Collusion Prevention via Asymmetric Information

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Abstract

This paper studies vertical collusion in the three tier hierarchy of a principal, a monitor and an agent. Monitor and agent share private information on the agent's cost type which the principal seeks to elicit. Collusion is detected with a given probability. We add to this a private signal the principal can send to the monitor, refining his information on the likelihood of detection. The principal thus introduces asymmetric information between the collusive parties but also enables the monitor to coordinate collusion more easily. We derive the principal's optimal signal strategy and show that she can benefit from the use of such a signal, even if it is costly.

KEYWORDS: collusion, asymmetric information, monitoring

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1 Introduction

A principal commissioning an agent to implement a project may be unable to observe the agent's production costs or choice of effort. She hence employs an intermediary to elicit the agent's private information. The intermediary, however, can be bribed by the agent to misreport this information. The resulting question of how to "monitor the monitor" (Rahman, 2012, p. 2767), how to "police the police" (Kofman and Lawarrée, 1996, p. 117) has troubled the literature since the seminal exposition of collusion in Tirole (1986). This paper analyses the scope for combating collusion by introducing asymmetric information between the collusive parties, thus reducing the efficiency of the bribing process.

Employing a monitor as an intermediary to a principal-agent relationship can help the principal to extract information about the agent's type but also causes rent payments to the monitor in order to incentivise him not collude with the agent. We find that the principal can benefit from sending private signals to the monitor, thus creating an informational asymmetry between agent and monitor and lowering rent payments to the latter.

Consider a firm's headquarter receiving a valuable order. The production unit's costs for executing the order are unobservable to the headquarter but can be elicited by hiring a monitor who can disclose this information. The monitor might, however, be bribed by the production unit's manager to provide a false report. The headquarter can check ex post whether the monitor's report was truthful by sending a supervisor with a certain probability. Anticipating this detection, the monitor requires the production unit's manager to offer a bribe which compensates him for the risk of getting caught and being punished (e.g. losing his job). This setting resembles the standard problem of collusion in a vertical three tier hierarchy as in Tirole (1992).

The headquarter now considers to privately inform the monitor when the supervisor's inspection is imminent. That is, it sends a private signal – an e-mail, for example – to the monitor which the production unit's manager cannot observe. The monitor now is better informed about the likelihood of being caught colluding than without such signal. That is, it might be even easier for him to coordinate on a bribe with the manager. The latter, however, is unaware of the monitor's belief about detection and hence does no longer know the precise bribe required to convince the monitor to forge the report. The headquarter has introduced asymmetric information between the collusive parties. On the one hand, the signal is costly and allows the monitor to coordinate with the agent, but on the other hand it reduces bribing efficiency. This paper hence asks whether the headquarter can benefit from introducing such private signals.

The application can readily be extended to publicly procured projects: if there is little or no competition, bidding firms will be tempted to overstate their production costs. The authorities, unaware of a bidder's true costs, require participating firms to employ internal monitors that provide information on the tender and evidence of the costs. Again, these monitors might be subject to collusion such that they conceal the true production costs. The authorities thus at times send external monitors to verify the work of their internally employed counterparts. Initially, these audits are fully randomised controls. There is, however, the possibility to inform an internal monitor about upcoming inspections without letting the respective firm know. Will such a signal make it easier for internal monitors to forge reports only when detection is unlikely or can it aid the authorities in decreasing collusion by reducing the incentives that must be provided to monitors for truth telling?

This paper shows that the principal – that is, an uninformed headquarter or the authorities – can indeed benefit from introducing asymmetric information between the colluding parties. This is achieved e.g. by credibly committing to an audit. The agent – i.e. the collusive manager or the bidding firm – is unaware of the signal the monitor observed and hence does not know what bribe she must offer and whether it is going to be accepted by the monitor. The principal, who can "outbid" the agent in order to elicit a truthful report from the monitor, can thus obtain information on the agent's costs at a lower price. Despite the signal's cost and the additional information it yields to the monitor, we find that it can be beneficial for the principal if bribing is sufficiently costly for the agent (and hence the costs of outbidding are sufficiently low).

The mechanism behind this result is the following: a private signal is sent to the monitor which sometimes informs him that a bribe, if accepted, will be detected with certainty in this instance. The ex post probability of detection remains unchanged, the signal merely acts as a refinement of the monitor's information set. Although the signal decreases the monitor's uncertainty of detection occurrence, it also decreases the information rent he obtains *on average*. When the signal is such that it does *not* inform the monitor about imminent control, he updates his belief about the detection likelihood according to Bayes' rule, is more informed and requires a higher incentive to reveal an agent's cost type. But by sending the (costly) signal, the principal can decrease the occurrence of these payments. There are hence two countervailing effects of the private signal: an increase in the required incentives to elicit truth telling and a decrease in the frequency of these payments. The paper shows that, if side contracts are sufficiently inefficient, the principal benefits from the use of such a signal.

The standard model of vertical collusion in a three tier hierarchy is established in Tirole (1986) and Tirole (1992). A vast literature on collusion in such set-up has emerged, see Laffont and Rochet (1997) for a survey. Different authors have analysed optimal incentives to collusive monitors, e.g. Baron and Besanko (1984) and Rahman (2012). Similar to the introductory examples, some consider the employment of a second monitor to supervise the first: Kofman and Lawarrée (1993) do so for a setting of moral hazard, Kofman and Lawarrée (1996) with the second monitor also being corruptible.

In the model we present, the principal benefits from introducing asymmetric information between the colluding parties. Laffont and Martimort (1997) consider such asymmetry between multiple collusive agents, Faure-Grimaud, Laffont and Martimort (2003) focus on corruption between agent and monitor but with the latter being risk averse. The set-up of Ortner and Chassang (2014) is the most similar to ours. The authors, however, focus on asymmetry with respect to wages, which they randomise while providing the monitor with more information on the wage distribution than the agent has. We instead introduce asymmetry in the precision of information on the likelihood of collusion detection. Also, in contrast to their work, we adopt a framework along the lines of the mechanism design literature, with contractual payments contingent on all observables. This is applied to the context of vertical collusion e.g. by Strausz (1997), Laffont and Martimort (2000) and more recently by Celik (2009). For an empirical analysis of the relevance of collusion, see e.g. Duflo et al. (2013).

The paper proceeds as follows: section 2 describes the model by adding private signalling to the standard set-up of a three tier hierarchy. In section 3, the principal's maximisation problem is solved and the optimal signal strategy is derived. It is compared to the benchmark where no such signal is available and it is shown that under certain conditions the principal can benefit from giving away this information. Comparative statics are provided. Section 4 concludes. All proofs are in the appendix.

2 Model

The set-up follows the three-tier procurement model with asymmetric information as studied in Tirole (1992): a principal (she) procures a project of value R to her. It can realised by an agent with production costs ϑ which are either low (ϑ_L) with probability α or high (ϑ_H) with probability $1-\alpha$. Both a monitor (he) and the agent (she) can observe the true production costs ex ante, whereas the principal only knows their distribution.

The monitor sends a report $r \in \{L, H\}$ on the cost type to the principal but may lie about the truth if bribed by the agent. Following the standard models on collusion, we assume the monitor can only forge the report if he agrees with the agent to do so – that is, he cannot threaten the agent to lie about the agent's true cost type (see Kofman and Lawarrée (1993) for a justification). In a similar vein, we assume the side contracts between agent and monitor to be enforceable.

Collusion is achieved by a take-it-or-leave-it offer by the agent to the monitor. Side contracts are costly in the way that if a bribe b is offered, only kb is obtained by the monitor, where $k \in (0, 1)$. The parameter k thus measures the efficiency of the bribing process. The principal can detect collusion with probability β by observing the signal of a collusion detection device $s \in \{C, N\}$ (collusion, no collusion), where $\Pr(s = C|\vartheta_r \neq \vartheta) = \beta$ and $\Pr(s = C|\vartheta_r = \vartheta) = 0$, i.e. there are no false positives.[1]

We add to this standard model of collusion in vertical hierarchies the possibility of the principal to send a costly signal $a \in \{0, 1\}$ to the monitor. $a = 1$ informs the monitor that collusion is certain to be detected: $\Pr(s = C|\vartheta_r \neq \vartheta, a = 1) = 1$. A signal realisation $a = 0$, on the other hand, causes the monitor to update his posterior about detection following Bayes' rule such that the ex post detection likelihood remains at β: $\Pr(s = C|\vartheta_r \neq \vartheta, a = 0) \equiv \tilde{\beta}$. That is, the overall probability of collusion detection does not change. The principal publicly commits to a signal probability $\gamma = \Pr(a = 1)$, which can also be interpreted as γ being chosen by the principal and the realisation of a being drawn by nature. The agent thus is unaware of a when offering a bribe to the monitor but does know γ. Figure 1 depicts the probability of collusion detection from the viewpoint

[1] This collusion detection device can also be interpreted as an additional, non-corruptible (external) monitor, supervising the bribable (internal) one, as in Kofman and Lawarrée (1993).

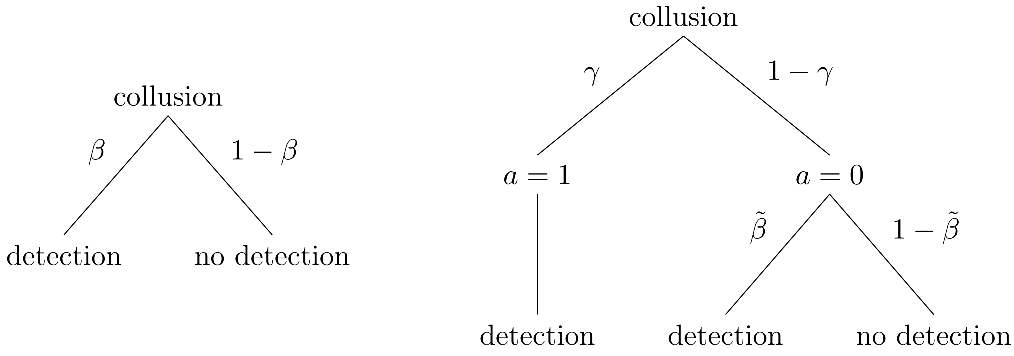

Figure 1: Probability of collusion detection from the perspective of the agent (left) and the monitor (right). Only the latter observes a. Note that $\gamma + (1-\gamma)\tilde{\beta} = \beta$, i.e. the overall detection probability is not changed by the signal a.

of the agent (who does not observe a) and the monitor (who observes a), respectively.

The principal faces signal costs $\frac{1}{2}c\gamma^2$. We assume the monitor does not collude when he knows to be caught (i.e. for $a = 1$) and that $R > \vartheta_H + \frac{1}{2}c$, i.e. the project is so valuable the principal will always want to implement it. This assumption rules out additional equilibria where the principal risks not realising the project by offering a low wage after a high cost report (not knowing whether the report is truthful or not). All parties are risk neutral.

The principal offers a wage w_{rs} to the agent and a transfer t^a_{rs} to the monitor. The results presented here remain unchanged if we also allow for the wage to the agent to be contingent on a, i.e. by specifying w^a_{rs} (see section 3.5). The restriction to w_{rs}, however, is more appealing as the agent cannot observe a and hence would not know her payoff when considering whether to accept or reject a contract w^a_{rs}. Limited liability of both the monitor and the agent requires all payments to be non-negative.

Definition 1. *A contract φ is given by a tuple* $\left\langle (w_{rs}, (t^a_{rs})_{a\in\{0,1\}})_{r\in\{L,H\},\, s\in\{C,N\}}, \gamma \right\rangle \in \mathbb{R}^4_+ \times \mathbb{R}^{2\cdot 4}_+ \times [0,1]$.

To summarise, we present the timing:

1. The principal offers a contract with payment schemes w to the agent, t to the monitor; announces γ.
2. Nature draws ϑ and reveals it to monitor and agent; principal/nature reveals a to the monitor.
3. The agent makes a "take it or leave it offer" to the monitor such that he misreports ϑ, the monitor decides to accept/reject.
4. r, s revealed.
5. The agent decides on execution of project,[2] payments realise.

[2]The monitor always always finds it profitable to accept the principal's payment offer, hence no explicit choice is stated.

We introduce the following notation: The principal can only realise the project value R if she grants the agent a wage equal to at least her true production costs. The agent's choice to carry out the project, given a her true cost type ϑ and a wage offer w_{rs}, is denoted by

$$\mathbb{1}(\vartheta, w_{rs}) = \begin{cases} 1 & \text{if } w_{rs} \geq \vartheta, \\ 0 & \text{else.} \end{cases}$$

Her payoff is hence given by

$$(w_{rs} - \vartheta)^+ \equiv (w_{rs} - \vartheta) \cdot \mathbb{1}(\vartheta, w_{rs}) = \max\{0, w_{rs} - \vartheta\}.$$

3 The Optimal Contract

3.1 Bribing Behaviour

Before deriving the principal's optimal contract offer both under a benchmark scenario and for the model at hand, we analyse the choices of the monitor to accept bribes and of the agent to offer them, respectively. Bribing only is relevant in the case of $\vartheta = \vartheta_L$, where the agent wants to conceal her low costs. When the agent makes an offer to the monitor, she does not know a and hence whether or not the monitor will accept or reject it. Denote by $b_{\min}$ the bribing level making the monitor just indifferent between collusion and truth telling after having observed $a = 0$. Since the ex post probability of collusion detection remains at the prior probability β, the monitor updates his belief regarding detection after observing $a = 0$ according to Bayes' rule:

$$\begin{aligned} \tilde{\beta} &\equiv \Pr(s = C | \vartheta_r \neq \vartheta, a = 0) \text{ s.t. } \beta = \gamma + (1 - \gamma) \\ \Rightarrow \tilde{\beta} &= \frac{\beta - \gamma}{1 - \gamma} \end{aligned} \tag{1}$$

We write the monitor's expected utility under bribery (B) and no bribery (NB) after observing $a = 0$ as $U_M^{NB}(a = 0)$ and $U_M^B(a = 0)$, respectively. $b_{\min}$ is then given by:

$$\begin{aligned} & U_M^{NB}(a=0) \geq U_M^B(a=0) \\ \Leftrightarrow \quad & t_{LN}^0 \geq \tilde{\beta}(t_{HC}^0 + kb) + (1 - \tilde{\beta})(t_{HN}^0 + kb) \\ \Rightarrow \quad & b_{\min} = \tfrac{1}{k(1-\gamma)} \left[(1-\gamma)(t_{LN}^0 - t_{HN}^0) + (\beta - \gamma)(t_{HN}^0 - t_{HC}^0)\right] \end{aligned} \tag{2}$$

The monitor will thus reject any bribe $b \leq b_{\min}$ and accept bribes $b > b_{\min}$ (we assume rejection in case of indifference for expositional ease). Similarly, there is a level $b_{\max}$ rendering the agent indifferent between offering such a bribe and not colluding. Since she knows only the distribution of a but not the realisation, she is unaware whether a bribing offer b will be accepted by the agent. We denote by U_A^B her utility when offering a bribe (which does not necessarily imply collusion) and by U_A^{NB} when no attempt to bribe is made. $b_{\max}$ can then be computed as:

$$\begin{aligned} & U_A^{NB} \geq U_A^B \\ \Leftrightarrow\ & (w_{LN}-\vartheta_L)^+ \geq (1-\gamma)\big[\tilde{\beta}((w_{HC}-\vartheta_L)^+ - b) + (1-\tilde{\beta})((w_{HN}-\vartheta_L)^+ - b)\big] \\ & \qquad + \gamma\big[(w_{LN}-\vartheta_L)^+ - (1-k)b\big] \\ \Rightarrow\ & b_{\max} = \tfrac{1}{1-k\gamma}\big[(1-\beta)(w_{HN}-\vartheta_L)^+ + (\beta-\gamma)(w_{HC}-\vartheta_L)^+ \\ & \qquad - (1-\gamma)(w_{LN}-\vartheta_L)^+\big] \end{aligned} \tag{3}$$

Note that if the agent offers a bribe b which is rejected (if $a = 1$), she nevertheless faces an "inefficiency loss" of $(1-k)b$. This resembles the cost of concealing (potential) side payments which have to be made in secrecy. It follows that there will be no collusion if

$$b_{\min} \geq b_{\max}. \tag{4}$$

Definition 2. *A contract φ is collusion proof if it satisfies the collusion proofness constraint (4).*

3.2 Benchmark

We first derive the principal's optimal choice and expected utility if the private signal a to the agent was not available. The model then reduces to a game of collusion with ex post detection, where we have $\gamma = 0$. We can thus omit t_{rs}^1 and write $t_{rs} = t_{rs}^0\ \forall(r,s)$. Given the revelation principle, an optimal contract can be found among those which are collusion proof (see e.g. Laffont and Rochet (1997)). Adapting the collusion proofness constraint (4) with $\gamma = 0$, the principal's problem becomes:

$$\begin{aligned} \max_{w_{rs},t_{rs}}\ & \alpha((R-w_{LN})\cdot \mathbb{1}(\vartheta_L, w_{LN}) - t_{LN}) \\ & + (1-\alpha)((R-w_{HN})\cdot \mathbb{1}(\vartheta_H, w_{HN}) - t_{HN}) \\ \text{s.t. }\ & b_{\min}\big|_{\gamma=0} \geq b_{\max}\big|_{\gamma=0} \end{aligned} \tag{5}$$

Given that transfers are non-negative and at least compensate the agent for her production costs, we do not require additional participation constraints.

Lemma 1. *If the principal cannot sent a private signal to the agent, the optimal contract yields her an expected utility of*

$$U_P = R - \vartheta_H + \alpha\Delta\vartheta(1-k(1-\beta)). \tag{6}$$

The term $\alpha\Delta\vartheta k(1-\beta)$ is the information rent the principal has to pay to the monitor in order to elicit a truthful report. The rent is decreased through the bribing inefficiency k and the probability of collusion detection β.

3.3 The Principal's Problem

We now add the possibility for the principal to send a private signal $a = 1$ to the monitor with a publicly known probability of γ. The number of contract parameters increases as the transfers to the monitor can now be conditioned on the realisation of a. Does the principal benefit from using such signal, given that it reveals more detailed information about the likelihood of detection to the monitor? After all, the monitor's observation of a might also aid him in successfully colluding with the agent, now being better informed when he might be caught accepting a bribe.

As shown in Proposition 1, the central result of this paper, the answer is affirmative. For certain regions of the exogenous parameters α (probability of a low cost type, where the agent might be tempted to bribe the monitor), β (ex ante probability of collusion detection), $\Delta\vartheta = \vartheta_H - \vartheta_L$ (difference in production cost types), k (efficiency of the side contract) and c (signal costs), there is an interior solution $\gamma^* \in (0, 1)$ the principal finds optimal. Interior solutions are of particular interest since the corner solutions $\gamma^* \in \{0, 1\}$ do not convey asymmetric information: if the agent learns that $\gamma = 0$ or $\gamma = 1$, she effectively learns the realisation of a. We focus on a qualitative statement here, with the quantitative details stated in the proof in the appendix and comparative statics given in section 3.4, visualising the requirements on the exogenous parameters.

Proposition 1. *The principal can benefit from revealing a private signal $a \in \{0, 1\}$ to the monitor with publicly observable probability $\gamma^* \in (0, 1)$ given certain ranges of the parameters α, β, $\Delta\vartheta$, k and c.*

For an intuition, we compare the principal's expected utility given γ for the benchmark scenario and for the model at hand. In the benchmark, it is given by (see Lemma 1)

$$U_P^{\text{bench}} = R - \vartheta_H + \alpha\Delta\vartheta(1 - k(1 - \beta)), \tag{7}$$

whereas in the extended model it changes to (see proof of Proposition 1)

$$U_P^{\text{model}}(\gamma) = R - \vartheta_H + \alpha\Delta\vartheta(1 - k\frac{1-\gamma}{1-k\gamma}(1 - \beta)) - \frac{1}{2}c\gamma^2. \tag{8}$$

Moving from the setting without a private signal to the one with such a possibility, the transfer to a monitor having observed a low cost type and $a = 0$ changes from

$$t_{LN}^{\text{bench}} = k\Delta\vartheta(1 - \beta) \tag{9}$$

to

$$t_{LN}^0 = \frac{k}{1-k\gamma}\Delta\vartheta(1 - \beta) \geq t_{LN}^{\text{bench}} \quad \forall\gamma \in [0, 1], k \in (0, 1), \tag{10}$$

with the latter equation obtained from the proof of Proposition 1. That is, the monitor's information rent *in*creases through the use of signal a: as the probability of detection after $a = 0$ has decreased to $\tilde{\beta} = \frac{\beta-\gamma}{1-\gamma}$, the costs to incentivise the agent for a truth telling

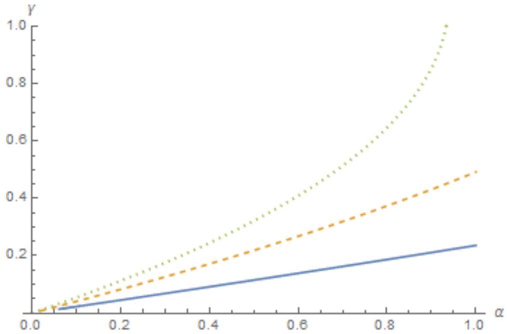

Figure 2: γ as a function of α, for $k_{\text{solid}} < k_{\text{dashed}} < k_{\text{dotted}}$

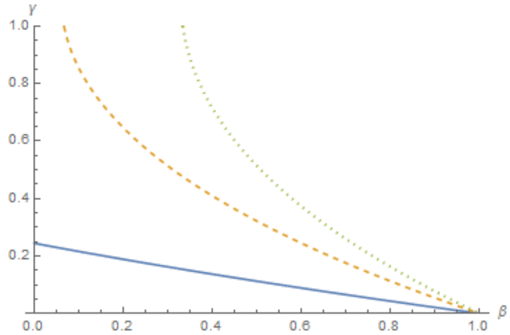

Figure 3: γ as a function of β, for $\Delta\vartheta_{\text{solid}} < \Delta\vartheta_{\text{dashed}} < \Delta\vartheta_{\text{dotted}}$

*in*crease. The probability of paying this rent, however, *de*creases: conditional on $\vartheta = \vartheta_L$, the rent only needs to be paid in $(1-\gamma)$ of the cases, i.e. when collusion detection is not certain. Hence, the principal's gain from sending a private message to the monitor is given by

$$U_P^{\text{model}}(\gamma) - U_P^{\text{bench}} = \alpha\Delta\vartheta k(1-\beta)(\frac{1-\gamma}{1-k\gamma} - 1) - \frac{1}{2}c\gamma^2, \tag{11}$$

which is positive when $\gamma^* > 0$ (and zero for $\gamma^* = 0$). As discussed in section 3.1, the agent does not know whether her collusive offer is going to be accepted by the monitor. The principal can benefit from this uncertainty by "outbidding" the agent. As opposed to the agent, she can condition her offer to the monitor (to be paid when a truthful low cost report is made) on the realisation of a. Furthermore, to match any offer b the agent makes to the agent, the principal only needs to raise kb since she does not face bribing inefficiencies. If the signal costs are not too high, she can thus benefit from revealing additional information to the monitor in order to outbid the agent more efficiently.

3.4 Comparative Statics

As can be seen from equation (11), the optimal choice of γ depends on the parameters α, β, $\Delta\vartheta$, k and c. Figure 2 plots γ as a function of the probability α that the agent has low costs, for different values of the bribing inefficiency k. The higher α, the higher the likelihood that the principal can benefit from her private signal to the monitor: if $\vartheta = \vartheta_H$, no collusion will occur and the signal only causes costs. For low values of α, the principal thus reduces her use of the signal by choosing a lower γ. With increasing k – pictured by a move from the solid to the dashed and to the dotted plot –, bribing becomes more efficient and hence more informational asymmetry between monitor and agent is required to deter them from colluding.

In Figure 3, the influence of the ex ante probability of collusion detection β on the optimal choice of γ is shown. The higher β, the more likely a revelation of collusion. Agent and monitor are then less inclined to collude and the benefit to the monitor from providing

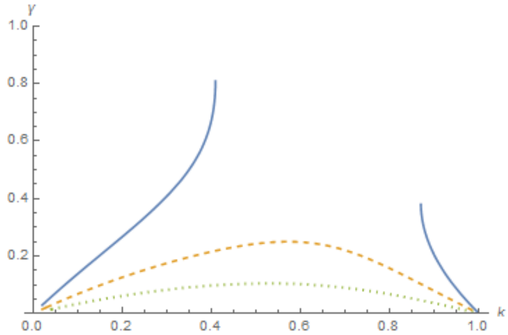

Figure 4: γ as a function of k, for $c_{\text{solid}} < c_{\text{dashed}} < c_{\text{dotted}}$

the costly signal a as a further measure of bribery reduction decreases. The (uncertain) detection in β is sufficient and, as opposed to a, costless. For a given probability β, however, the principal chooses a higher γ if the difference $\Delta\vartheta$ between high and low production costs increases: the stakes are higher given such a change, i.e. the loss from not revealing a low cost type increases. A higher γ helps to ensure revelation.

Lastly, Figure 4 plots γ as a function of the bribing inefficiency for different values of the signal costs.[3] For low k, the bribing is so inefficient that detection through β is sufficient to deter agent and monitor. Hence, the use of γ increases as k grows for low values. As k becomes very large, however, the additional information rent that must be paid to the monitor given the private signal, i.e. $t^0_{LN} - t^{\text{bench}}_{LN}$ (which is increasing in k), outweighs the benefits. For high k, the principal tries to reduce this payment by reducing the frequency of occurrence: she reduces γ to ensure less cases where the rent needs to be paid (as well as a lower rent itself). If the signal costs c increase, the use of the signal decreases as expected intuitively.

3.5 Extensions

An initial assumption required the project's value R to be large, i.e. above $\vartheta_H - \frac{1}{2}c$. This allowed us to restrict attention to equilibria where the principal always finds it worthwhile to implement the project. Now consider a contract that induces monitor and agent collude: a high cost report now may conceal costs that in fact are low. When facing such a high cost report, the principal hence has two options: she can offer a wage compensating for high costs by setting $w_{HN} = \vartheta_H$, ensuring the agent will accept the contract irrespective of her type but risking to pay her a rent if the true type is ϑ_L and collusion was not detected. Or she can specify $w_{HN} = \vartheta_L$, which will be accepted by an agent with low costs who had bribed the monitor to forge a false report, but will be rejected by an agent who truly is of high costs. In the latter case, the project will not be realised even if the principal would benefit from doing so by offering a wage ϑ_H instead.[4]

If the model is modified such that the collusion proofness principle no longer holds

[3] Given the steep gradient for c_{solid}, the graph looks "cut off" where it actually is rapidly in-/decreasing.

[4] See Strausz (1997) for an analysis of the issue of renegotiation proofness in these cases.

(e.g. by not having payments contingent on a) and the optimal contract induces bribery, a decrease of R could introduce equilibria where $w_{HN} = \vartheta_L$ is optimal (as opposed to the present solutions). This offer will be rejected in $(1 - \alpha)$ of the cases, that is whenever the true costs are high. A question of further research would be whether the results presented here carry through to such a setting, i.e. whether the principal can still gain from the use of a private signal to the monitor and, if so, how the results change quantitatively.

As already mentioned above, extending the contracts in the current model such that the wages to the agent are also contingent on the realisation of a does not alter the results. Deriving optimal payment schemes w^a_{rs}, one finds $w^1_{rs} = w^0_{rs} = w^*_{rs}\ \forall(r,s)$, with w^*_{rs} given by the wages obtained in the proof of Proposition 1.

A more promising extension seems to be an alternative approach to the collusion process between agent and monitor. So far, it is given by a take-it-or-leave-it offer from the agent, who does not know the monitor's minimum required bribing bid due to the asymmetry of information. If it was instead to the monitor to make an offer, could he then extract the rent that in the current model the principal is saving as compared to the benchmark (given by the difference in utilities computed in equation (11))? How do the results change if the bribe is determined via Nash bargaining, with a varying distribution of bargaining power between the colluding parties? If the agent can elicit the monitor's private information on the signal during the negotiation stage, e.g. by offering him a "menu" of bribes, she might be able to skim part of the rent herself. The adverse selection problem of the principal vis-à-vis agent and monitor would then be extended by an additional adverse selection problem of the agent when optimising the side contracts offered to the monitor.

4 Conclusion

Giving away more information to a collusive party in order to reduce the costs of collusion prevention may seem counterintuitive. This paper shows that, under certain conditions, it can nevertheless be an optimal strategy. Introducing asymmetric information between monitor and agent makes the latter ignorant of the bribe required to cause the monitor to forge a report. There will thus be an inefficiency in the bribing process which the principal can exploit by "outbidding" the agent's bribe at a lower cost. This is achieved by merely informing the monitor about the use of some mechanism which detects collusion, i.e. without increasing the overall use of the mechanism. We have shown how the optimal signal choice varies with the parameters of the setting and computed the principal's gain from having the option of private signalling at hand.

An uninformed headquarter, or the authorities, might be worried about their monitors being corruptive. That is, reports of investigations may be forged due to bribery by the agent being monitored. The principal hence seeks to "monitor the monitors" by randomly checking their reports. At first sight, it may seem optimal to leave the monitors as uninformed as possible with respect to the occurrence of these checks. As shown here, however, it can be profitable for the principal to leak details on the timing *if* it can be ensured that the information is only obtained by the monitor, not the collusive agent. If private signalling is possible, the trickling of details on audits within the respective units of an organisation can thus turn out to be beneficial.

Appendix

Proof of Lemma 1. Using the revelation principle, we can restrict attention to collusion proof contracts. The collusion proofness constraint is given by equation (4) with $\gamma = 0$ and the principal's problem can be rewritten as:

$$\begin{aligned}\max_{w_{rs},t_{rs}} \ & \alpha\big[(R - w_{LN}) \cdot \mathbb{1}(\vartheta_L, w_{LN}) - t_{LN}\big] + (1-\alpha)\big[(R - w_{HN}) \cdot \mathbb{1}(\vartheta_H, w_{HN}) - t_{HN}\big] \\ \text{s.t.} \quad & \tfrac{1}{k}(\beta(t_{HN} - t_{HC}) + (t_{LN} - t_{HN})) \\ & \geq \beta((w_{HC} - \vartheta_L)^+ - (w_{HN} - \vartheta_L)^+) + ((w_{HN} - \vartheta_L)^+ - (w_{LN} - \vartheta_L)^+)\end{aligned}$$

The objective function is weakly decreasing in all transfers t_{rs} to the monitor and the constraint has more slack for lower t_{HN} and t_{HC}. We thus set $t_{rs} = 0 \ \forall (r,s) \neq (L,N)$ and conclude that at the optimum, the collusion proofness constraint is binding (else, the principal could benefit from reducing t_{LN}). We obtain

$$\begin{aligned}\max_{w_{rs}} \alpha\big[&(R - w_{LN}) \cdot \mathbb{1}(\vartheta_H, w_{HN}) - k\big\{\beta((w_{HC} - \vartheta_L)^+ - (w_{HN} - \vartheta_L)^+) \\ &+ ((w_{HN} - \vartheta_L)^+ - (w_{LN} - \vartheta_L)^+)\big\}\big] + (1-\alpha)(R - w_{HN}) \cdot \mathbb{1}(\vartheta_H, w_{HN}),\end{aligned}$$

which is piecewise linear in all w_{rs}. It is decreasing in w_{rs} on each interval and has a step discontinuity with a positive jump at $w_{LN} = \vartheta_L$ and at $w_{HN} = \vartheta_H$ (there also is a downwards jump at $w_{HN} = \vartheta_L$ caused by a low cost type being incentivised to collude). Since $R > \vartheta_H$ by assumption, the principal finds it profitable to implement the project even if the true costs are high. Optimal wages to the agent are thus given by $w_{rN} = \vartheta_r, w_{rC} = 0$ for $r \in \{L, H\}$, yielding a transfer to the monitor of $t_{LN} = k\Delta\vartheta(1-\beta)$. The principal's expected utility is obtained by plugging the payments into the objective function. □

Proof of Proposition 1. Since the principal's payment to the monitor and the agent are contingent on all the respective observables – that is, report r and detection s for the agent and in addition signal a for the monitor –, the revelation principle still holds: the search for an optimal contract can be restricted to the set of collusion proof contracts (see e.g. Laffont and Rochet (1997)). With the collusion proofness constraint given by equation (4), the principal's maximisation problem is:

$$\begin{aligned}\max_{w_{rs},t^a_{rs},\gamma} \ & \alpha\big[(R - w_{LN}) \cdot \mathbb{1}(\vartheta_L, w_{LN}) - \gamma t^1_{LN} - (1-\gamma)t^0_{LN}\big] \\ & + (1-\alpha)\big[(R - w_{HN}) \cdot \mathbb{1}(\vartheta_H, w_{HN}) - \gamma t^1_{HN} - (1-\gamma)t^0_{HN}\big] - \frac{1}{2}c\gamma^2 \\ \text{s.t.} \quad & \frac{1}{k(1-\gamma)}\big[(1-\gamma)(t^0_{LN} - t^0_{HN}) + (\beta-\gamma)(t^0_{HN} - t^0_{HC})\big] \\ & \geq \frac{1}{1-k\gamma}\big[(1-\beta)(w_{HN} - \vartheta_L)^+ + (\beta-\gamma)(w_{HC} - \vartheta_L)^+ - (1-\gamma)(w_{LN} - \vartheta_L)^+\big]\end{aligned}$$

Given the method of proof used for Lemma 1, we can apply a similar procedure to the problem at hand. First, note that the objective function is weakly decreasing in all transfers t^a_{rs} to the monitor and that the constraint has more slack for lower t^0_{HN} and t^0_{HC}. Hence, we obtain $t^a_{rs} = 0 \; \forall (r, s, a) \neq (L, N, 0)$. The remaining transfer t^0_{LN} is the information rent that must be paid to the monitor in order to incentivise him to truthfully reveal a low cost type. At the optimum, it is set such that the collusion proofness constraint is binding. The maximisation problem can hence be rewritten as:

$$\begin{aligned}\max_{w_{rs},\gamma} \quad & \alpha\big[(R - w_{LN}) \cdot \mathbb{1}(\vartheta_L, w_{LN}) - \frac{k(1-\gamma)}{1-k\gamma}\big\{(1-\beta)(w_{HN} - \vartheta_L)^+ \\ & + (\beta - \gamma)(w_{HC} - \vartheta_L)^+ - (1-\gamma)(w_{LN} - \vartheta_L)^+\big\}\big] \\ & + (1-\alpha)\big[(R - w_{HN}) \cdot \mathbb{1}(\vartheta_H, w_{HN})\big] - \frac{1}{2}c\gamma^2\end{aligned}$$

We again find that the maximand is piecewise linear in all w_{rs} and decreasing on each interval. The step continuities with positive jumps remain at $w_{LN} = \vartheta_L$ and at $w_{HN} = \vartheta_H$ and a negative jump at $w_{HN} = \vartheta_L$. Given $R > \vartheta_H + \frac{1}{2}c$, the principal will always want to implement the project, irrespective of true costs. Optimal wages to the agent thus equal those derived in Lemma 1, with $w_{rN} = \vartheta_r, w_{rC} = 0$ for $r \in \{L, H\}$. This resemblance comes at no surprise since in both scenarios the agent is just compensated for her true production costs while the information rent is skimmed by the monitor. The monitor's payment for a truthful low-cost report when no signal was sent is obtained from the binding collusion proofness constraint:

$$t^0_{LN} = \frac{k}{1-k\gamma}\Delta\vartheta(1-\beta)$$

It remains to determine the optimal choice of γ. Rewriting the objective function once more, we find

$$\max_{\gamma} R - \vartheta_H + \alpha\Delta\vartheta(1 - k\frac{(1-\gamma)}{1-k\gamma}(1-\beta)) - \frac{1}{2}c\gamma^2,$$

yielding the principal's expected utility given γ and optimal payment schemes, as stated in equation (7). The first order condition yields a polynomial of third order with one non-imaginary solution for γ, given by

$$\gamma^* = \Bigg(-2\sqrt[3]{2}c^2k^2 + 4ck\Big[2c^3k^3 - 27\alpha(\beta-1)c^2\Delta\vartheta(k-1)k^5$$
$$+ 3\sqrt{3}\sqrt{\alpha(\beta-1)\left(-c^4\right)\Delta\vartheta(k-1)k^8\left(4c - 27\alpha(\beta-1)\Delta\vartheta(k-1)k^2\right)}\Big]^{1/3}$$
$$- \Big[4c^3k^3 - 54\alpha(\beta-1)c^2\Delta\vartheta(k-1)k^5$$
$$+ 6\sqrt{3}\sqrt{\alpha(\beta-1)\left(-c^4\right)\Delta\vartheta(k-1)k^8\left(4c - 27\alpha(\beta-1)\Delta\vartheta(k-1)k^2\right)}\Big]^{2/3}\Bigg)$$
$$\cdot \Bigg(6ck^2\Big[2c^3k^3 - 27\alpha(\beta-1)c^2\Delta\vartheta(k-1)k^5$$
$$+ 3\sqrt{3}\sqrt{\alpha(\beta-1)\left(-c^4\right)\Delta\vartheta(k-1)k^8\left(4c - 27\alpha(\beta-1)\Delta\vartheta(k-1)k^2\right)}\Big]^{1/3}\Bigg)^{-1}.$$

Simulations as in Figures 2-4 allow for an easier interpretation of this result by plotting the interior solutions of γ as a function of the parameters α, β, $\Delta\vartheta$, k and c. The principal's benefit from the use of a signal with positive probability follows from the difference in utilities $U_P^{\text{model}}(\gamma) - U_P^{\text{bench}}$, see equation (11). It is, by construction of the optimal value γ, positive whenever $\gamma^* > 0$ and zero for $\gamma^* = 0$. □

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