Non-Monetary Collusion and Optimal Use of Information*

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Abstract

This paper develops a theory of non-monetary collusion, where agents exchange favors. We examine the optimal use of information

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in a simple hierarchy. It is shown that when only the supervisor's information about the agent is used, collusion does not arise, since favors cannot be exchanged. When also the agent's information about his superior is used, collusion arises, and there is an interesting trade-off between the benefits of using additional information and the costs of collusion. We outline precise conditions under which additional information should and should not be used. Under certain conditions the principal may be better off by using less than all the available information.

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1 Introduction

Why is all the available information typically not used in real-world organisations? When the available information is partially used, why is it the case that only superiors' information about their subordinates is used, and workers' information about their superiors is ignored?

This paper proposes a simple model to explain these stylized facts in terms of organisation members' possibilities to engage in harmful side-contracting. We model non-monetary collusion as mutually beneficial information manipulation, where agents exchange favours by jointly concealing information from a principal. It is shown that under certain conditions it is optimal for the principal not to use all the available information, since then the principal can deter collusion and gain more valuable information without additional cost. The principal may simply be better off by using less information.

In contrast to the existing literature, we consider the case where collusion is modelled as a simultaneous exchange of favours, which takes the form of mutually beneficial information concealment. This type of collusion, in contrast to monetary bribes, is something one certainly expects to find in real-world organisations. For example, co-workers may agree not to reveal some unfavourable information to their superiors, a foreman and a worker can jointly cover up each other's mistakes.

We develope a simple hierarchial model with the self-interested supervisor who also has a production role and the agent who potentially also has a monitoring role. The model captures many features of existing organisations. Supervisors are supposed to report the principal on their subordinates, but often they have a productive function of their own, which may take various forms such as cost minimization, coordination of production, coordination of management. Furthermore, in any organisation in which workers and managers work closely, workers also gain information about their superiors, and sometimes they also have the possibility to communicate that information to the top of the hierarchy. In practice, this monitoring by workers may be in the form of questionnaires distributed to the workers in which they are asked to assess the manager's management and coordination activities, advisory activities, management style, the manager's "type".

It is shown that when only one supervisory information source is used (Organisation Form I), collusion problems do not arise, because favours cannot be exchanged. A collusion-proof equilibrium is achieved without extra costs. When two supervisory information sources are used (Organisation Form II), collusion does arise. In general, more information is better, but in our model it makes non-monetary collusion possible, and this creates additional costs which are borne by the principal. Thus, a trade-off arises with respect to whether it is more beneficial to use only one source of supervisory information and avoid the costs of collusion or to use both supervisory information sources and bear the costs of collusion.

We describe precise conditions under which additional information the agent may provide about his superior should and should not be used. It is first shown as a benchmark that when collusion is not an issue, all available information should indeed be used. When collusion is a problem, the principal has to balance the benefits which new detailed information provides against the costs of collusion.

We consider first the case where the value of information the supervisor and the agent have about each other is equally important. In this case the decision whether to use additional information the agent may provide (in Organisation II) depends on the probability of collusion. When the probability of collusion is low enough, the benefits of additional information are higher than the costs of collusion. Thus Organisation II should be adopted. However if the probability of collusion is high enough, the costs of potential collusion outweigh any benefits of new detailed information the agent may provide.

Next we consider the case where the value of supervisory information may differ, but where the probability of collusion is kept fixed. Indeed we are able to show that value of information has a crucial effect on which Organisation ends up being the most profitable. When the asymmetry between the supervisor and the agent is great enough, it is optimal to use only one supervisory information source. Under enough asymmetry Organisation I is the most profitable one. In other words, the principal can increase profits by restricting the information flows within the organisation.

The main contribution of this paper lies in the development of a theory of non-monetary collusion that we expect to find in many real-world organisations. It is shown that the decision concerning the use of supervisory information is endogenously determined. In particular, the choice of organisation mode itself affects whether collusion arises or not.

It is interesting to contrast the simple organisations considered here to the ones observed in real world. Typically, tasks in most organisations are assigned in such a way that only the superiors perform monitoring tasks. Our model provides a rational explanation for the separation of monitoring and production tasks. In particular, we offer an additional explanation for the division of labour in organisations, since here the gains from specialization are not coming through technology, but from the fact that specialization prevents non-monetary collusion.

This paper is related to a small and relatively new literature of collusion in organisations.[1] Tirole (1986) is a seminal paper which introduced the principal-supervisor-agent model in the analysis of collusion in organisations. The analysis has been extended and applied for example in the context of auditing: Kofman and Lawarrée (1993) and regulation:Laffont–Tirole (1991). These papers consider monetary collusion between the monitor and the monitored party, and the main issue in these studies lies in the analysis of how a principal can reduce the costs of collusion.[2]

[1] See Tirole (1992) for a survey of this literature.

[2] Recently some authors have addressed the issues of breaking collusion more directly.

We depart from the existing literature of collusion by introducing an idea that in organisations more relevant and realistic type of collusion takes a non-monetary form. We choose to emphasize the relationship between the optimal use of information and task assigments in organisations. Recently, Laffont and Meleu (1997) have independently considered reciprocal supervision and collusion. They analyze both monetary and non-monetary collusion. Even though their model has similarities to the one presented here, there are important differences as well. For example, the moral hazard problem where the agent reveals his own type to the other agent so that they will both be rewarded more generously by the principal does not arise here. Consequently then, it is never optimal to let collusion occur in equilibrium in the present paper.

The remainder of this paper is organized as follows. In section 2 we present the model. It is analysed in section 3. Section 4 discusses the separation of monitoring and production tasks, and section 5 concludes.

See for instance Felli (1996) and Koffman and Lawarrée (1996).

2 The Model

2.1 The Parties

The model we construct borrows basic features from Tirole (1986) and Laffont and Tirole (1991). We consider a simple, three-tier hierarchy with three players: a principal (P), a supervisor (S), and an agent (A). The principal is a risk-neutral residual claimant of an organisation who hires a supervisor and an agent to perform production and monitoring tasks on an indivisible project. The supervisor and the agent have quasi-linear preferences i.e. they are risk neutral in income and risk averse in effort. P does not have time to supervise either the agent or the manager because, by assumption, his attention is limited. A is a productive agent at the bottom of the hierarchy. S is a middle manager who has a dual role: he contributes to production, but, in addition, he monitors A and reports his information to P (Organisation I). In Organisation II A's information about his superior may also be used.

The agent, A has private information about a random cost parameter θ_1. He can reduce costs by exerting effort e_1, which he only observes. The disutility of effort is denoted as $\psi(e)$, $\psi'(e_1)>0$ and $\psi''(e_1)>0$. θ_1 can be interpreted, for instance, as the agent's type or technological variable related to production. Later, we refer to $\underline{\theta}_1$ as a good state of nature and to $\overline{\theta}_1$ as a bad state of nature. The production cost of the process in which A is involved can be written as follows: $c_1=(\theta_1-e_1)$. θ_1 has a binary support $\{\underline{\theta}_1, \overline{\theta}_1\}$ with probability p and (1-p) respectively, $\underline{\theta}_1<\overline{\theta}_1$ and $\Delta\theta_1=(\overline{\theta}_1-\underline{\theta}_1)$. The supervisor, S also has private information about random cost parameter θ_2, and he can also reduce costs by exerting effort e_2, which only he knows.

This effort presents him with a disutility, which in monetary terms is $\psi(e_2)$. We also assume that $\psi'(e_2)>0$ and $\psi''(e_2)>0$.[3] The cost of the supervisor's fine-tuning production task can then be written as follows: $c_2=(\theta_2-e_2)$. θ_2 also has a binary support $\{\underline{\theta}_2, \overline{\theta}_2\}$, and without loss of generality we assume that with probability p: $\theta_2=\underline{\theta}_2$, and with probability (1- p): $\theta_2=\overline{\theta}_2$. In addition $\underline{\theta}_2<\overline{\theta}_2$ and $\Delta\theta_2=(\overline{\theta}_2-\underline{\theta}_2)$.When hiring the agent and the supervisor, P must offer contracts which guarantee them at least their reservation utility, which is normalized to zero. We also assume that both the agent and the supervisor are protected by limited liability; that is, individual rationality constraints must hold ex post in all states of nature. The principal pays the wage w_1 to the agent and w_2 to the supervisor. They are functions of realized costs. The agent's utility is $U_1 = w_1-(\theta_1-c_1)$, and the supervisor's utility is $U_2 = w_2-(\theta_2-c_2)$. The ex post individual rationality (IR) constraints are as follows:

$$\underline{U}_i = \underline{w}_i - \psi(\underline{\theta}_i - \underline{c}_i) \geqslant 0, i = 1, 2. \tag{1}$$

$$\overline{U}_i = \overline{w}_i - \psi(\overline{\theta}_i - \overline{c}_i) \geqslant 0, i = 1, 2. \tag{2}$$

To induce the agent and the supervisor to exert effort, the contract must satisfy incentive compatibility (IC) constraints:

$$\underline{w}_i - \psi(\underline{\theta}_i - \underline{c}_i) \geqslant \overline{w_i} - \psi(\underline{\theta}_i - \overline{c}_i), i = 1, 2, \tag{3}$$

$$\overline{w}_i - \psi(\overline{\theta}_i - \overline{c}_i) \geqslant \underline{w}_i - \psi(\overline{\theta}_i - \underline{c}_i), i = 1, 2. \tag{4}$$

[3]To rule out the optimality of stochastic contracts we assume that $\psi'''(e_i) \geqslant 0$,i =1, 2.

In addition to cost-reducing activities, the supervisor and the agent sometimes learn each other's type. Thus, they are able to help the principal reduce informational rents by reporting their observations of each other. We assume that observing and reporting do not require any effort. The important point is that the principal does not have to pay for that supervisory information. To see why, note that once the agent and the supervisor have been offered the incentive compatible contracts, they have no incentive to lie in their reports on each other. Once offered a second-best contract the supervisor is indifferent between reporting the agent's type or concealing it if he has learned it. More precisely, he has no incentive to conceal that information, because a report does not affect his own welfare. This applies to agent as well. In short, the principal gets supervisory information with no additional cost: i.e., the wage for supervisory information can be set as equal to zero.

It is assumed that the random cost parameters θ_1 and θ_2 are independently distributed, and therefore there are no gains to be achieved by conditioning the agent's and the supervisor's compensation on each other's types.[4] Note that we assume that θ_1 and θ_2 are not necessarily identically distributed. In particular, we later consider $\Delta\theta_2 \leq \Delta\theta_1$, which captures the idea that the supervisor's fine-tuning activity involves less uncertainty than the agent's main production task. As usual with the combined moral hazard and adverse selection, it is also assumed that even if P observes realized costs c_1 and c_2, he cannot disentangle their components. For example, P does not

[4] We use IC constraints which state that truth-telling is a dominant strategy. We could have used Bayesian IC constraints without changing the results. This follows from the assumption of independent production and the fact that we use ex post IR constraints.

know whether the realized high cost $\overline{c}_1$ is due to A's laziness or a bad state of nature.

The principal, P hires S and A to realize an indivisible project which has exogenously set gross value R. The principal's expected utility is:

$$E[R - c_1 - c_2 - w_1 - w_2]. \tag{5}$$

In the above, expectations are formed for all possible states of nature.

2.2 Information structure

One of the key elements of the information structure is that P observes neither random cost parameters θ_1 and θ_2 nor signals of them. However, the principal has priors over θ_1 and θ_2. We write σ_2 as the signal the supervisor has of the agent's type θ_1. The supervisor can, therefore, help the principal control A by reporting any information he learns to the principal. Similarly, the agent gets signal σ_1 about the supervisor's type θ_2, and thereby he can help the principal control the supervisor. The supervisor and the agent learn signals about each other's types with probability l. The probability of learning signals is exogenously determined.

We follow the same line as Tirole (1986) and most of the existing literature in assuming that signals are hard information: that is, they are verifiable. Having observed the other's type, one can report it to P, and by assumption that report is verifiable. Given that a random cost parameter has value θ, a signal can take two values,$\sigma = \{\theta\ ,\ \emptyset\}$. In other words, the true state of nature is either observable or not. If signal $\sigma = \{\ \theta\}$, one can report r=θ or r=$\emptyset$. That is, one can report the true state of nature or remain silent and claim that one has not observed anything. However, one cannot report a "wrong" state of nature; that claim is by assumption unverifiable. If signal $\sigma = \emptyset$ then one can only report r=$\emptyset$. The main point here is that the principal cannot distinguish whether the agent or the supervisor has actually observed a true state of nature or not.

We also assume that A (S) learns whatever signal S (A) learns. In other words, both A and S know a state of nature. Bearing in mind that random variables θ_1 and θ_2 are independently distributed, we must consider all sixteen cases. Fortunately, most cases behave symmetrically, which greatly simplifies the analysis. The details of states of nature are described in Appendix A.

2.3 Collusion

In principle, collusion may take either a monetary or non-monetary form. We concentrate only on non-monetary side transfers, since monetary transfers (bribes) are typically illegal in most societies and usually strictly forbidden in any organisations. Also in some cases it may be easy for the principal to monitor monetary transfers, and thus transactions costs related to monetary transfers can be very high.

In contrast, non-monetary side transfers are rather difficult to monitor, and on the whole, non-monetary collusion is a rather more realistic and frequently-observed type of collusion in real-world organisations. This idea is modelled by assuming that transaction costs related to monetary transfers are infinite. The members of an organisation are able to collude only by exchanging favours, and transaction costs of non-monetary transfers are assumed to be zero.[5]

The possibility of collusion is, of course, related to the supervisor's and the agent's monitoring roles. The agent and supervisor prefer the principal to be uninformed about the true state of nature when it is good, since they can earn rents because of the asymmetry of information between themselves and the principal. Here the monitored party "buys" the monitor's silence with a favour in return, and he also remains quiet about the true state of nature. Within Organisation II, both A and S have discretion over each other's activities, and the side contract takes the form of "a favour and a counter favour".[6] In our static model these favours and counter favours are exchanged simultaneously.

We assume, as does most of the literature, that side contracts are enforceable (enforceability approach). Of course, side contracts are unenforceable in a court of law due to the very nature of their illegality. There is strong reciprocity between the agent and the supervisor. When they both face a "good" state of nature, and when they have observed each other's type, reporting honestly would make both of them worse off. In contrast, by remaining silent, they both end up better off. Note that in contrast to monetary side payments that are paid ex post, here agents need to coordinate at the reporting stage, and after that there are no enforceability problems.[7] It is important to note

[5] Laffont and Meleu (1997) consider both monetary and non-monetary collusion, and in this sense the model presented here is a special case of their model, since here the transaction costs related to monetary bribes are assumed to be infinite.

[6] Tirole (1988) reviews four possible categories of non-monetary transfers: human relations, acts of cooperation, supervision, and authority.

[7] For more about enforceable and self-enforcing side contracts, see Tirole (1992).

that non-monetary side transfers are invisible. The transaction technology of the non-monetary transfers is extremely efficient. In fact, there are no actual transfers between the agent and the supervisor. What happens is a mutual explicit agreement of silence, in which the benefits flow directly to the colluding parties.

2.4 Timing

The timing of the model is summarized in Figure1. At stage 0, all parties learn relevant information. A and S learn their types and signals, and P learns the prior distributions of types. At stage 1, P designs a main contract which determines wages. At stage 2, A and S may secretly draw up an enforceable side contract. At stage, 3 A and S report r_1 and r_2 respectively to the principal. At stage 4, A and S choose effort levels. At stage 5, costs are realized; and finally, at stage 6 wages are paid to A and S according to the terms of the main contract.

3 The Analysis

3.1 Organisation I: Principal-Productive Supervisor-Agent

In this section we consider a situation where the middle manager monitors the worker and reports to the principal, but where the worker's information about his superior is not used. We begin our analysis with a case of perfect information (first best). The principal has full information about θ_1 and θ_2, and therefore he can always implement the first-best and optimal efforts e* from both A and S. There is no need for monitoring. The principal's problem is simply:

$$Max_{e_1,e_2}[R-(\theta_1-e_1)-w_1-(\theta_2-e_2)-w_2], \quad (6)$$
$$s.t.\ w_i-\psi(e_i) \geq 0, i=1,2.$$

i=1 is the agent and i=2, the supervisor. The solution to (6) is ψ'(e*)= 1, w_1= ψ(e*) and U_1=0 for the agent and ψ'(e*)= 1, w_2= ψ(e*) and U_2=0 for the supervisor. We state the solution as a Lemma 1:

Lemma 1 *Under perfect information the principal keeps both the agent and the supervisor at their reservation utility levels and induces efficient levels of effort e* in all states of nature. The wage levels are independent of the state of nature.*

Proof. The first-best results follow directly from the principal's maximization problem subject to IR constraints.□

We next analyse a benchmark case - that of *a collusion-free equilibrium* - in which collusion does not exist, and the supervisor behaves honestly. Once the principal offers the supervisor a normal second-best contract, he does not have any incentive to lie in his reports about the agent's type, because the reports do not effect his own utility at all. If the supervisor has learned the agent's type, he reports it truthfully to the principal. P then has perfect information about A's type, and there the solution coincides with the first best. If the supervisor has not learned the agent's type, then of course P also remains uninformed about it. The principal's problem is:

$$Max_{e_1,e_2} E[R-(\theta_1-e_1)-w_1-(\theta_2-e_2)-w_2], \tag{7}$$
$$s.t.\ (1)\text{-}(4).$$

By a standard result in contract theory the individual rationality constraint is binding for the inefficient type and the incentive compatibility constraint is binding for the efficient type. Thus, we can simplify the principal's problem and solve the relaxed problem with binding constraints. The binding IR and IC constraints are:

$$\overline{w}_i-\psi(\overline{\theta}_i-\overline{c}_i)=0, i=1,2. \tag{8}$$

$$\overline{w}_i-\psi(\overline{\theta}_i-\overline{c}_i)=\underline{w}_i-\psi(\overline{\theta}_i-\underline{c}_i)=\Phi(\overline{e}_i), i=1,2. \tag{9}$$

In equation (9), $\Phi(\overline{e}_i)$= $\psi(\overline{e}_i)$ - $\psi(\overline{e}_i$-$\Delta\theta_i$) is a rent function with Φ'($\overline{e}_i$) >0. It indicates that a rent enjoyed by the efficient type is an increasing function of the effort level required from the inefficient type. This function demonstrates effectively the important trade-off between incentives and rent extraction.

The principal's problem is to maximize (7) subject to (8) and (9). We derive a solution which involves a combination of the first-best and second-best contracts for the agent in Appendix B. The supervisor's contract is a normal second-best contract. There is no need to compensate the supervisor for his reports about the agent's type, because the supervisor is hired and compensated for production anyway, and his utility is independent of reports. With the help of the supervisor the principal is able to reduce the asymmetric information between himself and the agent. The solution for (7) forms a collusion-free contract, which we refer to as Lemma 2:

Lemma 2 *The collusion-free contract within Organisation I provides for the agent a combination of the first-best and second-best contracts. The supervisor's contract is a normal second-best contract.*

Proof. See Appendix B.

Assume now that non-monetary transfers between A and S can take place. After the principal offers a main contract, A and S may secretly sign a side contract. When offered a collusion-free contract, A and S must figure out whether they can do better by colluding. It follows immediately that the supervisor cannot do any better than with the collusion-free contract. The agent, however, has an incentive to collude; the supervisor's reports reduce his own utility. The agent prefers that the principal be uninformed about his type in good states of nature so that he can earn informational rent $\Phi(\overline{e}_i)$. However, the agent cannot provide any favours for the supervisor as compensation for favourable reports. Therefore non-monetary collusion does not arise. The collusion-free contract as defined in Lemma 2 is also (trivially) a collusion-proof contract. Thus we have proposition 3:

Proposition 3 *In Organisation I, the agent is unable to do any favours for the supervisor, and therefore collusion problems do not arise. The collusion-free contract coincides with a collusion-proof contract.*

Proof: In Organisation I, the agent does not have discretion over the supervisor and thus, by definition, non-monetary side-transfers cannot be exchanged. The second part of the proposition follows immediately.$\square$

Within Organisation I, the principal always asks for reports from the supervisor. This follows from the fact that he is not obliged to reward the supervisor separately for his reports because he is compensated for production anyway. The principal's expected profits within Organisation I are higher than in the case where no reports are available. Within Organisation I, the principal acquires more detailed supervisory information about the agent's type without any additional costs.

It is interesting to contrast this theoretical result with the behaviour of actual organisations. As a general rule in most organisations, a superior monitors subordinates. Think, for example, of the hierarchial organisational behaviour in the armed forces and the civil service. Roughly speaking, they all have in common the fact that only the superiors' information about their subordinates is used, and no direct communication from bottom to the top takes place. As far as only non-monetary transfers between a middle manager and a worker are possible, that sort of monitoring and reporting pattern does not give rise to the possibility of collusion by exchanging favours.

3.2 Organisation II: Principal-Productive "Supervisors"

In this sectioI have to show:

1. Why preventing better than allowing happen: i.e. collusion proofness applies to non-moneatary collusion as well.

2. If rewards only based on own reports: then allowing may be /or is better

3. Here rewards based on both reports optimal: since that prevents for paying for the A/S in a case when they would have reported in any case.

From now on, we allow for the possibility that a workers's information about his superior can also be used. Without the possibility of collusion, new, detailed information which the worker can provide about his superior would be used without hesitation to tighten the middle managers's incentive scheme. However, the possibility of collusion creates new costs which the principal must take into consideration when deciding whether or not to use two supervisory information sources. In short, the principal has to balance the benefits of using all supervisory information with the costs of collusion.

The perfect-information case within Organisation II naturally coincides with the first-best of Organisation I. Supervisory information is not needed, and wages are independent of the state of nature. (See Lemma 1)

Consider next the *collusion-free case*. Suppose that the principal offers both A and S normal second-best contracts. Thus A and S earn informational rents when the state of nature is a good one, and they are kept on their reservation utility levels when the state of nature is a bad one. The key point concerning supervisory information is that, for example, the agent cannot increase his own welfare by concealing information he has learned about the supervisor. Thus, both the agent and the supervisor behave honestly, and P does not have to motivate them to report the supervisory information they hold. The principal is, however, ignorant of A's and S's types in the remaining states of nature. The principal's problem is:

$$Max_{e_1,e_2} E[R - (\theta_1 - e_1) - w_1 - (\theta_2 - e_2) - w_2], \tag{10}$$
$$s.t. \text{ (8)-(9)}.$$

With the binding constraints the above problem is easy to solve. The solution to the principal's problem in the collusion-free case is simply a combination of the first- and second-best contracts for both the supervisor and the agent. A detailed solution is stated in Appendix B. The collusion-free contract within Organisation II is merely a replica of the collusion-free contract within Organisation I, except that here the supervisor's wage schedule is also tailored to the supervisory information the agent provides. The collusion-free contract within Organisation II is stated as Lemma 4:

Lemma 4 *The Collusion-free contract within Organisation II provides for both the agent and the supervisor a combination of the first-best and second-best contracts.*

Proof. See Appendix B.

Assume now that *A and S can collude,* and the collusion-free contract defined in Lemma 4 is offered to them. The question then becomes, can they do any better by colluding and manipulating the supervisory information they have? Clearly for both of them there are strictly positive gains to be realized by coordinating their reports. Namely, they both would like to keep the principal uninformed when they face a good state of nature, and thus earn informational rents instead of being kept on their reservation utility level. Recall that in Organisation I, A could not compensate S for his favourable reports in any way, and in particular he could not do any favours for him. Now within Organisation II, both A and S can compensate each other's favours with counter favours.

From the principal's point of view giving discretion also to A creates a new way to acquire more detailed supervisory information. It also introduces a way to form a side contract, which takes the form of "a favour and counter favour" . To put it more simply, an explicit, non-monetary side contract is simply the following agreement:" When we both face a good state of nature, and if you do not report my type, neither will I report your type". This side contract has a monetary equivalent, which of course equals the rents the agent and the supervisor are able to earn in a good state of nature. It is important to realize here that the rents just flow to A and S, and there are no actual transfers between A and S.

In contrast to monetary side-contracts, non-monetary collusion can occur only in one state of nature: namely when both A and S are efficient and perfectly observe each other's type.[8] Note that this is the only state of nature when favours and counter favours take place simultaneously, which facilitates profitable non-monetary collusion.[9]

The principal's problem is that he cannot distinguish when A and S are colluding and when they actually have not learned each other's types, because they can send the same messages in both cases. In particular, in a state of collusion, they are able to jointly conceal information from the principal.

To prevent side contracts the principal has to pay S and A as much as they would gain from not releasing supervisory information about each other - the principal must match the gains that result from collusion. In short, in order to prevent collusion the principal must provide both A and S informational rents in the state of nature when they are able to collude. The principal has

[8]Monetary side-contracts would also arise when only one of the colluding parties faces a good state of nature, because there the monitored party would buy the monitor's silence with money.

[9]Collusion in other cases would require repetition. Recently, Martimort (1997) has developed a model of dynamic collusion based on repeated interaction of agents.

to respect the following coalition incentive constraint

$$[w_1 - \psi(e*) + w_2 - \psi(e*)] \geq [\underline{w}_1 - \psi(\underline{\theta}_1 - \underline{c}_1) + \underline{w}_2 - \psi(\underline{\theta}_2 - \underline{c}_2)]. \quad (11)$$

The left hand side of equation (11) states A's and S's utility when they truthfully reveal supervisory information ($r_1 = \theta_2$, $r_2 = \theta_1$), and the right hand side states their utility when they conceal it ($r_1 = r_2 = 0$). The principal has to respect the above coalition incentive constraint by rewarding the agent and the supervisor such that they are as well off as when colluding. When $w_i = \psi(e^*) + \Phi(\overline{e}_i)$, i=1,2 A and S have no reason to collude at all, and then collusion does not arise in equilibrium.[10]

It is important to note here that in all other states of nature, the agent and the supervisor will report honestly because non-monetary side transfers cannot be exchanged. And, more importantly, there the agent and the supervisor can not increase their own welfare by concealing the supervisory information they hold. The principal's problem under non-monetary collusion is:

$$Max_{e_1,e_2} E[R - (\theta_1 - e_1) - w_1 - (\theta_2 - e_2) - w_2], \quad (12)$$
$$s.t.\ (8), (9), (11).$$

The detailed solution to this problem is derived in Appendix B. The solution for the principal's problem is a collusion-proof contract, which we state as:

Lemma 5 *The collusion-proof contract within Organisation II provides for both the agent and the supervisor a combination of first-best and second-best contracts. Furthermore* $\widetilde{e}_i < \overline{e}_i$, *and* $w_i = \psi(e^*) + \Phi(\widetilde{e}_i)$, *i=j=1,2 in the*

[10] The equilibrium is actually a weakly collusion-proof.

case when $\{\underline{\theta}_1, \underline{\theta}_2\}$ has been reported to the principal. Otherwise the optimal collusion-proof contract is similar as the independent collusion-free contract characterized in Lemma 4.

Proof. See Appendix B.

The optimal collusion-proof contract involves further distortion $(\widetilde{e_i})$ in the inefficient type's effort as compared to the collusion-free case. This further distortion is introduced due to the possibility of collusion in order to reduce the informational rents the principal has to leave for A and S.

The general properties of the collusion-proof contract are similar to those in Laffont and Tirole (1991), where the authors derive a collusion-proof contract when a regulator and a firm collude by transferring money. Here collusion technology is more efficient, since collusion by exchanging favours does involve any transaction costs. The principal optimally rewards the supervisor and the agent for their supervisory information only in the case when they could have colluded. This, however, occurs here less often than in Laffont and Tirole (1991), since here monetary bribes are not feasible.[11]

When deciding whether to use one or two supervisory information sources, the principal has to balance with a trade-off, which arises from the benefits and costs of using two information sources. To judge whether it is profitable to use one or two supervisory information sources, one has to compare the principal's expected profits under Organisations I and II. The question then is, should all available supervisory information be used or not?

[11] In fact, collusion occurs here with probability $p^2 l^2$ and in Laffont-Tirole (1991) it occurs with probability pl.

3.3 What is the Optimal Organisation?

- **The major point:** Why P can not implement the allocation under OII, that he can implement under OI:

- First, it is easy to see that when collusion is not an issue, P does always prefer OI, since there he is strictly better off.

- Second, under potential collusion. P can allow collusion, and let it happen with prob. $p^2 l^2$ by not rewarding supervisory information. Then if collusion does not arise too often, P is better off than in OI. This is implemented in OII by offering sb-contract.

- Thirdly, due to possibility of collusion, the P optimally adjusts effort levels. Thus with prob. $p^2 l^2$ A and S have no reason to collude, since they receive the same amount by reporting truthfully. This is implemented in OII by offering a collusion-proof contract.

The decision whether or not to use all supervisory information available depends on both the benefits one can accrue by using that information and on the costs of collusion which arise immediately when two information sources are combined. So far, we have assumed that the value of supervisory information the agent and the supervisor hold is equally valuable. From here on the value of their information may differ. When the value of supervisory information differs, some comparative statics are required to see how this affects the optimal use of information within organisations.

Symmetric Supervisor and Agent

This section analyses the symmetry between the supervisor and the agent.

By symmetry we refer to random variables θ_1 and θ_2, which are identically distributed: that is, they have equal supports, $\Delta\theta_1$=$\Delta\theta_2 = \Delta\theta$. In terms of the value of supervisory information, this means that the monetary value of the supervisor's and the agent's reports is equal. Now a distribution $\Delta\theta$ is fixed, and we let p and l vary. Note that in the case of no collusion, the following result follows immediately:

Lemma 6 *Without the problem of collusion, and when the agent and the supervisor are symmetric and report honestly, Organisation II will always dominate Organisation I.*

Proof. To prove this we need only two steps. Note first that in Organisation II, the principal can ignore the agent's information about the supervisor (i.e., not ask the agent to report supervisory information). This means that in OII the principal can do at least as well as he can in OI. To see that in fact the principal does strictly better, note that in OII the principal can acquire more detailed supervisory information at no cost. Therefore, the principal is strictly better off under Organisation II.□

The simple economics behind the above result is that in Organisation II with the aid of honest reports, the principal eliminates the rents and ex post inefficiency which the supervisor's second-best contract without A's reports would include. Does the possibility of collusion change which organisation ends up being the dominant one?

Indeed it can be shown that Organisation II may dominate also under collusion. However this is true only in the case when the probability pl is low enough. Thus we have:

Proposition 7 *Under symmetry and potential collusion, the decision which organisation mode is optimal depends on the probability pl:*

(i) When $pl > (pl^*)$,the costs of collusion are high enough to outweight any benefits, and OI is a dominant one, and

(ii)when $pl < (pl)^*$ it is optimal to use every single piece of available supervisory information, and OII is a most profitable organisation.

Proof. See Appendix B.

The intuition behind Proposition 7 is straightforward. When the probability of pl is low, collusion arises less often and the benefits of additional information provided by the agent are higher. Therefore, the principal adopts OII, and he asks for reports from both the agent and the supervisor.

However when the probability of pl is high, then also collusion occurs more often, and the costs of potential collusion are higher than the benefits of new detailed information in OII. Then the principal ignores the information the agent may have on the supervisor, and adopts OI.

Asymmetry between Supervisor and Agent

From now on we shall focus on the case in which the agent and the supervisor are no longer symmetric. In particular, the supervisor's fine-tuning production task includes smaller variation amongst random variables than does the agent's main production task, that is, $\Delta\theta_1 \geqslant \Delta\theta_2$. Basically we are curious to know how this asymmetry, often observed in practice, affects the optimal use of supervisory information. Another interpretation of this difference is that the quality of the supervisor's information is higher. Note that asymmetry does not change anything in the collusion-free case, and Organisation II is still the dominant one.

An interesting question then is, whether the possibility of non-monetary collusion under asymmetry changes which organisation ends up being the most profitable one. To this end it is necessary to compare the principal's expected profits under both Organisations I and II over all possible values of ($\Delta\theta_1$-$\Delta\theta_2$) given fixed p and l. Comparing the principal's expected profits leads to Proposition 8:

Proposition 8 *a) When pl > (pl*),the costs of collusion are high enough to* *outweight any benefits, and OI is a dominant one as in the case of symmetry. Increasing the difference of ($\Delta\theta_1$-$\Delta\theta_2$) makes OI even more favourable for the principal.*

b) When pl < (pl) the asymmetry matters, and which organisation ends up being dominant depends on the difference ($\Delta\theta_1$-$\Delta\theta_2$). In particular,*

(i) it is optimal to use every single piece of available supervisory information and adopt OII if 0 < ($\Delta\theta_1$-$\Delta\theta_2$) < k,*

(ii) when ($\Delta\theta_1$-$\Delta\theta_2$) = k, the principal's expected profits under Organisations I and II are equal, and finally*

(iii) when ($\Delta\theta_1$-$\Delta\theta_2$) > k, it is optimal to use only the supervisory information the supervisor hold about the agent, and Organisation I is adopted.*

Proof. See Appendix B.

The economics behind Proposition 8 is quite straightforward. It demonstrates that the decision as to whether or not to use all supervisory information is endogenously determined. This, in turn, determines the organisation mode firms adopt in different environments. When making the decision whether to use the additional supervisory information a worker can provide, an organisation designer has to balance the benefits of that information and the costs of collusion which arise immediately when the second information source is used. This trade off defines which organisational mode is the optimal one.

The first part of Proposition 8 simply repeats the argument already present in Proposition 7. Increasing the asymmetry makes OI even further favourable for the principal. The second part of Proposition 8, which is further clarified in Figure 2 states our main result. When asymmetry is introduced, and it is high enough only Organisation I survives. In particular, the optimality of OII (as in Proposition 7) disappears when asymmetry is high enough.

That is, when the agent and the supervisor are not "too asymmetric" it is optimal to adopt the mode of Organisation II. This follows simply from the fact that the benefits of new detailed information are greater than the costs of potential collusion in OII. However, when asymmetry increases, Organisation I may provide greater profits. When the asymmetry is greater than threshold value k*, the expected profits under OI are higher, and this is because the costs of collusion are high enough to offset any gain from new, detailed information in Organisation II. Therefore under this regime Organisation I dominates Organisation II. The intuition behind the domination result is evident. When the value of the agent's supervisory information about the supervisor decreases (i.e., when ($\Delta\theta_1$-$\Delta\theta_2$) increases), the gains from new additional information decrease, and evidently the costs of collusion becomes higher than the benefits. Therefore, it is optimal to break collusion by ignoring the agent's supervisory information by adopting Organisation I.

The results indicate that reporting patterns in all organisations are endogenously determined when the members of those organisations are able to exchange non-monetary side-transfers. When collusion is not an issue, all available supervisory information should be used. However, when collusion may arise, it is shown that there are instances when it is optimal for the principal not to listen to the worker at the bottom of the hierarchy: not only is his supervisory information less valuable, but also listening to the worker raises the possibility that harmful side-trade will take place. In addition, the model gives a precise prediction who should be a middle-manager. The supervisor should be an agent who has on his possession the most valuable supervisory information, and under some cases he should not be monitored. This is a nice result, since it says that the supervisor will perform his task better if he is not monitored by anyone. In sum, not only the decision whether or not it is optimal to use all available supervisory information is endogenous, but so is the decision who should be a supervisor in the first place.[12]

The main result of this paper is that in some environments it is optimal for the principal to ignore intentionally some additional supervisory information, because by doing so he can get some other and more important supervisory information without further cost. Thus, it may be optimal for the principal to commit not to use the workers' information about their superiors so as to deter non-monetary collusion and guarantee that the superiors will truthfully report their observations of their subordinates' types. This, however, will be achieved only if Organisation I is adopted.

4 A Discussion: Separation of Monitoring and Production Tasks

Since the days of Adam Smith, the gains from specialization in general have been put forth as a main reason for the division of labour in economies. This applies to the organisation as well as to the firm. The workers typically per-

[12]See also Aghion and Tirole (1997) who consider the delegation of authority in an incomplete contract framework. They conclude that authority should be delegated to the agent whose preferences are most congruent with the principal's.

form specific tasks, and task sharing or task overlapping is not implemented as often as is technically possible.

In this section we argue that there may be some other reasons for specialization as well that are related to the agents' opportunities to exchange non-monetary side transfers. In particular, separation of monitoring and production tasks works as powerful incentive device that prevents the possibility that members of an organisation are able to exchange favours.

Suppose that, in addition to paying attention to the normal incentive considerations, the principal has the option to design agents' jobs as well. In the analysis above we have shown that non-monetary collusion problems do indeed arise when the supervisor and the agent are able to exchange favours (reciprocity). In this context an interesting question that presents itself is whether or not the principal can design the agents' jobs in such a way that non-monetary side transfers cannot be exchanged.

The first step towards more specialized structures is Organisation I derived earlier in this paper. That is the simplest organisation based on specialization which automatically avoids any non-monetary collusion problems since in OI favours can not be exchanged. It is important to notice however, that this solution has its costs as well. The cost of OI is that the principal has to pay the informational rents for the supervisor. The natural question then becomes, is there a task assignment structure that could lleviate this problem as well.

Assume that in an organisation there is an idle third agent (C). Then it is clear that there is a way to assign production and supervision tasks in a way that no reciprocity exists, and thus collusion does not arise either. This could be implemented as follows. The supervisor produces and monitors the agent. The agent in turn only produces, and C monitors the supervisor. Now it is obvious that collusion does not arise, since the supervisor and the agent can not exchange any favours, and that applies to the supervisor and C as well. If also C has private information about its type, the principal assigns one monitoring task to the agent. When the agent monitors C and other tasks are assigned as above collusion can not arise, since there exist no two members of an organisation who could exchange favours.

What is important in the solution described above is that the monitoring party needs no motivation to report truthfully; he does so willingly when he is paid at least his reservation wage. It is important to note, however, that compensation for supervisory tasks can not necessarily be set equal to zero as in our analysis. This is due to the fact that the supervising agent's only task is to monitor, and the wage depends on his reservation wage. Therefore, when the supervisory wage can be set relatively low, we know that the specialization mode is called for as the optimal task-assignment mode.

Specifically, through the specialization the principal can reap the full benefits of additional supervisory information in addition to being able to avoid any of the costs of collusion. Here task assignment works as an effective incentive device against collusion. By separating production and supervisory tasks, the principal makes the existence of non-monetary collusion impossible. What is important for the results is that at least one member of organisation is not monitored, since this quarantees that the monitor performs his monitoring task honestly. In addition, no one should monitor his own monitor. That is, organisations should be designed so as to break the circle of favours.

It is interesting to expand these observations to a broader context. These results may help us to understand how it is that the often observed hierarchial organisation mode can be the optimal solution to the problem of non-monetary collusion between the members of that hierarchy. Namely, designing production and supervisory tasks in an optimal way eliminates all collusion problems as long as monetary side-transfers are excluded, as was assumed here. Taken together, this implies a hierarchy with a principal at the top, a supervisor in the middle, and a worker at the bottom. Hierarchial structures are often characterized as inefficient. Here, however, a standard hierarchial solution turns out to be the optimal response to the chronic problem of non-monetary collusion. The possibility that members of an organisation can exchange non-monetary favours may be an important factor in determining how different tasks should be assigned between workers. Finally notice that here the gains from specialization are not coming through technology, but from the fact that specialization prevents non-monetary collusion.

5 Concluding Remarks

In this paper we have analysed the optimal use of supervisory information under circumstances of potential collusion. The paper proposes a theory of non-monetary collusion, where the members of an organisation collude by simultaneously exchanging favours. Collusion is possible only when all available information is used, and the principal has to decide whether to use only one information source and avoid collusion altogether, or use two information sources and bear the costs of collusion.

It has been shown that under circumstances of collusion it may be optimal not to use all available information. In particular, when the agent and the supervisor are asymmetric enough, it may be optimal not to listen to the worker at the bottom of a hierarchy, since that prevents collusion and the supervisor provides more valuable supervisory information at no further cost. The main result of the paper is not only that the use of information is endogenously determined, but so is the decision to whom the supervision task should be assigned. The supervisor should be an agent who has on his possession the most valuable information. An interesting result is that the supervisor performs his supervision task better when he is not monitored by some third party. On the whole, the paper presents us with general guidelines about whose information in a real-world organisation should and should not be used, and the simple reason why all available supervisory information is typically not used.

The issues of task assignment deserve closer analysis than they receive here. It seems that it is possible to design tasks in such a way that non-monetary collusion simply does not arise. The next step is to figure out whether it is possible to assign tasks in such a way that monetary side transfers can be deterred as well. This however is left for future research.

Appendix A

All possible "states of nature"

1. p$^2l^2$: $\theta_1 = \underline{\theta}_1, \sigma_1 = \underline{\theta}_2$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \underline{\theta}_1$
2. p$^2(1-l)l$: $\theta_1 = \underline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \underline{\theta}_1$
3. p(1-p)(1-l)l: $\theta_1 = \underline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \underline{\theta}_1$
4. p(1-p)l^2 : $\theta_1 = \underline{\theta}_1, \sigma_1 = \overline{\theta}_2$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \underline{\theta}_1$
5. p$^2l(1-l)$: $\theta_1 = \underline{\theta}_1, \sigma_1 = \underline{\theta}_2$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \emptyset$
6. p$^2(1-l)^2$: $\theta_1 = \underline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \emptyset$
7. $p(1-p)(1-l)^2$: $\theta_1 = \underline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \emptyset$
8. p(1-p)l(1-l): $\theta_1 = \underline{\theta}_1, \sigma_1 = \overline{\theta}_2$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \emptyset$
9. (1-p)pl(1-l):$\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \underline{\theta}_2$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \emptyset$
10. (1-p)p(1-l)^2 : $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 = \emptyset$
11. (1-p)$^2(1-l)^2$: $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \emptyset$
12. (1-p)$^2l(1-l)$: $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \overline{\theta}_2$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 = \emptyset$
13. (1-p)pl^2: $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \underline{\theta}_2$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 =$ $\overline{\theta}_1$
14. (1-p)p(1-l)l:$\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \underline{\theta}_2, \sigma_2 =$ $\overline{\theta}_1$
15. (1-p)$^2(1-l)l$: $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \emptyset$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 =$ $\overline{\theta}_1$
16. (1-p)$^2l^2$: $\theta_1 =$ $\overline{\theta}_1, \sigma_1 = \overline{\theta}_2$ $\quad$ $\theta_2 = \overline{\theta}_2$, $\sigma_2 =$ $\overline{\theta}_1$

Appendix B

Proof of Lemma 2

Under a collusion-free regime the principal offers a normal second best contract to the supervisor, and thus the supervisor has no incentive to lie when reporting about the agent's type. Therefore, the principal acquires the supervisor's information about the agent's type in cases 1-4 and 13-16, and there the first-best solution, $\psi'(e*) = 1$ and w=$\psi(e*)$ will apply. In the remaining cases, the principal knows only the priors of the agent's type. Since the principal does not learn any additional information about the supervisor, he knows only the priors of the supervisor's type. The principal's problem is thus reduced to two independent programs: one for the agent and one for the supervisor.

We know that at the optimum the IR constraint of the inefficient type and the IC constraint of the efficient type are binding. If they were not binding the principal could increase his profits by offering a lower wage to the inefficient type without violating the IR constraint, and thus the original solution would not be optimal. We use this result, and solve the principal's relaxed problem with binding constraints. Since the two programs are independent, we only consider the principal's problem concerning the agent:

$$
\begin{aligned}
& Max_{\underline{e}_1,\overline{e}_1} p[R - (\underline{\theta}_1 - \underline{e}_1) - \psi(\underline{e}_1) - \psi(\overline{e}_1) + \psi(\overline{e}_1 - \Delta\theta_1)] + \\
& (1-p)[R - (\overline{\theta}_1 - \overline{e}_1) - \psi(\overline{e}_1)]
\end{aligned}
\tag{B.1}
$$

The first-order conditions with respect to $\underline{\mathrm{e}}_1$and $\overline{e}_1$ are as follows:

$$
\begin{aligned}
&= \quad p(1 - \psi'(\underline{e}_1)) = 0, \text{and} \\
&= \quad p(-\psi'(\overline{e}_1) + \psi'(\overline{e}_1 - \Delta\theta_1)) + (1-p)(1 - \psi'(\overline{e}_1)) = 0.
\end{aligned}
\tag{B.2}
$$

From above we get:

$$
\psi'(\underline{e}_1) = 1, \text{and } \psi'(\overline{e}_1) = 1 - \frac{p}{1-p}(\psi'(\overline{e}_1) - \psi'(\overline{e}_1 - \Delta\theta_1)) \tag{B.3}
$$

Later on we use the following notation: $\Phi'(\overline{e}_1) = (\psi'(\overline{e}_1) - \psi'(\overline{e}_1 - \Delta\theta_1))$. The first-order conditions for the supervisor are calculated in a similar fashion, but for the sake of brevity we do not include them here. With the help of the first-order conditions we can now solve for the optimal effort levels and wages. First, the principal has perfect information about the agent's type in cases 1-4 and 13-16, and then the first-best solution will apply: $\psi'(e*) = 1, w* = \psi(e*)$, and $\mathrm{U}_1 = 0$. In the good states of nature, cases 5-8, the solution is $\psi'(\underline{e}_1) = 1$, $\underline{w}_1 = \psi(\underline{e}_1)+ \Phi(\overline{e}_1)$, and $\underline{\mathrm{U}}_1 = \Phi(\overline{e}_1)$;and in the bad states of nature, cases 9-12, the solution is $\psi'(\overline{e}_1) = 1 - \frac{p}{1-p}(\Phi'(\overline{e}_1))$, $\overline{w}_1 = \psi(\overline{e}_1)$,and $\overline{U}_1 = 0$.

The solution for the supervisor is a normal, second best contract. In the good states of nature the solution is $\psi'(\underline{e}_2) = 1$, $\underline{w}_2 = \psi(\underline{e}_2)+ \Phi(\overline{e}_2)$, and $\underline{\mathrm{U}}_2 = \Phi(\overline{e}_2)$, and in bad state of nature the solution is $\psi'(\overline{e}_2) = 1-\frac{p}{1-p}(\Phi'(\overline{e}_2))$, $\overline{w}_2 = \psi(\overline{e}_2)$,and $\overline{U}_2 = 0$.

It follows from the convexity of disutility function $\psi(e_i)$ that $\overline{e}_i < e* = \underline{e}_i$, and $\overline{w}_i < w* < \underline{w}_i, i = 1, 2$. These wages and effort levels form the collusion-free contract defined in Lemma 2.

We still must make sure that our solution does not violate the ignored efficient type's IR and inefficient type's IC constraints. Notice first that the efficient type's IC constraint and the inefficient type's IR constraint imply efficient type's IR constraint, and therefore it will never bind. Finally notice that the solution for the principal's problem do satisfy the inefficient type's IC constraint, since:

$$\overline{w}_i - \psi(\overline{\theta}_i - \overline{c}_i) \geqslant \underline{w}_i - \psi(\overline{\theta}_i - \underline{c}_i), i = 1, 2.$$

$$0 \geqslant \underline{w}_i - \psi(\overline{\theta}_i - \underline{c}_i), i = 1, 2.$$

$$0 \geqslant \underline{w}_i - \psi(\overline{\theta}_i - \underline{c}_i) = \psi(\underline{e}_i) + \psi(\overline{e}_i) - \psi(\overline{e}_i - \Delta\theta_i) - \psi(\overline{\theta}_i - \underline{c}_i), i = 1, 2.$$

$$= (\psi(\overline{e}_i) - \psi(\overline{e}_i - \Delta\theta_i)) - (\psi(\overline{\theta}_i - \underline{c}_i) - \psi(\overline{\theta}_i - \underline{c}_i - \Delta\theta_i)), i = 1, 2.$$

$$= \Phi(\overline{\theta}_i - \overline{c}_i) - \Phi(\overline{\theta}_i - \underline{c}_i) < 0, i = 1, 2.$$

The above inequality is due to fact that $\underline{c}_i < \overline{c}_i$ i.e. $\underline{e}_i > \overline{e}_{i,}\ i = 1, 2$. Therefore the inefficient type's IC constraint never binds. $\square$

Proof of Lemma 4

Under a collusion-free regime, the principal offers the supervisor and the agent normal second-best contracts, and he inherits the supervisory information which the the supervisor and the agent hold concerning one another. The solution is identical to that presented above, with the distinction that now the principal is also able to tighten the supervisor's incentive scheme with the supervisory information provided by the agent. Otherwise the problem is the normal adverse selection problem.

As a space saving measure we do not state the first-order conditions here, but skip ahead directly to the characterization of the collusion-free contract within Organization II. For an agent in Organization II, a collusion-free contract includes $\psi'(e*) = 1, w* = \psi(e*)$, and $\mathrm{U}_1 = 0$ in the perfect information cases and $\psi'(\underline{e}_1) = 1$, $\underline{w}_1 = \psi(\underline{e}_1) +$ $\Phi(\overline{e}_1)$, and $\underline{\mathrm{U}}_1 = \Phi(\overline{e}_1)$ in the good states of nature (cases 5-8), and $\psi'(\overline{e}_1) = 1 - \frac{p}{1-p}(\Phi'(\overline{e}_1))$, $\overline{w}_1 = \psi(\overline{e}_1)$,and $\overline{U}_1 = 0$ in the bad states of nature (cases 9-12). For the the supervisor the solution is $\psi'(e*) = 1, w* = \psi(e*)$, and $U_2 = 0$ in the perfect information cases, and in the good states of nature (cases 2, 6, 10, 14) the solution is $\psi'(\underline{e}_2) = 1$, $\underline{w}_2 = \psi(\underline{e}_2)+ \Phi(\overline{e}_2)$, and $\underline{U}_2 = \Phi(\overline{e}_2)$, and in bad state of nature (3, 7, 11, 15) the solution is $\psi'(\overline{e}_2) = 1-\frac{p}{1-p}(\Phi'(\overline{e}_2))$, $\overline{w}_2 = \psi(\overline{e}_2)$,and $\overline{U}_2 = 0$.

The rest of the proof proceeds exactly in the same way as in the proof of Lemma 2, and thus it is omitted here.

Proof of Lemma 5

If the principal offers the collusion-free contract derived in Lemma 4, the supervisor and the agent can do better by colluding and manipulating supervisory information. They can profitably collude when they perfectly observe each other's type. When both the supervisor and the agent are efficient and have observed each others' types (case 1), they can coordinate and send the same messages as in the case when they have not observed anything (case 6). By concealing supervisory information, they have learned they are able to enjoy informational rents. The principal's problem is that he cannot distinguish between cases 1 and 6.

In all other cases, when the agent and the supervisor observe each other's type, they will report it honestly, because the agent or the supervisor cannot increase his own utility by concealing supervisory information. Thus , collusion is an issue only in case 1, when the supervisor and the agent are able to exchange favours, and that occurs with probability $p^2 l^2$. Due to potential collusion problems the principal must motivate the supervisor and the agent to report honestly their supervisory information in case 1. the principla must compensate the supervisor and the agent for their supervisory information such that they are equally well off as when colluding. The compensation for supervisory information is determined by the binding coalition incentive constraint:

$$[w_1 - \psi(e*) + w_2 - \psi(e*)] \geq [\underline{w}_1 - \psi(\underline{\theta}_1 - \underline{c}_1) + \underline{w}_2 - \psi(\underline{\theta}_2 - \underline{c}_2)]. \quad \text{(B.4)}$$

In (B.4) the left hand side shows the agent's and the supervisor's utility in case, when ($r_1 = \underline{\theta}_2$,$r_2 = \underline{\theta}_1$). The right hand side shows their utility in case 6, when they have not actually learned (or they have concealed) supervisory information ($r_1 = r_2 = \varnothing$). Note that U_i goes to U*=0, i=1,2 when the supervisor and the agent report honestly. To make the supervisor and the agent report truthfully and not to collude, it has to be the case that

$$\begin{aligned} w_i &= \psi(\underline{\theta}_i - \underline{e}_i) + \Phi(\overline{\theta}_i - \overline{c}_i) = \psi(\underline{e}_i) + \Phi(\overline{e}_i), i = 1, 2. \quad \text{(B.5)} \\ \text{when } (r_1 &= \underline{\theta}_2, r_2 = \underline{\theta}_1) \end{aligned}$$

When the principal satisfies (B.5), he has perfect information about the agent's type in cases 1-4 and 13-16, and the supervisor's type in cases 1, 4, 5, 8, 9, 12, 13 and 16. In other cases asymmetric information exists, and there teh efficient type's IC constraint and the inefficient type's IR constraint are binding. Since non-monetary collusion can take place only in one case, the coalition incentive constraint has to be satisfied with probability $p^2 l^2$. The principal's problem can be considered in two parts: one for the agent and one for the supervisor, which are identical; and thus we calculate explicitly only the agent's optimal contract. The principal's problem is:

$$
\begin{aligned}
&Max_{\underline{e}_1,\overline{e}_1}\ \mathrm{p}^2 l^2[R-(\underline{\theta}_1-e*)-\psi(e*)-\Phi(\overline{e}_1)] \\
&+p^2(1-l)l[R-(\underline{\theta}_1-e*)-\psi(e*)] \\
&+p(1-p)(1-l)l[R-(\underline{\theta}_1-e*)-\psi(e*)] \\
&+p(1-p)l^2[R-(\underline{\theta}_1-e*)-\psi(e*)] \\
&+p^2 l(1-l)[R-(\underline{\theta}_1-\underline{e}_1)-\psi(\underline{e}_1)-\Phi(\overline{e}_1)] \\
&+p^2(1-l)^2[R-(\underline{\theta}_1-\underline{e}_1)-\psi(\underline{e}_1)-\Phi(\overline{e}_1)] \\
&+p(1-p)(1-l)^2[R-(\underline{\theta}_1-\underline{e}_1)-\psi(\underline{e}_1)-\Phi(\overline{e}_1)] \\
&+p(1-p)l(1-l)[R-(\underline{\theta}_1-\underline{e}_1)-\psi(\underline{e}_1)-\Phi(\overline{e}_1)] \\
&+(1-p)pl(1-l)[R-(\overline{\theta}_1-\overline{e}_1)-\psi(\overline{e}_1)] \\
&+(1-p)p(1-l)^2[R-(\overline{\theta}_1-\overline{e}_1)-\psi(\overline{e}_1)] \\
&+(1-p)^2(1-l)^2[R-(\overline{\theta}_1-\overline{e}_1)-\psi(\overline{e}_1)] \\
&+(1-p)^2 l(1-l)[R-(\overline{\theta}_1-\overline{e}_1)-\psi(\overline{e}_1)] \\
&+(1-p)pl^2[R-(\overline{\theta}_1-e*)-\psi(e*)] \\
&+(1-p)p(1-l)l[R-(\overline{\theta}_1-e*)-\psi(e*)] \\
&(1-p)^2(1-l)l[R-(\overline{\theta}_1-e*)-\psi(e*)] \\
&+(1-p)^2 l^2[R-(\overline{\theta}_1-e*)-\psi(e*)].
\end{aligned}
$$

The first-order conditions with respect to $\underline{e}_1$ are:

$$
\begin{aligned}
&= (1-l)p[1-\psi'(\underline{e}_1)]=0, \text{and thus} \\
\psi'(\underline{e}_1) &= 1
\end{aligned}
$$

For the efficient type we get the same solution as in the collusion-free case - no distortion on the top: $\underline{e}_1 = e* = 1$. The first-order conditions with respect to $\overline{e}_1$:

$$\begin{aligned} &= (1-l)(1-p)[1-\psi'(\overline{e}_1)] - [p^2l^2 + (1-l)p]\Phi'(\overline{e}_1) = 0 \\ \psi'(\overline{e}_1) &= 1 - \frac{p}{1-p}[1 + \frac{pl^2}{1-l}]\Phi'(\overline{e}_1). \end{aligned}$$

The inefficient type's effort is further distorted due to possibility of collusion, which occurs with probability p^2l^2. We label the further distorted effort level $\widetilde{e}_i < \overline{e}_1$. The first-order conditions with respect to $\underline{e}_2$ and $\overline{e}_2$ follow in a similar fashion, and they are not stated here.

With the above first-order conditions we can solve the optimal contract. For the agent, the optimal collusion-proof contract offers $\psi'(e*) = 1, w* = \psi(e*)$, and $U_1 = 0$ under perfect information, $\psi'(\underline{e}_1) = 1$, $\underline{w}_1 = \psi(\underline{e}_1)+ \Phi(\widetilde{e}_1)$, and $\underline{U}_1 = \Phi(\widetilde{e}_1)$ in the good states of nature (cases 5-8), and $\psi'(\widetilde{e}_1) = 1 - \frac{p}{1-p}[1 + \frac{pl^2}{1-l}]\Phi'(\widetilde{e}_1), \overline{w}_1 = \psi(\widetilde{e}_1)$,and $\overline{U}_1 = 0$ in the bad states of nature (cases 9-12). Notice that in case 1 that happens with probability p^2l^2, the principal has to provide informational rent the agent, and thus $w_1 = \psi(e*) + \Phi(\widetilde{e}_1)$, and $U_1 = \Phi(\widetilde{e}_1)$. For the supervisor, the solution is similar: $\psi'(e*) = 1, w* = \psi(e*)$, and $U_2 = 0$ in the perfect information cases, and $\psi'(\underline{e}_2) = 1$, $\underline{w}_2 = \psi(\underline{e}_2)+ \Phi(\widetilde{e}_2)$, and $\underline{U}_2 = \Phi(\widetilde{e}_2)$ when S is efficient (cases 2, 6, 10, 14), and $\psi'(\widetilde{e}_2) = 1 - \frac{p}{1-p}[1 + \frac{pl^2}{1-l}]\Phi'(\widetilde{e}_2)$, $\overline{w}_2 = \psi(\widetilde{e}_2)$,and $\overline{U}_2 = 0$ when S is inefficient (3, 7, 11, 15). The principal has to provide also the supervisor informational rent in case 1, and consequently then $w_2 = \psi(e*) + \Phi(\widetilde{e}_2)$, and $U_2 = \Phi(\widetilde{e}_2)$. These results give rise to Lemma 5. The ignored constraints are automatically satisfied with similar arguments as earlier.

This contract is indeed a collusion-proof one, since the agent and the supervisor can not do any better by colluding. In particular, consider case 1, which is the only possibility for profitable collusion. If the agent and the supervisor colluded, they would gain the same informational rents, $\Phi(\widetilde{e}_1)$, $\Phi(\widetilde{e}_2)$ that they get in case 6 ($r_1 = r_2 = \varnothing$). The collusion-proof contract, however, offers them in case 1 as much when they truthfully report supervisory information ($r_1 = \underline{\theta}_2$,$r_2 = \underline{\theta}_1$). There are no gains to be achieved by colluding.□

Proof of Proposition 7

Since the gross value of the project is exogenously set as R, all that matters is the expected total costs under both organisation modes.We divide the proof into two parts, and analyse first the costs related to the agent. Since we consider here a symmetric case, we label $\Delta\theta_1$=$\Delta\theta_2$=$\Delta\theta$. Now $\Delta\theta$ is fixed, and we let p and l vary.

Notice that Organisation I is a special case of Organisation II where A's supervisory information about S is not used. When the principal decides to use A's information about S, the possibility of collusion arises. Therefore the principal has to satisfy the coalition incentive constraint, and thus the wage the principal has to pay the agent increases with this informational rent:$\Phi(\overline{e}_1)$. This occurs with probability $p^2 l^2$.

Notice that to simplify the proof we use $\overline{e}_1$rather than the optimized value $\widetilde{e}_1$. In other words, we just compare two objective functions the principal is maximizing. The total expected costs related to the agent are indeed always higher in Organisation II. The difference between the expected profits between OII and OI boils then down to: $\Delta\pi_A = -p^2 l^2 \Phi(\overline{e}_1)$.

When the principal decides to use A's information, the expected total costs related to the supervisor will decrease, since with the help of the agent's supervisory information about the supervisor(OII), the principal avoids paying the informational rents $\Phi(\overline{e}_2)$ in cases 5, 9, and 13. These savings accrue with probability pl(1-pl), since the principal has to provide the supervisor the informational rent in case 1 to motivate him to report information about the agent. In addition, with the help of the new information, the principal avoids inefficiency in four cases (4, 8, 12, 16), and there the solution is at the first-best level. These savings occur with probability (1-p)l. Therefore the profits increase when OII is adopted:

$$\Delta\pi_S = pl(1-pl)\Phi(\overline{e}_2) + (1-p)l[(\overline{\theta}_2 - \overline{e}_2) + \psi(\overline{e}_2) - (\overline{\theta}_2 - e*) - \psi(e*)]$$

Since symmetry, $\Phi(\overline{e}_1) = \Phi(\overline{e}_2)$, and $\Delta\pi = \Delta\pi_A + \Delta\pi_S$.

$$\Delta\pi = pl(1-2pl)\Phi(\overline{e}) + (1-p)l[(\overline{\theta}_2 - \overline{e}_2) + \psi(\overline{e}_2) - (\overline{\theta}_2 - e*) - \psi(e*)]$$

Define D= $[(\overline{\theta}_2 - \overline{e}_2) + \psi(\overline{e}_2) - (\overline{\theta}_2 - e*) - \psi(e*)]$, and notice that $\Phi(\overline{e}) > D > 0$. Now $\Delta\pi$ can be written as:

$$\Delta\pi = pl(1-2pl)\Phi(\overline{e}) + (l-pl)D$$

Whether $\Delta\pi$ is smaller or greater than zero depends on pl. Now it is obvious that $\exists$ (pl)* such that $\Delta\pi = 0$. Consequently we have :

(i) if pl >(pl*), $\Delta\pi < 0$. That is, the costs from collusion are high enough to outweight any benefits from the additional information the agent provides, and therefore Organisation I dominates,

(ii) if pl <(pl*), $\Delta\pi > 0$. In this case the costs from collusion are small compared to the benefits of additional information the agent provides. This is due to fact that now the probability of collusion is low. In this case all available information should be used, and Organisation II dominates. □

Proof of Proposition 8

From now on we allow asymmetry: $\Delta\theta_1 \geqslant \Delta\theta_2$, and fix p and l. In, particular we want show that when $(\Delta\theta_1 - \Delta\theta_2)$ increases only Organisation I survives. That is, the costs from collusion becomes so high that the principal decides to use only one supervisory information source, and adopts Organisation I.

In proving Proposition 8 we use the expression derived in earlier proof. Notice that since asymmetry: $\Phi(\overline{e}_1) \neq \Phi(\overline{e}_2)$, $\Delta\pi$ becomes:

$$\Delta\pi = -p^2l^2\Phi(\overline{e}_1) + pl(1-pl)\Phi(\overline{e}_2) + (l-pl)D$$

In above D $= [(\overline{\theta}_2 - \overline{e}_2) + \psi(\overline{e}_2) - (\overline{\theta}_2 - e*) - \psi(e*)] > 0$.

The easiest way to show our main results is to fix $\Delta\theta_1$ and let $\Delta\theta_2$ approach zero, then of course $(\Delta\theta_1 - \Delta\theta_2)$ increases.

Part a): When pl > (pl*), the costs from collusion are high enough to outweight any benefits, and we know that under symmetry $\Delta\pi < 0$. Incresing $(\Delta\theta_1 - \Delta\theta_2)$ makes OI even more favourable for the principal, since it pushes $\Delta\pi$ even more below zero.

Part b): pl < (pl*), we know that the benefits of new detailed information are higher than the costs from collusion, and thus under symmetry $\Delta\pi > 0$. Consider now asymmetry and let $\Delta\theta_2 \to 0$, then the last two terms of above equation approach zero as well. That is, when $(\Delta\theta_1 - \Delta\theta_2)$ increases at the end only the costs from collusion concerning the agent: $-p^2l^2\Phi(\overline{e}_1)$ remain.

If asymmetry is not high enough: $0 < (\Delta\theta_1\text{-}\Delta\theta_2) < k^*$, OII may still dominate, and there is *also* $(\Delta\theta_1\text{-}\Delta\theta_2) = k^*$, when OI and OII are equally good. And Finally when $(\Delta\theta_1\text{-}\Delta\theta_2) > k^*$, only Organisation I survives. □

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