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# Subjective Evaluation and Information–Efficiency in Organizations

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## Abstract

Subjective performance evaluation is modeled as auditing without commitment. A superior, who has to decide *whether* an *where* to audit the work done by a subordinate, takes into account all interim information he has obtained in the meantime. This invites workers to cover up and withhold information in order to make an audit more difficult and thus divert their superior from making one. We show that this strategy usually raises the cost of setting work incentives, so that incentives are softened. However, in some instances the opposite holds. When worker's on-the-job information is valuable for entrepreneurial decisions, work incentives have to be softened in order improve the internal flow of information.

**JEL classification:** J41, D23.

**Keywords:** Principal–agent relationship, auditing without commitment, internal organization, information transmission, influence activity.

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## Zusammenfassung

Subjektive Leistungsbeurteilung durch einen Vorgesetzten wird modelliert als “Qualitätsprüfung ohne Selbstbindung”. Ein Vorgesetzter muß sich entscheiden, *ob* und *wo* er eine Inspektion des Arbeitsergebnisses vornimmt; dabei wird er alle Interim-Informationen berücksichtigen, die er bis zu diesem Zeitpunkt erhalten hat. Das hat zur Folge, daß die Untergebenen alle Informationen zurückhalten und verwischen, die einen Verdacht erregen und daher eine Inspektion durch den Vorgesetzten erleichtern könnten. Ihr Ziel ist es, die Anreize ihres Vorgesetzten so zu beeinflussen, daß dieser von einer Inspektion ganz absieht. Es zeigt sich, daß diese Strategie meistens das Setzen von Leistungsanreizen erschwert, so daß die innerbetrieblichen Anreize reduziert werden. Allerdings ist auch der umgekehrte Fall denkbar. Wenn die Vor-Ort-Informationen des Arbeiters sehr wertvoll für unternehmerische Entscheidungen sind, dann werden die Leistungsanreize reduziert, um den innerbetrieblichen Informationsfluß zu verbessern.

# 1 Introduction

The evaluation of a worker poses difficult problems. Since adequate ‘objective’ performance indicators are rarely available most firms base their performance pay —wage raises, bonuses, or promotions— on ‘subjective’ performance evaluations by the superiors. These have their own problems, however. Superiors often lack the ability or the incentives to make and defend fair appraisals. And workers try to influence their ratings in various ways, taking their best advantage of the superiors’ problems in making the appraisals. One important influence activity is the distortion of information.<sup>1</sup> E. E. Lawler points out that “there may also be a tendency for the subordinate to withhold negative information about performance in order to look good during the performance appraisal. This can cloud the degree to which a valid performance discussion takes place; and if the appraisal data are used for planning purposes, such withholding of information can contribute to poor planning.” (Lawler, 1990 p.97).

This paper shows how workers can influence their appraisals by distorting information. It points out that it is the *subjectivity* of the performance evaluation which makes it particularly sensitive to information distortions, and thus tends to invite distortions. Such distortions take place during the whole working period (not just during the appraisal talks) and can have far-reaching consequences for a firm. The model captures both aspects mentioned by Lawler, namely, that performance measurement gets more difficult when workers distort information and that information distortion can adversely affect management’s knowledge base. It will be shown that firms will often (but not always) respond by softening work incentives, since this reduces workers’ incentives to distort information.

Before sketching our approach in general terms, consider an example. Suppose a firm produces complex software for other companies, and there is a worker who deals with one of its client firms. He has to install the software, adapt it to the client’s needs, and give support and advice. After some time, the client encounters shortcomings of the software in certain applications. The worker is afraid that this is due to mistakes he might have done during the early installation phase. If he tries to fix the problems now, other people in his own firm will probably notice it and questions might arise. As an alternative, he can try to convince the client that the software was not designed for these applications in the first place. The client, still unfamiliar with the new system, is a bit disappointed about the product, but accepts the explanation. And the software firm will never learn that these problems have come up.

However, this information may be valuable to the software firm. If the software can still be adapted to the client’s needs, the latter one would be more satisfied. If it cannot be adapted, the software firm, having learned this, could try to develop a better product. Or, if it has other compatible software on offer, it could sell a second product to the client. In view

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<sup>1</sup>Information distortion is a typical influence activity according to Milgrom and Roberts (1990, 1992 p.600).

of this, the software firm might change its internal policy and assure workers that they will not be blamed for malfunctions that come up. However, if this goes too far workers will not care about the correct installation and there will be many malfunctions that can be avoided, since the only way to set incentives is to make workers responsible for their work. Hence, workers' tendency to make cover-ups makes it more difficult to set incentives and to obtain valuable information from them. The tradeoff between incentives to work and incentives to inform will play a central role in our model.<sup>2</sup>

We model a firm with two members, a manager (principal) and a worker (agent). The worker exerts effort in order to reduce the probability of making a mistake in his job. There is a state of nature on which it depends *where* a mistake is most likely to occur, and the worker has the choice of either informing the manager or dissipating this information at a cost. Afterwards the manager decides whether to look for a mistake, at a cost, or not. If he does, he has to decide *where* to look for a mistake. Clearly, the information about the state of nature, besides possibly having an intrinsic value for the manager, is helpful in the evaluation process since it tells where a mistake is most likely to be found. But this is precisely why the worker wants to erase it: Dissipating the information raises the expected evaluation cost of the manager, so that the latter may find it too costly to evaluate. Information dissipation is thus a powerful tool in the hands of workers: By tilting manager's incentives to evaluate, *it may prevent an audit in the first place*, and without an accurate audit (i.e. some kind of explanation) the worker cannot be blamed for anything.

This effect, which can only occur under *subjective* performance evaluation, is likely to have a broad and systematic impact on ratings and on the behavior of workers. Cover-ups and the withholding of information are widely observed in practice and are surely more pervasive than the outright falsification of audit *results*, which would also be conceivable under objective performance evaluation.<sup>3</sup> In practice, there are innumerable instances of workers trying to hide information about their work environment because they fear negative consequences if their superiors are too well informed. They cover up traces that might stir suspicions about

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<sup>2</sup>In a related paper, Levitt and Snyder (1997) consider a worker who observes an intermediate signal about the success of his own effort and may inform the principal about it. Since his success will finally become public information (contractible), worker's information may serve as an early warning in that model. For example, a salesman may inform his superior that a customer will probably not buy, so that the superior can either overtake the talks with this customer or decide to quit the talks right away. The pivotal (and special) assumption by Levitt and Snyder is that this intervention erases the verifiable information about worker's success. Based on this assumption they find a tradeoff between incentives to work and incentives to communicate. In contrast, our paper derives such a tradeoff even if the firm cannot intervene at all, or if it can intervene without affecting the information about worker's mistake.

<sup>3</sup>In the model we will assume that the result of an audit cannot be falsified. We also assume that there is no recontracting (collusion).

a potential misbehavior, they withhold information that would be useful for entrepreneurial decisions just because this information might also give a hint where they have encountered difficulties, and so on.

In this model, the subjective element of performance evaluation is in the manager's decision to audit.<sup>4</sup> Pivotal is the assumption that, if a worker cannot be blamed for having made a mistake, it is impossible to say whether he has really been successful at work or just not audited accurately. The manager is therefore unable to commit *ex ante* to make an audit, but will decide on it during the course of events. His incentives to audit will be affected by all *interim information* which he obtains prior to his auditing decision. We will be particularly interested in two pieces of interim information: Firstly, the manager privately observes worker's effort and thus knows the chances of finding a mistake; secondly, if he learns the state of nature, it tells him *where* to look for a mistake.<sup>5</sup>

Note that in our model the performance evaluation is partly objective and partly subjective.<sup>6</sup> It is not completely arbitrary, since we assume that an accurate audit is needed in order to blame an unsuccessful worker and cut his wage. In reality, a superior cannot simply rate his workers just by his personal impressions. He has to explain and justify the ratings to a number of people, in particular to the appraisees themselves and sometimes even in courts; see Lawler (1990). It is this need for providing evidence, applying accepted evaluation criteria, and convincing people —i.e. the need for 'verification'— that is particularly costly to him. It also creates an asymmetry: A good rating is cheaply granted, since the appraisee will not demand explanation, while a bad rating has to be defended and supported by some kind of evidence. The bias for good ratings implied by this asymmetry is widely observed in practice. And since it is particularly the *bad* events which need to be backed by harder information, workers have the incentive to make the access to information more difficult.

The model shows that in many cases cover-up strategies raise the cost of setting incentives, so that incentives are softened. However, it should be mentioned that the opposite case is also conceivable, so that a firm may actually benefit from worker's information distortion.

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<sup>4</sup>A suggested definition: A performance evaluation is *subjective* if, at a given work result, the *manager* has some discretion on the evaluation result. Under subjectivity, distortions could also be due to personal feelings of the manager towards a worker, leading to 'favoritism' in the sense of Prendergast and Topel (1997). In our model, such personal preferences will play no role.

<sup>5</sup>The paper adds to an emerging literature on auditing without commitment. Khalil (1997) presents a hidden information model in which the principal obtains interim information about worker's performance. Jost (1991, 1996) and Strausz (1997) consider moral hazard situations without interim information, since worker's effort choice and principal's auditing decision are made simultaneously. Ours is a moral hazard model in which these decisions are made sequentially and interim information plays an important role.

<sup>6</sup>We postpone a more detailed discussion of our approach to subjective performance evaluation in light of the theoretical and empirical literature to the final section 5.

This is due to a strategic effect, since information distortion may enable the firm to induce higher work efforts by the pure *threat* to make an inspection (i.e. without having to carry out this threat in equilibrium — recall that inspections are costly).<sup>7</sup> However, the withholding of pieces of information which might be useful for entrepreneurial decisions is always detrimental to the firm’s interests.<sup>8</sup>

The model is introduced in section 2 and analyzed in section 3. All proofs are in the Appendix. Section 4 provides an extension which highlights the worker’s role as an information producer. Section 5 summarizes and also discusses our general approach to subjective performance evaluation in light of the literature.

## 2 The Model

There are two members of a firm, a worker (agent) and an owner–manager of the firm (principal); both are risk–neutral. The worker can either be successful in his job or make a mistake; the more effort he exerts the higher is his probability  $p$  of making no mistake (he does not observe whether a mistake realizes). We normalize by saying that  $p \in [0, 1]$  is his effort and let  $C(p)$  denote his related disutility.<sup>9</sup> Let  $C(0) = 0$ ,  $C' \geq 0$ ,  $C'' > 0$ , and  $C(p)$  defined for all  $p \in [0, 1]$ . If he makes a mistake his productivity is zero, otherwise the manager (i.e. firm) gets a benefit of  $b > C'(0)$ . Worker’s effort and manager’s proceeds and profit are noncontractible, so that an incentive contract has to be based on some other performance indicator which will be introduced below.

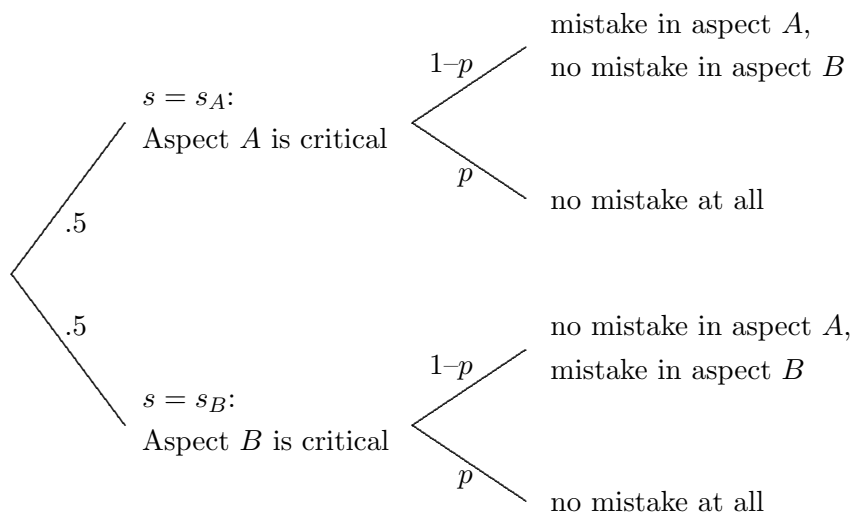
The worker’s task consists of two aspects  $\theta \in \{A, B\}$ , and there is a state of nature  $s \in \{s_A, s_B\}$ . In state  $s_A$  the work aspect  $A$  is the ‘critical’ one, which means that there is a danger of making a mistake in that aspect (with probability  $1 - p$ ), while aspect  $B$  is not in danger. Vice versa for state  $s_B$ . Hence in state  $s_\theta$  there can only be a mistake in aspect  $\theta$  (i.e. there can be at most one mistake). The two states are ex ante equally probable. Figure 1 illustrates. The realization of  $s$  is not observed by the manager, but will leak through to him unless the worker dissipates this information at a cost  $\gamma > 0$ .

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<sup>7</sup>There is now some literature on situations where a firm would prefer to reduce its own information in order to improve incentives; see for example Crémer (1995), Kessler (1998), Maggi and Rodríguez–Clare (1995), Aghion and Tirole (1997), and Mitusch (2000).

<sup>8</sup>In different but related contexts, Aghion and Tirole (1997) and Mitusch and Strausz (1999) show that a worker is reluctant to communicate information for fear that the information may lead to *policy decisions* which are unfavorable to him. In contrast, in the present model the worker is indifferent about the policy decisions, but fears side–effects of the information on the manager’s *auditing decisions* and thus on his own standing.

<sup>9</sup>For example,  $C(p) = p/(1 - p)$  is equivalent to the assumption that an effort  $e \geq 0$  leads to a no–mistake probability  $p(e) = e/(1 + e)$  and a disutility of  $e$ .



The worker's effort reduces the probability  $1 - p$  of making a mistake in the critical aspect.

Figure 1: A task with two aspects,  $A$  and  $B$

We assume that the manager's impression of the worker is perfect and costless: He observes the effort  $p$ . Thus, if he could be trusted, the best contract would simply ask him to reward the worker according to his personal impression. However, he cannot be trusted; he would always claim that the worker is lazy, in order to save on the wage bill. He must therefore be required to 'explain' a bad rating. We assume that he can produce, at cost  $k > 0$ , verifiable information about the occurrence of mistake in each of the work aspects,  $A$  or  $B$ . It costs  $2k$  to investigate both aspects.

An inspection and the related expenditures are unobservable. This implies that not-looking for a mistake cannot be distinguished (in courts) from not-finding a mistake. Consequently, a contract cannot commit the manager to audit, and attention is focused on his *incentives* to audit. Since he observes worker's effort, he knows the probability  $1 - p$  of there being a mistake, and this helps him to decide whether to audit or not.

In practice, superiors often learn some details about their workers' environments. For example, he may notice where the worker has problems. This is captured by the assumption that the manager will *usually* learn the state  $s_\theta$  before auditing. In that case he will only inspect the critical work aspect,  $\theta$ , if at all. However, a worker can sometimes manage to hide such traces. This is captured by the assumption that he can hide  $s_\theta$ . If he does, the manager must conclude that each work aspect contains a mistake with probability  $(1 - p)/2$ , i.e. his probability of finding a mistake at the first inspection falls from  $(1 - p)$  to  $(1 - p)/2$



due to worker’s manipulation. This raises manager’s expected evaluation cost (as will be seen), which is exactly why the worker may want to hide the information about the state of nature. Figure 2 summarizes the timing of events.

**Stage 1:** A contract is signed.

**Stage 2:** A state of nature  $s \in \{s_A, s_B\}$  realizes, not yet observed by the manager.

**Stage 3:** The worker chooses an effort  $p \in [0, 1]$  which is observed by the manager. The worker may hide the information about  $s$  at cost  $\gamma > 0$ , i.e. prevent it from leaking through to the manager. Otherwise it now leaks through.

**Stage 4:** The manager may inspect each work aspect at cost  $k > 0$ .

**Stage 5:** Output accrues and wage is paid according to contract and evaluation result.

Figure 2: Timing of the model

The contractual wage will naturally depend on the following state variable:

$$\sigma = \begin{cases} l & \text{means: “a mistake has been proven to exist”} \\ h & \text{means: “no mistake has been proven to exist”}. \end{cases}$$

Note that the state of the indicator  $\sigma$  is a result of three factors: (i) worker’s effort, i.e. the probability of making no mistake, (ii) a random influence, i.e. the realization of a mistake, and (iii) manager’s effort in performance measurement, i.e. whether he searches for a mistake.

The contract space is further defined by the following assumptions. First, both for realism and simplicity we rule out message–dependent contracts. Such a contract would require a written statement by the worker about the state of nature and set three different wages,  $(w_h, w_l^{\text{true}}, w_l^{\text{false}})$ , depending on  $\sigma \in \{l, h\}$  and whether worker’s message is correct in case  $\sigma = l$  (since a mistake reveals the state). However, the distinction between  $w_l^{\text{true}}$  and  $w_l^{\text{false}}$  is useless if the worker does not observe  $s_\theta$  by himself, or if the distinction between a mistake in aspect A and B is not reliable enough to be used in courts. The first of these two assumptions is theoretically safer and sufficient for most parts of the model; only section 4 requires the second assumption which also appears to be the more realistic one.

Hence the contractual wage can only depend on  $\sigma$ . Next, we assume that the manager *commits* to two wages  $(w_l, w_h)$ . Alternatively, one could imagine a two–stage procedure in which the manager will offer to recontract to a *safe* wage at stage 4 when both parties know  $p$ . If the manager could then make a take–it–or–leave–it offer, he would in some cases be better off than under commitment, since he could save the inspection cost. However, while

it is standard to assume that the principal has all the bargaining power at stage 1, it is not clear that he would have it at stage 4 as well. If the *worker* had all the bargaining power, then the manager would in most cases be worse off than under commitment. Hence, it is not self-evident what the ‘right’ assumption is. More importantly, most of our qualitative results are robust to such variations.

The payoffs are as follows.

$$\text{Worker's utility} = w_\sigma - C(p) - \text{dissipation cost} \quad (1)$$

where dissipation cost is  $\gamma$  if he dissipates and zero otherwise. The worker accepts a contract if he gets a non-negative expected utility (his market alternative is normalized to zero). He can be punished up to an amount  $W \geq 0$ , transferable to the firm, so that wage payments have to obey  $w_\sigma \geq -W$ .<sup>10</sup> Since we will derive different types of incentive contracts, we will be interested how the feasibility and ranking of these contracts depend on worker’s transferable wealth  $W$ . For example, assuming  $W = \infty$  allows us to study what happens if the worker can be required to pay even huge fines if accused for a mistake. Our leading case is  $W = 0$ , however, which implies efficiency wages where rents are shifted to the worker; in this case one would like to know what exactly hinges on the assumption that fines are ruled out.

The manager’s (i.e. firm’s) expected gross benefit is  $bp$  for a given  $p$ . Therefore:

$$\text{Manager's expected utility} = bp - E[w_\sigma + \text{evaluation cost}] \quad (2)$$

where evaluation cost is  $2k$  if he inspects both work aspects,  $k$  if he inspects only one aspect, and zero if he makes no inspection.

While  $p$  denotes the actual effort choice by the worker, let capital  $P \in [0, 1]$  denote the level of *incentives*, i.e. the effort which is to be induced by a contract. As a benchmark, consider the first-best contract. If the manager could be trusted one would avoid inspection and require an effort  $P^{fb}$  which is given by

$$b = C'(P^{fb}). \quad (3)$$

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<sup>10</sup>Expression (1) is the utility net of  $W$ . Note that, if the worker’s market alternative is initially some positive wage  $\bar{w}$ , then he gets this payment upfront and it follows that  $W \geq \bar{w}$ .

### 3 Analysis

#### 3.1 The actions induced by a contract

##### 3.1.1 The manager's evaluation policy

At stage 4, the manager's profit from finding a mistake is  $(w_h - w_l)$ , since his payment to the worker will then be reduced by this amount. Clearly, if  $w_h \leq w_l$ , he will not evaluate, and as a consequence the worker will exert no effort. In the following assume  $w_h > w_l$ .

Suppose the manager has learned  $s_\theta$ . Then he will find a mistake with probability  $1 - p$  (in aspect  $\theta$ ), and the cost of inspection is  $k$ . Thus his expected profit from evaluation is  $(1 - p)(w_h - w_l) - k$ . He will *not* evaluate if this is non-positive (on the tie-breaking rule in case of indifference see fn.14 below), which is equivalent to

$$p \geq \frac{w_h - w_l - k}{w_h - w_l} =: \varphi_1. \quad (4)$$

This is the *no-evaluation condition* for the case the manager is informed about  $s$ .<sup>11</sup>

Now suppose the worker has dissipated information about  $s$ . Then each aspect of the task may contain a mistake with probability  $(1 - p)/2$  from the manager's point of view. If he inspects one work aspect, he will then have to decide whether to inspect the other one as well.

**Lemma 1** *If the manager cannot observe  $s_\theta$ , he will not evaluate at all if*

$$p \geq \frac{w_h - w_l - 1.5k}{w_h - w_l + 0.5k} =: \varphi_2. \quad (5)$$

*Otherwise he will make inspections until he has either found a mistake or inspected both aspects.*

Note that  $\varphi_2 < \varphi_1$  for any given pair  $(w_l, w_h)$ : By withholding the information, the worker makes it more difficult for the manager to find a mistake, i.e. he raises his expected evaluation cost. The smaller work effort  $p = \varphi_2$  is then sufficient to render evaluation unattractive.<sup>12</sup>

<sup>11</sup>Throughout, we will assume that a mistake cannot be repaired. If the manager could reduce his loss by an amount  $\delta$  after finding a mistake, this would increase his incentive to evaluate and raise the critical  $\varphi_1$  to  $\frac{\delta + w_h - w_l - k}{\delta + w_h - w_l}$ . The basic structure of the model is the same as long as  $\delta$  is not too large.

<sup>12</sup>It is worth noting that Lemma 1 can be generalized to any number  $M$  of measurement points, as long as there is at most one mistake in them. For any integer  $M \geq 1$ , the general no-evaluation condition is  $p \geq \varphi_M := \frac{2(w_h - w_l) - (M+1)k}{2(w_h - w_l) + (M-1)k}$ . If  $p < \varphi_M$  the manager will evaluate until he has either found a mistake or inspected all  $M$  points. The critical level  $\varphi_M$  is decreasing in  $M$  and  $k$  for any given  $(w_l, w_h)$ .

Note also that the higher the ‘wage spread’  $w := w_h - w_l$  the stronger is the incentive to evaluate and the higher is the critical  $\varphi_i$  both  $i = 1, 2$  that renders evaluation unattractive. (We will also write  $\varphi_i(w)$  with  $\varphi'_i > 0$ .) Hence, the optimal contract will largely be determined by the need to provide ex post evaluation incentives to the manager himself.<sup>13</sup>

### 3.1.2 The worker’s effort choice and decision whether to dissipate information

At stage 3, the worker chooses an effort  $p$  and decides whether to hide the information about the state  $s$  or not. If the manager were committed to evaluate, the performance evaluation would be ‘objective’ and there would be no reason to hide information. The worker’s expected utility of exerting  $p$  would be  $pw_h + (1 - p)w_l - C(p)$ . However, since the manager is not committed, the worker has two alternatives which avoid inspection altogether: He can either exert  $p \geq \varphi_1$  or exert  $p \geq \varphi_2$  and also dissipate information. Both strategies assure him the high wage  $w_h$ .

The number of relevant alternatives of the worker can be reduced by the following considerations. Obviously, there is no reason to exert more than  $\varphi_1$ ; more precisely he satisfies  $p \leq \max\{\varphi_1, 0\}$ . And if he dissipates information, then  $p \leq \max\{\varphi_2, 0\}$ .<sup>14</sup> Moreover, recall that by Lemma 1 an inspection is always perfect if it is made, i.e. the manager then finds a mistake with *certainty* if there is one. As a consequence, from the worker’s point of view, information dissipation is only useful in combination with the effort  $p = \max\{\varphi_2, 0\}$ , since it would not make sense to hide  $s_\theta$  at an effort and then induce inspection anyway by  $p < \varphi_2$ . The worker’s optimization problem therefore reduces to choosing the maximum from the following set of utilities:

$$\left\{ w_h - C(\max\{\varphi_1, 0\}), \quad w_h - C(\max\{\varphi_2, 0\}) - \gamma, \quad \tilde{p}w_h + (1 - \tilde{p})w_l - C(\tilde{p}) \right\} \quad (6)$$

$$\text{where } \tilde{p} := \arg \max_{p \in [0,1]} pw_h + (1 - p)w_l - C(p). \quad (7)$$

If the first element of (6) is its maximum, the worker does not dissipate information and exerts  $p = \max\{\varphi_1, 0\}$ . If the third element is the maximum, he does not dissipate and sets  $p = \tilde{p}$ .<sup>15</sup> However, if the second element of (6) is its maximum, the worker dissipates information at the cost  $\gamma$  and exerts  $p = \max\{\varphi_2, 0\}$ .

<sup>13</sup>This is in line with other models on auditing without commitment, see fn.5.

<sup>14</sup>Recall our tie-breaking rule that the manager does not inspect when he is indifferent. Suppose he would make inspections with some probability. Then the worker can avoid inspection with *certainty* by exerting  $p = \varphi_1 + \varepsilon$  resp.  $p = \varphi_2 + \varepsilon$ , for an arbitrarily small  $\varepsilon$ . Thus, introducing stochastic inspection strategies would make no difference in this model.

<sup>15</sup>There is no need to impose the constraint  $p \leq \varphi_1$  on the max-problem (7): If  $\tilde{p} > \varphi_1$  then the third element of (6) is necessarily smaller than the first one.

### 3.2 Contract design: Feasible and cost-minimal contracts

At stage 1 of the game the manager makes his choice of  $w_l$  and  $w_h$ . We will proceed as follows. In this section we assume that he wants to induce a given *desired* effort level  $P \in [0, 1]$ . Since there are several ways of inducing an effort, we have to see which contracts can induce a given  $P$ , and thus also which  $P$  are implementable at all. Then we will identify the cost-minimizing contract for a given  $P$ . However, here we will confine ourselves to the most interesting cases, sometimes by referring to  $b$  already. This gives us a relevant part of the manager's cost function, which will then, in section 3.3, be related to his benefit function  $bP$  in order to determine the optimal strength of incentives and the optimal type of contract implied by it (for a restricted range of parameters).

There are three potential contract-candidates that may induce a desired effort  $P$ . One of them is tailored such that  $\varphi_1 = P$ . In order to induce the effort  $p = \varphi_1$ , the first element of (6) has to be its maximum. Such a contract shall be called AV because it 'avoids' inspections. To satisfy  $\varphi_1 \equiv P$ , (4) requires that

$$w_h^{\text{AV}} - w_l^{\text{AV}} = k/(1 - P). \quad (8)$$

The second contract-candidate is tailored such that  $\varphi_2 = P$ . In order to induce  $p = \varphi_2$ , the second element of (6) has to be its maximum. Such a contract shall be called AVD because it 'avoids' inspections but also induces information 'dissipation'. To satisfy  $\varphi_2 \equiv P$ , (5) requires that

$$w_h^{\text{AVD}} - w_l^{\text{AVD}} = \frac{3 + P}{1 - P} \frac{k}{2}. \quad (9)$$

The third contract-candidate is tailored such that  $P = \tilde{p}$ . In order to induce  $p = \tilde{p}$ , the third element of (6) has to be its maximum. This contract shall be called AC because it 'accepts' inspections (induces it with certainty). To satisfy  $\tilde{p} \equiv P$ , (7) requires that

$$w_h^{\text{AC}} - w_l^{\text{AC}} = C'(P). \quad (10)$$

A contract is called *feasible for a given  $P$*  if and only if it induces the right choice from (6). Hence, there will be two more feasibility conditions for each contract, in addition to (8), (9), resp. (10).  $P$  is called *implementable* if at least one contract is feasible for that  $P$ .

Before going on, let us interpret the three contract types. Under contracts AV and AVD the worker aims at preventing inspections. He works just hard enough, and shows it, in order to convince his manager that it is not worthwhile to look for mistakes. These contracts build on the subjective element of evaluation. Contract AC, in contrast, induces inspection with certainty. If it is feasible, the outcome is just the same as if the manager would be committed

to evaluate. This contract is clearly of less interest to us, and we will see to get rid of it. In order to see which contract the manager chooses we now have to analyze the feasibility of contracts and, when more than two are feasible for a  $P$ , identify the cost-minimizing one.

**Lemma 2** *For any  $W \geq 0$  it holds:*

1. *For any given  $P$ : If both  $w_h$  and  $w_l$  are reduced by the same amount, the feasibilities of all contracts are unaffected.*
2. *At any  $P$ , contract AV induces lower cost than any other feasible contract (AVD or AC).*
3. *For small enough  $P$ , contract AV is feasible.*

By statement 1, feasibility depends only on the wage *spread*, as given by either (8), (9), or (10), for every  $P$ . Consequently, at a cost-minimizing contract, the firm reduces  $w_l$  as far as possible, until either the worker's participation constraint or his wealth constraint  $w_l \geq -W$  binds. By statement 2, for any given  $P$  the manager would prefer to use contract AV. We will return to this. By statement 3, the preferred contract AV is indeed feasible for  $P$  close enough to zero; the reason is that the worker can then assure himself the high wage by a small effort.

However, for larger  $P$  the feasibility structure of contracts can be quite complex and irregular.<sup>16</sup> Moreover, there is no clearcut dominance relationship between contracts AVD and AC if both are feasible and AV is not. Assuming that the effort cost function is 'strongly convex' in the following sense (which implies  $C(1) = \infty$ ) will help to simplify:

**Assumption 1**  $C'(p)(1-p)^2$  is non-decreasing, i.e.  $C''/C' \geq 2/(1-p)$ .

With this assumption, the following Propositions 1 to 3 on the feasibilities of the three contract types can be obtained. We start by stating those on AV and AC. On first reading one may concentrate on the first sentence of each proposition. Proposition 1 states that contract AV is feasible if *and only if*  $P$  is small enough, i.e. below some critical  $P^{AV}$ . Note that this is a strengthening of statement 3 of Lemma 2. Proposition 2 states that contract AC can only be feasible if  $P$  is large enough, i.e. larger than some critical  $P^{AC}$ . The other parts of the propositions are explained below.

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<sup>16</sup>As an illustration, consider the linear effort cost function  $C(p) = \beta p$ . Suppose  $\gamma = \infty$  so that contract AVD and the second element of (6) are irrelevant. If  $\beta \leq 4k$ , then contract AV is feasible for all  $P \in (0, 1]$ . However, if  $\beta > 4k$ , AV is feasible for  $P \leq 1/2 - \sqrt{1/4 - k/\beta}$  as well as for  $P \geq 1/2 + \sqrt{1/4 - k/\beta}$ . The reason is that the wage spread of AV,  $k/(1-P)$ , is strongly convex. (Assumption 1, below, will assure that  $C(p)$  is even stronger convex so that a reswitch cannot occur.) Note finally that with the linear  $C(p) = \beta p$  contract AC is not feasible at all. Hence, if  $\beta > 4k$ , the effort levels  $P \in (1/2 - \sqrt{1/4 - k/\beta}, 1/2 + \sqrt{1/4 - k/\beta})$  are not implementable.

**Proposition 1 (AV–contracts)** *There is a critical  $P^{AV} \in (0, 1)$  such that contract AV is feasible if and only if  $P \leq P^{AV}$ .*

*There is also a critical level of dissipation cost  $\gamma_1 > 0$ , increasing in  $k$ , such that:*

*For  $\gamma > \gamma_1$ ,  $P^{AV}$  is independent of  $\gamma$  and increasing in  $k$ , with  $(k, \gamma) \rightarrow (\infty, \infty) \Rightarrow P^{AV} \rightarrow 1$ .*

*For  $\gamma \leq \gamma_1$ ,  $P^{AV}$  is independent of  $k$  and increasing in  $\gamma$ , with  $\gamma \rightarrow 0 \Rightarrow P^{AV} \rightarrow 0$ .*

The critical  $P^{AV}$  is everywhere continuous in  $k$  and  $\gamma$ . Since it changes its nature at  $\gamma = \gamma_1$ , we denote by  $P^{AV}(\gamma_1)$  its level for  $\gamma \geq \gamma_1$ .

**Proposition 2 (AC–contracts)** *There is a critical  $P^{AC} \in [0, 1)$  such that contract AC is only feasible if  $P \geq P^{AC}$ . If  $\gamma = \infty$ , then  $P \in [P^{AC}, 1)$  is also sufficient for feasibility.*

*The critical  $P^{AC}$  is independent of  $\gamma$  and increasing in  $k$ , with  $k \rightarrow \infty \Rightarrow P^{AC} \rightarrow 1$ . It holds  $P^{AC} < P^{AV}(\gamma_1)$ .*

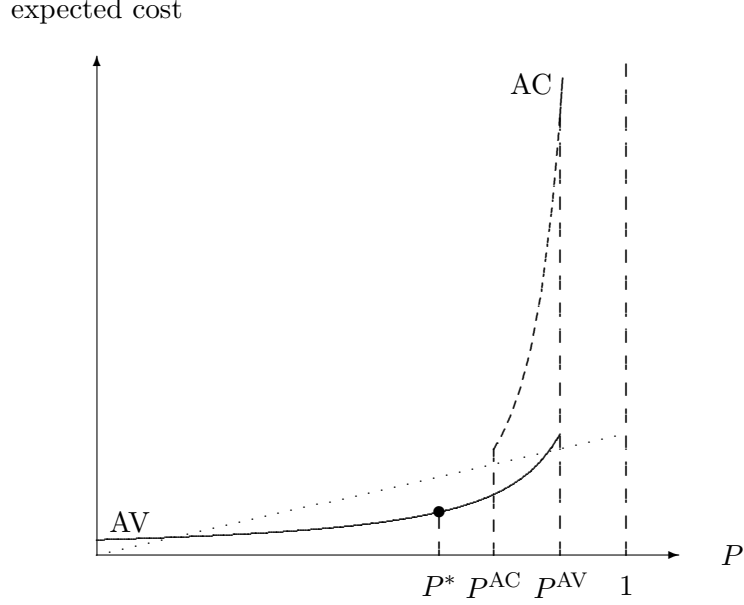
$P^{AC}$  is also continuous. For a discussion of these results it is convenient to assume  $\gamma = \infty$  which ensures that the third contract, AVD, and the whole issue of information dissipation are absent.

### 3.2.1 The case of no information dissipation ( $\gamma = \infty$ )

By Proposition 2,  $\gamma = \infty$  implies that contract AC is feasible for all  $P \in [P^{AC}, 1)$ , and that  $P^{AC} < P^{AV}$ , where  $P^{AV} = P^{AV}(\gamma_1)$ . Thus every  $P \in (0, 1)$  is implementable, either by contract AV or AC.

What causes the boundaries at  $P^{AV}$  and  $P^{AC}$ ? Recall that manager's evaluation incentives are increasing in the wage spread  $w$  and decreasing in worker's effort  $p$ . If the wage spread is relatively small, the worker will choose the effort  $\varphi_1(w)$  which avoids inspection. If  $w$  increases,  $\varphi_1(w)$  and worker's effort cost  $C(\varphi_1(w))$  increase with it. But with the strongly convex effort cost function the worker will give up at some critical wage spread, say at  $\hat{w}_1$ . At that point manager's evaluation incentives get so strong that it gets too costly for the worker to prevent inspection. He therefore accepts being inspected — and losing the high wage with probability  $1 - p$ . As a consequence, he reduces his effort drastically to  $p = (C')^{-1}(w) < \varphi_1(w)$ . The critical  $P^{AV}$  and  $P^{AC}$  of the two contract types are given by the critical wage spread, i.e.  $\hat{w}_1 = k/(1 - P^{AV}) = C'(P^{AC})$  where  $P^{AV} = P^{AV}(\gamma_1)$ .

The critical  $P^{AV}$  and  $P^{AC}$  are increasing in  $k$  because the critical wage spread  $\hat{w}_1$  is. The latter is so because manager's evaluation incentives are decreasing in  $k$ , hence a higher wage spread is needed to induce evaluation (at any  $P$ ). Then the worker finds it more attractive to prevent inspection, and as a consequence the critical  $\hat{w}_1$  increases.



Curve AV: Cost under contract AV,  $k/(1-P)$ . Contract AV is feasible for  $P \leq P^{\text{AV}} = P^{\text{AV}}(\gamma_1)$ . Curve AC: Cost under contract AC,  $PC'(P) + k$ . Contract AC is feasible for  $P \in [P^{\text{AC}}, 1)$ , but dominated by AV for  $P \in [P^{\text{AC}}, P^{\text{AV}}]$ . The dotted line is the firm's gross benefit,  $bP$ . In this example, contract AC is never relevant because it would imply a negative profit. (Contract AVD is irrelevant since  $\gamma = \infty$ .) The optimal contract is type AV, and the optimal strength of incentives is  $P^* = 1 - \sqrt{k/b}$ . Specifications:  $C(p) = p/(1-p)$ ,  $k = 2$ ,  $b = 16$ ,  $W = 0$ ,  $\gamma = \infty$ .<sup>17</sup>

Figure 3: Manager's cost function when  $W = 0$  and  $\gamma = \infty$

Figure 3 illustrates the feasible ranges of the two contracts and the implied cost function of the manager. Under contract AV the manager will pay the wage  $w_h^{\text{AV}} = k/(1-P) + w_l$  with certainty and bear no inspection cost (the figure assumes  $w_l = W = 0$ ). But this works only for  $P \leq P^{\text{AV}}$ . For  $P > P^{\text{AV}}$ , the manager will have to use contract AC. Under this contract the worker will be evaluated with certainty so that the high wage  $w_h^{\text{AC}}$  will only be paid if he has not made a mistake, i.e. with probability  $P$ . On the other hand, the manager has to pay the inspection cost and  $w_h^{\text{AC}}$  can be quite high. The figure shows that contract AC is already feasible before  $P^{\text{AV}}$  (the dashed part) but more costly than AV. The proof of statement 2 of Lemma 2 shows that  $\text{cost}^{\text{AC}} > \text{cost}^{\text{AV}}$  for all  $P$  where AC is feasible.

Note that in Figure 3 contract AC is not profitable at all, since manager's gross profit  $bP$  (the dotted line) is everywhere below its cost. This depends obviously on  $b$ , but also on  $k$ :

<sup>17</sup>As a more general example, suppose  $C(p) = p/(1-p)$ , which satisfies Assumption 1 with equality, and  $k \geq 1/2$ . Then  $\gamma_1 = (8k-1)/4$  and  $P^{\text{AV}} = 1 - 1/(4k)$  for  $\gamma > \gamma_1$  while  $P^{\text{AV}} = \max\{\frac{\gamma}{1+\gamma}, \frac{4\gamma-1}{4\gamma+1}\}$  for  $\gamma \leq \gamma_1$ . Moreover,  $P^{\text{AC}} = 1 - 1/(2k)$ . Thus in Figure 3,  $P^{\text{AV}} = 0.875$  and  $P^{\text{AC}} = 0.75$ .



**Remark 1** *An increase of  $k$  drives out contract AC. If  $W = 0$  and  $b = \alpha k$  for any number  $\alpha > 0$ , then contract AC is unprofitable for all  $P \geq P^{AC}$  if  $k$  is sufficiently large.*

The first statement is easily shown:  $P \geq P^{AC}$  implies  $\text{cost}^{AC}(P) > C(P^{AC})$ . Since  $C(P)$  is strongly convex and  $P^{AC}$  is increasing in  $k$  (bounded only by 1),  $C(P^{AC})$  becomes arbitrarily large as  $k$  is increased.<sup>18</sup> In fact,  $k$  drives out contract AC very fast. The second statement (shown in the Appendix) strengthens this for the case  $W = 0$ : Even if  $b$  is tied to  $k$  by an arbitrary  $\alpha$ , an increase of  $k$  still drives out contract AC. Remark 1 will allow us to exclude the less interesting contract AC from consideration, by assuming that  $k$  is ‘sufficiently large’. At the same time this does not prevent us from assuming that  $b > \alpha k$  for some  $\alpha$ , if  $W = 0$ .

### 3.2.2 The effects of information dissipation on the feasibilities of contracts AV and AVD ( $\gamma < \infty$ )

When discussing the case  $\gamma < \infty$  we will disregard contract AC. Thus, according to Remark 1 we assume that  $k$  is sufficiently large (where its lower bound also depends on  $b$ ) and determine manager’s cost function only by reference to contracts AV and AVD.

For  $\gamma < \infty$  information dissipation comes into play. Consider first what happens to contract AV. By Proposition 1, once  $\gamma$  falls below  $\gamma_1$ , the feasibility range of AV falls with it, even vanishing as  $\gamma \rightarrow 0$ . For  $\gamma < \gamma_1$ , the critical  $P^{AV}$  is that  $P$  where the worker starts to substitute information dissipation efforts for work efforts, since the latter get increasingly costly. When the switch occurs, work effort falls drastically from  $\varphi_1(k/(1 - P)) \equiv P$  to  $\varphi_2(k/(1 - P)) < P$ . Failure on the firm’s part to anticipate this strategy would lead to a drastic loss of performance and efficiency.

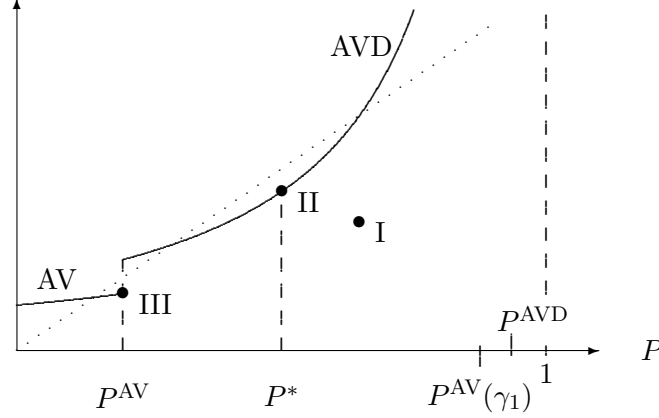
For  $\gamma < \infty$  contract AVD, which already presumes and induces dissipation, comes into play. There is of course always a prohibitive level of dissipation cost, say  $\gamma_h$ , such that contract AVD is not feasible at all if  $\gamma > \gamma_h$ . Once  $\gamma$  is below this  $\gamma_h$ , but still close to it, several less interesting subcases may emerge (if  $\gamma_h > \gamma_1$ ) which could only be characterized implicitly. However, for  $\gamma \leq \gamma_1$  these subcases have disappeared and a more regular structure of contracts obtains. Therefore we will focus on  $\gamma \leq \gamma_1$ . The following proposition states that, if  $\gamma$  is sufficiently low, contract AVD is always feasible for a range  $P \in (P^{AV}, P^{AVD}]$ :

**Proposition 3 (AVD–contracts)** *If contract AVD is feasible at all, there is a critical  $P^{AVD} \in (0, 1)$  such that it is only feasible for  $P \leq P^{AVD}$ . If  $\gamma \leq \gamma_1$  and  $P^{AVD} > P^{AV}$ , then contract AVD is feasible for all  $P \in (P^{AV}, P^{AVD}]$ .*

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<sup>18</sup>Note that this argument (and the whole of Remark 1) does not depend on the fact that  $k$  is a part of  $\text{cost}^{AC}$ .

expected cost



Curve AV: The cost induced by contract AV,  $k/(1 - P)$ . Contract AV is feasible for  $P \leq P^{AV}$ . For  $\gamma \geq \gamma_1 = 3.75$  the upper bound for AV would be given by  $P^{AV}(\gamma_1)$ , see Figure 3. However, since  $\gamma = 0.25$ ,  $P^{AV}$  is now much lower. Curve AVD: The cost induced by contract AVD,  $\frac{3+P}{1-P} \frac{k}{2}$ . Contract AVD is feasible for  $P \in (P^{AV}, P^{AVD}]$ . The dotted line is the firm's gross benefit,  $bP$ . Contract AC (not shown) is never relevant because it would imply a negative profit (see Figure 3). Point I is the optimal contract from Figure 3. Now the best AV-contract is point III. But this is dominated by point II, the best AVD-contract, which is therefore the optimal contract, and the optimal strength of incentives is  $P^* = 1 - \sqrt{2k/b}$ . Specifications as for Figure 3 except that  $\gamma = 0.25$ .<sup>19</sup>

Figure 4: Firm's cost function when  $W = 0$  and  $\gamma$  is low.

The critical  $P^{AVD}$  is increasing in  $k$ , with  $k \rightarrow \infty \Rightarrow P^{AVD} \rightarrow 1$ , and decreasing in  $\gamma$ , with  $\gamma \rightarrow 0 \Rightarrow P^{AVD}(\gamma) > P^{AV}(\gamma_1)$ .

The critical  $P^{AVD}$  emerges for the same reason as the critical  $P^{AV}$  in the case  $\gamma \geq \gamma_1$ : For  $P > P^{AVD}$  it does not pay any more for the worker to avoid inspection, since his effort cost  $C(P) + \gamma$  would be too high.

Note that it is possible that  $P^{AVD}(\gamma_1) < P^{AV}(\gamma_1)$ .<sup>20</sup> Contract AVD is then *irrelevant* for  $\gamma$  smaller, but close to  $\gamma_1$ . Although it is then *feasible* for some  $P \leq P^{AV}$ , these  $P$  can also, and cheaper, be induced by contract AV. However, a decrease of  $\gamma$  simultaneously reduces  $P^{AV}$  and raises  $P^{AVD}$ , by Propositions 1 and 3. At some  $\gamma > 0$  contract AVD does become relevant, i.e.  $P^{AVD}(\gamma) > P^{AV}(\gamma)$ . And for very low  $\gamma$ ,  $P^{AV}(\gamma)$  approaches zero while  $P^{AVD}(\gamma)$  gets even larger than  $P^{AV}(\gamma_1)$ .

<sup>19</sup>By fn.17 this example implies  $\gamma < \gamma_1 = 3.75$  and  $P^{AV} = \gamma/(1 + \gamma) = 0.2$ . Moreover,  $P^{AVD} = 0.934$ .

<sup>20</sup>One can show: If AVD is not feasible for  $\gamma > \gamma_1$ , then  $P^{AVD}(\gamma_1) < P^{AV}(\gamma_1)$ . Furthermore: The explicitly solvable examples  $C(p) = p/(1 - p)$  and  $C(p) = p/(1 - p)^2$  imply that AVD is not feasible for  $\gamma > \gamma_1$ .

Figure 4 illustrates the same example as Figure 3 (with another vertical scale) with the exception that  $\gamma$  is now fairly low. The feasibility range of contract AV is sharply reduced, since  $P^{\text{AV}}$  has fallen from  $P^{\text{AV}}(\gamma_1)$  (compare Figure 3) to a much lower level. In contrast, the relevant feasibility range ( $P^{\text{AV}}, P^{\text{AVD}}$ ] of contract AVD is quite large.

### 3.3 Contract design: The optimal contract

Having (partly) identified feasible and cost-minimal contracts for given  $P$ , we now turn to the optimal choice of incentives, which will be denoted by  $P^*$ , and the optimal type of contract implied by it. The manager chooses  $P^*$  in order to maximize the difference between his gross benefit  $bP$  and the lowest cost of inducing  $P$ . The latter depends on worker's seizable wealth  $W$ .<sup>21</sup> We will first analyze the case  $W = 0$  and then discuss the effects of an increase of  $W$ , mainly focusing on the other extreme  $W = \infty$ .

Before going on we note that our incentive contracts are efficiency wage contracts if the scope for 'bonding' is limited, i.e. if  $W$  is small. For *any*  $W$  and any contract type the 'quality of work', i.e. the worker's effort and productivity, is increasing in the wage  $w_h$  (while the low wage  $w_l$  is always reduced as far as possible). Thus, as in efficiency wage models, the wage directly drives the quality of the work delivered. Moreover, if  $W = 0$  the worker earns a rent in the firm (proof in Appendix):

**Remark 2** *If  $W = 0$ , the worker earns a strictly positive rent in the firm at almost all implementable  $P$ . The only exceptions might occur at (i)  $P = P^{\text{AV}}$  if  $\gamma \geq \gamma_1$  and (ii)  $P = P^{\text{AVD}}$  if contract AVD is used.*

#### 3.3.1 The case of limited liability ( $W = 0$ )

Start by dropping all restrictions mentioned on the parameters  $b$ ,  $k$ , and  $\gamma$  (except that they are strictly positive) and consider contract AV. With  $w_l = W = 0$ , the manager faces  $\text{cost}^{\text{AV}} = w_h = k/(1 - P)$ . Cost is independent of worker's effort cost function  $C(p)$  since the worker earns a rent. Expected profit is therefore  $bP - k/(1 - P)$ , which is maximized by

$$P = 1 - \sqrt{k/b}. \quad (11)$$

The resulting profit is non-negative if  $b \geq 4k$ . Note that statement 2 of Lemma 2 says that AV is cheaper than any other feasible contract, whether or not AV is itself feasible. Hence, if (11) satisfies  $P \leq P^{\text{AV}}$ , it is the *global* optimum, since it cannot be better to induce  $P > P^{\text{AV}}$

<sup>21</sup>In contrast,  $W$  does not affect the *feasibility* of any contract (by statement 1 of Lemma 2). As a consequence, the critical  $P^{\text{AV}}$ ,  $P^{\text{AC}}$ ,  $P^{\text{AVD}}$ , and  $\gamma_1$  of Propositions 1 to 3 are independent of  $W$ .

under a more costly contract. Thus, for  $W = 0$ :

$$\begin{aligned} \text{If } b < 4k & \quad \text{then } P^* = 0. \\ \text{If } b \geq 4k \text{ and } 1 - \sqrt{k/b} \leq P^{\text{AV}} & \quad \text{then } P^* = 1 - \sqrt{k/b} \text{ under contract AV.} \end{aligned} \quad (12)$$

The conditions  $b \geq 4k$  and  $1 - \sqrt{k/b} \leq P^{\text{AV}}$  are consistent if  $k$  and  $\gamma$  are sufficiently large.<sup>22</sup> In fact, if  $b = \alpha k$  for *any*  $\alpha > 0$ , then  $1 - \sqrt{k/b} \leq P^{\text{AV}}(\gamma_1)$  is satisfied for  $k$  sufficiently large, since Proposition 1 states that  $(k, \gamma) \rightarrow (\infty, \infty) \Rightarrow P^{\text{AV}} \rightarrow 1$ . Thus, (12) describes two relevant cases.

The result (11) is quite intuitive. The optimal strength of the incentives under contract AV increases with the incremental profits created by additional effort ( $b$ ) and decreases in the inspection cost ( $k$ ). If inspection cost increase, the worker will be safe from inspection at a lower effort level; to counteract this effect and restore evaluation incentives of the manager the wage would have to be increased. However, with the limited liability constraint binding, worker's rent would then also go up. Therefore it is not optimal to restore incentives in full; one would rather save a bit on the wage bill.<sup>23</sup>

Let's compare  $P$ , as given by (11), to the first-best effort given by (3). While the latter is independent of  $k$ , the former is decreasing in  $k$ , and it holds that  $k \geq b(1 - P^{fb})^2 \iff P \leq P^{fb}$ .<sup>24</sup> Consider also worker's rent under AV,  $w_h - C(P)$ : It is increasing in  $k$ , and it is increasing in  $b$  if  $P < P^{fb}$ , but decreasing in  $b$  if  $P > P^{fb}$ .<sup>25</sup> Obviously, if inspection cost are small, i.e.  $k < b(1 - P^{fb})^2$ , it pays for the firm to recoup part of the worker's rent by eliciting a high effort.

Starting from a situation where (12) holds, consider an increase of  $b$ , a decrease of  $k$ , or a decrease of  $\gamma$ . Clearly, when  $1 - \sqrt{k/b} \leq P^{\text{AV}}$  is violated just a bit, the manager will stay for a while with contract AV at  $P^* = P^{\text{AV}}$ , since the alternative contracts are pronouncedly more expensive. Only when  $b$  gets much higher, resp.  $k$  or  $\gamma$  much lower, he will finally switch to another contract. What happens then? We confine attention to the case that  $k$  is sufficiently

<sup>22</sup>In our example (fn.17):  $1 - \sqrt{k/b} \leq P^{\text{AV}} \iff \{16k^3 \geq b \text{ and } \gamma \geq (2\sqrt{b/k} - 1)/4\}$ . The first condition in the braces is consistent with  $b \geq 4k$  since  $k \geq 1/2$ . Thus, if the conditions in the braces are satisfied, then we know that  $P^* = 1 - \sqrt{k/b}$  under AV, without having to investigate the other contracts.

<sup>23</sup>At the optimum, the efficiency wage is  $k/(1 - P) = \sqrt{bk}$  and manager's profit is  $bP - k/(1 - P) = b - 2\sqrt{bk}$ .

<sup>24</sup>In our example (fn.17),  $P^{fb} = 1 - \sqrt{1/b}$  and therefore  $P^* \leq P^{fb} \iff k \geq 1$ . Both cases are possible, since any  $k \geq 1/2$  is admitted.

<sup>25</sup>Using  $w_h = k/(1 - P)$  and  $P = 1 - \sqrt{k/b}$  one obtains:

$$\begin{aligned} \frac{d \text{ rent}}{dk} &= \frac{1}{1 - P} + \frac{\partial P}{\partial k} \left[ \frac{k}{(1 - P)^2} - C'(P) \right] = 0.5\sqrt{b/k} + 0.5\sqrt{1/(kb)}C'(P) > 0 \\ \frac{d \text{ rent}}{db} &= \frac{\partial P}{\partial b} \left[ \frac{k}{(1 - P)^2} - C'(P) \right] = \frac{\sqrt{k/b}}{2b} [b - C'(P)] \geq 0 \iff P \leq P^{fb}. \end{aligned}$$

large so that contract AC drops out.<sup>26</sup> Note that by Remark 1 we can still have  $b > 4k$  or, if we wish,  $b > 40k$ .

**The effects of information dissipation on the optimal contract** Consider contract AVD. Under that contract expected profit is  $bP - (3 + P)k/[2(1 - P)]$ , independent of  $C(p)$  and  $\gamma$ . This expression is maximized by

$$P = 1 - \sqrt{2k/b}. \quad (13)$$

Note that  $1 - \sqrt{2k/b} \leq P^{\text{AVD}}$  holds if  $k$  is sufficiently large (Proposition 3). The resulting profit is non-negative if  $b \geq (7/2 + 2\sqrt{3})k \approx 7k$ . Optimal incentives under AVD, if given by the interior solution (13), have the same general properties as those under AV (where in this case  $P \leq P^{fb} \iff k \geq b(1 - P^{fb})^2/2$ ).

Comparing (13) and (11), one notes that incentives are always lower under AVD than they would be under AV if the latter's constraint were not binding. This is so because providing incentives under contract AVD is more expensive than under AV, both in absolute and marginal terms:

$$w_h^{\text{AVD}} - w_h^{\text{AV}} = \frac{(3 + P)k}{2(1 - P)} - \frac{k}{1 - P} = \frac{k(1 + P)}{2(1 - P)}. \quad (14)$$

This difference is positive and increasing in  $P$  and  $k$ . As information dissipation raises manager's expected inspection cost, a larger wage spread is needed to provide him with evaluation incentives. With  $W = 0$ , this means that a higher 'gross rent' (before deducing  $\gamma$ ) has to be given to the worker. It is then preferable to reduce incentives a bit compared to the case without information dissipation.

We are now able to draw a more complete picture of the effects of information dissipation. Suppose that  $k$  is sufficiently large, so that AC drops out and also  $1 - \sqrt{k/b} \leq P^{\text{AV}}(\gamma_1)$  holds. Consider a gradual decrease of the dissipation cost  $\gamma$ . By (12), all  $\gamma \geq \gamma_1$  imply  $P^* = 1 - \sqrt{k/b}$  under contract AV. Once  $\gamma$  falls short of  $\gamma_1$ ,  $P^{\text{AV}}$  decreases with  $\gamma$ . At some  $\gamma < \gamma_1$  the critical  $P^{\text{AV}}$  hits  $1 - \sqrt{k/b}$ . If, at that  $\gamma$ , contract AVD is already feasible for some interval  $(P^{\text{AV}}, P^{\text{AVD}}]$  (see Proposition 3), and  $\gamma$  falls further, the manager will not immediately jump to contract AVD. Instead, he will reduce incentives in order to avoid information dissipation, i.e. he stays at  $P^* = P^{\text{AV}}$  under contract AV. However, under that policy incentives have to be reduced more and more as  $\gamma$  decreases further. At some  $\gamma$  the manager will switch to contract AVD (if  $b > 7k$ ). At this point both the wage spread and the work incentives jump

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<sup>26</sup>Under contract AC profit would be  $bP - PC'(P) - k$  and optimal incentives characterized by  $C'(P^*) + P^*C''(P^*) = b$ , which is independent of  $k$  and implies  $P^* < P^{fb}$  if  $C''' \geq 0$ , by (3).

upward. Incentives jump from  $P^{AV}$  to  $\min\{1 - \sqrt{2k/b}, P^{AVD}\}$ , however, not as high as they were when  $\gamma$  was *very* high. As  $\gamma$  falls further optimal incentives will not respond any more.

Figure 4 above illustrates a situation shortly after the jump from  $P^{AV}$  to  $1 - \sqrt{2k/b}$ . The vertical distance between the dotted  $bP$ -line and point II is just a bit larger than that between the dotted line and point III. Thus, II is better than III. For a  $\gamma$  slightly higher than the one chosen in the figure it would be the other way round; point III would be a bit more to the right and optimal.

We can summarize the effects of information dissipation as follows. If dissipation cost  $\gamma$  is low, our above reasoning suggests that information dissipation makes it harder to set work incentives.<sup>27</sup> The manager softens incentives *either* because he wants to avoid dissipation *or* because he accepts dissipation and faces the problem that providing evaluation incentives to himself becomes more expensive, which implies (for  $W = 0$ ) that providing incentives to the worker becomes more expensive. Dissipation will only be accepted if  $\gamma$  is *very* low, so that avoiding dissipation would be too expensive in terms of foregone work incentives. When dissipation is accepted, wage and incentives are freed from this constraint and therefore make a pronounced upward jump.

### 3.3.2 The impact of the wealth constraint $W$

How robust are the results derived for  $W = 0$  to changes of  $W$ ? Consider the other extreme,  $W = \infty$ , where manager's expected cost is:  $\text{cost}^{AV} = C(P)$ ,  $\text{cost}^{AVD} = C(P) + \gamma$ ,  $\text{cost}^{AC} = C(P) + k$ . As before, confine attention to the following experiments: (i) For  $\gamma = \infty$ , so that AVD drops out, a gradual increase of  $b$  starting from zero. (ii) For  $k$  sufficiently large, so that AC drops out and (here)  $P^{AV}(\gamma_1) \geq P^{fb}$ , a gradual decrease of  $\gamma$  starting from infinity.

In both cases the manager starts with  $P^* = P^{fb}$  under contract AV, without any efficiency loss. Once  $P^{fb} > P^{AV}$ , he will stay at  $P^* = P^{AV}$  for a while in order to avoid agency cost of  $k$  resp.  $\gamma$ ; incentives are then distorted. Finally he will switch: In experiment (i) to contract AC with  $P^* = P^{fb}$ , in experiment (ii) at some  $\gamma < \gamma_1$  to contract AVD with  $P^* = \min\{P^{fb}, P^{AVD}\}$ .

Hence,  $W = 0$  and  $W = \infty$  yield qualitatively the same results in these experiments. For intermediate levels of  $W$  these patterns will still look similar, but the analysis would be more involved, since for every contract one would have to determine the ranges where the wealth constraint binds and where it doesn't.

The main difference (in these experiments) is that  $W = \infty$  always implies  $P^* \leq P^{fb}$  while  $W = 0$  may also imply  $P^* > P^{fb}$ . Moreover, the first-best incentives  $P^* = P^{fb}$  are more

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<sup>27</sup>This was demonstrated for the case  $P^{AV}(\gamma_1) \geq 1 - \sqrt{k/b}$ . Although the statement is not generally true, it seems to characterize the 'regular' case; see the discussion in section 3.4.

likely for  $W = \infty$  than for  $W = 0$ , since large fines can be levied on the worker (that  $W = \infty$  implies almost always  $w_l < 0$  is just a corollary of the efficiency wage result for  $W = 0$ ; Remark 2). Effectively, worker's private wealth is used to provide evaluation incentives for the manager. The more realistic case is that of limited liability, when evaluation incentives for the manager have to be provided by raising worker's wage. The worker then earns a rent, and this leads to more inefficiency. Some other differences between the cases  $W = 0$  and  $W = \infty$  will now be explored.

### 3.4 A possibility: Firms may prefer high inspection cost and may benefit from worker's information dissipation

While the manager wishes the parameters  $b$  and  $W$  to be as large as possible, his preferences concerning  $k$  and  $\gamma$  are not as clearcut. They will now be discussed.

What are the manager's preferences about  $(k, \gamma)$  jointly? This is easy to answer for  $W = \infty$ : He would then prefer  $\gamma = \infty$  and his own inspection cost  $k$  to be either zero or *large enough* to assure that  $P^{\text{AV}} \geq P^{\text{fb}}$ . If  $k = 0$ , contract AC is efficient (and AV not feasible at all).<sup>28</sup> But if  $k$  is restricted to a positive range, then AV is the only efficient contract. In order to assure  $P^{\text{AV}} \geq P^{\text{fb}}$  Proposition 1 requires that  $k$  and  $\gamma$  are sufficiently large. A high  $k$  is beneficial because it raises the wage spread that provides evaluation incentives under AV, and this keeps up the worker's incentives to deter evaluation. Note that it is costless for the manager to increase the wage spread, since he can draw on the worker's wealth.

If  $W = 0$ , the manager would also prefer  $\gamma = \infty$ , but his preferences concerning  $k$  are less clearcut because the wage spread needed to provide evaluation incentives cannot be levied on the worker any more. The manager would clearly prefer  $k$  to be zero or close to zero and use contract AC. But if that is not possible his second best choice of  $k$  would be such that  $1 - \sqrt{k/b} = P^{\text{AV}}$  just holds, because his profit function has a local maximum in  $k$  at that point.<sup>29</sup>

Now suppose  $k$  is fixed and large (so that AC drops out) and ask: What are the manager's preferences about the worker's cost of information dissipation  $\gamma$ ? Again this is easier to answer for  $W = \infty$ , where  $\text{cost}^{\text{AV}} = C(P)$  and  $\text{cost}^{\text{AVD}} = C(P) + \gamma$ . For  $\gamma \rightarrow 0$  the cost difference vanishes, and AVD gets feasible for a larger range of effort levels than AV, since  $\gamma \rightarrow 0 \Rightarrow P^{\text{AVD}}(\gamma) > P^{\text{AV}}(\gamma_1)$  by Proposition 3.<sup>30</sup> This is an advantage if high effort levels

<sup>28</sup>However, we have always assumed that  $k > 0$  and will continue to do so.

<sup>29</sup>To explain this: For small  $k$  the manager chooses an AC-contract ( $P^* > P^{\text{AV}}$ ) and profit is decreasing in  $k$ . As  $k$  increases, he switches at some point to  $P^* = P^{\text{AV}}$  under AV, and as long as it is optimal to stay there profit is increasing in  $k$ , since  $P^{\text{AV}}$  is. Once the *interior* AV-contract gets optimal,  $P^* = 1 - \sqrt{k/b} \leq P^{\text{AV}}$ , profit is again decreasing in  $k$ . In our example (fn.17),  $P^* = P^{\text{AV}} \iff k = \sqrt[3]{1/(16b)}$ .

<sup>30</sup>In the example of Figure 4:  $P^{\text{AV}}(\gamma_1) = 0.875$  and  $P^{\text{AVD}}(\gamma = 0) = 0.936$ .

are desired, i.e. if  $b$  is high, i.e. if  $P^{fb}$  is high. Indeed, if  $P^{fb} > P^{AV}(\gamma_1)$ , then there exists a  $\bar{\gamma} \in (0, \gamma_1)$  such that the manager strictly prefers all  $\gamma < \bar{\gamma}$  to all  $\gamma \geq \gamma_1$ .

The intuition is that worker's information dissipation raises manager's expected evaluation cost and thus has a similar effect as an increase of the inspection cost parameter  $k$ , which is generally desired when  $W = \infty$ . *It is therefore possible that a firm benefits from worker's information dissipation, because it allows to set stronger incentives.* It would then prefer dissipation cost to be as *low* as possible.<sup>31</sup> Note, however, that in contrast to an increase of  $k$  there is now a countereffect, since the worker has to be compensated for his dissipation effort under contract AVD when  $W = \infty$ .

For  $W = 0$ , it is far less probable that the manager profits from information dissipation. The reason is that his cost under AVD is then pronouncedly higher than that under AV, see (14). Note that this cost difference is independent of  $\gamma$ , i.e. it does not at all vanish for  $\gamma \rightarrow 0$  (as is the case if  $W = \infty$ ). Hence,  $b$  has to be *very* high if a low  $\gamma$  is to be desirable. For moderate levels of  $b$  the manager would clearly suffer from information dissipation and prefer  $\gamma$  to be *high*. We therefore conclude that this latter case is the 'regular' case.

## 4 Extension: Valuable on-the-job information

In modern firms obtaining workers' on-the-job information is often very important for entrepreneurial decisions. How do work incentives under subjective performance evaluation affect a worker's willingness to pass such information?

Suppose the worker observes  $s_\theta$  and the manager can make an additional non-contractible profit  $\pi \geq 0$  if he learns it.<sup>32</sup> Thus the value of this information is  $\pi$ . Two opposed cases have to be distinguished. First, suppose the additional profit  $\pi$  can be made *after* stage 4, the evaluation stage. Then, if the worker has dissipated information, there is an *additional incentive* for the manager to make an inspection, because finding a mistake in aspect  $\theta$  will reveal that  $s = s_\theta$  and enable the profit  $\pi$ . In other words, inspections have a positive side-effect for the manager when the worker has dissipated the information.<sup>33</sup> Then, for  $\pi$  high enough, *the worker will not dissipate information*, but rather leave it intact *in order to reduce manager's evaluation incentives*. As a consequence the feasibility range of contract AV will

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<sup>31</sup>Compare the literature cited in fn.7.

<sup>32</sup>This can easily be modeled: Suppose the manager can decide on a project or action as follows. In state  $s_A$ , a net gain of  $\pi$  can be made by taking an action  $a_A$ , but a net loss greater than  $\pi$  will result if another action  $a_B$  is taken. Vice versa for state  $s_B$ . Then he will only carry out a project if he has been informed about the state of nature.

<sup>33</sup>As a consequence,  $\varphi_2$  will raise to  $\frac{\pi+w-1.5k}{\pi+w+0.5k}$ . This is similar to the situation, mentioned in fn.11, that a mistake can be repaired after it has been found in an inspection. Then inspections also serve an extra purpose for the manager.



increase (weakly) and that of AVD will shrink (maybe even vanish).

However, suppose now that the profit opportunity is gone at stage 4. It is only available at stages 2 or 3. Then, making the profit  $\pi$  hinges on the working of pure communication (cheap talk) since the manager has no opportunity to find out  $s_\theta$  by himself in time. Moreover, since manager's evaluation decision at stage 4 is then independent of  $\pi$ , the feasibility ranges of contracts are unaffected by  $\pi$ . The worker is willing to inform his superior about  $s_\theta$  truthfully at stage 2 if and only if it is not worthwhile for him to dissipate this information, i.e. iff the second element of (6) is not its maximum. Therefore, the manager will make the additional profit  $\pi$  under contracts AV or AC, but not under contract AVD which spoils communication. We may therefore add  $\pi$  to the manager's cost under contract AVD. In Figure 4, the AVD curve shifts upwards by  $\pi$ . At some critical  $\pi$  the optimal contract would switch from point II with  $P^* = 1 - \sqrt{2k/b}$  to point III with  $P^* = P^{AV}$ . Although the latter contract provides only very weak work incentives, it restores the worker's willingness to pass his important on-the-job information.

This suggests that the demand for softening work incentives may be due to an organizational goal which is only loosely connected to the worker's original task. The critical  $\pi$  where the jump away from AVD occurs marks a shift in the firm's priorities concerning its employee: If  $\pi$  is below the critical level, he is primarily regarded as a production worker (AVD contract); if  $\pi$  is above it, he is primarily an information producer ( $P^* = P^{AV}$ ).

## 5 Summary

In a principal-agent model with a low degree of verifiability a contract has been derived that can be related to several stylized facts about subjective performance evaluation (SPE). We used this model to show the tension between incentives to work and incentives to communicate resp. cover-up under SPE. In this section we will first discuss our approach to SPE in light of the literature and then summarize our results on communication resp. information distortion.

**Subjective performance evaluation** We assumed that a performance appraisal depends on the manager's discretion but that it is not completely arbitrary, since the worker's remuneration eventually depends on 'verifiable' information. In practice, superiors have to explain and justify their appraisals to the workers, and sometimes even in courts, so that even SPE is to some degree 'objective'. One should think of the objective elements as some harder pieces of evidence, like an incident that cannot be denied by the worker. A subjective element is in the superior's decision whether to collect such pieces of incriminating evidence and defend them in the appraisal talks or not. In the model this is captured by the properties that the manager has to make a costly audit if he wants to blame the worker, but that he cannot

commit *ex ante* to make such an audit. Note that the purpose of an audit is to produce *bad* information about worker's performance.

Our approach to SPE differs particularly from that of Baker, Gibbons, and Murphy (1994) who assume that SPE is an implicit contract based on reputation. In their model SPE is always perfect if reputation works (and they discuss the conditions under which reputation works). However, as Prendergast and Topel (1993) noted, this approach makes it hard to model the particular distortions observed in practice which are due to subjectivity.<sup>34</sup> We therefore took the other extreme as a starting point and assumed that the manager cannot be trusted at all. He must then be required to justify his ratings, and the focus shifts to the cost of justification and the decisions involved.

Prendergast and Topel (1997) provide a model that captures some effects of subjectivity. In their model 'favoritism' is a personal preference of the superior towards his subordinate (altruism). In our model, in contrast, 'favoritism' is a prejudice of the superior about the performance of his worker. If he has the impression that a worker is good, he will not even bother to evaluate him accurately but rather give him a high ranking. On the other hand, if a worker has a bad standing in the eyes of his superior he will be inspected with scrutiny and may have to bear consequences. Thus, 'good workers' (the favorites) and 'bad workers' are treated differently. Such unequal treatment is very common in practice and often leads to conflicts and resentments on the part of the unfavored. In our simple model the latter kinds of problems are assumed away since the superior's impression of his worker is assumed to be perfect (he observes the 'objective' effort  $p$ ) and the worker perfectly adapts his effort to the level ( $P$ ) which makes him appear a 'good' worker.<sup>35</sup>

This model derives a nonlinear incentive scheme. The firm expects its worker to make a certain 'normal' effort (namely  $P$ ). A worker cannot expect much reward if his effort exceeds that normal level, instead of just meeting it; however, if it falls short of it, he has to be prepared to bear consequences. Such critical work standards seem to play a role in SPE.<sup>36</sup> In the model the punishment for not meeting the norm is admittedly a bit extreme,

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<sup>34</sup>Milkovich and Wigdor (1991, p.55,66) in their survey of the psychological literature list the following types of problems in performance ratings: leniency (a bias towards good ratings), restriction in range (or compression of ratings), personal bias (or favoritism), unreliability of ratings, and halo. Our model addresses some of these problems, as will be explained.

<sup>35</sup>In this summary we always refer to the contracts AV or AVD and disregard the less interesting contract AC which warrants a different interpretation.

<sup>36</sup>In the two firms investigated by Abraham and Medoff (1980), workers are evaluated against some level of performance deemed normal ("Expected Results" resp. "expected performance"). Milkovich and Wigdor (1991 Fig.6-1) present a representative 'sample merit grid' with five rating levels. However, it seems that level 3 ("fully satisfactory") is the critical norm an employee is expected to come up to. Most workers (70% ) just meet that standard and the reward for meeting it is substantial (3-5% wage increase whereas almost no wage increase is granted at rating levels 1 or 2; the rating levels 4 and 5 are associated with smaller steps in the

since the wage ( $w_l$ ) is then zero or even negative.<sup>37</sup> On the other hand, the punishment will never be imposed in equilibrium, which is consistent with the fact that managers tend to give top ratings to almost *all* employees (leniency and compression in ratings).<sup>38</sup> The flat-ratings phenomenon is often attributed to the fact that managers have weak incentives to make accurate appraisals, an explanation that conforms well to our model because the critical work effort which discourages inspection ( $\varphi_1$  resp.  $\varphi_2$ ) is a decreasing function of the superior's inspection cost ( $k$ ).

Note, however, that the flat-ratings phenomenon in itself need not indicate a problem, according to our model (in contrast to a conventional view). If the *threat* of a bad rating is still active, it may stimulate considerable effort. We have seen that an SPE contract can even implement the first-best by pure threats. This happens when the first-best effort is not too high and the worker is not protected by limited liability. However, this strong result implies that the worker has to pay large fines when blamed for a mistake. In the more realistic case of limited liability the SPE contract is an efficiency wage contract. It is then likely that the firm will elicit an effort which is different from the first-best, either too high or too low, so that there is an inefficiency.

**Information distortion** The sensitivity of SPE to interim information opens the door for distortions and influence activities. This paper has emphasized just one of the ensuing problems, namely, that threatening workers with inspection, without committing oneself to actually make them, tends to disturb internal communication. A worker's primary aim is to convince his manager that an inspection is a futile attempt — one way to achieve this is to work hard and show it, but another way is to build defenses against inspections. Workers tend to build up such defenses in various ways, they object being watched closely and learn tricks and strategies to hide information from their superiors.

This paper has abstracted from the possibility that a worker could also try to actually forge an inspection result, as well as from any form of collusion (recontracting). Its focus is on a more subtle, and more pervasive, effect of information manipulation. Superiors are sensitive to any information that stirs suspicions about a possible mistake or misbehavior of a

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wage increase).

<sup>37</sup>In more general terms, the model predicts that bad behavior is rarely detected but, if it is, leads to strong consequences. Landy and Farr (1980, p.80) note in their review of the empirical psychological literature: "These findings ... suggest that unfavorable information may be less accurately perceived but given more weight in the judgment process." This 'psychological' fact may have the 'economical' reason that unfavorable information will have to be defended in one way or another if it is to enter a report.

<sup>38</sup>See Abraham and Medoff (1980) or Baker, Jensen, and Murphy (1988). In the above-mentioned five-level 'sample merit grid' of Milkovich and Wigdor (1991 Fig.6-1), 90% of all employees are rated at levels 3 or 4 so that the ratings are compressed to two good rating levels.

subordinate. For a worker, preventing such suspicions to arise is the best way of escaping an accurate audit, and without an audit he cannot be blamed for anything. Hence, a worker has a strong incentive to withhold any information that might stir suspicions. As a consequence, a large portion of the information which is in principle available in a firm will be shielded away from the higher ranks who have the authority to decide on both personell and entrepreneurial matters.

The first major effect of information distortion is that it raises the cost of performance appraisals. Usually (i.e. under plausible circumstances) this makes it more costly to set work incentives. The second major effect is that the whole organization may suffer when the internal flow of information is disturbed. The only way to avoid information dissipation strategies or mitigate their consequences is to soften work incentives, i.e. reduce the ‘normal’ work standards. The model thus offers another explanation for the prevalence of relatively weak work incentives in organizations.

There are, however, some instances where a firm *benefits* from worker’s information dissipation, precisely because it allows to set *stronger* work incentives and still avoid the cost of actual inspections. This is so because the bonus for avoiding a mistake induces a sequential contest between the worker and the manager — where the manager can get the bonus by detecting a mistake, and the worker is the Stackelberg leader by choosing a work effort. If the bonus is not too high, the worker will assure himself the bonus by exerting a deterringly high effort, so that the manager will not make an inspection. However, at some critical size of the bonus the worker will drop this strategy for its high effort cost. Information dissipation makes it more difficult for the manager to find a mistake, putting him at a disadvantage in this sequential contest. If the bonus is raised to restore manager’s evaluation incentives, then worker’s incentive to choose the deterrence strategy increases strictly. From an ex ante perspective this means that higher efforts can be induced by the pure threat of inspection. However, it also means that worker’s rent goes up, if he is wealth-constrained.

It is therefore conceivable that a firm may actually facilitate information dissipation by its workers (compare the literature on strategic ignorance cited in fn.7). The firm will then expect a high ‘normal’ effort from its workers and set a high wage spread, i.e. announce strong negative consequences for a bad rating. In practice it could follow the policy that one single bad incident will foreclose promotion for a long time. However, several conditions have to be met for such a strategy to be optimal, so that this case should generally be seen as atypical (especially if the worker is wealth-constrained). One important condition would be that worker’s on-the-job information is unimportant, so that his productive potential is confined to his own task. Once his qualities as an information producer become more important the firm will once again try to prevent information dissipation and reduce work incentives in

order to improve the internal flow of information.

## Appendix: Proofs

### Proof of Lemma 1

The first inspection (say at aspect  $A$ ) reveals a mistake with probability  $0.5(1-p)$ . If the manager finds no mistake he updates the probability of finding one at the second inspection (at aspect  $B$ ) to  $\frac{0.5(1-p)}{0.5(1-p)+p} = \frac{1-p}{1+p}$ , compare Figure 1. Hence his payoff from the second inspection is  $\frac{1-p}{1+p}(w_h - w_l) - k$ .

The payoff from just one inspection is  $0.5(1-p)(w_h - w_l) - k$ . However, if this is positive, the second inspection is also profitable, since  $\frac{1-p}{1+p} > 0.5(1-p)$ . Thus, if inspection is profitable at all, the manager will continue to evaluate. His payoff from evaluation is  $(1-p)(w_h - w_l) - 0.5(1-p)k - [1 - 0.5(1-p)]2k$  (if there is a mistake it will eventually be found, and with probability  $[1 - 0.5(1-p)]$  there will be two inspections). This is positive iff (5) holds. ■

### Proof of Lemma 2

1. All feasibility conditions are linear in the wage spread  $w := w_h - w_l$ . This is clear for (8)–(10). Also  $\varphi_1$  and  $\varphi_2$  depend only on the wage spread  $w$ , see (4) and (5). The expressions in (6) are then also linear in  $w$ ; just subtract  $w_l$  from all of them.

2. For a given  $P$ , the manager's expected cost is

$$\begin{aligned} \text{cost}^{\text{AV}} &= w_h^{\text{AV}} = k/(1-P) + w_l^{\text{AV}} \\ \text{cost}^{\text{AC}} &= Pw_h^{\text{AC}} + (1-P)w_l^{\text{AC}} + k = PC'(P) + k + w_l^{\text{AC}} \\ \text{cost}^{\text{AVD}} &= w_h^{\text{AVD}} = \frac{(3+P)k}{2(1-P)} + w_l^{\text{AVD}}. \end{aligned}$$

By the first statement of this lemma,  $w_l$  will be reduced as far as possible.

Consider contract AV for a given  $P$ . If  $W \geq k/(1-P) - C(P)$  the participation constraint will be made binding by  $w_l^{\text{AV}} = C(P) - k/(1-P)$ , and  $\text{cost}^{\text{AV}} = C(p)$ . In the other case the wealth constraint will be made binding by  $w_l^{\text{AV}} = -W$ , and  $\text{cost}^{\text{AV}} = k/(1-P) - W$ .

Similar for AVD. If  $W \geq \frac{(3+P)k}{2(1-P)} - C(P) - \gamma$ , then  $\text{cost}^{\text{AVD}} = C(P) + \gamma \geq \frac{(3+P)k}{2(1-P)} - W$ . Otherwise,  $\text{cost}^{\text{AVD}} = \frac{(3+P)k}{2(1-P)} - W > C(P) + \gamma$ . Thus, in every case,  $\text{cost}^{\text{AV}} < \text{cost}^{\text{AVD}}$ .

Similar for AC. If  $W \geq PC'(P) - C(P)$ , then  $\text{cost}^{\text{AC}} = C(P) + k \geq PC'(P) + k - W$ . In the other case,  $\text{cost}^{\text{AC}} = PC'(P) + k - W \geq C(P) + k$ . Feasibility of AC for  $P$  requires that  $w = C'(P)$ , by (10), and  $P < \varphi_1(w)$ , since otherwise the worker would prefer to exert  $\varphi_1$  (formally, the third element of (6) must exceed the first one, which rewrites as  $(1-P)w \leq$

$C(\max\{\varphi_1(w), 0\}) - C(P)$ , and  $C$  is increasing). Thus feasibility requires  $\varphi_1^{-1}(P) < w$ , equivalent to  $k/(1 - P) < C'(P)$ , equivalent to  $k/(1 - P) - W < PC'(P) + k - W$ . Thus, whenever AC is feasible, then  $\text{cost}^{\text{AV}} < \text{cost}^{\text{AC}}$ . **3.** is trivial. **■**

### Proof of Proposition 1 (AV-contracts)

Contract AV is feasible for a *wage spread*  $w := w_h - w_l$  if and only if the first element of (6) weakly exceeds the others at that  $w$ . This yields two feasibility conditions which can then be translated into conditions in terms of  $P$  by use of (8).

Assumption 1 will mainly be used to sign the following derivatives: For  $i = 1, 2$ ,

$$dC(\varphi_i(w))/dw = C'(\varphi_i(w))\varphi_i'(w) = C'(\varphi_i(w))(1 - \varphi_i(w))^2/(ki) > 0. \quad (15)$$

**First condition: The first element of (6) weakly exceeds the third one.** By (6), the worker prefers  $\max\{\varphi_1(w), 0\}$  over  $\tilde{p}(w)$  if and only if

$$0 \leq (1 - \tilde{p}(w))w + C(\tilde{p}(w)) - C(\max\{\varphi_1(w), 0\}) =: \Psi_1(w). \quad (16)$$

One shows, using (15), that  $\Psi_1(w)$  is concave,  $\Psi_1(0) = 0$ ,  $\Psi_1(k) > 0$ , and  $\Psi_1(\infty) < 0$ . Hence the condition ' $\Psi_1(\hat{w}_1) = 0$  and  $\hat{w}_1 > 0$ ' yields exactly one  $\hat{w}_1 > k$ , and (16) is satisfied for all  $w \leq \hat{w}_1$ . This is equivalent to  $P \leq \varphi_1(\hat{w}_1) = 1 - k/\hat{w}_1 =: \hat{P}_1$ . Below we will see that  $\hat{P}_1 = P^{\text{AV}}$  for  $\gamma \geq \gamma_1$ . Note that  $\hat{P}_1$  is independent of  $\gamma$ . By differentiation of  $\Psi_1(\hat{w}_1) \equiv 0$  one shows that  $\frac{\partial \hat{w}_1}{\partial k} > \frac{\hat{w}_1}{k}$ ; use  $(1 - \varphi_1(\hat{w}_1))^2/k = k/\hat{w}_1^2$ . Hence  $\hat{P}_1$  is increasing in  $k$ . To see that  $k \rightarrow \infty \Rightarrow \hat{P}_1 \rightarrow \infty$ : (16) implies  $C(\tilde{p}(\hat{w}_1)) - C(\hat{P}_1) < 0$ , and the property follows from  $\hat{w}_1 > k$  and  $w \rightarrow \infty \Rightarrow \tilde{p}(w) \rightarrow 1$ .

**Second condition: The first element of (6) weakly exceeds the second one.** By (6), the worker prefers  $\max\{\varphi_1(w), 0\}$  over  $\max\{\varphi_2(w), 0\}$  if and only if

$$\gamma \geq C(\max\{\varphi_1(w), 0\}) - C(\max\{\varphi_2(w), 0\}) =: \Omega(w). \quad (17)$$

One shows, using (15), that  $\Omega(w)$  is zero for  $w \leq k$  and strictly increasing (its derivative bounded away from zero) for  $w > k$ . Hence there exists a critical  $\bar{w} > k$  such that condition (17) is satisfied if and only if  $w \leq \bar{w}$ . This is equivalent to  $P \leq \varphi_1(\bar{w}) = 1 - k/\bar{w} =: \bar{P}_1$ . Below we will see that  $\bar{P}_1 = P^{\text{AV}}$  for  $\gamma < \gamma_1$ . Since  $\bar{w}$  is increasing in  $\gamma$  (by differentiation of  $\Omega(\bar{w}) \equiv \gamma$ ) with  $\lim_{\gamma \rightarrow 0} \bar{w} = k$ , it follows that  $\bar{P}_1$  is increasing in  $\gamma$  with  $\gamma \rightarrow 0 \Rightarrow \bar{P}_1 \rightarrow 0$ . (17) yields the following characterization of  $\bar{P}_1$ :  $C(\bar{P}_1) - C\left(\max\left\{\frac{3\bar{P}_1 - 1}{3 - \bar{P}_1}, 0\right\}\right) = \gamma$ . Hence  $\bar{P}_1$  is independent of  $k$ .

**Necessary and sufficient condition.** We have thus shown that the necessary and sufficient feasibility condition of contract AV is  $P \leq \min\{\hat{P}_1, \bar{P}_1\} =: P^{\text{AV}}$ . The critical  $\gamma_1$  is given by  $\gamma_1 := \Omega(\hat{w}_1)$ , so that  $\gamma < \gamma_1 \iff \bar{w} < \hat{w}_1 \iff \bar{P}_1 < \hat{P}_1$ . Since  $\Omega(w)$  and  $\hat{w}_1(k)$  are increasing functions, so is  $\gamma_1(k)$ . ■

### Proof of Proposition 2 (AC–contracts)

This proposition is a byproduct of the proof of Proposition 1 (‘First condition’). There we have shown that the first element of (6) exceeds the third one if and only if  $w \leq \hat{w}_1$ . Hence, a *necessary* feasibility condition for contract AC is  $w \geq \hat{w}_1$ . For  $\gamma = \infty$  this is also sufficient. From (10),  $w \geq \hat{w}_1$  is equivalent to  $C'(P) \geq \hat{w}_1$ , i.e.  $P \geq \tilde{p}(\hat{w}_1) =: P^{\text{AC}}$ . Since  $\hat{w}_1$  is independent of  $\gamma$ , so is  $P^{\text{AC}}$ . Since  $\hat{w}_1(k)$  and  $\tilde{p}(\hat{w}_1)$  are increasing functions,  $P^{\text{AC}}$  is increasing in  $k$ . In the proof of Proposition 1 we have shown that  $k \rightarrow \infty$  implies  $\tilde{p}(\hat{w}_1) \rightarrow 1$ , i.e.  $P^{\text{AC}} \rightarrow 1$ . We have also seen that  $C(\tilde{p}(\hat{w}_1)) - C(\hat{P}_1) < 0$ . Since  $C$  is increasing and  $\hat{P}_1 = P^{\text{AV}}$  for  $\gamma \geq \gamma_1$ , this implies  $P^{\text{AC}} < P^{\text{AV}}(\gamma_1)$ . ■

### Proof of Remark 1

For  $W = 0$  manager’s profit under AC is  $bP - PC'(P) - k < P[b - C'(P)]$ . This is negative for all  $P \geq P^{\text{AC}}$  if  $b - C'(P^{\text{AC}}) < 0$ .

For  $k$  not too small it holds  $P^{\text{AC}} \equiv \tilde{p}(\hat{w}_1) = (C')^{-1}(\hat{w}_1) > 0$ ; see proof of Proposition 2. Using this and  $b = \alpha k$ :  $b - C'(P^{\text{AC}}) = \alpha k - \hat{w}_1$ . The proof of Proposition 1 (‘First condition’) showed that  $\frac{\partial \hat{w}_1}{\partial k} > \frac{\hat{w}_1}{k}$ . Therefore  $\hat{w}_1$  grows in  $k$  and will exceed  $\alpha k$ , for any  $\alpha$ . Hence  $b - C'(P^{\text{AC}})$  becomes negative for  $k$  sufficiently large. ■

### Proof of Proposition 3 (AVD–contracts)

**First condition: The second element of (6) weakly exceeds the third one.** By (6), the worker prefers  $\max\{\varphi_2(w), 0\}$  over  $\tilde{p}(w)$  if and only if

$$\gamma \leq (1 - \tilde{p}(w))w + C(\tilde{p}(w)) - C(\max\{\varphi_2(w), 0\}) = \Psi_2(w). \quad (18)$$

One shows, using (15), that  $\Psi_2(w)$  is concave,  $\Psi_2(0) = 0$ ,  $\Psi_2(1.5k) > 0$ , and  $\Psi_2(\infty) < 0$ . Denote  $\gamma_h := \arg \max_w \Psi_2(w)$ . If  $\gamma > \gamma_h$ , condition (18) cannot be satisfied for any  $w$ . If  $\gamma \leq \gamma_h$ , such that (18) holds for some  $w$ , then there exists a unique  $\hat{w}_2 > 1.5k$  such that (18) is violated for all  $w > \hat{w}_2$ . This yields the *necessary* feasibility condition:  $\gamma \leq \gamma_h$  and  $P \leq \varphi_2(\hat{w}_2) =: P^{\text{AVD}}$ . By differentiations of  $\Psi_2(\hat{w}_2) \equiv \gamma$  (for  $\gamma \leq \gamma_h$ ), one shows that  $\hat{w}_2$  is decreasing in  $\gamma$  and that  $\frac{\partial \hat{w}_2}{\partial k} > \frac{\hat{w}_2}{k}$ ; use  $(1 - \varphi_2(\hat{w}_2))^2 / (2k) = 2k / (\hat{w}_2 + 0.5k)^2$ .

Hence  $P^{\text{AVD}}$  is decreasing in  $\gamma$ , and  $\frac{\partial P^{\text{AVD}}}{\partial k} = \frac{2k}{(\hat{w}_2 + 0.5k)^2} \left[ \frac{\partial \hat{w}_2}{\partial k} - \frac{\hat{w}_2}{k} \right] > 0$ . As (16) and (18) imply  $\Psi_2(w) > \Psi_1(w)$  it follows:  $\gamma \rightarrow 0 \Rightarrow \hat{w}_2 > \hat{w}_1 \Rightarrow P^{\text{AVD}}(\gamma) > P^{\text{AV}}(\gamma_1)$ . To see that  $k \rightarrow \infty \Rightarrow P^{\text{AVD}} \rightarrow \infty$ , proceed similar as in the proof of Proposition 1 ('First condition').

**Second condition: The second element of (6) weakly exceeds the first one.** In the proof of Proposition 1 ('Second condition') we have shown that this condition is equivalent to  $\Omega(w) \geq \gamma$ , which is equivalent to  $w \geq \bar{w}$ . Defining  $\bar{P}_2 := \varphi_2(\bar{w})$  this translates into the necessary condition  $P \geq \bar{P}_2$  for contract AVD.

**Necessary and sufficient condition in terms of  $P$  when  $\gamma \leq \gamma_1$ .** The necessary and sufficient feasibility conditions for AVD are:  $\Psi_2(w) \geq \gamma$  and  $\Omega(w) \geq \gamma$ . The latter is condition is equivalent to  $w \geq \bar{w}$ . But  $w \leq \hat{w}_2$  is only *necessary* for  $\Psi_2(w) \geq \gamma$ . We want to show that  $\gamma \leq \gamma_1$  implies: (i)  $\bar{w} \leq \hat{w}_2$  and (ii) AVD is feasible *if and only if*  $w \in [\bar{w}, \hat{w}_2]$ .

Generally  $\Psi_2(w) \equiv \Psi_1(w) + \Omega(w)$ , by the definitions of these functions. This implies  $\Psi_2(\hat{w}_1) = 0 + \gamma_1 \geq \gamma$ , since  $\Psi_1(\hat{w}_1) = 0$  by definition of  $\hat{w}_1$ ,  $\gamma_1 := \Omega(\hat{w}_1)$ , and we assume  $\gamma \leq \gamma_1$ . But  $\Psi_2(\hat{w}_1) \geq \gamma$  implies  $\hat{w}_1 \leq \hat{w}_2$ , and since  $\gamma \leq \gamma_1$  implies  $\bar{w} \leq \hat{w}_1$ , we conclude that  $\bar{w} \leq \hat{w}_2$ . This is (i). Moreover,  $\Psi_2(\bar{w}) = \Psi_1(\bar{w}) + \gamma \geq \gamma$ , since  $\Omega(\bar{w}) = \gamma$  is just the definition of  $\bar{w}$  and  $\Psi_1(\bar{w}) \geq 0$  is implied by  $\bar{w} \leq \hat{w}_1$ . But  $\Psi_2(\bar{w}) \geq \gamma$  implies that  $\Psi_2(w) \geq \gamma$  holds for all  $w \in [\bar{w}, \hat{w}_2]$ , since  $\Psi_2(w)$  is humpshaped and cuts  $\gamma$  from above at  $\hat{w}_2$ . This is (ii).

Hence, AVD is feasible for  $\gamma \leq \gamma_1$  if and only if  $w \in [\bar{w}, \hat{w}_2]$  (non-empty), which is equivalent to  $P \in [\bar{P}_2, P^{\text{AVD}}]$ . Note that  $\gamma \leq \gamma_1$  implies  $P^{\text{AV}} = \bar{P}_1 = \varphi_1(\bar{w}) > \varphi_2(\bar{w}) = \bar{P}_2$ . By Proposition 1 and the above,  $\gamma \rightarrow 0 \Rightarrow P^{\text{AVD}} > P^{\text{AV}}$ . ■

## Proof of Remark 2

Since  $W = 0$  implies  $w_h = w$ , we obtain (using definitions (16) and (18) for AV resp. AVD):

$$\begin{aligned} \text{Worker's rent}^{\text{AV}} &= w - C(\varphi_1(w)) = \Psi_1(w) + \tilde{p}(w)w - C(\tilde{p}(w)). \\ \text{Worker's rent}^{\text{AVD}} &= w - C(\varphi_2(w)) - \gamma = \Psi_2(w) + \tilde{p}(w)w - C(\tilde{p}(w)). \\ \text{Worker's rent}^{\text{AC}} &= \tilde{p}(w)w - C(\tilde{p}(w)), \quad \text{where } \tilde{p}(w) \equiv P > 0. \end{aligned}$$

Since  $\tilde{p}(w)$  is the maximizer of worker's concave payoff  $pw - C(p)$ , the term  $\tilde{p}(w)w - C(\tilde{p}(w))$  is non-negative, and strictly positive if  $\tilde{p}(w) > 0$ . The proof of Propositions 1 ('First condition') showed that  $\Psi_1(w) \geq 0$  is a feasibility condition of AV and that under AV:  $P \in (0, P^{\text{AV}}) \Rightarrow \Psi_1(w) > 0$  (for  $\gamma < \gamma_1$  this holds even at  $P = P^{\text{AV}}$ ). Similar for AVD. ■



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