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Supervision in Firms

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Abstract

To control, evaluate, and motivate their agents, firms employ supervisors. As shown by empirical investigations, biased evaluation by supervisors linked to collusion is a persistent feature of firms. This paper studies how deceptive supervision affects agency relationships. We consider a three-level firm where a supervisor is in charge of producing a verifiable report on an agent's output. Depending on the output he has observed, the supervisor may either collude with the agent or with the principal, and make an uninformative report. We show that the proliferation of collusive activities in firms: modifies the configuration of the optimal preventive policy, may increase the expected cost of preventing each type of collusion, is beneficial to the supervisor and detrimental to the agent, and is not always harmful.

Keywords: Firm; Group decision; Control; Biased supervision.

JEL Classification: D20; D73; L20; M50.

Résumé

Les firmes emploient des superviseurs pour contrôler, évaluer et motiver leurs employés. Ainsi que le montrent les études empiriques, les biais d'évaluation associés à la collusion sont fréquents dans les firmes. Cet article étudie les conséquences de ce type de biais sur les relations hiérarchiques d'agence. Nous considérons une firme principal-superviseur-agent dans laquelle le rôle du superviseur est de faire un rapport sur la production de l'agent. Suivant le niveau de production observé, le superviseur peut former une coalition avec le principal ou avec l'agent et dissimuler l'information obtenue. L'article montre que la prolifération des formes de collusion à l'intérieur de la firme : modifie la configuration de la politique préventive optimale, peut accroître le coût espéré de la prévention de chaque forme de collusion, profite au superviseur et nuit à l'agent, et n'est pas toujours néfaste.

Mots-clés: Firme; Décision de groupe; Contrôle; Supervision biaisée.

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1 Introduction

This paper investigates how deceptive supervision affects firms. As stressed by the influential work of Berle and Means (1932), an essential feature of the modern corporation is the separation of ownership and control. To control, evaluate, and motivate their agents, modern corporations employ professional supervisors whose roles are to acquire and transmit information about these agents. Once informed, a supervisor may engage in collusive activities, withhold valuable information, and therefore produce a biased report. Worldwide scandals have revealed how pervasive collusion among members of both regulated and unregulated hierarchical agency relationships is.[1] Preventing collusive supervision has become a central concern of firms. Since the pioneering studies of Antle (1984) and Tirole (1986), a large literature has been devoted to the issue of collusion between the supervisor and the agent within principal-supervisor-agent relationships.[2]

It has recently been shown that the harmfulness of supervisor/agent collusion is very sensitive to the environment in which it may occur and that this type of collusion is often costless to deter (e.g., Vafaï 2002; Cont 2004 and references therein). These findings question the relevance of the literature on supervisor/agent collusion. We analyze how a firm is impacted by biased supervision and notably identify a cause for supervisor/agent collusion harmfulness, namely the presence of more than a single type of collusion.

Agency models of unofficial activities in hierarchies have also been criticized on the ground that they focus exclusively on unofficial activities involving members of lower levels (e.g., Perrow 1986; Dow 1987). Milgrom and Roberts (1988) argue that the cost of unofficial activities between superiors is the major cost of transacting in hierarchies. The main shortcoming of the literature on collusion in hierarchical firms is that it only focuses on downward collusion, that is, on collusion

[1] Two of the many recent examples are collusion scandals at the Canadian Radio-television and Telecommunications Commission and at the Japanese Ministry of Health, Labor and Welfare.

[2] This literature is reviewed by Tirole (1992).

between the supervisor and the agent, or, equivalently, on reporting biases beneficial to the agent.

In addition to supervisor/agent collusion, a principal-supervisor-agent firm is also vulnerable to collusion between the principal and the supervisor. Empirical studies find evidence of supervisory reporting biases both beneficial (i.e., over-reporting) and detrimental (i.e., under-reporting) to the supervisor's subordinate (e.g., Holzbach 1978; Gabris and Michell 1988; Murphy and Cleveland 1995; Arvey and Murphy 1998). While these biases may be the consequences of the personal preferences or tendencies of the supervisor[3], they may also be the consequences of informal agreements between the supervisor and the agent - as it is the case when these two employees collude - or between the principal and the supervisor. Indeed, as shown, for example, by Crozier (1967) and Crozier and Friedberg (1980) in their studies of big French regulated monopolies, a supervisor's loyalty to her/his principal may result in principal/supervisor collusion, and thus in an unfair treatment of the supervisor's subordinate. Is this type of collusion also often harmless? Is there any interaction between the two types of collusion or, equivalently, does it matter that a firm is vulnerable to multiple types of collusion rather than to a single one? To answer these questions, we consider a general environment where a three-level firm may be vulnerable to both supervisor/agent and principal/supervisor collusion. The paper thus accounts for the above-mentioned criticisms by considering both collusion involving members of lower and upper levels of hierarchies.[4]

In our three-level hierarchy with moral hazard a supervisor is responsible for providing a principal with a report about an agent's output. The supervisor operates an imperfect control technology that reveals hard (unforgeable) information/evidence about the agent's output only with a certain probability. The informed supervisor then has the possibility to withhold information and claim

[3]For example, one of the most studied of these tendencies is known as the horns and halo effect (e.g., Klimoski and London 1974). This effect refers to a supervisor's tendency to be unduly influenced by an unfavorable (horns) or favorable (halo) first impression on a subordinate.

[4]While various forms of corrupt behavior inside institutions have been studied by economists - such as sabotage (e.g., Lazear 1989; Bose, Pal and Sappington 2010), rent-seeking (e.g., Murphy, Shleifer and Vishny 1993), and corruption (e.g., Silva, Kahn and Zhu 2007) - the focus of this paper is collusive activities taking place in multi-level agency relationships with hard information in the tradition of Tirole (1986, 1992).

that control has not been decisive. If control reveals hard evidence that the agent has produced a high output, that is, if the information obtained by the supervisor is unfavorable to the principal - in the sense that the principal then has to pay a higher wage to the agent than in the case where control is indecisive - the supervisor may collude with the principal and, in exchange for a bribe, make an uninformative report. If instead control reveals evidence that a low output has been produced, that is, if the information obtained by the supervisor is unfavorable to the agent - in the sense that the agent then receives a lower wage than in the case where control is indecisive - the supervisor may collude with the agent and, in exchange for a bribe, report that control has not been decisive.

We characterize the optimal contracts in this environment. To understand the extra modifications that the simultaneous threats of supervisor/agent and principal/supervisor collusion introduce in a firm, we first characterize the optimal contracts in a three-level hierarchy vulnerable to a single type of collusion. It is shown that collusion may be costlessly deterred in a firm exclusively vulnerable to supervisor/agent collusion. In other words, the sole possibility of supervisor/agent collusion is harmless. We then show that it is costly to deter principal/supervisor collusion in a firm exclusively vulnerable to this type of unofficial activity. Unlike supervisor/agent collusion, collusion between the principal and the supervisor is thus harmful. The possibility of principal/supervisor collusion raises the important question of who will guard the ultimate guardian? To optimally resolve this issue, the principal needs to impose a constraint on itself that prevents collusion with the supervisor. We finally analyze the general case where a firm is vulnerable to both types of collusion and show that, compared with the case where only a single type of collusive activity may occur, in the presence of two types of collusion: the configuration of the optimal preventive policy is modified, supervisor/agent collusion is not systematically harmless anymore, the efficiency of the firm is sometimes reduced, and the supervisor more often receives a rent, whereas the agent less often receives a rent. These results are the consequences of the existence of negative interactions between collusive activities. Indeed, compared with the single type cases, in certain circumstances the threat of a second type of collusion increases the cost of deterring each type of collusion.

These findings prove that the proliferation of collusive activities has major impacts on a firm, and hence considering only the possibility of supervisor/agent collusion in the analysis of multi-level hierarchies is deceptive. Although supervisor/agent collusion may be costlessly deterred in a firm vulnerable exclusively to this type of unofficial activity, this is not the case anymore when principal/supervisor collusion is also considered.

The remainder of this paper is organized as follows. The model is outlined in Section 2. Section 3 characterizes the optimal incentive contracts in the absence of collusion. Section 4 characterizes the optimal incentive contracts respectively when a single type of collusion is possible and when two types of collusion are possible. Section 5 concludes. Proofs are given in an Appendix.

2 The model

A risk neutral principal-supervisor-agent firm under moral hazard operates as follows. The agent is the productive unit. She has the choice between shirking, in which case her effort level is $e = 0$, and working hard by exerting $e = 1$. Working hard results in the production of a high output $x_H > 0$ with probability $\pi \in (0, 1)$ and the production of a low output $x_L \equiv 0$ with probability $1 - \pi$, whereas shirking results in the production of a low output. The agent's effort level is unobservable to the principal and the supervisor.

The principal (it) charges a supervisor (he) to acquire and transmit, through a verifiable report, hard information/evidence about the agent's output. The supervisor has access to an imperfect control technology that reveals hard evidence on the agent's output with probability $p \in (0, 1)$. The supervisor's report, r, can thus take the following values $r \in \{x_L, \emptyset, x_H\}$, where $r = \emptyset$ means that control has been indecisive. The evidence obtained by the supervisor is his private information, but, once revealed it is verifiable.[5] The supervisor may then withhold evidence by reporting $r = \emptyset$ whenever control has been decisive. Indeed, as standard in the literature on collusion[6], given that the evidence obtained by the supervisor is hard, the supervisor cannot misreport the high output as low output or the low output as high output.

The agent and the supervisor have the following utility functions $U^A(w,e) = w - \gamma e$ and $U^S(s) = s$, where w and s are their wages and $\gamma > 0$ is the agent's disutility of effort. Reservation utilities are normalized to zero.

Given that only the supervisor's report is verifiable, contracts are contingent on this report. Denoting by w the wage of the agent and by s that of the supervisor, contracts are thus $(w_L, w_\emptyset, w_H)$ and $(s_L, s_\emptyset, s_H)$. Employees are protected by limited liability, and hence the principal cannot make negative transfers to them.

It is assumed that x_H is large enough for it to be in the principal's interest to operate the firm. In this environment, the goal of the principal is thus to both motivate the agent to pick $e = 1$ and minimize the expected cost of the firm $C(w_L, w_\emptyset, w_H, s_L, s_\emptyset, s_H) \equiv p\,[\pi(w_H + s_H) + (1-\pi)(w_L + s_L)] + (1-p)(w_\emptyset + s_\emptyset)$.

Since the control technology is imperfect and information is hard, the supervisor has discretion to make a deceptive/biased report. Indeed, the supervisor may engage in two types of collusive activity.[7] When the supervisor acquires evidence that the output produced is x_L, he may collude with the agent and report $r = \emptyset$ instead of $r = x_L$. If supervisor/agent collusion occurs, the agent thus receives $w_\emptyset$ instead of w_L from the principal and pays a bribe to the supervisor. When the

[5] In other words, evidence is verifiable only by the person(s) to whom the supervisor reveals it. Evidence is publicly verifiable only when the supervisor produces his report.

[6] See Tirole (1992).

[7] As shown in Vafaï (2002, 2010), multi-level firms may also be vulnerable to other forms of unofficial activity. Vafaï (2010) considers collusive activities but does not investigate their interplay and their impact on the internal organization of the firm.

supervisor acquires evidence that the output produced is x_H, he may collude with the principal and report $r = \emptyset$ instead of $r = x_H$. If principal/supervisor collusion takes place, the principal therefore pays $w_\emptyset + s_\emptyset$ to its employees (plus a bribe to the supervisor) instead of $w_H + s_H$.

We make the assumption that when collusion occurs, the supervisor unofficially shows the private evidence acquired to his collusive partner. Expressed differently, in line with Tirole's (1986, 1992) standard models, collusion takes place under symmetric information on evidence among colluders.

We also make the following standard assumptions on collusive activities (see, for example, Tirole 1992). First, side transfers between the agent and the supervisor or between the principal and the supervisor are made at a rate $k \in (0, 1]$. If $k \in (0, 1)$, a side transfer creates a deadweight loss. A side transfer of size t is then only worth kt to the supervisor. Among the many possible explanations for this is that bribes may be non-monetary and/or organizing collusion has a cost. Collusion therefore becomes easier as k increases. If instead $k = 1$, the side transfer technology is totally efficient. Second, side transfers are enforceable. Third, collusion is only observable to colluders. Fourth, the supervisor has all the bargaining power when engaging in collusion. Fifth, the supervisor does not engage in collusion when indifferent, that is, when payoffs associated with colluding and not colluding are identical.

The evolution of the three-level agency relationship is thus the following: (1) The principal offers contracts to its employees contingent on the supervisor's report. (2) Employees accept or reject these contracts. (3) The agent picks $e = 0$ or $e = 1$ and control takes place. (4) Control reveals the agent's output with probability p and decisions of whether or not to engage in collusive activities are made. (5) The supervisor makes a report r. (6) Transfers and side transfers are realized.

3 Firm with unbiased supervision

This section investigates the ideal case where the supervisor does not engage in collusive activities. This corresponds to the case where $k = 0$. To motivate the agent to pick $e = 1$, the contract, $(w_L, w_\emptyset, w_H)$, offered by the principal must satisfy the agent's incentive constraint $p\left[\pi w_H + (1-\pi)w_L\right] + (1-p)w_\emptyset - \gamma \geq pw_L + (1-p)w_\emptyset$, or equivalently[8],

$$w_H - w_L \geq \frac{\gamma}{p\pi}. \tag{1}$$

Since transfers must be nonnegative, we have

$$w_L \geq 0, w_\emptyset \geq 0, w_H \geq 0, s_L \geq 0, s_\emptyset \geq 0, s_H \geq 0. \tag{2}$$

The agent's contract must also verify her participation constraint, $p\left[\pi w_H + (1-\pi)w_L\right] + (1-p)w_\emptyset - \gamma \geq 0$. Given that transfers must be nonnegative, this constraint is less restrictive that the agent's incentive constraint, and hence will not be considered.

Since supervision does not imply any cost, the supervisor will accept any contract $(s_L, s_\emptyset, s_H) \in \mathbb{R}^3_+$.

To motivate the informed supervisor to report truthfully, the supervisor's contract must also satisfy $s_L \geq s_\emptyset$ and $s_H \geq s_\emptyset$. Since the optimal contract offered to the supervisor in this case and in the subsequent cases verify these constraints, they will not be considered.

A firm where supervision is unbiased has the following program:

$$[P_0] \qquad \min_{w_L, w_\emptyset, w_H, s_L, s_\emptyset, s_H} \quad C(w_L, w_\emptyset, w_H, s_L, s_\emptyset, s_H)$$

$$\text{s.t. (1) and (2).}$$

[8] We make the standard assumption that the agent chooses to work when she is indifferent.

Proposition 1 summarizes the solution to this program.

Proposition 1. *Inside a firm with unbiased supervision:*

1. The optimal contracts are $(w_L, w_\emptyset, w_H) = (0, 0, \frac{\gamma}{p\pi})$ *and* $(s_L, s_\emptyset, s_H) = (0, 0, 0)$*. The expected cost of the firm is* $C^0 \equiv \gamma$*.*

2. Neither the supervisor nor the agent captures an informational rent.

When collusive supervision may not occur in a firm, the principal keeps both employees to their reservation utility levels.

4 Firm with biased supervision

This section considers respectively the cases where only a single type of collusion is possible and where both types of collusion may occur. As shown in Vafaï (2008), there is no loss of generality in restricting attention to contracts that deter collusive activities

4.1 Single type of bias in supervision

We will consider, respectively, the case where only supervisor/agent collusion may occur in a firm and the case where it is vulnerable only to principal/supervisor collusion (see Figure 1).

4.1.1 Downward biased supervision

In a the three-level hierarchy vulnerable exclusively to supervisor/agent collusion, this type of unofficial activity may occur when control reveals evidence that the agent's output is low. This happens either when the agent picks $e = 0$ or when she picks $e = 1$ but produces only x_L. If supervisor/agent collusion occurs, a bribe is transferred to the supervisor for biased reporting, that is, for reporting $r = \emptyset$ instead of $r = x_L$.

The prevention of supervisor/agent collusion imposes an extra constraint on the firm. Collusion takes place if it is profitable for both parties. If the agent chooses to collude with the supervisor, her utility is $w_\emptyset - b_D$ if she has picked $e = 0$, and $w_\emptyset - b_D - \gamma$ if she has picked $e = 1$ but the output has been x_L, where b_D is the bribe transferred to the supervisor. If the agent chooses not to collude with the supervisor, her utility is w_L if she has picked $e = 0$, and $w_L - \gamma$ if she has picked $e = 1$ but has produced only x_L. The agent thus finds collusion beneficial as long as $w_\emptyset - b_D \geq w_L$ - or, equivalently, as long as $w_\emptyset - b_D - \gamma \geq w_L - \gamma$ - that is, as long as $b_D \leq w_\emptyset - w_L$. The maximum bribe, $\bar{b}_D$, the agent is willing to offer for information concealment is hence $\bar{b}_D \equiv w_\emptyset - w_L$. The supervisor has all the bargaining power and may extract $\bar{b}_D$ from the agent. The supervisor will find collusion not profitable if his utility from producing an unbiased report, s_L, is higher than his utility from producing a biased report, $s_\emptyset + k\bar{b}_D$, that is, if

$$s_L \geq s_\emptyset + k(w_\emptyset - w_L), \tag{3}$$

where $w_\emptyset - w_L$ is the stake of supervisor/agent collusion. This constraint is the supervisor/agent no-collusion constraint. As explained in the Appendix, since it is optimal to set $s_\emptyset = 0$, constraint (3) indicates that there are two ways of deterring supervisor/agent collusion. The first way is to create incentive payments for the supervisor, that is, to offer $w_\emptyset > w_L$ and then to offer s_L sufficiently large. The second way to deter supervisor/agent collusion is to break down its stake, that is, to offer $w_\emptyset = w_L$. The program of a three-level firm vulnerable to supervisor/agent collusion is thus program $[P_0]$ with the extra constraint (3).

As may easily be seen, the collusion-free contracts of Proposition 1 also immunize the firm against supervisor/agent collusion. We may thus state:

Proposition 2. *Collusion between the supervisor and the agent is harmless.*

This result is in line with the growing body of literature, mentioned in the introduction, that proves that the harmfulness of supervisor/agent collusion depends crucially on the environment where it may occur and that this type of collusion can be costlessly prevented in a broad class of circumstances. Slightly modifying Tirole's (1986, 1992) standard models may result in supervisor/agent collusion becoming costless to deter or even beneficial. In the light of these results the relevance of the literature on supervisor/agent collusion has been questioned.

In contrast to that literature which exclusively considers supervisor/agent collusion, we show, in the next sections, that all types of collusion are not harmless and that in the presence of collusion between the principal and the supervisor, collusion between the supervisor and the agent is not harmless anymore. Expressed differently, we prove that investigating exclusively supervisor/agent collusion in firms is deceptive.

4.1.2 Upward biased supervision

In a hierarchical firm vulnerable only to principal/supervisor collusion, this type of unofficial activity may take place when control reveals evidence that the agent's output is high. If principal/supervisor collusion occurs, a bribe is transferred to the supervisor for biased reporting, that is, for reporting $r = \emptyset$ instead of $r = x_H$. The wage costs for the principal associated with not colluding and colluding with the supervisor are respectively $w_H + s_H$ and $w_\emptyset + s_\emptyset + b_U$, where b_U denotes the bribe paid for a biased report. The principal thus finds collusion beneficial as long as $w_\emptyset + s_\emptyset + b_U \leq w_H + s_H$. The maximum bribe, $\overline{b}_U$, it is then ready to pay for a biased report is $\overline{b}_U \equiv w_H + s_H - w_\emptyset - s_\emptyset$. The supervisor has all the bargaining power and may extract $\overline{b}_U$ from the principal. The supervisor does not find collusion beneficial if $s_H \geq s_\emptyset + k\overline{b}_U$. That is, if

$$s_H \geq s_\emptyset + \frac{k}{1-k}(w_H - w_\emptyset) \text{ for } k \in (0,1) \text{ or } w_\emptyset \geq w_H \text{ for } k = 1. \quad (4)$$

These constraints are the principal/supervisor no-collusion constraints. Since optimally $s_\emptyset = 0$, when $k \in (0, 1)$, there are two ways to deter principal/supervisor collusion. The first way is to create incentive payments for the supervisor, that is, to offer $w_H > w_\emptyset$ and then offer s_H sufficiently large. The second way to deter collusion between the principal and the supervisor is to break down its stake, that is, to offer $w_H = w_\emptyset$. We will refer to these policies respectively as an *incentive policy* and a *stake eliminating policy.*

The program of a hierarchical firm vulnerable exclusively to principal/supervisor collusion then writes:

$$[P_1] \qquad \min_{w_L, w_\emptyset, w_H, s_L, s_\emptyset, s_H} \quad C(w_L, w_\emptyset, w_H, s_L, s_\emptyset, s_H)$$

$$\text{s.t. (1), (2), and (4).}$$

Define $\widetilde{\pi} \equiv \frac{(1-k)(1-p)}{pk}$. The solution to this program is summarized in the following proposition.

Proposition 3. *Inside a firm vulnerable only to principal/supervisor collusion:*

1. The optimal policy is (a) an incentive policy with $(w_L, w_\emptyset, w_H) = (0, 0, \frac{\gamma}{p\pi})$ *and* $(s_L, s_\emptyset, s_H) = (0, 0, \frac{k\gamma}{(1-k)p\pi})$ *if* $k \in (0,1)$ *and (i)* $p \leq 1-k$*; (ii)* $p > 1-k$ *and* $\pi \leq \widetilde{\pi}$*. The expected cost of the firm is then* $C^1 \equiv \frac{\gamma}{1-k}$*. (b) a stake eliminating policy with* $(w_L, w_\emptyset, w_H) = (0, \frac{\gamma}{p\pi}, \frac{\gamma}{p\pi})$ *and* $(s_L, s_\emptyset, s_H) = (0,0,0)$ *if (i)* $k \in (0,1)$*,* $p > 1-k$ *and* $\pi > \widetilde{\pi}$*; (ii)* $k = 1$*. The expected cost of the firm is then* $C^2 \equiv \frac{[1-p(1-\pi)]\gamma}{p\pi}$*.*

2. Either the supervisor or the agent captures an informational rent. When the principal adopts an incentive policy (resp. a stake eliminating policy) this rent is captured by the supervisor (resp. the agent).

3. Collusion is harmful.

We optimally have $w_L = 0\ (= s_\emptyset)$, and thus $w_H = \frac{\gamma}{p\pi}$ from the agent's incentive constraint. To set $w_\emptyset$, the principal faces a trade-off. As shown in the Appendix, to cope with principal/supervisor collusion, it may either break down the stake of this type of collusion by offering $w_\emptyset = w_H = \frac{\gamma}{p\pi}$ - and hence $s_H = 0$ - or it may keep the stake of principal/supervisor collusion while creating incentives for the supervisor to make an unbiased report, that is, it may offer $w_H = \frac{\gamma}{p\pi} > w_\emptyset = 0$ - and thus $s_H = \frac{k\gamma}{(1-k)p\pi}$. We have referred to these policies respectively as a stake eliminating policy and an incentive policy. Compared with an incentive policy, a stake eliminating policy consists in paying a higher wage $w_\emptyset$ to the agent but a lower wage s_H to the supervisor. Clearly, when an incentive policy is adopted, a rent is paid to the supervisor, whereas when a stake eliminating policy is adopted a rent is paid to the agent. In other words, an incentive policy benefits the supervisor whereas a stake eliminating policy benefits the agent. Unlike supervisor/agent collusion, principal/supervisor collusion is systematically harmful.

Several cases should then be distinguished for $k \in (0, 1)$. If the control technology is strongly imperfect ($p \leq 1 - k$), that is, if it is likely that control will be indecisive, and hence it is likely that $w_\emptyset$ will be paid to the agent and s_H will not be paid to the supervisor, the principal's optimal policy is an incentive policy. In the alternative case where the control technology is weakly imperfect ($p > 1-k$), it is unlikely that control will be indecisive, that is, it is unlikely that $w_\emptyset$ will be paid to the agent. The principal's policy choice then depends on the quality of the production technology. When the production technology is relatively inefficient ($\pi \leq \widetilde{\pi}$), and thus it is unlikely that s_H will be paid to the supervisor, the optimal policy is an incentive policy.

Finally, in the case where $k = 1$ the optimal policy is a stake eliminating policy. Indeed, since in this case deterring principal/supervisor collusion requires that the principal sets $w_\emptyset \geq w_H$ and since the objective function is increasing in $w_\emptyset$, we optimally have $w_\emptyset = w_H = \frac{\gamma}{p\pi}$.

4.2 Multiple types of bias in supervision

We now consider the general case of a firm vulnerable to multiple types of bias in supervision (see Figure 2). The program of a hierarchical firm vulnerable to both supervisor/agent and principal/supervisor collusion is $[P_1]$ with the additional constraint (3). This extended program will be referred to as $[P_2]$.

Define $\overline{\pi} \equiv \frac{(1-k)[1-p(1-k)]}{pk(2-k)}$. Proposition 4 summarizes the solution to $[P_2]$.

Proposition 4. *Inside a firm vulnerable to both supervisor/agent and principal/supervisor collusion:*

1. The optimal policy is (a) an incentive policy with $(w_L, w_\emptyset, w_H) = (0, 0, \frac{\gamma}{p\pi})$ *and* $(s_L, s_\emptyset, s_H) = (0, 0, \frac{k\gamma}{(1-k)p\pi})$ *if* $k \in (0,1)$ *and (i)* $p \leq 1-k$*; (ii)* $p > 1-k$ *and* $\pi \leq \overline{\pi}$*. The expected cost of the firm is then* C^1*. (b) a stake eliminating policy with* $(w_L, w_\emptyset, w_H) = (0, \frac{\gamma}{p\pi}, \frac{\gamma}{p\pi})$ *and* $(s_L, s_\emptyset, s_H) = (\frac{k\gamma}{p\pi}, 0, 0)$ *if (i)* $k \in (0,1)$*,* $p > 1-k$ *and* $\pi > \overline{\pi}$*; (ii)* $k = 1$*. The expected cost of the firm is then* $C^3 \equiv \frac{[1-p(1-\pi)(1-k)]\gamma}{p\pi}$*.*

2. When the principal adopts a stake eliminating policy (a) the two types of collusion negatively interact, and hence the possibility of principal/supervisor collusion makes supervisor/agent collusion harmful. (b) both the supervisor and the agent capture informational rents. The supervisor captures the informational rent generated by the deterrence of supervisor/agent collusion, whereas the agent captures the informational rent generated by the deterrence of principal/supervisor collusion. (c) the efficiency loss sustained by the firm is higher compared with the cases where it is vulnerable to a single type of collusion.

3. When the principal adopts an incentive policy (a) the two types of collusion do not interact, and hence supervisor/agent collusion remains harmless. (b) only the supervisor captures an informational rent. This rent - generated by the deterrence of principal/supervisor collusion - is *identical to that extracted by the supervisor in the case where the firm is vulnerable only to principal/supervisor collusion. (c) the efficiency loss sustained by the firm is identical to that sustained in the case where only principal/supervisor collusion is possible.*

As explained above, the principal has the choice of two policies to deter principal/supervisor collusion. However, compared with the case where the firm is vulnerable only to principal/supervisor collusion, in the presence of both types of collusion, the stake eliminating policy has an extra cost. Indeed, using the stake eliminating policy and setting $w_\emptyset$ above 0 then makes supervisor/agent collusion costly to deter. Expressed differently, if the principal decides to adopt the stake eliminating policy, the prevention of one type of collusion increases the cost of the prevention of the other type of collusion. In this case, collusive activities negatively interact. When both types of collusion are accounted for, the expected cost of the stake eliminating policy thus rises from $C^2 \equiv \frac{[1-p(1-\pi)]\gamma}{p\pi}$ to $C^3 \equiv \frac{[1-p(1-\pi)(1-k)]\gamma}{p\pi}$ and reaches its highest level for $k = 1$. By contrast, the expected cost of the incentive policy is not affected by the proliferation of collusive activities. When the firm adopts the incentive policy, collusion between the supervisor and the agent thus remains harmless, and hence efficiency is not affected.

Regarding efficiency, we thus have that in the presence of both types of collusion the expected cost of collusion deterrence increases but not systematically. Hence, the proliferation of collusive activities does not systematically reduce the efficiency of the firm.

Since in a firm vulnerable to two types of collusion there is a negative interaction between collusive activities associated with the stake eliminating policy, this policy is less often adopted than in the case where only principal/supervisor collusion is possible. Formally, we have $\overline{\pi} > \widetilde{\pi}$ for $p > 1 - k$. As explained in the previous subsection, given that when the incentive policy is adopted the supervisor receives a rent and that the incentive policy is now more often adopted, the proliferation of collusive activities is advantageous for the supervisor and disadvantageous for the agent.

The following corollary - that summarizes our findings by expressing how the threat of two types of collusion affects a multi-level hierarchy compared with the case where only a single type of collusion is possible - shows how crucial it is to allow for more than a single type of collusion when investigating multi-level firms.

Corollary. *The proliferation of collusive activities in firms:*

1. *Modifies the configuration of the optimal policy.*

2. *May increase the expected cost of preventing each type of collusion.*

3. *Is not always harmful.*

4. *Is beneficial (resp. detrimental) to the supervisor (resp. the agent).*

5 Conclusion

In the last two decades the literature on principal-supervisor-agent firms has largely studied a specific type of bias in supervision, namely supervisor/agent collusion. We have extended the analysis of these hierarchies by also considering the possibility of principal/supervisor collusion. We have shown that the proliferation of collusive activities deeply affects the contractual choices of a hierarchical firm, and hence have proved that focusing on a single type of collusion in the analysis of hierarchies is deceptive.

Appendix

Proof of Proposition 1. Whether the firm is vulnerable or not to collusive activities, it is obviously optimal to set $s_\emptyset$ as low as allowed by the limited liability constraints, that is $s_\emptyset = 0$.

Since the expected cost of the firm is increasing in w_L and reducing this wage does not make constraints more severe (more specifically, it relaxes the agent's incentive constraint), it is optimal to set this wage as low as the limited liability constraint $w_L \geq 0$ makes it possible. We therefore have $w_L = 0$. From the same argument $w_\emptyset = s_L = s_H = 0$ and the principal optimally sets w_H as low as allowed by the agent's incentive constraint, that is, $w_H = \frac{\gamma}{p\pi}$ (since $w_L = 0$).

Proof of Proposition 3. To both soften constraints and lower the expected cost of the firm, w_L, w_H and s_L should be reduced. Given that the agent is protected by limited liability, it is optimal to set $s_L = 0$. By the same argument, $w_L = 0$ and the agent's incentive constraint becomes $w_H = \frac{\gamma}{p\pi}$. There are then two cases to consider with respect to k.

1. $k < 1$. Recalling that optimally $s_\emptyset = 0$ and substituting $w_H = \frac{\gamma}{p\pi}$ into the principal/supervisor no-collusion constraint, this constraint writes $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} - w_\emptyset)$. This constraint may then be relaxed by increasing $w_\emptyset$. However, since setting $w_\emptyset > \frac{\gamma}{p\pi}$ instead of $w_\emptyset \leq \frac{\gamma}{p\pi}$ increases the expected cost of the firm (because this cost is increasing in $w_\emptyset$) without allowing to reduce s_H below 0 (because of the limited liability constraint $s_H \geq 0$), the principal sets $w_\emptyset \in \left[0, \frac{\gamma}{p\pi}\right]$. The relevant constraint on s_H is then $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} - w_\emptyset)$, that is, the limited liability constraint $s_H \geq 0$ is redundant.

Given that the objective function is increasing in s_H and lowering this wage does not make the other constraints more severe, we have $s_H = \frac{k}{1-k}(\frac{\gamma}{p\pi} - w_\emptyset)$. Substituting this equation into the objective function of program $[P_1]$, this program becomes:

$$\min_{w_\emptyset} \quad \frac{\gamma}{1-k} + \frac{(1-k)(1-p)-p\pi k}{1-k} w_\emptyset$$

$$\text{s.t. } w_\emptyset \in \left[0, \frac{\gamma}{p\pi}\right].$$

Two cases have then to be distinguished.

Let $\Delta \equiv (1-k)(1-p) - p\pi k$. Then if $\Delta \geq 0$, that is, if $\pi \leq \widetilde{\pi} \equiv \frac{(1-k)(1-p)}{pk}$, the objective function is increasing in $w_\emptyset$. It is then optimal to set $w_\emptyset$ as low as possible, that is, $w_\emptyset = 0$. We then have $s_H = \frac{k\gamma}{(1-k)p\pi}$.

If instead $\Delta < 0$, that is, if $\pi > \widetilde{\pi}$, the objective function is decreasing in $w_\emptyset$, and it is hence optimal to set $w_\emptyset$ as high as possible. The principal then sets $w_\emptyset = \frac{\gamma}{p\pi}$. We then have $s_H = 0$.

Since we have $\widetilde{\pi} \geq 1$ if $p \leq 1-k$, and thus we then systematically have $\Delta \geq 0$, the optimal contracts are: (a) $(w_L, w_\emptyset, w_H) = (0, 0, \frac{\gamma}{p\pi})$ and $(s_L, s_\emptyset, s_H) = (0, 0, \frac{k\gamma}{(1-k)p\pi})$ for (i) $p \leq 1-k$; (ii) $p > 1-k$ and $\pi \leq \widetilde{\pi}$. The expected cost of the firm is then $C^1 \equiv \frac{\gamma}{1-k}$. (b) $(w_L, w_\emptyset, w_H) = (0, \frac{\gamma}{p\pi}, \frac{\gamma}{p\pi})$ and $(s_L, s_\emptyset, s_H) = (0, 0, 0)$ for $p > 1-k$ and $\pi > \widetilde{\pi}$. The expected cost of the firm is then $C^2 \equiv \frac{[1-p(1-\pi)]\gamma}{p\pi}$.

2. $k = 1$. Given that the principal's objective function is increasing in $w_\emptyset$ and s_H - and lowering these wages does not make constraints more severe in this case - we optimally have $w_\emptyset = \frac{\gamma}{p\pi} (= w_H)$ from the principal/supervisor no-collusion constraint and $s_H = 0$ from the limited liability constraints. The expected cost of the firm is then C^2.

Proof of Proposition 4. As in the previous proof, to both soften constraints and lower the expected cost of the firm, w_H should be reduced. The agent's incentive constraint thus becomes $w_H = \frac{\gamma}{p\pi} + w_L$. There are then two cases to consider with respect to k.

1. $k < 1$. Substituting $w_H = \frac{\gamma}{p\pi} + w_L$ into the principal/supervisor no-collusion constraint, this constraint writes $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} + w_L - w_\emptyset)$. This constraint may be relaxed by increasing $w_\emptyset$.

However, given that setting $w_\emptyset > \frac{\gamma}{p\pi} + w_L$ instead of $w_\emptyset \leq \frac{\gamma}{p\pi} + w_L$ both increases the expected cost of the firm (because this cost is increasing in $w_\emptyset$) and makes the supervisor/agent no-collusion constraint $s_L \geq k(w_\emptyset - w_L)$ more severe without allowing to reduce s_H below 0 (because of the limited liability constraint $s_H \geq 0$), we have $w_\emptyset \leq \frac{\gamma}{p\pi} + w_L$. The relevant constraint on s_H is then $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} + w_L - w_\emptyset)$. In other words, the limited liability constraint $s_H \geq 0$ may be disregarded.

Following a similar argument, we have that the relevant constraint on s_L is the supervisor/agent no-collusion constraint $s_L \geq k(w_\emptyset - w_L)$. Expressed differently, the limited liability constraint $s_L \geq 0$ may be disregarded. It is, indeed, possible to relax the supervisor/agent no-collusion constraint by increasing w_L. However, given that setting $w_L > w_\emptyset$ instead of $w_L \leq w_\emptyset$ both increases the expected cost of the firm (because this cost is increasing in w_L) and makes the principal/supervisor no-collusion constraint $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} + w_L - w_\emptyset)$ more severe without allowing to reduce s_L below 0 (because of the limited liability constraint $s_L \geq 0$), we have $w_L \leq w_\emptyset$. Summarizing, we have $w_\emptyset \leq \frac{\gamma}{p\pi} + w_L$ and $w_L \leq w_\emptyset$, that is $w_\emptyset \in \left[w_L, \frac{\gamma}{p\pi} + w_L\right]$ with $w_L \geq 0$, and hence the relevant constraints on s_L and s_H are respectively $s_L \geq k(w_\emptyset - w_L)$ and $s_H \geq \frac{k}{1-k}(\frac{\gamma}{p\pi} + w_L - w_\emptyset)$.

The objective function is increasing in s_L and s_H and lowering these wages does not make the other constraints more severe. We therefore have $s_L = k(w_\emptyset - w_L)$ and $s_H = \frac{k}{1-k}(\frac{\gamma}{p\pi} + w_L - w_\emptyset)$. These equations should be substituted into the objective function of program $[P_2]$, which then becomes:

$$\min_{w_L, w_\emptyset} \quad \frac{\gamma}{1-k} + \frac{p[(1-k)[1-(1-\pi)k]+\pi k]}{1-k} w_L + \frac{(1-k)[1-p[1-(1-\pi)k]]-p\pi k}{1-k} w_\emptyset$$

$$\text{s.t. } w_L \geq 0 \text{ and } w_\emptyset \in \left[w_L, \frac{\gamma}{p\pi} + w_L\right].$$

There are two cases to distinguish.

Noting $\Theta \equiv (1-k)\left[1 - p\left[1-(1-\pi)k\right]\right] - p\pi k$, if $\Theta \geq 0$, that is, if $\pi \leq \overline{\pi} \equiv \frac{(1-k)[1-p(1-k)]}{pk(2-k)}$, the objective function is increasing in $w_\emptyset$, and hence optimally $w_\emptyset = w_L$. After substituting this expression into the objective function of the above program, this function becomes $\frac{\gamma}{1-k} + w_L$. This function is increasing in w_L, and hence it is optimal to set w_L as low as possible, that is, $w_L = 0$. It follows that $w_\emptyset = 0$, and therefore $w_H = \frac{\gamma}{p\pi}$, $s_L = 0$ and $s_H = \frac{k\gamma}{(1-k)p\pi}$.

If $\Theta < 0$, that is, if $\pi > \overline{\pi}$, the objective function is decreasing in $w_\emptyset$, and $w_\emptyset$ should be set as high as possible. We then have $w_\emptyset = \frac{\gamma}{p\pi} + w_L$. After substituting this equation into the objective function of the above program, this function writes $\frac{[1-p(1-\pi)(1-k)]\gamma}{p\pi} + w_L$. Since this function is increasing in w_L, it is optimal to set w_L as low as possible, that is, $w_L = 0$. It follows that $w_H = w_\emptyset = \frac{\gamma}{p\pi}$, and thus $s_L = \frac{k\gamma}{p\pi}$ and $s_H = 0$.

Given that we have $\overline{\pi} \geq 1$ for $p \leq 1-k$, we then systematically have $\Theta \geq 0$ in this case. The optimal contracts are thus: (a) $(w_L, w_\emptyset, w_H) = (0, 0, \frac{\gamma}{p\pi})$ and $(s_L, s_\emptyset, s_H) = (0, 0, \frac{k\gamma}{(1-k)p\pi})$ for (i) $p \leq 1-k$; (ii) $p > 1-k$ and $\pi \leq \overline{\pi}$. The expected cost of the firm is then C^1. (b) $(w_L, w_\emptyset, w_H) = (0, \frac{\gamma}{p\pi}, \frac{\gamma}{p\pi})$ and $(s_L, s_\emptyset, s_H) = (\frac{k\gamma}{p\pi}, 0, 0)$ for $p > 1-k$ and $\pi > \overline{\pi}$. The expected cost of the firm is then $C^3 \equiv \frac{[1-p(1-\pi)(1-k)]\gamma}{p\pi}$.

2. $k = 1$. As above, since the firm's objective function is increasing in $w_\emptyset$ - and lowering this wage does not make constraints more severe in this case - we optimally have $w_\emptyset = w_H = \frac{\gamma}{p\pi} + w_L$ from the principal/supervisor no-collusion constraint and the agent's binding incentive constraint. Once $w_\emptyset = w_H = \frac{\gamma}{p\pi} + w_L$ is substituted into both the objective function of program $[P_2]$ and the supervisor/agent no-collusion constraint, this program writes:

$$\min_{w_L, s_L, s_H} \quad \frac{[1-p(1-\pi)]\gamma}{p\pi} + w_L + p\left[(1-\pi)s_L + \pi s_H\right]$$

$$\text{s.t. } w_L \geq 0,\ s_L \geq \frac{\gamma}{p\pi} \text{ and } s_H \geq 0.$$

Obviously $w_L = 0$, $s_L = \frac{\gamma}{p\pi}$ and $s_H = 0$. The expected cost of the firm is then $\frac{\gamma}{p\pi}$.

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Firm with a single type of bias in supervision

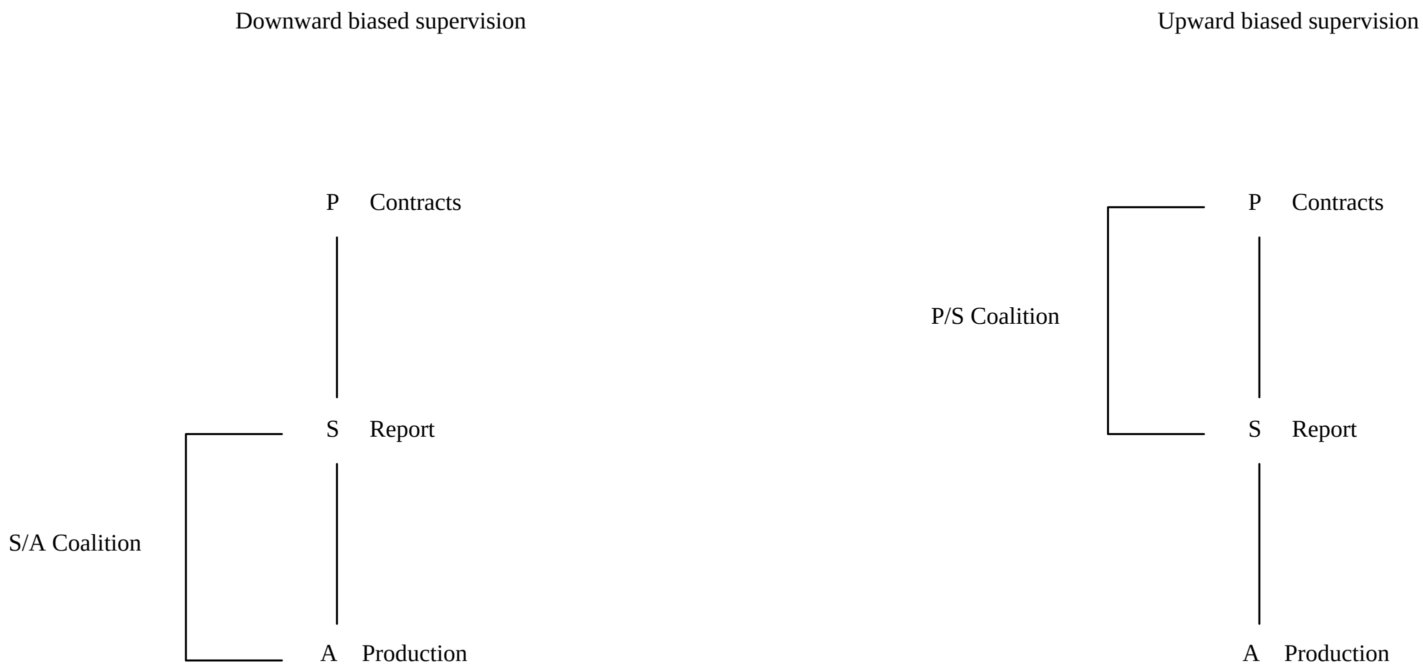

Figure 1 Principal (P), Supervisor (S) and Agent (A)

Firm with multiple types of bias in supervision

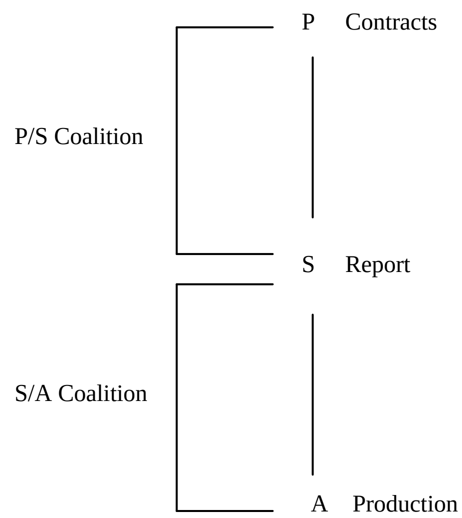

Figure 2 Principal (P), Supervisor (S) and Agent (A)