

# Optimal Monitoring under Non-Commitment

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## Abstract

It is a well known result in the literature of principal-agent relationships that if the principal has the possibility to monitor the agent's action at some cost, his monitoring probability is a decreasing function in the level of outcome. Moreover, the principal will reward the agent, if he is found to have complied with his interests.

The purpose of this article is to show that these results depend crucially on the assumption that the principal can commit to his monitoring device at the time of contracting. In fact, we show that in a situation in which the principal is not able to commit to his investment in his monitoring technology, (1) the principal's investigation intensity is increasing in the level of outcome and, (2) the agent's reward is lower in the case investigation reveals the agent's action than it is in the case in which investigation is uninformative.

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# 1 Introduction

It is a natural remedy to the moral hazard problem in principal-agent relationships that the principal acquires additional information about the agent's action and uses this information in contracting.<sup>1</sup> Of course, if monitoring is costly for the principal, he has to weight the costs and benefits of the additional information.<sup>2</sup> Several articles (see e.g. , Townsend [1979], Baiman/Demski [1980], Evans [1980], Kanodia [1985], Lambert [1986], Jewitt [1988], Jost [1991], Sinclair-Desgagné [1999] or Fagart/Sinclair-Desgagné [2003])<sup>3</sup> study the optimal design of the principal's monitoring policy and the monetary incentive device in this context, assuming that the principal can commit to his monitoring policy at the time of contracting. There are at least two broad findings in this literature: If monitoring costs are not too high and the agent is risk-averse, (1) the agent receives a higher remuneration, if he is found to have taken the action desired by the principal, compared to the case in which no monitoring takes place, and (2) the principal's monitoring probability is the higher the lower the level of outcome.

The interpretation of these results is straightforward. Suppose that the principal is interested in implementing a particular action, the agent should choose. His difficulty is to design a cost-minimizing incentive scheme which discourage the agent to select an action with less effort. If we assume that actions with higher effort increase the probability

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<sup>1</sup>This possibility was first proposed by Alchian and Demsetz [1972] and Jensen and Meckling [1976].

<sup>2</sup>If the principal can perfectly monitor the agent without costs, optimal risk sharing and the first-best solution is achievable. The articles by Holmström [1979], Shavell [1979] and Harris and Raviv [1979] show that even if the principal's observation is imperfect (and free of charge), it is always valuable and can be used to improve the welfare of both the principal and the agent.

<sup>3</sup>Townsend [1979] analyzes the design of monitoring policies in the context of a non-principal framework. Baiman/Demski [1980] assume imperfect monitoring and prove that the outcome region in which the principal monitors depends on the agent's risk aversion or risk tolerance, respectively. Evans [1980] shows that if the monitoring technology is perfect and deterministic, monitoring takes place when outcome levels are low. Kanodia [1985] studies situations in which the agent can acquire information before choosing an action. Dye [1986] and Jewitt [1988] prove that in a variety of contexts optimal monitoring policies are deterministic and that monitoring takes place with certainty if a low outcome level occurs. Lambert [1986] analyzes agencies in which the principal's information from monitoring the agent's action depends on the level of outcome. In Jost [1991], I study a a principal-agent relationship in which monitoring is independent of the realized outcome level. Sinclair-Desgagné [1999] shows that audits in high outcome levels can help raising incentives in a multi-tasking setting and Fagart/Sinclair-Desgagné [2003] analyze under which conditions choosing among various auditing policies is possible by comparing the resulting information systems.

of higher outcome levels (i.e. the Monotone Likelihood Ratio Condition holds), the expected level of outcome is the higher the higher the agent's effort level. Thus, if a low outcome level is revealed, it is more likely that the agent did not act in the principal's interests. Hence, by monitoring the agent in lower outcome levels and punishing him for non-compliance, the principal can discourage the agent from being lazy. Moreover, the principal can motivate the agent to act in his interests, if he pays the agent a reward for taking the desired action in the case of monitoring.

The purpose of this article is to show that this argument depends crucially on the role of commitment by the principal to his monitoring announcements.<sup>4</sup> Suppose, for example, that commitment is not possible because the principal monitors probabilistically and, since the agent cannot verify the principal's behavior, such a policy cannot be made credible. We show that in such a situation in which the principal is not able to commit to his monitoring device at the time of contracting, the optimal monitoring policy and the monetary incentive device may have the following properties: (1) If the principal monitors the agent's action, he pays the agent a lower reward than in the case of no monitoring. (2) The principal's monitoring probability is the higher the higher the level of outcome.

The economic intuition behind these results is as follows: Suppose that from an ex-ante perspective, the principal prefers to monitor the agent's action with positive probability but not with certainty, thus providing appropriate incentives for the agent to act in his interests. However, if the agent behaves as supposed, the principal would never have an ex-post incentive to monitor, for he can save on monitoring costs and the agent's reward. Of course, his behavior will be foreseen by the agent and the principal's ex-ante announcement to monitor will not be credibly ex-post. Thus, the principal has to rearrange his monetary incentive device in such a way that his threat to monitor becomes credible at the time of performance. Sequential rationality then requires that the agent has to cover the principal's marginal monitoring costs in the case of monitoring and, hence, the agent receives a lower reward if he is monitored compared to the case where he is not.

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<sup>4</sup>The role of commitment was emphasized in the literature on auditing and tax evasion (see e.g. Scotchmer [1986], [1987] or Reinganum/Wilde [1985], [1986]). In Sappington [1986] and Melumad/Mookerherjee [1989] the principal cannot commit to an auditing policy but to other variables that influence audit probabilities. Jost [1996] assumes non-commitment in a setup where the principal is privately informed about his monitoring cost. Khalil [1997] studies auditing without commitment in a principal-agent framework and Strausz [1997] studies when delegation of monitoring in case commitment to monitoring is not possible but both articles donot consider auditing and monitoring contingent on outcomes.

This result has two implications on the agent’s behavior, contrary to the situation in which commitment is possible: First, if the agent complies with the principal’s interests, he prefers not to get monitored. Thus, monitoring by the principal has a negative income effect. Second, a higher reward in the case of no monitoring increases the agent’s incentives not to choose the desired action. To overcome these effects, the principal then benefits when choosing a monitoring policy which increases in the outcome level. To see this note that according to the Monotone Likelihood Ratio Condition, higher outcome levels indicate a higher level of effort and vice versa. Thus, if the principal monitors the agent with high probability in high outcome levels, he can reward the agent for taking the desired action without increasing the agent’s incentives not to comply. On the other hand, if the principal monitors with low probability in low outcome levels, the principal can pay the agent a low reward without increasing the agent’s utility from a non-complying behavior and without violating the agent’s participation constraint.

The paper is organized as follows. In Section 2, we setup a principal-agent model with moral hazard and limited liability in which the principal has the possibility to invest in a monitoring technology. We consider two variants of this basic model: One in which the principal can commit ex-ante to his investment in his monitoring technology (called the "Commitment Game") and one in which he cannot (called the "Non-Commitment Game"). Section 3 studies the Commitment Game and reviews the basic results of the principal-agent literature with costly monitoring. In Section 4, we analyze the Non-Commitment Game and examine the properties of equilibrium. Section 5 concludes with some final remarks. The proofs are collected in the Appendix.

## 2 The Models

### 2.1 Timing and information structure

We describe two models with which we study the role of commitment with respect to the principal’s investigation policy. The underlying principal-agent framework can be described as follows: The principal offers a monetary incentive scheme to the agent for a joint venture. Under this arrangement, the agent is to take an action which is not directly verifiable for the principal. The action together with the realization of a random state of nature determines an outcome. Neither the agent nor the principal can observe the value of the random variable, whereas the outcome is public observable. After the realization of an outcome, the principal has the possibility to examine the action chosen by the agent, at a cost. The principal’s investigation, however, is imperfect and

there are two possible signals that come out an investigation: He learns the agent's action or he learns nothing new.<sup>5</sup> The principal can affect the informativeness of the investigation by investing in a better monitoring technology. The agent gets paid according to the preannounced arrangement and the variables observed during the relationship.

Two cases may be distinguished concerning the principal's investment in a better monitoring technology. First, in the Commitment Game, we assume that the principal can commit to his investigation policy ex-ante at the time of contracting. Second, in the Non-Commitment Game, we assume that the principal cannot do so and that the monetary effort exerted by the principal is unverifiable.

## 2.2 The basic framework

The agent is assumed to be risk-neutral with limited liability. He has no wealth and his reservation utility is given by zero. He chooses an action  $a$  from a set of actions  $\mathcal{A}$  which is assumed to be a two point action space,  $\mathcal{A} = \{0, 1\}$ .<sup>6</sup> For concreteness, we identify the action  $a = 1$  with working hard and action  $a = 0$  with being lazy. His costs for exerting effort  $a \in \{0, 1\}$  are denoted by  $a \cdot c_H$ , where  $c_H > 0$ . Note, that if the principal wants to implement  $a = 0$ , he should pay the agent a constant remuneration in every outcome without monitoring the agent. This yields optimal risk sharing. Therefore, the problem is of interest only if the principal wishes to implement  $a = 1$ . In the following, we assume that the principal prefers that the agent works hard, that is, his net profits are greater than those in the case in which the agent is lazy.

We assume only a finite number of possible outcome levels  $\mathcal{Q} = \{q_1, \dots, q_n\}$ , where  $q_1 < \dots < q_n$ . An action  $a \in \{0, 1\}$  determines an outcome  $q_i$  with probability  $\pi_i(a) \in (0, 1)$  and  $\sum_{i=1}^n \pi_i(a) = 1$  for all  $a \in \{0, 1\}$ . Throughout the paper, we assume that the action with the higher effort increases the probability of a higher outcome level. We model this property using the Monotone Likelihood Ratio Condition (MLRC), that is

$$\frac{\pi_j(0)}{\pi_j(1)} \text{ is non increasing in } j.$$

The principal is assumed to be risk neutral. He is interested in net profits, i.e. he maximizes gross profits minus the remuneration to the

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<sup>5</sup>Although assuming that an investigation may perfectly reveal the agent's action is not very realistic, the main point of this paper is to focus on the strategic aspects of the principal's inability to commit ex-ante to his investigation policy.

<sup>6</sup>Most of our results can be transferred to a situation in which the agent has a finite action space to his disposal. However, the analysis is more complicated without obtaining new insights from the general case.

agent minus his monitoring costs. If the agent has taken an action  $a \in \{0, 1\}$ , his gross profits are given by  $\sum_{j=1}^n \pi_j(a) \cdot q_j$ .

Let  $p \in [0, 1]$  be the intensity of the investigation, i.e. with probability  $p$  the agent's action is perfectly revealed and with probability  $1 - p$  the action is not revealed. The probability  $p$  is independent of the agent's action, hence, nonrevelation contains no information.  $p$  is a choice variable for the principal and depends on his monetary effort exerted by the principal. Let  $c(p)$  be the principal's investment in his monitoring technology, if he chooses  $p$ . If the principal exerts no effort, the monitoring technology still release a signal saying that the agent's action could not be determined. We assume that  $c(\cdot)$  is convex with  $c'(0) = 0$  and  $c'(1)$  sufficiently high such that the principal always has an incentive to invest but never invests with certainty. This assumption ensures that the principal always monitors probabilistically in the Commitment Game. Moreover, for the Non\_commitment game, we additionally assume that the principal's cost function  $c(p)$  is "not too steep" in the sense that

$$\frac{c''(p)}{c'(p)} > \frac{c'''(p)}{c''(p)}. \quad (A)$$

Assumption (A) is satisfied, for example, for every cost function of the form  $c(p) = cp^m$  with  $c > 0$  and  $m \geq 2$ .<sup>7</sup> Moreover,  $c(p) = cp^m$  is convex with  $c'(0) = 0$  and  $c'(1)$  sufficiently high for  $c$  or  $m$  sufficiently high.

Let  $C$  denote the set of monetary incentive schemes, the principal offers to the agent. Then an arrangement  $\gamma \in C$  is of the form  $\gamma = (w, v)$ , where

$$\begin{aligned} w &: \mathcal{Q} \rightarrow [0, \infty) \\ v &: \mathcal{A} \times \mathcal{Q} \rightarrow [0, \infty). \end{aligned}$$

The interpretation is as follows. Assume that the agent has taken an action  $a \in \{0, 1\}$  which led with probability  $\pi_j(a)$  to outcome  $q_j$ . If the principal's investigation reveals the agent's decision, he pays the agent a reward  $v(q_i, a)$ , whereas if the results of the investigation are uninformative about the agent's action, the reward will be independent of the taken action and is determined by  $w(q_i)$ . Note that the agent's reward is always non-negative due his limited liability.

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<sup>7</sup>For  $c(p) = cp^m$  we have  $c'(p) = cmp^{m-1}$ ,  $c''(p) = cm(m-1)p^{m-2}$  and  $c'''(p) = cm(m-1)(m-2)p^{m-3}$ , hence assumption (A) reduces to

$$\frac{1}{p}(m-1) > \frac{1}{p}(m-2)$$

which is always satisfied for  $p > 0$  and  $m \geq 2$ .

Suppose that the principal offers an arrangement  $\gamma$  and chooses an investigation intensity  $p_j$ , if an outcome  $q_j$  occurs,  $j = 1, \dots, n$ . Then we can write the principal's expected net profits, given the agent chooses an action  $a \in \{0, 1\}$  as

$$E\Pi(\gamma, p) = \sum_{j=1}^n \pi_j(a) \cdot (q_j - p_j \cdot v(q_j, a) - (1 - p_j) \cdot w(q_j) - c(p_j)).$$

Suppose that the principal offers a monetary incentive scheme  $\gamma$  and chooses an investigation policy  $p = (p_1, \dots, p_n)$ . Then the agent's expected utility, if he chooses an action  $a \in \{0, 1\}$  is

$$EU(a) = \sum_{j=1}^n \pi_j(a) \cdot (p_j \cdot v(q_j, a) + (1 - p_j) \cdot w(q_j)) - a \cdot c_H.$$

### 2.3 The Commitment Game

Consider the model in which the principal can commit to his monitoring policy at the time of contracting. The game between the principal and the agent has four stages.

1. The principal offers a monetary incentive scheme  $\gamma$  and announces an investigation policy  $p = (p_1, \dots, p_n)$ .
2. The agent decides whether to accept this arrangement or not. He accepts, if his expected utility is at least zero. Having signed the contract, the agent chooses an action  $a \in \{0, 1\}$ .
3. The action  $a \in \{0, 1\}$  together with the realization of a random variable results in an outcome  $q_j \in \mathcal{Q}$  with probability  $\pi_j(a)$ .
4. The principal investigates the agent with intensity  $p_j \in [0, 1]$  as announced. The agent then gets paid according to the monetary incentive scheme  $\gamma$  and the observed variables.

A strategy for the agent in this game is function  $\alpha : \gamma \times [0, 1]^n \rightarrow \{0, 1\}$ , such that he chooses an action  $\alpha(\gamma, p)$ , if an arrangement  $\gamma$  is offered and the principal announced a monitoring policy  $p$ . A strategy for the principal in this game is a tuple  $(\gamma, p)$ , where  $\gamma$  is a monetary incentive scheme and  $p \in [0, 1]^n$  is a function which assigns a probability  $p_j$  to the principal's monitoring decision in outcome  $q_j$ . In the spirit of Selten [1975], we employ the equilibrium concept of subgame-perfectness. We will call a tuple  $(\gamma^*, p^*, \alpha^*(\cdot, \cdot))$  a subgame-perfect equilibrium, if the following conditions hold:

- i. The principal's strategy  $(\gamma^*, p^*)$  maximizes his expected net profits, given the agent accepts contracting and chooses a strategy  $\alpha^*(\cdot, \cdot)$ , i.e.  $E\Pi(\gamma^*, p^*) \geq E\Pi(\gamma, p)$  for all  $(\gamma, p)$ .

ii. The agent's strategy  $\alpha^*(\cdot, \cdot)$  maximizes his expected utility for every strategy  $(\gamma, p)$  of the principal, i.e.  $EU(\alpha(\gamma, p)) \geq EU(a)$  for  $a \in \{0, 1\}$ .

## 2.4 The Non-Commitment Game

In the Non-Commitment Game we assume that the investigation policy announced by the principal at the time of contracting is not binding at the time of performance. Thus, we deal with the following game in four stages:

1. The principal offers a monetary incentive scheme  $\gamma$ .
2. The agent chooses an action  $a \in \{0, 1\}$ , given he accepts contracting.
3. An outcome  $q_j$  is determined by the agent's action and some random variable.
4. The principal decides whether to exert monetary effort or not, that is, he decides on an investigation intensity  $p_j$ . The reward to the agent is then determined by the arrangement  $\gamma$  and the observed variables.

The principal in this game faces the following credibility problem with respect to his investigation policy. Suppose that the monetary incentive scheme and the preannounced investigation policy induces the agent to act in his interests and that the agent's action led to an outcome in which the principal preannounced investment. Since the investigation is costly, the principal can save cost, if he does not invest. This, of course, will be foreseen by the agent and the principal's preannounced investigation will not be credible ex-post. We capture this issue due to the principal's inability to commit to his investigation policy and require sequential rationality by the principal with respect to his investigation intensity: (1) The principal chooses his investigation intensity to minimize his implementation costs, given the agent's action. (2) The agent decides on his action, given the principal derives his investigation intensity by (1).

A strategy for the agent in the Non-Commitment Game then is a function  $\alpha : \gamma \rightarrow \{0, 1\}$ , where  $\alpha(\gamma)$  denotes his choice of action, if  $\gamma$  is offered. A strategy for the principal is a tuple  $(\gamma, p(\cdot))$ , where  $p(\cdot)$  denotes his monitoring policy,  $p : \mathcal{Q} \rightarrow [0, 1]^n$ . An equilibrium of the game then is a tuple  $(\gamma^{**}, p^{**}(\cdot), \alpha^{**}(\cdot))$  with the following properties:

- i. Given  $(\alpha^{**}(\cdot), p^{**}(\cdot))$ , the principal offers a monetary incentive scheme  $\gamma^{**}$  which maximizes his expected net profits, i.e.  $E\Pi(\gamma^{**}, p^{**}(\gamma^{**})) \geq E\Pi(\gamma, p^{**}(\gamma))$  for all  $\gamma \in C$  and induces the agent to accept contracting.
- ii. Given  $(\gamma, p^{**}(\cdot))$ , the agent chooses a strategy  $\alpha^{**}(\cdot)$  to maximize his expected utility. That is,  $EU(\alpha^{**}(\gamma)) \geq EU(a)$  for all  $a \in \{0, 1\}$ .
- iii. Given  $(\gamma, \alpha^{**}(\cdot))$ , the principal chooses an investigation policy



$p^{**}(\gamma)$  such that  $E\Pi(\gamma, p^{**}(\gamma)) \geq E\Pi(\gamma, p)$  for all  $p \in [0, 1]^n$ .

### 3 The Commitment Game

To analyze the Commitment Game described in Section 2.3, suppose that the principal wishes to implement the action  $a = 1$ . If an investigation is undertaken and the results reveal the agent's action, the principal will penalize the agent for any deviation from  $a = 1$ . The agent's incentives not to perform the high action are the lower the higher his loss in utility. Hence, it is optimal for the principal to pay the agent the lowest possible remuneration for any non-compliance with his interests. Using the principle of maximum deterrence by Baron/Besanko [1984], we assume without loss of generality that  $v(q_j, 0) = 0$  for all outcomes  $q_j$ . As a consequence, we can restrict the class of monetary incentive schemes to arrangements of the form

$$\begin{aligned} \gamma = (v_1, \dots, v_n, w_1, \dots, w_n) \quad & \text{with} \\ v(q_j, 1) &= v_j \\ v(q_j, 0) &= 0 \\ w(a, q_j) &= w_j \quad \text{for all } j = 1, \dots, n, a \in \{0, 1\}. \end{aligned}$$

The principal's problem of minimizing his expected costs to implement the action  $a = 1$  then leads to the following optimization program:

$$\text{Choose } (v_1, \dots, v_n, w_1, \dots, w_n, p_1, \dots, p_n) \text{ to minimize} \quad (P_1)$$

$$\sum_{j=1}^n \pi_j(1) \cdot (p_j \cdot v_j - (1 - p_j) \cdot w_j + c(p_j)) \text{ s.t.}$$

$$EU(1) \geq EU(0)$$

The incentive compatibility constraint ensures that the agent actually chooses the desired action.<sup>8</sup> Note that the agent's participation constraint  $EU(1) \geq 0$  is automatically satisfied given the incentive constraint and the limited liability constraint  $v_j \geq 0$  and  $w_j \geq 0$ .

**Proposition 1** *Let  $(\gamma^*, p^*, \alpha^*(\cdot, \cdot))$  be an equilibrium of the Commitment Game. Then the equilibrium is characterized by the following properties:*

1. *The principal investigates in all outcome levels with positive intensity less than one. Moreover, his investigation intensity is a decreasing*

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<sup>8</sup>As it is common in principal-agent models, we assume that if the agent is indifferent between two pure actions, he chooses the one the principal prefers.

function in outcomes: Let  $j^* \in \{2, \dots, n-1\}$  be the outcome level such that  $\pi_j(0) > \pi_j(1)$  for  $j \leq j^*$ . Then

$$1 > p_1^* = \dots = p_{j^*}^* > p_{j^*+1}^* > \dots > p_n^* > 0.$$

2. If the principal's investigation reveals the agent's action, the agent receives a constant reward, independent of the realized outcome. If the results of the investigation are uninformative about the agent's action, the agent is paid nothing for outcome level  $j \leq j^*$  and a positive reward for  $j > j^*$  but less than in case of revelation, i.e.

$$\begin{aligned} v_1^* &= v_2^* = \dots = v_n^* = v^* \\ w_1^* &= \dots = w_{j^*}^* = 0 < w_{j^*+1}^* = \dots = w_n^* = w^* \\ w^* &\leq v^* \end{aligned}$$

**Proof.** see Appendix. ■

The first part of the proposition is a well known result in the literature on principal-agent model with monitoring and has in our framework the following straightforward interpretation: Using the Monotone Likelihood Ratio Condition, the principal knows that if the agent works lazy, the expected level of outcome is lower than the one if he works hard. Hence, if a low outcome level occurs, it is more likely that the agent did not comply with the principal's interests. Thus, a higher investigation intensity in lower outcome levels discourages the agent from being lazy.

The second part of this proposition states that if an investigation is undertaken and the results reveal the agent's action, the agent is paid according to the action he chooses, independent of the outcome level. This result corresponds to a first-best situation in which the principal can observe directly the agent's behavior. If the investigation is uninformative, the agent's reward depends to some extent on the realized outcome. In particular, the assumption of the Monotone Likelihood Ration Condition ensures that the agent is paid more when a higher outcome is observed. An increasing payment schedule in outcomes provides additional incentives for the agent to work hard: A higher effort increases the probability of a higher outcome level. This result corresponds to a second-best situation in which the principal has no monitoring technology available (see Grossman/Hart [1983]). Note, that the agent receives less payment whenever his action is revealed compared to his reward if the principal's investigation is uninformative. Hence, an agent who complies with the principal's interests prefers the revelation of his behavior.<sup>9</sup>

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<sup>9</sup>The stepwise property of the equilibrium reward  $w_j^*$  and the constant investigation policy  $p_j^*$  for  $j \leq j^*$  is a consequence of the linearity of our model. In a

## 4 The Non-Commitment Game

We now analyze the game in which the principal cannot commit to his investigation policy at the time of contracting (see Section 2.4). Suppose that the principal wishes to implement the action  $a = 1$  and consider an arrangement  $\gamma$  that minimizes his expected costs. Suppose that the agent complies with the principal's interests. Then the principal's expected costs in outcome  $q_j$  when choosing an investigation intensity  $p_j$  are given by

$$p_j \cdot w_j + (1 - p_j) \cdot v_j + c(p_j).$$

Sequential rationality with respect to the principal's investigation intensity then requires that the principal trades off the expected payment to the agent in case the investigation reveals no additional information about the agent's action and the sum of the agent's payment if investigation is informative and his investment into the monitoring technology. Suppose that it is optimal for the principal to choose an investigation intensity  $p_j \in (0, 1)$  if outcome  $q_j$  occurs. Sequential rationality then requires that

$$w_j = v_j + c'(p_j) \tag{SR}$$

and the agent's reward  $w_j$  in case no additional information about the agent's action is revealed is uniquely determined by the investigation intensity  $p_j$  and the agent's payment  $v_j$ . Moreover, since  $c'(0) = 0$ , equation (SR) is satisfied also in the case in which the principal does not investigate: We simply set  $v_j = w_j$ . Note too, that it cannot be optimal for the principal to investigate the agent with an intensity close to one, for his investment then is arbitrarily high. Hence, the principal's problem to implement the action  $a = 1$  can be stated as follows:

$$\begin{aligned} &\text{Choose } (v_1, \dots, v_n, p_1, \dots, p_n) \text{ to minimize} && (P_2) \\ &\sum_{j=1}^n \pi_j(1) \cdot [v_j + (1 - p_j) \cdot c'(p_j) + c(p_j)] && \text{subject to} \end{aligned}$$

$$EU(1) \geq EU(0).$$

**Proposition 2** *Let  $(\gamma^{**}, p^{**}(\cdot), \alpha^{**}(\cdot))$  be an equilibrium of the Non-Commitment Game. If the cost function satisfies property (A) and the*

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framework in which the agent would be risk-averse, it can be shown that the agent's rewards  $w_j^*$  and the principal's policy  $p_j^*$  are strictly decreasing over the entire range of outcomes.

agent's effort cost  $c_H$  are sufficiently low, the equilibrium is characterized by the following properties:

1. The principal investigates in all outcome levels with positive intensity less than one. The investigation intensity is strictly increasing in outcomes, i.e.

$$0 < p_1^{**} < \dots < p_n^{**} < 1.$$

2. The agent's reward is increasing in outcome levels, independent of whether the principal's investigation is informative about his action or not. Moreover, the agent covers the principal's marginal costs in case the results of the investigation reveal his action: Let  $j^* \in \{2, \dots, n-1\}$  be the outcome level such that  $\pi_j(0) > \pi_j(1)$  for  $j \leq j^*$ , then

$$\begin{aligned} v_1^{**} &= \dots = v_{j^*}^{**} = 0 < v_{j^*+1}^{**} = \dots = v_n^{**} = v^{**} \\ w_1^{**} &< \dots < w_{j^*}^{**} < w_{j^*+1}^{**} < \dots < w_n^{**} \text{ with} \\ w_j^{**} &= c'(p_j^{**}) \text{ for all } j = 1, \dots, j^*. \text{ and} \\ w_j^{**} &= v^{**} + c'(p_j^{**}) \text{ for all } j = j^* + 1, \dots, n. \end{aligned}$$

**Proof.** see Appendix. ■

The second part of the proposition follows immediately from the Monotone Likelihood Ratio Condition and the principal's inability to commit to his investigation policy at the time of contracting. The assumption of the Monotone Likelihood Ratio Condition guarantees that the agent's reward is increasing in the outcome level if the principal's investigation is uninformative. The sequential rationality constraint then requires that the principal pays the agent a lower reward in every outcome if his investigation reveals the agent's action. Moreover, according to equation (SR), the reduction in payment is equal to the marginal costs given by the principal's investment in the informativeness of his investigation. That is, investigation is credible at the time of performance only if the agent pays for the investment if his action is revealed. Note, that different to the Commitment Game, an agent who complies with the principal's interests does not prefer the revelation of his behavior: He receives less payment whenever his action is revealed compared to his reward if the principal's investigation is uninformative.

The first part of the proposition is a consequence of this structure of the monetary incentive scheme: Monitoring the agent, if he has already taken his action and the outcome has already occurred only redistributes the outcome. The principal, therefore, can only use investigation to reward the agent for acting in his interests. The Monotone Likelihood Ratio Condition implies that the agent gets more the higher the outcome. Moreover, using the Monotone Likelihood Ratio Condition,

the principal knows that if the agent works lazy, the expected level of outcome is lower than the one if he works hard. Hence, if a low outcome level occurs, it is more likely that the agent did not comply with the principal's interests. In contrast to the case of commitment, however, the principal now cannot use his investigation as an additional incentive device: Sequential rationality requires that the agent's share of the outcome is higher the lower the principal's intensity of investigation. If, as in the case of commitment, the investigation intensity would be decreasing in the outcome level, the principal could not reward the agent for acting in his interests - investigation in low outcome levels gives an agent who works hard the lowest possible expected reward - and would instead increase the agent's incentive to work lazy - not investigating in high outcome levels gives an agent who works lazy the highest possible expected reward. In order to guarantee that the agent accepts contracting and to give the agent appropriate incentives to act in his interests, the principal uses investigation to ensure an adequate redistributing of the outcome: He chooses a high investigation intensity in high outcome levels so that he can reward the agent for taking the desired action. He can do this because it is more likely that a high level of outcome occurs if the agent complied. And, he chooses a low investigation intensity in low outcome levels and pays the agent a low reward. This does not punish an agent who complied for it is less likely that working hard leads to a low level of outcome.

## 5 Concluding Remarks

The purpose of this paper was to study the qualitative impact of commitment on contracting in principal-agent relationships. In particular, we focus on the sensitivity of the principal's ability to commit to an investigation policy. We demonstrate that the structure of the principal's investigation policy and the reward system may depend crucially on the principal's ability or inability to commit to his investment in the monitoring technology at the time of contracting.

Of course, the principal is better off if commitment to his investigation policy is possible: Whatever the design of his investigation policy and monetary incentives is in case of non-commitment, he always can implement this policy and reward system in case of commitment. The reverse, however, is in general not true for the optimal incentive device in case of commitment is not credible ex post if the principal's investigation announcements are not binding at the time of performance.

The fact that the principal prefers to commit to his investigation policy rather than to announce a non-binding investigation policy implies that he has always an incentive to resolve his commitment inability..

Several institutional remedies to the principal's commitment problem are possible: For example, the delegation of the investigation to a third party may be one possibility for the principal to implement the commitment solution in case of non-commitment, see Melumad and Mookherjee [1989]. In situations in which the principal and the agent are engaged in an ongoing relationship - the case of a multiperiod principal-agent model - the principal has additional possibilities to resolve his commitment problem. For example, he can investigate in a reputation that he sticks to his investigation announcements, see Wilson [1983]. Moreover, there could be other benefits from investigation besides its incentive or redistribution effects. New information could be obtained from an investigation that could help to improve the agent's performance now or in future periods or that could help other agents to improve their performance. To sum up one would expect that the principal can resolve his commitment inability in a more general framework.

# Appendix

**Proof of Proposition 1:** We use the Kuhn-Tucker conditions of program  $(P_1)$  to characterize the structure of equilibrium. Let  $\lambda$  be the Lagrange multiplier for the incentive rationality constraint. Then we can rewrite the Lagrange function as

$$\begin{aligned} \mathcal{L} = & \sum_{j=1}^n \pi_j(1) \cdot (p_j \cdot v_j + (1 - p_j) \cdot w_j + c(p_j)) \\ & - \lambda \cdot \left( \sum_{j=1}^n \pi_j(1) \cdot (p_j \cdot v_j + (1 - p_j) \cdot w_j) - c_H \right) \\ & + \lambda \cdot \left( \sum_{j=1}^n \pi_j(0) \cdot ((1 - p_j) \cdot w_j) \right), \end{aligned}$$

Using the notation  $\delta_j = \frac{\pi_j(0)}{\pi_j(1)}$  for all  $j = 1, \dots, n$ , the first-order derivatives are as follows:

$$\frac{\partial}{\partial v_j} \mathcal{L} = \pi_j(1) p_j (1 - \lambda) \quad (1)$$

$$\frac{\partial}{\partial w_j} \mathcal{L} = \pi_j(1) (1 - p_j) \cdot (1 - \lambda (1 - \delta_j)) \quad (2)$$

$$\frac{\partial}{\partial p_j} \mathcal{L} = \pi_j(1) ((1 - \lambda) (v_j - w_j) + c'(p_j) - \lambda \delta_j w_j) \quad (3)$$

We first claim that  $\lambda$  is strictly greater than 1. For suppose that this claim is false and that  $\lambda < 1$ . Then the derivatives (1) and (2) of the principal's problem  $(P_1)$  are both positive,  $0 < 1 - \lambda < 1 - \lambda(1 - \delta_j)$  implying that  $v_j = w_j = 0$  for all  $j$ . But then (3) implies  $p_j = 0$  for all  $j$ , a contradiction. Now suppose that  $\lambda = 1$ . Again, derivative (2) implies  $w_j = 0$  for all  $j$ , hence, (3) implies  $p_j = 0$  for all  $j$ , a contradiction. In sum,  $\lambda > 1$ .

Derivative (1) then is strictly negative for all  $j$ , implying  $v_j^* = v^* > 0$  and derivative (2) is negative whenever  $\delta_j < 1 - 1/\lambda$ , implying  $w_j^* = w^* > 0$ . Otherwise,  $w_j^* = 0$ . Setting derivative (3) equal to zero then gives for  $\delta_j < 1 - 1/\lambda$

$$c'(p_j^*) = (\lambda - 1) (v^* - w^*) + \lambda \delta_j w^*,$$

hence  $p_j^* > 0$  as long as  $v^* \geq w^*$  and  $p_j^*$  is increasing in  $\delta_j$  since the costs of investigation are increasing with its informativeness. For  $\delta_j > 1 - 1/\lambda$  we have

$$c'(p_j^*) = (\lambda - 1) v^*$$

and  $p_j^* = p^* > 0$ . Moreover,  $p^* > p_j^*$  for  $\delta_j < 1 - 1/\lambda$  since  $(\lambda - 1)v^* > (\lambda - 1)(v^* - w^*) + \lambda\delta_j w^*$ . Finally, for  $\delta_j = 1$  we have  $w_j^* = 0$  and  $p_j^* = p^*$ .

Q.E.D. ■

**Proof of Proposition 2:.** Again, we consider the Kuhn-Tucker conditions of problem  $(P_2)$ : Let  $\lambda$  be the Lagrange multiplier for the incentive compatibility constraint in  $(P_2)$ , we can rewrite the Lagrange function as

$$\begin{aligned} \mathcal{L} = & \sum_{j=1}^n \pi_j(1) \cdot (v_j + (1 - p_j) \cdot c'(p_j) + c(p_j)) \\ & - \lambda \cdot \left( \sum_{j=1}^n \pi_j(1) \cdot (v_j + (1 - p_j) \cdot c'(p_j)) - c_H \right) \\ & + \lambda \cdot \left( \sum_{j=1}^n \pi_j(0) \cdot (1 - p_j) \cdot (v_j + c'(p_j)) \right), \end{aligned}$$

The first-order derivatives now are as follows:

$$\frac{\partial}{\partial v_j} \mathcal{L} = \pi_j(1) (1 - \lambda(1 - \delta_j) - \lambda\delta_j p_j) \quad (4)$$

$$\begin{aligned} \frac{\partial}{\partial p_j} \mathcal{L} = & \pi_j(1) (1 - p_j) c''(p_j) \cdot \\ & \left( 1 - \lambda(1 - \delta_j) + \lambda \frac{(1 - \delta_j) c'(p_j) - \delta_j v_j}{(1 - p_j) c''(p_j)} \right) \end{aligned} \quad (5)$$

We first show that  $\lambda$  is strictly greater than one. For suppose that  $\lambda \leq 1$ . Then derivative (4) is strictly positive,  $1 - \lambda(1 - \delta_j) - \lambda\delta_j p_j = 1 - \lambda + \lambda\delta_j(1 - p_j) > 0$ , implying that  $v_j = 0$  for all  $j$ . But then the incentive compatibility constraint cannot be satisfied, a contradiction. Hence,  $\lambda > 1$ .

Consider now derivative (4). Note that the RHS of (4) is increasing in  $\delta_j$ . Hence, there exists an outcome level  $j^*$  such that  $1 - \lambda + \lambda\delta_j(1 - p_j) > 0$  for  $j > j^*$  and  $1 - \lambda + \lambda\delta_j(1 - p_j) < 0$  for  $j < j^*$ .

Suppose that  $j > j^*$ . Then  $v_j = 0$ . Moreover,  $1 - \lambda(1 - \delta_j) > \lambda\delta_j p_j > 0$ , hence, derivative (5) implies that  $p_j > 0$  if and only if  $(1 - \delta_j) c'(p_j) < 0$ . Hence,  $\delta_j > 1$  and the optimal investigation intensity  $p_j^*$  is given by

$$\left( \frac{c'(p_j^*)}{(1 - p_j^*) c''(p_j^*)} \right) = 1 + \frac{1}{\lambda(\delta_j - 1)}. \quad (6)$$

Since the RHS of equation (6) is decreasing in  $\delta_j$ , the LHS of (6) must be decreasing in  $\delta_j$  as well. Taking  $\delta$  as a continuous variable, this implies



that

$$\frac{\partial}{\partial \delta} \left( \frac{c'(p^*)}{(1-p^*)c''(p^*)} \right) < 0 \text{ i.e.}$$

$$\frac{\partial p^*}{\partial \delta} \cdot [c''(p^*)^2 (1-p^*) + c''(p^*)c'(p^*) - c'''(p^*)c'(p^*) (1-p^*)] < 0.$$

Since  $\frac{c''(\cdot)}{c'(\cdot)} > \frac{c'''(\cdot)}{c''(\cdot)}$  by assumption (A), the second term is always positive. Hence,  $\frac{\partial p^*}{\partial \delta} < 0$ .

Suppose now that  $j < j^*$ . Then  $v_j = v$ , and  $1 - \lambda(1 - \delta_j) < 0 < \lambda\delta_j p_j$  implies that  $\delta_j < 1$ . Hence, using derivative (5),  $p_j > 0$  if and only if  $(1 - \delta_j)c'(p_j) - \delta_j v_j > 0$  and the optimal investigation intensity  $p_j^*$  is then given by

$$\left( \frac{c'(p_j^*) - \frac{\delta_j}{1-\delta_j}v}{(1-p_j^*)c''(p_j^*)} \right) = 1 - \frac{1}{\lambda(1-\delta_j)}. \quad (7)$$

As before, the RHS of equation (7) is decreasing in  $\delta_j$ , hence, the LHS of (7) must be decreasing in  $\delta_j$  as well. That is,

$$\frac{\partial}{\partial \delta} \left( \frac{c'(p^*) - \frac{\delta}{1-\delta}v}{(1-p^*)c''(p^*)} \right) < 0.$$

Calculating the derivative then implies that

$$\begin{aligned} & \frac{\partial p}{\partial \delta} \cdot [c''(p^*)^2 (1-p^*) + c''(p^*)c'(p^*) - c'''(p^*)c'(p^*) (1-p^*)] \\ & < \frac{v}{(1-\delta)} \left( \frac{c''(p^*) (1-p^*)}{1-\delta} + \frac{\partial p}{\partial \delta} \cdot \delta [c''(p^*) - c'''(p^*) (1-p^*)] \right) \end{aligned}$$

For  $v = 0$  this inequality is identical to the previous one. Hence, for  $v$  sufficiently small, the inequality is satisfied only if  $\frac{\partial p^*}{\partial \delta} < 0$ . Since  $v$  is uniquely determined by the agent's incentive compatibility constraint, and positively related to the agent's effort cost  $c_H$ , the claim follows.

Note, that for  $\delta_j = 1$ , derivative (5) implies that  $p_j > 0$  if and only if  $v_j > 0$ . Since  $v_j = 0$  requires  $p_j = 1$  which is not feasible,  $v_j = v > 0$ . Moreover, it is easy to show that  $p_j$  is increasing when moving from outcome level  $j^*$  to  $j^* + 1$ . To see this note that for the function

$$f(p(x), x) = \left( \frac{c'(p) - x}{(1-p)c''(p)} - y \right) = 0$$

the envelope theorem ensures that

$$\frac{\partial p}{\partial x} = -\frac{\frac{\partial f}{\partial x}}{\frac{\partial f}{\partial y}} = \frac{xc''(p^*) (1-p^*)}{A - x [c''(p^*) - c'''(p^*) (1-p^*)]} > 0$$

with  $A := c''(p^*)^2(1-p^*) + c''(p^*)c'(p^*) - c'''(p^*)c'(p^*)(1-p^*) > 0$  by assumption (A) and for  $x$  sufficiently small.

Q.E.D. ■

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