Would Less Financial Decentralization Reduce Public Sector Size across Sectors in Europe

Michele Cincera  
SBS-EM, ECARES, Université Libre de Bruxelles

Antonio Estache  
SBS-EM, ECARES, Université Libre de Bruxelles and CEPR

Alexander Wolf  
SBS-EM, ECARES, Université Libre de Bruxelles

ECARES working paper 2012-029
Abstract

We examine a hierarchical model where a principal hires a risk averse supervisor to monitor the effort exerted by a productive agent. We assume that the supervisor can misreport the collected evidence without incurring any cost. We develop a corruption-proof contract which makes it sequentially rational for the supervisor to report truthfully. Crucial features of our contract are the timing at which the report is sent and the supervisor’s payment scheme. In particular, the report must be sent before the outcome observation and the principal must reward the supervisor if and only if her report maximizes the conditional probability of the realized outcome. We also highlight a non-trivial interplay between corruption incentives, the signal precision and the supervisor’s risk aversion.

Keywords: Corruption, Moral Hazard, Soft Information, Supervision, Truthful Reporting.

1 Introduction

In many hierarchical organizations a supervisor is hired to reduce the information asymmetries between the principal and the productive agent. Frequently, the principal finds it difficult to assess the trustworthiness of the supervisor’s reports. This
problem becomes more severe when evidence can be easily manipulated. In the extreme, the supervisor can falsify evidence at negligible costs. We call this the case of purely-soft information.

Supervision based on purely-soft information may arise because reliable alternatives are excessively costly. This usually happens at the bottom levels of large organizations such as big corporations, financial institutions, law firms, etc. There, principals delegate monitoring activities to middle-level managers who observe the performances of their subordinates and set their compensations. Moreover, it may be the case that supervision based on purely-soft information is the only available option. This typically occurs in market regulation or in procurement of sophisticated goods, where principals typically lack the knowledge to understand technical aspects of products, projects, and investments and need to turn to an external expert who provides a subjective evaluation.

In all these cases, the agent is tempted to bribe the supervisor to obtain a favorable report. To avoid corruption, the principal has to design a corruption-proof contract to induce truthful reporting from the supervisor, as first pointed out by Tirole (1986). When information is purely-soft, the conventional wisdom in the literature is that corruption cannot be addressed and the principal is better off by dispensing with the supervisor. The intuition behind this claim is that with purely-soft information the supervisor has too much falsification power: if the supervisor can always maximize her payoff by manipulating evidence by herself, it would be impossible for the principal to induce truthful reporting without hurting the compensation scheme proposed to the agent (Laffont and Tirole, 1991a, Laffont and Tirole, 1991b and Khalil et al., 2010).

The main contribution of our paper is to show that the supervisor’s report can be useful in a framework where information is purely-soft. This result crucially depends on the timing at which this report is sent, which determines the completeness of the supervisor’s information about the state of the world. In particular, we consider a Moral Hazard setting where the effort exerted by a productive agent is imperfectly observed by a corruptible supervisor, whose report is based on purely-soft information. The effort randomly impacts on the verifiable outcome obtained by the principal of the organization.

If the report is asked after the profit realization, the supervisor’s report becomes useless, as claimed by the previous literature. In this case, the supervisor does not face any uncertainty about the state of nature when writing her report and she uses her falsification power to choose the message which maximizes her utility. This makes it unfeasible to ensure truthful reporting, thereby inducing the agent to exert no effort.

To make the supervisor’s report useful, it is necessary to require the report before the outcome realization. In this way, the completeness of the supervisor’s information about the state of the world is reduced. As the supervisor must choose her report under uncertainty, the impact of her falsification power is mitigated. Truthful reporting is then ensured by means of a payment scheme which rewards the supervisor if and only if her report is the most aligned with the realized outcome.

To highlight the robustness of our result, we consider circumstances that are
very unfavorable to the principal. Purely-soft information aside, we assign all the bargaining power to the supervisor at the side-contracting stage so that the lure of collusion is the highest possible. By doing so, the principal will have to take into consideration the tightest corruption incentive compatibility constraints. In addition, we do not introduce any exogenous limit to the ability of the parties to collude. The agent and the supervisor can write a perfectly enforceable side-contract before or after the outcome realization, and, unlike what is generally assumed in this strand of research, the side-transfers do not depreciate. We find that, even at these conditions, there exists a non-negligible set of parameter values such that our corruption-proof contract outperforms the alternative solution where the supervisor is not hired. Clearly, if we relax any of the assumptions mentioned above, the relative performance of the corruption-proof contract improves.

Furthermore, we find an intriguing and non-trivial interplay between the corruption incentives, the precision of the signal observed by the supervisor, and her degree of risk aversion. When the bribes the agent can afford to pay are high, the principal would prefer to hire a supervisor who is not excessively risk averse. In this case, a more precise signal reduces the cost of ensuring truthful reporting by the supervisor. On the other hand, when the potential bribes are low, we attain a counterintuitive result. In this case, it is better for the principal to hire a highly risk averse supervisor provided that the signal is not overly precise. As a result, the cost of implementing our mechanism does not always decrease in the signal precision.

Our result is in stark contrast to the existing literature on supervision in hierarchies. In this literature, the tightness of the constraints the principal needs to impose to deter corruption depends on the quality of the evidence the supervisor collects. Information is said to be hard when evidence can be hidden, but can be falsified by neither the supervisor alone nor by the agent-supervisor coalition. As a result, any threat of writing a report which hurts the agent (extortion/framing) is empty. The only relevant concern that the principal has to prevent is a collusive agreement (bribery) where both the agent and the supervisor benefit from the collective manipulation of the report. On the other hand, information is said to be soft when evidence can also be manipulated. Thus far, the literature has assumed that the supervisor can manipulate evidence only with the agent’s cooperation. By contrast, we consider a purely-soft information model in that evidence can also be manipulated by the supervisor alone at no cost.

The first contributions have considered collusive agreements only, whereas any threat of extortion has been ruled out by assumption. Kofman and Lawarree (1993) adapt the framework developed by Tirole (1986) for a soft-information case. They show that collusion between the supervisor and the agent can be addressed provided that a second and incorruptible supervisor is called to play with a positive probability. Baliga (1999) and Faure-Grimaud et al. (2003) work out a collusion-proof contract which requires that both the agent and the supervisor send a report on the

---

1 This is equivalent to assuming that, when there is room for corruption, the side-contract is signed with probability one.

2 In Tirole (1986), the author analyzes how to prevent the emergence of deviant coalitions when the supervisor collects hard evidence about the agent’s private information.
agent’s type. To deter bribery, the supervisor is rewarded when she sends reports which are unfavorable to the agent. Clearly, such a payment scheme creates incentives for extortion, but in these models the agent is endowed with an exit option when menaced by the supervisor.

Khalil et al. (2010) consider a moral-hazard setting in which the agent can be threatened by the supervisor. They show the existence of a trade-off between the two sides of corruption⁢³ and the find that in equilibrium it may be optimal to allow a certain amount of bribery, while extortion must always be prevented. The reason is straightforward: as the agent has to pay the supervisor not to hide positive evidence, extortion acts as a punishment after good behavior. Nevertheless, in their paper information is not purely soft: the supervisor can forge evidence only with the cooperation of the agent, whereas she bears an infinite cost when she tries to falsify evidence by herself. In our model, the trade-off between bribery and extortion disappears: the agent knows that the supervisor chooses the report under uncertainty and, once corruption-proof constraints are set, she is always better off reporting the truth. As a result, any threat of extortion becomes empty and bribery is the only relevant concern.

The remainder of the paper is organized as follows. In section 2 we develop our set-up. In section 3, we show that the common wisdom on purely-soft information is indeed valid whenever the report is asked after the outcome realization. In section 4, we present the corruption-proof contract and we illustrate the main findings of our paper. In section 5, we conclude.

2 The model

We consider a three-tier contracting relationship involving a principal, a supervisor, and an agent. The principal (it) is the owner of the firm and needs an agent (he) who carries out a productive task. Agent’s effort crucially affects the profit of the firm but it is unobservable by the principal. The principal may hire a supervisor (she) who is better informed about the agent’s effort choice. The principal ties the agent’s compensation to the realized profit and to a report filled out by the supervisor.

The agent is risk averse and receives a salary, \( w \), from the principal to perform his task. He decides whether to exert high or low effort, that is, \( e \) can take two values, \( e \in \{0; 1\} \). Effort implies a cost in terms of utility to the agent which is given by \( ge \) where \( g \) is a positive constant. The agent values his wage through a strictly increasing and strictly concave utility function \( u(w) \), which satisfies standard Inada conditions (i.e., \( u'(0) = +\infty \) and \( u'(+\infty) = 0 \)). The overall utility is given

---

³Their contribution aside, extortion has been analyzed only by assuming penalties imposed by some incorruptible enforcement agents. Moreover, most papers have focused on environments different from the internal hierarchy of a firm. For example, Mookherjee and Png (1995) and Hindriks et al. (1999) consider tax-evasion models and focus on reforms in public bureaucracies and on the redistributive properties of the tax scheme, respectively; Acemoglu and Verdier (2000) study the choice between a market failure and the bureaucratic corruption following government intervention. Finally, Polinsky and Shavell (2000) examine an optimal enforcement problem.
by: \( U(w, e) = u(w) - ge. \)

The principal is risk neutral and it is the residual claimant of the profit generated by the agent’s activity. The profit, \( \pi \), can take on only two values: \( \pi = \{\pi_l, \pi_h\} \), with \( \pi_h > \pi_l \). If the effort is high \( (e = 1) \), the profit is high with probability \( \gamma > 1/2 \).

Conversely, if the effort is low \( (e = 0) \), the profit is high with probability \( 1 - \gamma \).

The supervisor receives a monetary transfer \( t \) from the principal to monitor the agent. She can costlessly observe a signal \( s \in \{0, 1\} \) over the effort exerted by the agent which is correct with probability \( p \in (1/2, 1] \), while it is wrong with probability \( 1 - p \). The supervisor’s report \( r \) is defined on the same space as the signal and therefore it can take on two values, i.e., \( r = \{0; 1\} \). Her utility function is given by \( v(t) \), where \( v'(t) > 0 \) and \( v''(t) \leq 0 \), for any \( t \in \mathbb{R}^+ \). Both the agent and the supervisor are protected by limited liability, i.e., \( w \geq 0 \) and \( t \geq 0 \) and their outside option is normalized to zero. Being \( w \) and \( t \) contingent on both \( \pi \) and \( r \), we denote by \( w_{h1} \) and \( t_{h1} \) the transfers received by the agent and the supervisor, respectively, after \( \pi = \pi_h \) and \( r = 1 \). The other transfers are defined analogously.

Notice that the agent and the supervisor are both protected by limited liability. This implies that the principal needs to deal with the usual insurance-efficiency trade-off when contracting with the productive agent. This makes it attractive for the principal to buy the supervisor’s superior information set. However, its attractiveness is mitigated as the supervisor is also wealth-constrained. We also assume that both the agent and the supervisor are risk-averse to highlight how the principal can allocate risk between them to reduce the insurance cost.\(^5\)

We assume that the agent and the supervisor may make an enforceable side-contract before or after the agent makes his effort choice. The side-contract specifies the report the supervisor sends to the principal and a side-transfer which is function of both the realized profit and the report.

A distinguishing feature of our model is that information is assumed to be purely soft: as discussed in the Introduction, this implies that there are no exogenous limits to the supervisor’s ability to falsify evidence. Therefore she will rationally choose the report which maximizes her expected payoff.

Consistently with the literature on supervision, we assume that information is nested along the hierarchy. The agent has the finest information structure: he privately knows his effort decision and he observes the signal \( s \). The supervisor observes \( s \) only while the principal observes neither the effort nor the signal.

The timing of moves is the following:

1. the principal offers the general contract which specifies the transfers to the agent and to the supervisor as a function of the profit and of the supervisor’s report.

2. The supervisor and the agent simultaneously either accept or reject the principal’s offer: \(^4\)

\(^4\)If, more generally, we assume that \( Pr(\pi_h | e = 1) = \gamma \), and \( Pr(\pi_h | e = 0) = \eta \), with \( \gamma > \eta \), then it is possible to show that our results continue to hold.

\(^5\)See Section 4.3
(a) If the agent rejects the general contract, production does not take place and the game ends.
(b) If only the agent accepts the general contract, he will receive a compensation contingent solely on profit.
(c) If both the agent and the supervisor sign the general contract, they have a first opportunity to make an enforceable side-contract.

3. If the game continues, the agent decides whether to work \((e = 1)\) or to shirk \((e = 0)\).

4. If both agent and the supervisor signed the general contract, they observe the signal \(s\) and they have a second opportunity to write an enforceable side-contract.

In what follows we consider two alternative scenarios. First, we consider the case where the report is asked after the profit realization, in order to study what happens under purely-soft information if the time-line usually adopted in the literature is kept. Second, we show that the principal can benefit from requesting the report at a different timing.

3 The importance of the timing

Our first result concerns the role played by the timing of the report in determining whether the supervisor can be effectively trusted in a purely-soft information framework. In this section, we analyze what happens if, after having reached point 4, the game follows this time-line:

5.a. Profit realizes.
6.a. The supervisor sends the principal the report \(r\). This message is public information within the firm, i.e., the agent can observe it\(^6\). Transfers take place.

In the following proposition, we show that if the supervisor’s report is asked after the profit realization and information is purely soft, corruption cannot be deterred.

**Proposition 1.** If the report is sent after the profit realization and information is purely soft, it is impossible to simultaneously address the threats of bribery and extortion while guaranteeing that the agent exerts high effort.

**Proof.** This proof consists of three steps: first, we focus on the case where the supervisor is honest. Second, we allow for the supervisor to be corruptible but we temporarily ignore the threat of extortion, assuming that information is soft for the supervisor-agent coalition only. Finally, we take into account a purely-soft information framework.

\(^6\)The fact that the report is public information supports the idea that side-contracts are enforceable and allows to prevent the emergence of principal-supervisor coalitions.
1. As the supervisor is honest, the principal can buy her information set at zero cost\(^7\). If so, in its maximization problem the principal will only take into account the agent’s participation constraint (PC):

\[
g(\gamma[p(w_{h1}) + (1 - p)u(w_{h0})] + (1 - \gamma)[p(w_{l1}) + (1 - p)u(w_{l0})] - g ≥ 0 \quad (PC)
\]

and the agent’s incentive compatibility constraints (IC)\(^8\) which, after some simple algebra, can be rewritten as:

\[
(p + \gamma - 1)[u(w_{h1}) - u(w_{l0})] + (p - \gamma)[u(w_{l1}) - u(w_{h0})] ≥ g \quad (IC)
\]

It can be easily shown that (PC) is automatically satisfied once (IC) binds and the transfers are minimized. To induce the agent to exert high effort, he must receive a higher salary when the supervisor sends a positive report, for any possible state of nature, i.e., \(w_{r1} > w_{r0}\), \(\forall \pi \in \{\pi_h, \pi_l\}\). In this scenario, the first-best is achieved when \(p = 1\).

2. Since extortion is excluded by assumption, bribery is the only relevant issue. The agent is tempted to shirk and to offer the supervisor a bribe to report \(r = 1\) if she has observed \(s = 0\). To tackle collusion between the agent and the supervisor, the latter must receive a prize to report \(r = 0\), namely, \(t_{\pi0} ≥ \Delta w_{\pi} = w_{r1} - w_{r0}\), for any possible profit realization. Whereas, \(t_{\pi1}\) is optimally set equal to zero.

3. Once both sides of corruption are allowed, the rewards to prevent bribery create incentives for extortion. Since the report is sent after the profit realization, the supervisor can menace the agent to misreport evidence unless he transfers her the extra-wage he were entitled to receive after a good report, \(\Delta w_{\pi} = w_{r1} - w_{r0}\), \(\pi\) being known by the supervisor. The principal should impose \(t_{\pi1} ≥ t_{\pi0}\), \(\forall \pi \in \{\pi_l, \pi_h\}\) to address the threat of extortion. Note that this condition can be satisfied along with the no-bribery constraint, \(t_{\pi0} ≥ \Delta w_{\pi} = w_{r1} - w_{r0}\), only if \(t_{\pi1} = t_{\pi0}\), \(\forall \pi \in \{\pi_l, \pi_h\}\). As the supervisor receives the same transfer in any possible state of nature, she can be easily corrupted by the agent. As a result, the principal does not obtain any benefit from hiring the supervisor.

\[\Box\]

This proposition shows that, if the report is sent after the profit realization, the widely held claim that supervision is worthless when information is purely-soft is indeed valid. Maintaining this timing of the report, the previous literature has been forced to either depart from the assumption of purely soft information or to disregard the possibility of extortion.

---

\(^7\)This is equivalent to assuming that it is the principal who observes the signal \(s\).

\(^8\)The (IC) takes on the following form:

\[
(1 - \gamma)[pu(w_{h0}) + (1 - p)u(w_{h1})] + \gamma[pu(w_{l0}) + (1 - p)u(w_{l1})] ≥ g \quad (IC)
\]
4 The corruption-proof contract

In this Section we explore the possibility of tackling simultaneously bribery and extortion by requiring the report before the profit realizes. Stages 5 and 6 of the game become as follows:

5.b. The supervisor sends the principal the report $r$. Again, this message is public information within the firm.

6.b. Profit realizes and transfers take place.

Under this new timing, the supervisor is uncertain about the outcome realization and she selects the report which maximizes her expected utility. The principal must construct a mechanism that makes truthful reporting incentive compatible. To this end, the principal must impose the corruption incentive compatibility constraints in such a way that, at each information set of this sequential game, it is rational for the supervisor to report the truth. Since a high (low) effort level is positively correlated with high (low) profit and $p > 1/2$, to induce truthful reporting we must set:

$$t_{h1} \geq t_{h0},$$

and

$$t_{l0} \geq t_{l1}.$$  

In practice, the supervisor must be made effectively accountable for her report. Because of the supervisor’s limited liability, reports which are not aligned with the realized outcomes are set equal to zero in order to minimize the expected payment to the supervisor, while harsher punishments are not allowed. As a result, the optimal payment rule takes the following form:

$$t_{\pi r} \begin{cases} \geq 0 & \text{if } r = \arg \max Pr[\pi|e], \\ = 0 & \text{otherwise}, \end{cases}$$

for any $\pi \in \{\pi_l, \pi_h\}$. In words, the supervisor can be paid only if her report maximizes the conditional probability of the realized profit. Since we assume that $\gamma > 1/2$, the transfer rule implies that:

$$t_{hr} \begin{cases} \geq 0 & \text{if } r = 1, \\ = 0 & \text{otherwise}. \end{cases}$$

and

$$t_{lr} \begin{cases} \geq 0 & \text{if } r = 0, \\ = 0 & \text{otherwise}. \end{cases}$$

In the next subsection, we will set out the corruption constraints which will determine the actual values of the payments. Throughout the paper, we assume that the supervisor holds all the bargaining power at the side contracting stage. It is worth noticing that corruption could be prevented at a strictly lower cost if we assume a different bargaining power distribution.
4.1 The no-corruption constraints

Since the side-contract can be signed before or after that the signal has been observed, the principal has to take into account both ex-ante and ex-post corruption-proofness constraints. These are by no means related to the ex-ante and ex-post monitoring presented in other papers, for instance in Hiriart et al. (2010)\(^9\). There, the terms ex-ante and ex-post refer to whether the supervisory authorities carry out their monitoring activities before or after the occurrence of an accident. In our case, the terms ex-ante and ex-post refer to whether the agent and the supervisor collude before or after the signal observation.

Ex-ante bribery

A first corruption attempt may occur before the agent chooses his effort level: the agent may propose to make a side-contract wherein he will exert no effort and the supervisor will report high effort in exchange for a transfer. Formally, the side-contract is a triplet \(\{e = 0, r = 1, \tau_\pi\}\) where \(\tau_\pi = \{\tau_h, \tau_l\}\), is a profit contingent side-transfer from the agent to the supervisor. Since the supervisor holds all the bargaining power, \(\tau_\pi = \Delta w_\pi\) for any \(\pi \in \{\tau_h, \tau_l\}\). The supervisor will accept such a deal unless the expected payoff she will obtain by revealing the truth is higher than the expected side-transfer for both possible signal realizations \((s = 0\) and \(s = 1\)).

Thus we have the two first ex-Ante Corruption Incentive Compatibility constraints (ACIC1) and (ACIC2):

\[
\begin{align*}
&\frac{p\gamma v(t_{h1}) + (1 - p)(1 - \gamma) v(t_{h1})}{E(v(t)|s=1,r=1)} \geq \frac{(1 - \gamma) v(t_{h1} + \Delta w_h) + \gamma v(\Delta w_l)}{E(v(t,\Delta w)|e=0,r=1)} & \text{(ACIC1)} \\
&\frac{p\gamma v(t_{l0}) + (1 - p)(1 - \gamma) v(t_{l0})}{E(v(t)|s=0,r=0)} \geq \frac{(1 - \gamma) v(t_{h1} + \Delta w_h) + \gamma v(\Delta w_l)}{E(v(t,\Delta w)|e=0,r=1)} & \text{(ACIC2)}
\end{align*}
\]

Once the agent has exerted effort and the signal has been observed it must be sequentially rational for the supervisor to report truthfully. Therefore, when \(s = 1\), the following ex-Ante Corruption Incentive Compatibility constraint must hold:

\[
\begin{align*}
&\frac{p\gamma v(t_{h1}) + (1 - p)(1 - \gamma) v(t_{h1})}{E(v(t)|s=1,r=1)} \geq \frac{p(1 - \gamma) v(t_{h0}) + (1 - p) \gamma v(t_{l0})}{E(v(t)|s=1,r=0)} & \text{(ACIC3)}
\end{align*}
\]

Analogously, when \(s = 0\), it must be that:

\[
\begin{align*}
&\frac{p\gamma v(t_{l0}) + (1 - p)(1 - \gamma) v(t_{l0})}{E(v(t)|s=0,r=0)} \geq \frac{p(1 - \gamma) v(t_{h1}) + (1 - p) \gamma v(t_{h1})}{E(v(t)|s=0,r=1)} & \text{(ACIC4)}
\end{align*}
\]

It is worth noting that the construction of these constraints is the direct result of our mechanism: the supervisor is paid if and only if the conditional probability

\(^{9}\text{In their paper, the authors consider a hard-information framework in which the probability that the accident occurs stochastically depends on the effort exerted by the firm charged to undertake a risky activity. They show that separating ex-ante and ex-post monitors increases the likelihood of ex-post investigation, helping capture prevention and improving welfare.}\)
of the profit realization is maximized by the report she has sent.

**Ex-post bribery**

Further room for corruption may arise *ex-post*, when the signal is realized. If \( s = 0 \), the agent would have an incentive to bribe the supervisor. Again, as the supervisor holds all the bargaining power, the agent has to transfer her a bribe \( \Delta w_s \), for all \( \pi \in \{ \pi_h, \pi_l \} \). Had he eventually exerted effort, its cost would be sunk. In this case, the principal must set the following *ex-Post Corruption Incentive Compatibility* constraint to persuade the supervisor to reveal truthfully:

\[
\begin{align*}
\frac{p \gamma v(t_h) + (1 - p)(1 - \gamma)v(t_h)}{E(v(t)|s=0,r=0)} & \geq \\
\frac{p[(1 - \gamma)v(t_h + \Delta w_h) + \gamma v(\Delta w_l)] + (1 - p)[\gamma v(t_l + \Delta w_l) + (1 - \gamma)v(\Delta w_l)]}{E(v(t),\Delta w_r|s=0,r=1)}
\end{align*}
\]

**Extortion/Framing**

As defined by Khalil et al. (2010), *extortion* takes place when the supervisor obtains a payment from the agent by threatening him to send an unfavorable report. *Framing* occurs when the extortion fails and the supervisor puts into practice her threat. The agent accepts the extortion agreement only if framing is sequentially rational for the supervisor. In our setting, the supervisor may attempt to extort the agent twice: before (at stage 2) or after (at stage 4) the signal observation.

Before the signal is observed, the agent knows that the supervisor will find it worthwhile to take the realized signal into consideration when filling her report. This is because the agent knows that if he does not accept the extortion agreement, the supervisor is paid solely by the principal according to the payment-rule. Therefore, as the agent is not committed to any behavior, the supervisor is better off writing her report after having observed the signal so as to increase her amount of information. Since the agent anticipates that at stage 2 the supervisor has no incentive to commit herself to reporting \( r = 0 \) for each \( s \in \{0, 1\} \), any ex-ante framing menace is incredible.

As shown by the following Lemma, any extortion attempt taking place at stage 4 (*ex-post framing*) cannot be successful when bribery is prevented.

**Lemma 1.** If constraint (ACIC3) is fulfilled, any extortion threat from the supervisor to the agent is non-credible.

**Proof.** First, note that if \( s = 0 \), the supervisor has no incentives to send a positive report. Instead, if \( s = 1 \), the supervisor has incentives to threaten the agent to report \( r = 0 \). She will ask a profit-contingent bribe \( \Delta w_\pi \) for any \( \pi \in \{ \pi_h, \pi_l \} \). Nevertheless, the agent knows that if he rejects the side-contract the supervisor is better off reporting the signal she observed, i.e., \( r = 1 \), because of (ACIC3). Therefore the agent will never sign such a side-contract. \( \square \)
Corollary 1. Lemma 1 implies that our mechanism eliminates the trade-off between bribery and extortion that arises when the report is asked after the profit realization.

No-effort deal

Finally note that the principal also needs to discourage the supervisor-agent coalition from making a no-effort deal. There, the agent chooses \( e = 0 \), the supervisor truthfully reports \( r = 0 \) and makes a side-transfer to the agent to compensate him for the loss of the information rent. To prevent this kind of collusion, a new ex-ante corruption incentive compatibility constraint must be taken into account, the no-effort deal constraint:

\[
\frac{p\gamma v(t_{h1}) + (1-p)(1-\gamma)v(t_{h1})}{E(v(t)|s=1,r=1)} \geq \frac{\gamma v(t_{l0} - \xi)}{E(v(t)|e=0,r=0)} \quad \text{(NED)}
\]

where \( \xi = u^{-1}\left(\frac{UR}{\gamma}\right) \) is the expected equivalent transfer received by the agent and \( UR \) represents the value of the rent in terms of expected utility.

The following lemma clarifies which constraints are relevant in the principal’s maximization problem.

Lemma 2. For any given parametrization of the model, there exists an \( \varepsilon(\gamma, p, u, v) \in (0,1) \) such that the relevant constraints in the principal’s problem are:

1. (NED) and (PCIC) if \( p \geq 1 - \varepsilon \);
2. (ACIC3) and (PCIC) if \( p < 1 - \varepsilon \).

Proof. See Appendix A. \( \square \)

4.2 The principal’s problem

To obtain the corruption-proof transfers the principal minimizes the total expected transfer \( ET(s) \):

\[
\gamma[p(w_{h1} + t_{h1}) + (1-p)(w_{h0})] + (1-\gamma)[p(w_{l1}) + (1-p)(w_{l0} + t_{l0})]
\]

subject to (NED), (ACIC3), (PCIC), (IC), and to the agent’s and the supervisor’s limited liability constraints, \( w_{\pi,r} \geq 0 \) and \( t_{\pi} \geq 0 \), for any \( \pi \in \{\pi_h, \pi_l\} \) and for any \( r \in \{0; 1\} \). In light of Lemma 2, either (NED) or (ACIC3) will be taken into account in the maximization procedure. The other constraint will be checked ex-post.

The following propositions summarize our results:

Proposition 2. The corruption-proof contract implies that

(i) \( w_{h1}^* > 0 \);
(ii) \( w_{l1}^* > 0 \) only if \( p > \gamma \), while \( w_{l1}^* = 0 \) otherwise;
(iii) \( w_{h0}^* > 0 \) only if \( p < \gamma \), while \( w_{h0}^* = 0 \) otherwise;
(iv) \( w_{l0}^* = 0 \);

11
where the superscript s stands for the second-best solutions when the supervisor is hired.

Proof. See Appendix A. □

$w_{s1}^s$ is strictly positive only if the signal observed by the supervisor is relatively more informative than the profit about the agent’s choice. Conversely, $w_{h0}^s$ is strictly positive only if the signal is relatively less informative than the profit.

**Proposition 3.** The corruption-proof contract implies that

(i) if the supervisor perfectly observes the agent’s effort, $w_{h1}^s = w_{l1}^s = u^{-1}(g) = w^{fb}$, otherwise $w_{h1}^s > w_{l1}^s$;

(ii) for $p \in (1/2, 1]$, $w_{h1}^s > w_{h0}^s$;

(iii) the transfer received by the supervisor are $t_{h1}^s, t_{h0}^s > 0$, for any $p \in (1/2, 1]$;

where $w^{fb}$ refers to the first-best solution, where the principal directly observes the agent’s effort.

Proof. See Appendix A. □

If $p = 1$, the signal observed by the supervisor is a sufficient statistic for the agent’s effort. As a result, the principal may ignore the profit signal when setting the agent’s compensation. For $p \in (1/2, 1)$, both signals are employed to determine the amount of the contingent salaries.

More specifically, we have that:

a. for $p \in (\gamma, 1)$, the agent is paid only if $r = 1$, since the report of the supervisor is based on a signal which is relatively more precise than the profit. The profit signal only impacts on the difference between $w_{h1}$ and $w_{l1}$.

b. If $p = \gamma$, the agent is paid if and only if $\pi = \pi_h$ and $r = 1$.

c. For $p \in (1/2, \gamma)$, the principal pays the agent only when the profit turns out to be high, while $w_{l1}$ is set equal to zero as the signal that the supervisor observes is not very accurate and only affects the difference between $w_{h1}$ and $w_{h0}$.

Let us discuss the impact of $p$ on the expected total transfers paid by the principal. Not only does an increase in $p$ affect the expected wage paid to the agent, $Ew(s)$, but it also impacts on the expected transfer received by the supervisor, $Et(s)$.

While it is well-known that $Ew(s)$ is decreasing in $p$\textsuperscript{10}, it is less obvious whether a more accurate signal will reduce $Et(s)$. On the one hand, a more accurate signal reduces the cost of insuring the agent, and, as a result, it decreases the transfer $t_{h0}$ and $t_{h1}$ received by the supervisor. On the other hand, a more precise signal increases the probability with whom the supervisor is paid by the principal.

The following Remark summarizes the implications of these countervailing effects of the signal precision on the expected total transfer, $ET(s)$.

\textsuperscript{10}When a more precise statistic is available, lower salaries are needed to insure a risk-averse agent. See Holmstrom (1979) for further insights.
Proposition 4. A more precise signal has an ambiguous impact on the expected payment received by the supervisor, $Et(s)$. Consequently the overall effect of a higher $p$ on the total expected transfer, $ET(s)$, is uncertain.

Proof. See appendix A. □

As a result, it might be the case that the principal is better off hiring a supervisor whose monitoring skills are not excessively efficient.

In the next Subsection we highlight the existence of a non-trivial interplay between corruption incentives and the supervisor’s risk aversion. This discussion will also be helpful to understand the relationship between $p$ and the total expected transfer.

4.3 When to hire a supervisor

So far, we have focused on a three-tier hierarchy. Nevertheless, the principal may decide not to hire the supervisor and to tie the agent’s compensations to the profit only. This alternative organizational structure provides the benchmark to which we compare the corruption-proof contract. We will show that both options can be valuable. The ultimate choice depends on the potential gains from corruption and the supervisor’s risk-aversion.

For any given $p \in (1/2, 1]$, the potential gains from corruption, $\Delta w_h$ and $\Delta w_l$, are influenced by $g$, $\gamma$, as well as by the concavity of the agent’s utility function $u(\cdot)$. From (PCIC), we can see how the concavity of $v(\cdot)$ affects the impact of $\Delta w_h$ and $\Delta w_l$ on the transfers received by the supervisor, $t_{h1}$ and $t_{l0}$. For ease of exposition, we rewrite below the (PCIC):

$$\begin{align*}
&\frac{[2p\gamma + 1 - p - \gamma]v(t_{l0})}{E(v(t)|s=0, r=0)} \geq \frac{[p + \gamma - 2p\gamma]v(t_{h1} + \Delta w_h) + [2p\gamma + 1 - p - \gamma]v(\Delta w_l)}{E(v(t), \Delta w|s=0, r=1)} \tag{PCIC}
\end{align*}$$

If the supervisor does not collude with the agent, not only does she forego some bribes from the agent, but she also relinquishes a payment from the principal. However, while the agent would pay her in any possible state of nature, the principal’s payment would occur only in a relatively unlikely state given the observed signal. To prevent corruption, the principal pays the supervisor a transfer in a relatively more likely state. For the same reason, $t_{h1}$ and $t_{l0}$ will be higher than $\Delta w_h$ and $\Delta w_l$.

When the cost of inducing $e = 1$ is high (because $g$ is large or $\gamma$ is low or the agent’s degree of risk aversion is high) the principal is better off hiring a supervisor who is not particularly risk-averse. In this case, $\Delta w_h$ and $\Delta w_l$ are sizable and their relative impact on the utility of the supervisor rises with her degree of risk aversion.

Conversely, when it is relatively cheap to induce high effort (because $g$ is small or $\gamma$ is high or the agent’s degree of risk aversion is low), then $\Delta w_h$ and $\Delta w_l$ are rather small. However, they will be valued more by a supervisor who has a low degree of risk aversion. Therefore the principal can reduce the costs of the corruption-proof contract by employing a supervisor who has a higher degree of risk aversion.
To determine whether the principal will hire a supervisor, we need to consider the solution to the standard principal-agent problem. In our case, the principal would choose $w_h$ and $w_l$ to minimize the following program:

$$\gamma w_h + (1 - \gamma) w_l$$

subject to the agent’s participation and incentive compatibility constraints. It is easy to show that the agent is paid a salary $w_{ns}^h = u^{-1}\left(\frac{g}{2\gamma - 1}\right)$ if the profit is high and $w_{ns}^l = 0$ otherwise.

By sequential rationality, the principal will hire the supervisor if and only if the expected total transfer he has to pay under the corruption-proof contract, $ET(s)$, is smaller or equal than under the standard solution without the supervisor, $ET(ns) = \gamma w_{ns}^h$. This choice crucially depends on the specific functional forms of $u(\cdot)$ and $v(\cdot)$, as well as on the other parameters ($g$, $p$, and $\gamma$).

To show that both organizational forms can be profitable, we assume that the agent and the supervisor’s preferences are described by two different constant absolute risk aversion (CARA) utility functions, as it is commonly assumed in this literature\(^{11}\). This numerical exercise is also useful to illustrate the interplay between the corruption incentives and the supervisor’s risk aversion depicted above. Let $\alpha$ and $\sigma$ denote the agent and the supervisor’s degree of absolute risk aversion, respectively. In Appendix B, we set out the optimal transfer values implied by the corruption-proof contract and by the standard principal-agent hierarchy.

In Figure 1 we compare the expected cost of the corruption-proof contract (the continuous line) and of the standard solution (dotted line) as a function of $\sigma$ for two different values of $\alpha$. The other parameters are held constant\(^{12}\).

![Figure 1: Impact of a change in $\alpha$ on the expected transfers as functions of $\sigma$.](image)

When the agent is almost risk neutral (figure 1.a), the principal does not need to pay him high salaries. As long as the supervisor is not too risk averse, she can be easily corrupted since she cares about the total expected transfer rather than the way these transfers are distributed over the states of nature. Nevertheless, as $\sigma$ increases, it becomes increasingly cheaper for the principal to prevent collusion.

\(^{11}\)We have also tested other concave utility functions.

\(^{12}\)In particular, $\gamma = 0.65$, $g = 0.7$, $p = 0.92$. 

14
and, as a result, the principal will hire a supervisor only if she is sufficiently risk averse.

On the other hand, when the degree of risk aversion of the agent rises (figure 1.b), the agent receives higher salaries and thereby he can afford to pay higher bribes to the supervisor. Then, when \( \sigma \) is high, it is very costly for the principal to improve upon the insurance scheme offered by the agent. In this case, the principal will hire a supervisor only if she is not excessively risk averse.

By way of example, here we have just considered the impact of different values of \( \alpha \) on the expected transfers as functions of \( \sigma \). In Appendix B we show that changes in \( \gamma \) and \( g \) have a similar impact.

We have not yet investigated the effect of a change in the signal precision on the principal’s choice. In Proposition 4 we highlighted that \( p \) plays an ambiguous role because a higher \( p \) may result in a higher or lower expected transfer to the supervisor, \( ET(s) \). Starting from the two situations depicted above, we can see that the impact of an increase in \( p \) has an opposite sign on \( ET(s) \) depending on the magnitude of the potential gains from corruption.

When the cost of inducing \( e = 1 \) is relatively low, the salaries received by the agent are not particularly high and thereby the corruption incentives are rather low. In this scenario, if \( p \) goes up, the effect of the increase in the probability of paying the supervisor and the agent outweighs the reduction of the transfers paid by the principal and, paradoxically, the expected total transfer increases in \( p \).

On the other hand, when it is costly to induce high effort a more precise signal considerably reduces the sizable incentive compatible salaries paid to the agent. This implies a decrease of \( ET(s) \) because this effect dominates the higher probability with which the supervisor and the agent are paid.

These intuitions are graphically shown in Figures 2.a and 2.b, where the behavior of the expected total transfers as functions of \( p \) are depicted for two different combinations of \( \alpha \) and \( \sigma \). For ease of comparison, we keep the other parameter values as in Figures 1.a and 1.b.

![Figure 2: Impact of a change in \( \sigma \) and \( \alpha \) on the expected transfers as functions of \( p \).](image)

In figure 2.a we consider a scenario in which \( \alpha = 0.1 \) and \( \sigma = 0.6 \). As we can see, the principal decides to hire the supervisor if and only if the signal she collects has a precision lower than roughly 0.94. By contrast, in figure 2.b, \( \alpha \) and \( \gamma \) are set
equal to 0.4 and 0.2, respectively. Here, the principal finds it worthwhile to hire a supervisor if and only if \( p \) is above approximately 0.85.

From a qualitative perspective, our findings are robust to several parametrization of the model. These and other numerical exercises also show that the corruption-proof contract dominates the solution without the supervisor for an open set of parameter values and for different specification of the utility functions. Undoubtedly, the range of values for which the corruption-proof contract proves superior to its alternative would increase if we eased any of the assumptions held so far, e.g. by assuming that the side-transfers depreciated at a rate \( \delta \in (0, 1) \).

5 Conclusions

In this paper we have shown how the principal can benefit from the superior information set of a corruptible supervisor when the latter can falsify her report without costs. This result stands in contrast to the previous literature, which dismissed the usefulness of supervision in presence of purely-soft information.

Main features of our corruption-proof contract are (i) the timing of the report, which is asked before the profit realization, and (ii) the contingent payment scheme. Taken together, they make it sequentially rational for the supervisor to choose a truthful reporting strategy.

In spite of assuming very unfavorable conditions for the principal, our corruption-proof contract proves superior to the standard solution for a non-negligible set of parameters.

Finally, we have also highlighted an interesting interplay between corruption incentives and the supervisor’s risk aversion. In particular, when the potential gains from corruption are low, the principal prefers to hire a relatively highly risk-averse supervisor whose monitoring skills are not overly efficient. Conversely, when the potential gains from corruption are high, the principal is better off hiring a less risk-averse supervisor. In this case, the higher the signal precision, the lower the cost of ensuring truthful reporting.

References


Appendix A

Proof of Lemma 2

This proof consists of four steps.

1. First, consider (PCIC) and (ACIC2). Notice that they share the same left-hand side. If we subtract to the right-hand side of the former the right-hand side of the latter, we obtain

\[(p + 2\gamma - 2p\gamma - 1)[v(t_{h1} + \Delta w_h) - v(\Delta w_l)]\]

Since for any \(p \in (2, 1]\), \(\Delta w_h \geq \Delta w_l\) and \(t_{h1} > 0\), the expression above is strictly positive if and only if \(p(1 - 2\gamma) > 1 - 2\gamma\), i.e., when \(p < 1\). Thus, (PCIC) implies (ACIC2).

2. Furthermore, for any \(\Delta w_{\pi} \geq 0\), with \(\pi = \{\pi_h, \pi_l\}\), (PCIC) implies (ACIC4). Therefore, (PCIC) rules out two constraints and explicitly sets the values of \(t_{l0}\) such that it is sequentially rational for the supervisor reporting \(r = 0\) whenever \(s = 0\) is observed. To minimize the expected cost of truthful reporting, (PCIC) must be binding in equilibrium.
3. (NED) and (ACIC1) share the same left-hand side. Since (PCIC) is binding, it is possible to rewrite the right-hand side of (ACIC1) as the left-hand side of (PCIC) minus the difference between the right-hand side of (PCIC) and the right-hand side of (ACIC1), i.e. $E(v(t, \Delta w)|e = 0, r = 1) = (ACIC)^{rhs} = (PCIC)^{rhs} - [(PCIC)^{rhs} - (ACIC)^{rhs}]$. Therefore, the supervisor’s expected utility to report $r = 1$ when $e = 0$ can be written as:

$$E(v(t, \Delta w)|e = 0, r = 1) = (2p\gamma + 1 - p - \gamma)v(t_0) - (2\gamma - 1)(1 - p)[v(t_h + \Delta w_h) - v(\Delta w_l)].$$

By taking the difference between the equation above and the right-hand side of (NED), we obtain that the right-hand side of (ACIC1) is greater than the right-hand side of (NED) if and only if

$$p > \frac{\gamma v(t_0 - \xi) + (2\gamma - 1)[v(t_h + \Delta w_h) - v(\Delta w_l)] - (1 - \gamma)v(t_0)}{(2\gamma - 1)[v(t_0) + v(t_h + \Delta w_h) - v(\Delta w_l)]} = A.$$

This threshold $A$ is smaller than one if and only if $\gamma[v(t_0 - \xi) - v(t_0)] > 0$, which is not the case for any positive rent obtained by the agent. As a result, for any $p \in (1/2; 1)$, (ACIC1) is automatically satisfied once (NED) holds, while they are equivalent for $p = 1$ (in this case, the agent does not obtain a rent). Therefore, we can simply get rid of (ACIC1).

4. Finally, (NED) and (ACIC3) share the same left-hand side. Let us consider the difference between the right-hand side of (NED) and the right-hand side of (ACIC3), i.e.:

$$\gamma v(t_0 - \xi) - (p + \gamma - 2p\gamma)v(t_0).$$

This difference is greater than zero if and only if the following condition holds:

$$p > \frac{\gamma v(t_0) - v(t_0 - \xi)}{(2\gamma - 1)v(t_0)} = B.$$

Notice that, when $\xi$ is low, the signal precision can be even very small for this inequality to be respected. Furthermore, $\xi$ is strictly decreasing in $p$. At the polar case $p = 1$, $\xi = 0$. We can conclude that there exists a left neighborhood of $p = 1$, say $[1 - \varepsilon; 1]$ such that (ACIC3) is automatically satisfied once (NED) holds for any $p \in [1 - \varepsilon; 1]$. On the other hand, (ACIC3) implies (NED) for any $p < 1$. \qed

**Proof of Proposition 2**

Here we solve a sub-constrained version of the principal’s problem, where we temporarily ignore (NED), (PCIC) and (ACIC3). By doing so, we find the optimal wages $w_{\pi r}$, $\pi = \{\pi_l, \pi_h\}$ and $r = \{0, 1\}$ which satisfy the agent incentive compatibility constraint and then we retrieve the minimum values of $t_{h1}$ and $t_0$ by making (PCIC) and one between (NED) and (ACIC3) bind. Then we check for limited liability constraints ex-post.
\[ \mathcal{L}^s = \gamma [\pi_h - p(t_{h1} + w_{h1}) - (1 - p)(w_{h0})] + (1 - \gamma)\pi_l - p(t_{l1} + (1 - p)(t_{l0} + w_{l0})] + \lambda [(p + \gamma - 1)u(w_{h1}) + (p - \gamma)u(w_{l1}) + (\gamma - p)u(w_{h0}) + (1 - p - \gamma)u(w_{l0}) - g] \]

FOCs
\[
\begin{align*}
\frac{\partial \mathcal{L}^s}{\partial w_{h1}} & = 0 \Rightarrow -p\gamma + \lambda [p + \gamma - 1]u'(w_{h1}) = 0 \quad (1) \\
\frac{\partial \mathcal{L}^s}{\partial w_{l1}} & = 0 \Rightarrow -p(1 - \gamma) + \lambda [p - \gamma]u'(w_{l1}) = 0 \quad (2) \\
\frac{\partial \mathcal{L}^s}{\partial w_{h0}} & = 0 \Rightarrow -(1 - p)\gamma + \lambda [\gamma - p]u'(w_{h0}) = 0 \quad (3) \\
\frac{\partial \mathcal{L}^s}{\partial w_{l0}} & = 0 \Rightarrow -(1 - p)(1 - \gamma) + \lambda [1 - p - \gamma]u'(w_{l0}) = 0 \quad (4)
\end{align*}
\]

i Provided that \( \lambda > 0 \), FOC (1) can be rewritten as
\[ \lambda = \frac{p\gamma}{[p + \gamma - 1]u'(w_{h1})}, \]
which tells us that \( w_{h1}^* \) is always positive for \( p \in (1/2, 1] \).

ii It is possible to rewrite FOC (2) as
\[ \lambda = \frac{(1 - \gamma)p}{[p - \gamma]u'(w_{l1})}, \]
thus, \( w_{l1}^* > 0 \) only if \( p > \gamma \).

iii Similarly, from FOC (3) we know that
\[ \lambda = \frac{\gamma(1 - p)}{[\gamma - p]u'(w_{h0})}. \]
Since the RHS of the equation above is nonnegative only if \( p < \gamma \).

iv By FOC (4) we can easily see that \( w_{l0}^* \) cannot be positive for any combination of \( p \in (1/2, 1] \) and \( \gamma \in (1/2, 1] \).

\[ \square \]

**Proof of Proposition 3**

i By FOCs (1) and (2) we know that, at the optimum it must be
\[ \frac{u'(w_{l1})}{u'(w_{h1})} = \frac{(1 - \gamma)[p + \gamma - 1]}{\gamma [p - \gamma]} \quad (5) \]
The right-hand side of (5) is strictly greater than 1 if and only if \( p(1 - 2\gamma) - 1 + 2\gamma > 0 \), i.e. if \( p < 1 \). For \( p = 1 \), (5) can be rewritten as
\[ \frac{u'(w_{l1})}{u'(w_{h1})} = \frac{1 - \gamma}{\gamma} \frac{\gamma}{(1 - \gamma)} = 1. \]
Since for $\gamma < 1$, and $p = 1$ Proposition 2 shows that $w_{h0}^s = w_{l0}^s = 0$, once we replace the equation above into the (IC) constraint, we find that the agent obtains the first-best salary independently of the profits level, otherwise $w_{h1}^s > w_{l1}^s$.

ii FOCs (1) and (3) imply the following condition

$$\frac{u'(w_{h0})}{u'(w_{h1})} = \frac{(1 - p)[p + \gamma - 1]}{p[\gamma - p]}, \tag{6}$$

The right-hand side of (6) is greater than one if and only if $p^2(1 - \gamma) > (1 - \gamma)$ which is always satisfied for $p > 1/2$. In this case, $w_{h1}^s > w_{l0}^s$ and the agent has a potential incentive to bribe the supervisor ($\Delta w_h > 0$).

iii Since for any $p \in (1/2, 1]$ we have $\Delta w_h > 0$ and $\Delta w_l \geq 0$, the corruption-proof contract must imply $t_{h}^s, t_{l}^s > 0$.

Proof of Proposition 4

The total expected transfer is:

$$ET(s) = \gamma[p(w_{h1}^s + t_{h}^s) + (1 - p)(w_{l0}^s)] + (1 - \gamma)[p(w_{l1}^s) + (1 - p)(w_{l0}^s + t_{l}^s)]$$

As this function is separable in the transfers to the agent and to the supervisor, the partial derivative with respect to $p$ can be written as:

$$\frac{\partial ET(s)}{\partial p} = \frac{\partial Ew(s)}{\partial p} + \frac{\partial Et(s)}{\partial p} \tag{7}$$

where the first summand of the right-hand side is:

$$\frac{\partial Ew(s)}{\partial p} = \gamma w_{h1} + p\gamma \frac{\partial w_{h1}}{\partial p} - \gamma w_{l0} + (1 - p)\gamma \frac{\partial w_{l0}}{\partial p} + (1 - \gamma)w_{l1}$$

$$+ p(1 - \gamma) \frac{\partial w_{l1}}{\partial p} - (1 - \gamma)w_{l0} + (1 - p)(1 - \gamma) \frac{\partial w_{l0}}{\partial p}$$

Holmstrom (1979) shows that when a more precise signal is employed, the agent is paid a lower salary with a higher probability and, thanks to the concavity of the agent’s utility function, the net effect on $Ew(s)$ is negative. As a result, $\Delta w$ is also decreasing in $p$.

The second summand of the right-hand side of equation 7 is:

$$\frac{\partial Et(s)}{\partial p} = \gamma t_{h1} + p\gamma \frac{\partial t_{h1}}{\partial p} - (1 - \gamma)t_{l0} + (1 - p)(1 - \gamma) \frac{\partial t_{l0}}{\partial p}$$

Here, we can disentangle the effect of $p$ on the probability of paying the supervisor ($p(1 - \gamma) t_{l0}$), which is positive for $t_{h1} > \frac{1-\gamma}{\gamma} t_{l0}$, from that on the transfers $t_{h1}$ and $t_{l0}$, which depends on the shape of the utility functions and on the parameters values. Thus, the overall effect is a-priori uncertain.
Appendix B

Constant absolute risk aversion utility functions

For the numerical exercise shown in the text, we just consider the case where \( p > \gamma \). If the agent and the supervisor’s utility functions are represented by \( u(w) = \frac{1}{\alpha} \left[ 1 - e^{-\alpha w} \right] \) and \( v(t) = \frac{1}{\sigma} \left[ 1 - e^{-\sigma t} \right] \) respectively, (5) can be rewritten as \( \frac{e^{wh}}{e^{wl}} = \left( \frac{1 - \gamma}{\gamma} \right)^{p + \gamma - 1} \). Thus,

\[
wh_1 = w_{l1} + \frac{1}{\alpha} \ln \left[ \frac{(1 - \gamma) p + \gamma - 1}{\gamma} \right] \quad (8)
\]

For such high values of \( p \), by substituting (8) into the (IC) constraint, we obtain

\[
[p + \gamma - 1] \left[ 1 - e^{-\alpha w_{l1}} \right] = g \alpha \left[ 1 - e^{-\sigma t_{l0}} \right]
\]

\[
e^{-\alpha w_{l1}} = \frac{[2p - 1 - g\alpha][1 - \gamma]}{p - \gamma}
\]

\[
w_{l1}^* = \frac{1}{\alpha} \ln \left[ \frac{p - \gamma}{(2p - 1 - g\alpha)(1 - \gamma)} \right].
\]

Consequently we have

\[
w_{h1}^* = \frac{1}{\alpha} \ln \left[ \frac{p + \gamma - 1}{(2p - 1 - g\alpha)\gamma} \right].
\]

To obtain \( t_{h1}^* \) and \( t_{l0}^* \), we have to solve the system made up by (NED) and (PCIC) for the optimal values of \( w_{h1} \) and \( w_{l1} \). First of all, we can rewrite (NED) as:

\[
[p\gamma + (1 - p)(1 - \gamma)] \left[ 1 - e^{-\sigma t_{h1}} \right] = \frac{\gamma}{\sigma} \left[ 1 - e^{-\sigma(t_{l0} - \xi)} \right]
\]

that implies

\[
t_{h1}^* = \frac{1}{\sigma} \ln \left[ \frac{2p\gamma + 1 - p - \gamma}{2p\gamma + 1 - p - 2\gamma + (\gamma)e^{-\sigma(t_{l0} - \xi)}} \right].
\]

Hence, we can replace the equation above into (PCIC):

\[
\frac{[2p\gamma + 1 - p - \gamma]}{\sigma} \left[ 1 - e^{-\sigma t_{l0}} \right] = \frac{[p + \gamma - 2p\gamma]}{\sigma} \left[ 1 - e^{-\sigma(t_{h1} + \Delta w_h)} \right] + \frac{[2p\gamma + 1 - p - \gamma]}{\sigma} \left[ 1 - e^{-\sigma \Delta w_l} \right],
\]

where \( \Delta w_h = w_{h1} \) and \( \Delta w_l = w_{l1} \). After some computation, we obtain:

\[
t_{l0}^* = \frac{1}{\sigma} \ln \left[ \frac{(2p\gamma + 1 - p - \gamma) \left[ (p + \gamma - 2p\gamma)e^{-\sigma (\Delta w_h - \xi)} \right]}{[2p\gamma + 1 - p - \gamma]} + \frac{[2p\gamma + 1 - p - \gamma] e^{-\sigma \Delta w_l}}{2p\gamma + 1 - p - \gamma} \right],
\]

where
\[\xi = \frac{1}{\alpha} \ln \left[ \left( 1 - \frac{(p\gamma + 1 - p - \gamma)(1 - e^{-\alpha w_{1}})}{\gamma} \right) - \frac{(\gamma - p\gamma)(1 - e^{-\alpha w_{1}})}{\gamma} \right]^{-1} \].

**Graphical analysis**

Here we complete the illustration of the comparison between the expected cost of the corruption-proof contract and that of the solution without supervisor as functions of \(\sigma\). In figure 3, we show the impact of a change in the cost of effort \(g\). In both graphs, \(\alpha = 0.4\), \(\gamma = 0.7\), \(p = 0.9\). As predicted, when \(g\) is relatively small (Figure 3.a), it is profitable to hire a supervisor whose degree of risk aversion is somewhat high. Whereas, when \(g\) is high (Figure 3.b), it is better to hire a supervisor as long as her degree of risk aversion is relatively low.

![Figure 3: Impact of a change in \(g\) on the expected transfers as functions of \(\sigma\).](image)

We also study the impact of \(\gamma\). In Figure 4, we consider a case in which \(\alpha = 0.4\), \(g = 0.75\), \(p = 0.9\). When the profit signal is not very noisy (\(\gamma\) high), it is advantageous to hire a supervisor who has a high degree of risk aversion. Whilst, when the profit signal is not very informative (\(\gamma\) low), the principal feels the benefits of hiring a supervisor as long as her degree of risk aversion is pretty low.

![Figure 4: Impact of a change in \(\gamma\) on the expected transfers as functions of \(\sigma\).](image)