ & - \lambda \left( \sum_{i=1}^n \pi_i(0) (p(v_i) s_{iL} + (1 - p(v_i)) s_{iH}) \right) \end{aligned}$$

$$\begin{aligned}
 & +\mu \left( \sum_{i=1}^n \pi_i(1) \left( p'(v_i) \frac{\partial v_i}{\partial \alpha} (s_{iH} - s_{iL}) \right) (\alpha - (1 - \alpha) \delta_i) \right) \\
 & - \sum_{i=1}^n \gamma_{ic} \left( p'(v_i) (s_{iH} - s_{iL}) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) + c \right) \\
 & + \sum_{i=1}^n \xi_{iH} s_{iH} + \sum_{i=1}^n \xi_{iL} s_{iL} + \sum_{i=1}^n \xi_{ic} v_i + \xi_\alpha (1 - \alpha),
 \end{aligned}$$

with

$$\frac{\partial v_i}{\partial \alpha} = \frac{p'(v_i)}{p''(v_i)} \frac{2\delta_i}{(1 - \alpha)^2 \delta_i^2 - \alpha^2}.$$

Then the FOCs read as:

$$\begin{aligned}
 \frac{\partial}{\partial s_{iH}} \mathcal{L}_4 &= \pi_i(1) p(v_i) \left( 1 - \lambda \left( 1 - \delta_i \frac{1 - p(v_i)}{p(v_i)} \right) \right) & \text{(P41)} \\
 & + \mu \pi_i(1) p'(v_i) \frac{\partial v_i}{\partial \alpha} (\alpha - (1 - \alpha) \delta_i) + \gamma_{ic} p'(v_i) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) \\
 & - \xi_{iH} = 0
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial}{\partial s_{iL}} \mathcal{L}_4 &= \pi_i(1) (1 - p(v_i)) \left( 1 - \lambda \left( 1 - \delta_i \frac{p(v_i)}{1 - p(v_i)} \right) \right) & \text{(P42)} \\
 & - \mu \pi_i(1) p'(v_i) \frac{\partial v_i}{\partial \alpha} (\alpha - (1 - \alpha) \delta_i) - \gamma_{ic} p'(v_i) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) \\
 & - \xi_{iL} = 0
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial}{\partial v_i} \mathcal{L}_4 &= \pi_i(1) (\alpha + (1 - \alpha) \delta_i) c & \text{(P43)} \\
 & + \pi_i(1) p'(v_i) (s_{iH} - s_{iL}) (1 - \lambda (1 + \delta_i)) \\
 & + \mu \pi_i(1) p'(v_i) \frac{\partial v_i}{\partial \alpha} (s_{iH} - s_{iL}) (\alpha - (1 - \alpha) \delta_i) \\
 & + \gamma_{ic} p''(v_i) (s_{iH} - s_{iL}) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) - \xi_{iv} = 0
 \end{aligned}$$

$$\begin{aligned}
 \frac{\partial}{\partial \alpha} \mathcal{L}_4 &= \sum_{i=1}^n \pi_i(1) (x_i - c v_i) (1 - \delta_i) - c_H & \text{(P44)} \\
 & + \mu \left( \sum_{i=1}^n \pi_i(1) p'(v_i) (s_{iH} - s_{iL}) \left( \frac{\partial^2 v_i}{\partial \alpha^2} (\alpha - (1 - \alpha) \delta_i) \right) \right. \\
 & \left. + \frac{\partial v_i}{\partial \alpha} (1 + \delta_i) \right) \\
 & - 2 \sum_{i=1}^n \gamma_{ic} \left( p'(v_i) (s_{iH} - s_{iL}) \frac{\delta_i}{(\alpha + (1 - \alpha) \delta_i)^2} \right) - \xi_\alpha = 0.
 \end{aligned}$$

To prove the proposition, I proceed in three steps. Suppose that auditing takes place for an outcome  $x_i$ ; that is,  $v_i > 0$ . Then I first consider the case in which the principal

believes the agent did not choose high effort. I show that  $s_{iL} = 0$  and that auditing only takes place in the highest possible of these outcomes. Second, I consider the case in which the principal believes the agent chose  $e = 1$ . I show that  $s_{iH} = 0$  and that auditing only takes place in the lowest possible of these outcomes. In a third step, I then prove that it is necessary for the principal to audit in two subsequent outcomes where she believes the agent chose  $e = 0$  in the lower one but chose  $e = 1$  in the higher one.

Step 1: Suppose that  $\alpha < \frac{\delta_i}{(1+\delta_i)}$ , that is, outcome  $x_i$  is sufficiently low,  $\delta_i$  sufficiently high. Then  $\alpha - (1 - \alpha) \delta_i < 0$  and (P41) reads as

$$\pi_i(1)p(v_i) \left( 1 - \lambda \left( 1 - \delta_i \frac{1 - p(v_i)}{p(v_i)} \right) \right) + \mu \pi_i(1)p'(v_i) \frac{\partial v_i}{\partial \alpha} (\alpha - (1 - \alpha) \delta_i) + \gamma_{ic} p'(v_i) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) = 0.$$

Since the second and third term are negative, it follows that

$$1 > \lambda \left( 1 - \delta_i \frac{1 - p(v_i)}{p(v_i)} \right).$$

Note that

$$1 - \delta_i \frac{1 - p(v_i)}{p(v_i)} > 0,$$

since otherwise the impact of  $s_{iH}$  on the agent’s incentives not to choose high effort would be higher than on his incentives to do so. Since

$$\frac{p(v_i)}{1 - p(v_i)} > \frac{1 - p(v_i)}{p(v_i)},$$

it follows that

$$1 > \lambda \left( 1 - \delta_i \frac{1 - p(v_i)}{p(v_i)} \right) > \lambda \left( 1 - \delta_i \frac{p(v_i)}{1 - p(v_i)} \right).$$

Then condition (P42) becomes

$$\begin{aligned} &\pi_i(1)(1 - p(v_i)) \left( 1 - \lambda \left( 1 - \delta_i \frac{p(v_i)}{1 - p(v_i)} \right) \right) \\ &- \mu \pi_i(1)p'(v_i) \frac{\partial v_i}{\partial \alpha} (\alpha - (1 - \alpha) \delta_i) - \gamma_{ic} p'(v_i) \left( \frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i} \right) \\ &- \xi_{iL} = 0, \end{aligned}$$

and the first three terms are positive; hence  $\xi_{iL} > 0$  and  $s_{iL} = 0$ . The principal’s incentive constraint (ICP4) then implies

$$s_{iH} = \left( \frac{\alpha + (1 - \alpha) \delta_i}{(1 - \alpha) \delta_i - \alpha} \right) \frac{c}{p'(v_i)}.$$

Hence, as long as the impact of  $s_{iH}$  on choosing high effort is positive, that is,  $1 - \delta_i \frac{1-p(v_i)}{p(v_i)} > 0$ , the overall contribution to the agent’s utility is

$$\left(1 - \delta_i \frac{1 - p(v_i)}{p(v_i)}\right) s_{iH} = \left(1 - \delta_i \frac{1 - p(v_i)}{p(v_i)}\right) \left(\frac{\alpha + (1 - \alpha) \delta_i}{(1 - \alpha) \delta_i - \alpha}\right) \frac{c}{p'(v_i)}.$$

Since

$$\begin{aligned} \frac{\partial}{\partial \delta_i} (1 - \delta_i x) \left(\frac{\alpha + (1 - \alpha) \delta_i}{(1 - \alpha) \delta_i - \alpha}\right) = \\ - \frac{(2\alpha (1 - \alpha) (1 - \delta_i x) + x (\alpha + (1 - \alpha) \delta_i) ((1 - \alpha) \delta_i - \alpha))}{((1 - \alpha) \delta_i - \alpha)^2} < 0, \end{aligned}$$

the impact of a given  $v_i$  is higher the lower  $\delta_i$ . Hence, whenever there is auditing  $v_i > 0$  with  $s_{iH} > 0 = s_{iL}$ , verification takes place in the lowest outcome  $\delta_i$  such that

$$\frac{\delta_{i+1}}{(1 + \delta_{i+1})} < \alpha < \frac{\delta_i}{(1 + \delta_i)}.$$

Step 2: Suppose that  $\alpha > \frac{\delta_i}{(1+\delta_i)}$ , that is, outcome  $x_i$  is sufficiently high,  $\delta_i$  sufficiently low. Then  $\alpha - (1 - \alpha) \delta_i > 0$  and (P42) reads as

$$\begin{aligned} \pi_i(1) (1 - p(v_i)) \left(1 - \lambda \left(1 - \delta_i \frac{p(v_i)}{1 - p(v_i)}\right)\right) \\ - \mu \pi_i(1) p'(v_i) \frac{\partial v_i}{\partial \alpha} (\alpha - (1 - \alpha) \delta_i) - \gamma_{ic} p'(v_i) \left(\frac{\alpha - (1 - \alpha) \delta_i}{\alpha + (1 - \alpha) \delta_i}\right) = 0. \end{aligned}$$

Since the second and third term are negative, I must have

$$1 - \lambda \left(1 - \delta_i \frac{p(v_i)}{1 - p(v_i)}\right) > 0.$$

Since the principal’s incentive constraint implies

$$p'(v_i) (s_{iL} - s_{iH}) = c \left(\frac{\alpha + (1 - \alpha) \delta_i}{\alpha - (1 - \alpha) \delta_i}\right),$$

$(s_{iL} - s_{iH})$  and  $v_i$  are complements and it is optimal to set  $s_{iH} = 0$  to reduce verification costs. Hence

$$s_{iL} = \left(\frac{\alpha + (1 - \alpha) \delta_i}{\alpha - (1 - \alpha) \delta_i}\right) \frac{c}{p'(v_i)}.$$

Hence, as long as the impact of  $s_{iL}$  on choosing high effort is positive, that is,  $1 - \delta_i \frac{p(v_i)}{1-p(v_i)} > 0$ , the overall contribution is

$$\left(1 - \delta_i \frac{p(v_i)}{1 - p(v_i)}\right) s_{iL} = \left(1 - \delta_i \frac{p(v_i)}{1 - p(v_i)}\right) \left(\frac{\alpha + (1 - \alpha) \delta_i}{\alpha - (1 - \alpha) \delta_i}\right) \frac{c}{p'(v_i)}.$$

Since

$$\frac{\partial}{\partial \delta_i} (1 - \delta_i x) \left( \frac{\alpha + (1 - \alpha) \delta_i}{\alpha - \delta_i (1 - \alpha)} \right) = \frac{(2\alpha (1 - \alpha) (1 - \delta_i x) + x (\alpha + (1 - \alpha) \delta_i) ((1 - \alpha) \delta_i - \alpha))}{((1 - \alpha) \delta_i - \alpha)^2} > 0,$$

the impact of a given  $v_i$  is higher the higher  $\delta_i$ . Hence whenever there is auditing  $v_i > 0$  with  $s_{iL} > 0 = s_{iH}$ , verification takes place in the highest outcome  $\delta_i$  such that

$$\frac{\delta_i}{(1 + \delta_i)} < \alpha < \frac{\delta_{i+1}}{(1 + \delta_{i+1})}.$$

Step 3: To show that the principal verifies the agent’s behavior in two subsequent outcomes  $x_{k-1}$  and  $x_k$  with

$$s_{k-1H} > 0 \text{ for } x_{k-1} \text{ and } s_{kL} > 0 \text{ for } x_k,$$

I argue to a contradiction. Suppose first that there would be only one outcome  $x_i$  such that  $v_i > 0$ . But then the agent optimally sets  $\alpha$  such that

$$\alpha - (1 - \alpha) \delta_i = 0,$$

since the principal then optimally sets  $v_i = 0$  according to (ICP) and the agent’s expected payment are highest without verification, a contradiction. Hence there are two outcomes in equilibrium with positive auditing efforts. Suppose second that both auditing outcomes would be such that  $s_{iH}, s_{i+1H} > 0$ . Then  $\alpha - (1 - \alpha) \delta_i < \alpha - (1 - \alpha) \delta_{i+1} < 0$  and the agent’s incentive constraint (ICA4),

$$\pi_i(1) \left( p'(v_i) \frac{\partial v_i}{\partial \alpha} s_{iH} \right) (\alpha - (1 - \alpha) \delta_i) + \pi_{i+1}(1) \left( p'(v_{i+1}) \frac{\partial v_{i+1}}{\partial \alpha} s_{i+1H} \right) (\alpha - (1 - \alpha) \delta_{i+1}).$$

is strictly negative since  $\frac{\partial v_i}{\partial \alpha}, \frac{\partial v_{i+1}}{\partial \alpha}$  are both positive. But this implies  $\alpha = 0$ , a contradiction. For the same reason, it is not possible that both auditing outcomes are such that  $s_{iL}, s_{i+1L} > 0$ . Hence Step 1 and 2 imply that both outcomes are subsequent with  $s_{iH}, s_{i+1L} > 0$ . □

*Proof of Proposition 5* Suppose that  $(s_{1L}^{**}, s_{1H}^{**}, \dots, s_{nL}^{**}, s_{nH}^{**}, v^{**}, \alpha^{**})$  is a solution of the principal’s problem

$$\mathcal{L}_5 = \left( \sum_{i=1}^n \pi_i(1) (x_i - cv) (\alpha + (1 - \alpha) \delta_i) \right) - \left( \sum_{i=1}^n \pi_i(1) (p(v) s_{iH} + (1 - p(v)) s_{iL}) \right) + (1 - \alpha) c_H$$

$$\begin{aligned}
 & +\lambda \left( \sum_{i=1}^n \pi_i(1) (p(v) s_{iH} + (1 - p(v))s_{iL}) - c_H \right) \\
 & -\lambda \left( \sum_{i=1}^n \pi_i(0) (p(v) s_{iL} + (1 - p(v))s_{iH}) \right) \\
 & +\gamma_u \left( p'(v) \sum_{i=1}^n \pi_i(1) (s_{iH} - s_{iL}) (\alpha - (1 - \alpha) \delta_i) + c \right) \\
 & + \sum_{i=1}^n \xi_{iH} s_{iH} + \sum_{i=1}^n \xi_{iL} s_{iL} + \xi_u v + \xi_\alpha (1 - \alpha).
 \end{aligned}$$

Then the FOCs read as:

$$\frac{\partial}{\partial s_{iH}} \mathcal{L}_5 = \pi_i(1) p(v) \left( 1 - \lambda \left( 1 - \delta_i \frac{(1 - p(v))}{p(v)} \right) \right) \tag{P51}$$

$$\begin{aligned}
 & +\gamma_u \pi_i(1) p'(v) (\alpha - (1 - \alpha) \delta_i) - \xi_{iH} = 0 \\
 \frac{\partial}{\partial s_{iL}} \mathcal{L}_5 & = \pi_i(1) (1 - p(v)) \left( 1 - \lambda \left( 1 - \delta_i \frac{p(v)}{1 - p(v)} \right) \right) \tag{P52}
 \end{aligned}$$

$$\begin{aligned}
 & -\gamma_u \pi_i(1) p'(v) (\alpha - (1 - \alpha) \delta_i) - \xi_{iL} = 0 \\
 \frac{\partial}{\partial v} \mathcal{L}_5 & = \sum_{i=1}^n \pi_i(1) (\alpha + (1 - \alpha) \delta_i) c \tag{P53}
 \end{aligned}$$

$$\begin{aligned}
 & -p'(v) \sum_{i=1}^n \pi_i(1) (s_{iH} - s_{iL}) (1 - \lambda (1 + \delta_i)) \\
 & +\gamma_u p''(v) \sum_{i=1}^n \pi_i(1) (s_{iH} - s_{iL}) (\alpha - (1 - \alpha) \delta_i) - \xi_u = 0 \\
 \frac{\partial}{\partial \alpha} \mathcal{L}_5 & = \sum_{i=1}^n \pi_i(1) (x_i - cv) (1 - \delta_i) - c_H \tag{P54}
 \end{aligned}$$

$$+\gamma_u p'(v) \sum_{i=1}^n \pi_i(1) (s_{iH} - s_{iL}) (1 + \delta_i) - \xi_\alpha = 0.$$

I prove the proposition in four steps. First I show that, in any outcome  $x_i$ , either  $s_{iL} = 0$  or  $s_{iH} = 0$  or both. Second, I remark that, if monitoring takes place, there exists at least one outcome with  $s_{iL} > 0$  and one with  $s_{iH} > 0$ . In a third step, I show that if, monitoring takes place,  $s_{iL} > 0$  only in outcome  $x_1$ , and  $s_{iH} > 0$  only in outcome  $x_n$ . And fourth, I characterize the optimal payments. In a final step, I then show that the optimal solution converges to the first-best solution if the unit verification costs  $c$  are sufficiently low.

Step 1: First note, that adding (P51) and (P52) gives

$$\pi_i(1) (1 - \lambda (1 - \delta_i)) - \xi_{iH} - \xi_{iL} = 0.$$

Hence, for all  $\delta_i$ ,

$$1 \geq \lambda (1 - \delta_i).$$

and either  $\xi_{iH} > 0$  and/or  $\xi_{iL} > 0$ , that is, either  $s_{iH} = 0$  and/or  $s_{iL} = 0$ , that is,  $s_{iH}s_{iL} = 0$ .

Step 2: Suppose that an outcome  $x_i$  exists with  $s_{iL} > 0$ . Then the first two terms of (P52) depend positively on  $\delta_i$ . Hence for all  $\delta_j > \delta_i$ ,  $s_{jL} = 0$ . Hence  $s_{1L} \geq 0$  and  $s_{iL} = 0$  for all  $i = 2, \dots, n$ . On the other hand, consider an outcome with  $s_{iH} > 0$ . Then (P61) implies

$$\begin{aligned} & \pi_i(1)p(v)(1 - \lambda) + \gamma_u\pi_i(1)p'(v)\alpha \\ & = \delta_i(\gamma_u\pi_i(1)p'(v)(1 - \alpha) - \lambda\pi_i(1)(1 - p(v))). \end{aligned}$$

Assume that the RHS of this equality would be positive. Then for all  $\delta_j > \delta_i$  it follows that  $\xi_{jH} > 0$ ; hence  $s_{jH} = 0$ . But this would imply that  $s_{1H} > 0$ , which is not possible by Step 1, a contradiction. As a consequence, the LHS has to be negative, and for all  $\delta_j < \delta_i$ ,  $s_{jH} = 0$ . Hence  $s_{nH} \geq 0$  and  $s_{iH} = 0$  for all  $i = 1, \dots, n - 1$ .

Step 3: Using Step 1 and 2, consider the agent's indifference constraint

$$\pi_n(1)(p(v) - \delta_n(1 - p(v)))s_{nH} + \pi_1(1)(1 - (1 + \delta_1)p(v))s_{1L} = c_H.$$

Since  $\delta_1 > 1 > \delta_n$  and  $p(v) > 1/2$ , it follows that  $p(v) - \delta_n(1 - p(v)) > 0$  and  $1 - (1 + \delta_1)p(v) < 0$ . Hence it is necessary that  $s_{nH} > 0$ . To see that  $s_{1L} > 0$ , I argue to a contradiction: Suppose that  $s_{1L} = 0$ , then the principal's incentive constraint reads as

$$-p'(v)\pi_n(1)s_{nH}(\alpha - (1 - \alpha)\delta_n) = c$$

and implies  $\alpha < \delta_n/1 + \delta_n$ . However, (P54) then implies that  $\xi_\alpha > 0$ ; hence  $\alpha = 1$ , a contradiction. Hence  $s_{1L} > 0$ . Note that this necessarily implies  $\alpha > \delta_n/1 + \delta_n$ : Suppose this would not be true and  $\alpha < \delta_n/1 + \delta_n$ . Then the principal's incentive constraint  $p'(v)\Delta s = c$  with

$$\Delta s := \pi_1(1)s_{1L}(\alpha - (1 - \alpha)\delta_1) - \pi_n(1)s_{nH}(\alpha - (1 - \alpha)\delta_n),$$

as the marginal reduction of the agent's payment due to monitoring implies that  $\Delta s$  and  $v$  are complements.<sup>18</sup> To save verification cost,  $\Delta s$  should be chosen as low as possible. Hence, if  $(\alpha - (1 - \alpha)\delta_n) < 0$ , the principal should set  $s_{1L} = 0$ , which contradicts our previous finding.

<sup>18</sup>This follows from the envelope theorem:

$$\frac{\partial v}{\partial \Delta s} = -\frac{p'(v)}{p''(v)\Delta s} > 0.$$



Step 4: The optimal payments are then characterized by the agent's and principal's incentive constraints:

$$s_{nH} = \frac{\pi_1(1)((1 + \delta_1) p(v) - 1)}{\pi_n(1)((1 + \delta_n) p(v)) - \delta_n} s_{1L} + \frac{c_H}{\pi_n(1)((1 + \delta_n) p(v)) - \delta_n}$$

$$s_{nH} = \frac{\pi_1(1)(\alpha - (1 - \alpha)\delta_1)}{\pi_n(1)(\alpha - (1 - \alpha)\delta_n)} s_{1L} - \frac{c}{p'(v)\pi_n(1)(\alpha - (1 - \alpha)\delta_n)}$$

Since  $(\alpha - (1 - \alpha)\delta_n) > 0$ , the second characterization of  $s_{nH}$  implies that  $\alpha - (1 - \alpha)\delta_1 > 0$ . If this would not be the case and  $\alpha - (1 - \alpha)\delta_1 < 0$ ,  $s_{nH}$  would be negative, which is not possible. Hence  $\alpha - (1 - \alpha)\delta_1 > 0$ . Note that an increase in the payment  $s_{nH}$  necessarily leads to higher increase in the payment  $s_{1L}$  to ensure the same expected payments  $\Delta s$  to the agent. Using the second characterization,

$$\frac{\partial s_{nH}}{\partial s_{1L}} = \frac{\pi_1(1)(\alpha - (1 - \alpha)\delta_1)}{\pi_n(1)(\alpha - (1 - \alpha)\delta_n)} > 1,$$

since

$$\frac{\alpha}{1 - \alpha} > \delta_1 > \frac{\pi_n(0) - \pi_1(0)}{\pi_n(1) - \pi_1(1)}.$$

Step 5: Suppose that the verification costs  $c$  are sufficiently low,  $c \rightarrow 0$ . Then (P53) implies that monitoring effort  $v \rightarrow \infty$ ; hence  $p(v) \rightarrow 1$ . Using (P54),  $\alpha \rightarrow 1$  and  $s_{nH} \rightarrow c_H/\pi_n(1)$ . □

*Proof of Corollary 2* If one indexes the agent's optimal behavior under auditing and monitoring as  $\alpha_A^{**}$ , respectively  $\alpha_M^{**}$ , the principal's equilibrium profits  $E\Pi_A^{**}$ , respectively  $E\Pi_M^{**}$  increase with outcome level  $x_i$  as follows.

$$\frac{\partial}{\partial x_i} E\Pi_A^{**} = \pi_i(0) + \alpha_A^{**}(\pi_i(1) - \pi_i(0))$$

$$\frac{\partial}{\partial x_i} E\Pi_M^{**} = \pi_i(0) + \alpha_M^{**}(\pi_i(1) - \pi_i(0)).$$

Hence

$$\frac{\partial}{\partial x_i} (E\Pi_M^{**} - E\Pi_A^{**}) = (\alpha_M^{**} - \alpha_A^{**})(\pi_i(1) - \pi_i(0)) > 0,$$

since  $\alpha_M^{**} > \alpha_A^{**}$  and, therefore,

$$E\Pi_M^{**} - E\Pi_A^{**} = (\alpha_M^{**} - \alpha_A^{**}) \sum_{i=1}^n (\pi_i(1) - \pi_i(0)) x_i + I^{**},$$

where  $I^{**}$  denotes the difference between the principal's costs – expected payments to the agent and expected verification costs – in case of monitoring and auditing. Hence, if the gains from choosing high effort  $\sum_{i=1}^n (\pi_i(1) - \pi_i(0)) x_i$  are sufficiently high, monitoring is better than auditing. The last part of the proof of Proposition 5 then shows that there exists a critical value  $c_m$  such that the principal decides for the optimal monitoring and incentive scheme of Proposition 5 for  $c \leq c_m$ , otherwise for the non-verification solution of Proposition 1. □

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