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Imperfect Monitoring of Monitoring Agents: One Reason Why Hierarchies Can Be Superior to "Lean" Organizations

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Imperfect Monitoring of Monitoring Agents: One Reason Why Hierarchies Can Be Superior to “Lean” Organizations.

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Effective monitoring requires proper incentives and detection skill. Detection skills depend on the extent of specialization in monitoring and on the number of agents to be supervised. This paper demonstrates that hierarchy and monitoring of monitors can provide the necessary incentives for the monitoring agents, which induces them to make use of their detection skill. The model draws on the theory of imperfect diagnosis and explains why hierarchies can be superior to “lean” organizations.

Wirksames Monitoring erfordert nicht nur angemessene Anreize, sondern auch Überwachungsfähigkeit. Diese hängt von der Spezialisierung auf Monitoring ab, aber auch von der Zahl der zu überwachenden Agenten. In diesem Beitrag wird gezeigt, dass die Einrichtung einer Hierarchie es erlaubt, Monitoren zu überwachen, um ihnen die nötigen Anreize zu vermitteln kann, ihre Überwachungsfähigkeit zu nutzen. Das Modell nutzt die Theorie imperfekter Diagnosen und erklärt, warum Hierarchien im Vergleich zu „lean organizations“ überlegen sein können.

JEL-Classification: L2, D2
Keywords: Hierarchy, Imperfect Diagnosis, Monitoring, Incentives

INTRODUCTION

Many problems may cause inefficient outcomes in organizations: the interests of Principals and Agents may be not perfectly aligned, team members can find themselves within a Prisoners’ Dilemma, or the players may be hesitant to make specific investments due to a lack of trust. From the viewpoint of contract theory, two ways are available to solve “rational cheating” problems. *Nagin, Rebitzer, Sanders & Taylor* (2002) present empirical evidence that employees’ behavior is in accordance with this model. Modifications of the monitoring rate,

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however, did not induce the theoretically predicted responses by the monitored agents. This effect is due to the lack of information on the side of the agents, who had to infer the monitoring rate. In the model presented here, the monitoring parameters are assumed to be common knowledge. *Slivinski* (2002) has pointed out that conflicts of interests can even exist in non-profit firms. Either, the agents are motivated by an output contingent payment. Or the monitoring of inputs, combined with punishment for shirking, is introduced to avoid undesired behavior.

Since the seminal papers of *Alchian und Demsetz* (1972) and *Holmstrom* (1982) the problem of team production has gained much attention in economic literature. *Alchian & Demsetz* (1972) have defined the team problem as a production function that aggregates the inputs of more than one agent to an output in a way that the partial cross derivatives are non-zero. In other words: the inputs are either complements (positive cross partials), i.e., the more another agent invests, the higher is the marginal productivity of the others. Or the inputs are substitutes (negative cross partials), thus the other agents' marginal productivity is decreasing in one agent's effort. They argue that budget-balanced sharing of the output (i.e., all agents' shares add up to exactly the total output) provides incentives for each team member to spend less than efficient effort.

Holmstrom (1982) has generalized this result and demonstrated that non-balanced sharing rules can implement first-best effort as a Nash equilibrium. If the agents promise each other to throw away the output if it turns out to be smaller than the optimal one, then they have an incentive to choose efficiently (if they expect each other to do the same). However, this Nash equilibrium is not subgame perfect, thus not credible. Since then, several papers were written attempting to find sub-game perfect sharing schemes that implement first best effort in simultaneous as well as sequential teams, e.g., *Rasmusen* (1987), *Strausz* (1999), *Lülfesmann* (2002).

The solution to the team problem which was originally proposed by *Alchian & Demsetz* (1972) was based on monitoring. One of the team members specializes in monitoring and concludes contracts with all the other agents, having the option to punish them if she detects underperformance. In *Kandel & Lazear* (1992), the other team members mete out the punishment (in the form of peer pressure). Hence, there is no need for hierarchical structures in their model. Social approval also plays a role in *Orr* (2001) who analyzes segmenting the workforce into workgroups, the incentive effect of which relies on mutual monitoring within those groups. Even though the author acknowledges that the workgroups require some degree of internal organization to overcome their internal public good problem (see Orr 2001, 50), there is no need for a hierarchical structure of the firm in his model. This could implement the efficient solution if the other team members expect to be punished if, and only if, they fail to deliver the desired effort. This, however, requires not only verifiability of the monitoring result (to exclude wrongful punishment), but also incentives on the side of the monitor to carry out the monitoring.

Following the proposal of *Alchian and Demsetz* (1972), this incentive problem can easily be solved by assigning to the monitor the role of the residual claimant. Yet, a problem remains, namely measurement costs (which may arise if information about the agents' actual effort cannot be obtained without costs). *Holmström* (1979) has demonstrated – in the principal-Agent context – how a signal about the hidden activities of the agent may help to conclude an incentive-compatible contract. *Bohn* (1987) und *Sappington & Demski* (1983) have applied this idea to the monitoring of several agents. *Varian* (1990) has analyzed the monitoring of agents by other agents, but without taking into account measurement costs. Another problem of hiring a monitoring agent has been focused by *Kofman & Lawarée* (1984) and by *Tirole* (1986): the monitor may have an incentive for collusion with the agent he has to supervise. Collusion means to forge a favorable report or to conceal a bad working result. *Kessler* (2000) has demonstrated that, if only concealing is possible, the collusion problem can be solved.

In this paper, the collusion problem is excluded. Instead, the other source of false reports by the monitor is focused: the monitor might commit errors when doing his report. This leads to a model of imperfect monitoring. The analysis, however, does not aim at the derivation of optimal contracts. Moreover, measurement costs are neglected, since the signals concerning the activity of the agents are assumed to be costless. However, positive measurement costs could easily be amended to the model.

Imperfect monitoring, as it is modeled in this paper, refers to the fact that a monitor may commit errors when trying to distinguish whether a specific agent has performed in the desired way or not. As in *Kessler* (2000), this paper assumes that monitoring consists of a report of the supervised agent's true performance. According to the traditional approach, monitors are assumed to supervise the truthfulness of an agent's report about his own effort, see *Kofman & Lawarée* (1984) and *Tirole* (1986). A different approach to modeling has been introduced in *Miller* (1997): in that paper, monitoring is imperfect since the partners can only observe a subset of the other partners' actions.

The problem of having to distinguish two states of the world which are not directly observable has long been analyzed by the diagnosis theory. This theory is based on the works of *Green & Swets* (1966), *Swets* (1988) and *Swets* (1996), who have demonstrated that the empirical foundation of this theory rests on signal detection experiments. According to one core insight of this theory it can be perfectly rational to neglect a diagnosis result, even if it is costless and informative, when making a decision, as derived by *Heiner* (1983). In such a case, a decision-maker would rely on "rules of thumb" rather than on his own diagnosis or detection skill. Conceptually, the model makes a distinction between the ability of the monitor to control the behavior of the monitored agent, and his willingness to do so. The model is based on the work of *Heiner* (1983), (1985), (1986) and (1990). *Kirstein & Schmidtchen* (1997) have applied this model to imperfect decision-making judges. *Kirstein* (2002) presents a two-level monitoring model of banks and supervising authorities.

From *Alchain & Demsetz* (1972), the model of imperfect monitoring takes over the assumption that a monitor who is the residual claimant has perfect incentives to actually make use of her detection skill. Therefore, if it is the firm owner who performs the monitoring, then his incentives are a problem that can be neglected. However, the firm owner is not necessarily the person with the highest monitoring abilities. If an agent specialized in monitoring, then she would be better able to distinguish low from high effort than the firm owner, who has to fulfill numerous tasks. Furthermore, the detection skill of a monitor (be it the owner or a specialized agent) may depend on the number of agents to be monitored. Detection skill is conceptualized by the correlation between the effort actually chosen by the monitored agent and the signal generated by the monitor. The higher this correlation, the better is the detection skill.

An owner may delegate the monitoring task to a monitor in order to make use of the better detection skills of the latter. This advantage can be due to specialization, or because the number of agents exceeds the capacity of the owner. However, delegation makes the incentive problem relevant. *Bradley* (1996) presents, in a brief research note, a model of imperfect monitoring by owners and hired supervisors, but neglects the incentive problem of the latter. It is simply assumed that hired monitors fulfill their duties. A divergence between the actual monitoring result and the monitor's report can have two possible causes: the lack of perfect detection skills may lead to an (involuntary) error, or the lack of incentives to report the signal truthfully may lead to a (voluntary) error.

Detection skill of the monitor and his incentives are crucial for the supervision quality, as it is outlined in figure 1. According to this descriptive model of two-stage monitoring, the incentives of the agents depend not only on the sanctions for undesired behavior, e.g. low effort, or the bonus for desired behavior (high effort). Moreover, the quality of the supervision is also relevant. This quality depends both on the detection skill of the monitor and on his incentives. It is subsequently shown, that an owner with imperfect detection skill can motivate a specialized monitoring agent with better detection skill to make use of his monitoring ability. Combined with an adequate sanction (or bonus), this can induce the agent to choose high effort. Note that this transfer of incentives, based on detection skill, is also possible over several layers in a hierarchy. Thus, the model provides a positive explanation for the emergence of hierarchies when the number of employees in a firm grows. It also allows for a normative interpretation: if an owner and the monitoring agents have limited detection skill, then the optimal size of each hierarchy level can be derived for a given number of agents who require supervision.

Insert Figure 1 about here

The paper is organized as follows: section 2 presents the basic monitoring model. For simplicity, the idea of diagnosis theory is explained in the context of only one agent. The concept of supervision quality (represented by the parameters R and W) is introduced and the condition for implementation of the desired behavior of the agent is derived. Then, diagnosis skill and the incentives of a monitor are analyzed. The relation between the concept of detection skill (represented by the parameters r and w) the supervision quality is derived. In section 3, the analysis is extended to the case of several agents. The impact of the number of agents on detection skill, and thus on supervision quality, is derived and conclusions for the design and emergence of hierarchies are drawn. Section 4 concludes the paper by presenting the main results.

BASIC MONITORING MODEL: ONE AGENT

Input Monitoring Instead of Output Contingent Incentives

Consider an employee facing two modes of activity: he can act in accordance with the interest of his principal, i.e. spend high effort and realize a high output. Or, he can act against his principal's interests and spend low effort, realizing only a low output. Assume that spending higher effort raises the agent's costs, but is beneficial for the principal. Thus, a conflict exists, and the principal seeks for a way to motivate the agent. Let me distinguish three cases:

1. the action chosen by the agent is perfectly observable (or the principal can simply conclude the activity level from the observed output level),
2. the input is completely unobservable, e.g. due to a random variable that influences the output, the distribution of which is known (but not its realization),
3. the agent's input cannot be observed without costs.

In the first case, the problem of input contingent incentives is trivial. This is a situation with perfect monitoring. The principal perfectly knows what the agent has chosen, and sanctions for undesired (or bonus payments for desired behavior) can be fixed contractually. The second case is the starting point of Principal-Agent theory, as far as it is concerned with moral hazard or ex-post opportunism. The direct conclusion from observable output on the unobservable input is impossible. If the output appears to be low, this can be due to laziness of the agent or to bad luck (a low realization of the random variable). However, it is possible to offer a contract to the agent that provides incentives contingent on the output and, thereby, implement high effort. Nevertheless, the agent has to bear the risk under such a contract, which would be inefficient if he is more risk-averse than the principal is. In such a situation, nothing more than a second-best contract is attainable, which balances the incentive and the risk allocation problem.

More difficult is the third case. Frequently, it is not really clear what the contribution of individual agents to the output of a large organization actually is. The marginal productivity of an employee in book-keeping or a human resource management department (with respect to the enterprises revenue) is hard to determine. Thus, the incentives of such an agent can hardly be made contingent on the firm's output. What remains, is monitoring of inputs, which is assumed to be difficult or costly in the case under scrutiny.

Input monitoring requires the agent to be observed, or to report the progress of his work to the principal. Both activities are time consuming, which does not only concern the agent's time, but also the principal's, thus incurring opportunity costs. In many situations, it is costly, but possible to gain information about the agent's effort. However, this information might be erroneous or "imperfect".

Monitoring and the Agent's Incentives

To modify the incentives of the agent, it is not sufficient to only monitor his effort. Additionally, a penalty for deviations (or a bonus for compliance) is required. *Varian* (1990, 156 f.) demonstrates that in general – and from the principal's point of view – rewards are more useful than penalties. In the framework of my model, this distinction does not play an important role, and the exposition is limited to penalties only for the sake of simplicity. This is true even under perfect monitoring. However, if monitoring is only imperfect, then the agent might fear that a penalty is imposed despite his compliance. Furthermore, the agent might hope that non-compliance remains undetected. In the framework of statistical decision theory, this refers to first type and second type errors. The first type error occurs if a penalty is imposed even though the agent has chosen the desired behavior. The second type error means that an agent is not punished even though he deviated from the desired behavior. Punishment can thus be justified (if the agent's effort actually was low) or not (if he has chosen high effort).

An agent, faced with a monitoring system, can be assumed to have expectations as to the probability of a punishment. The probability is contingent on his behavior. Assume that agents expect a justified punishment to be imposed with probability R, whereas an unjustified punishment occurs with probability W:

$$R = prob(\ punishment \mid effort{=}low)$$
$$W = prob(\ punishment \mid effort{=}high)$$

Then, W is the probability of the first type error, whereas (1-R) is the probability of the second type error. In *Becker & Stigler* (1974), the parameter W is neglected (or implicitly set equal to zero), the parameter R is exogenously given. In my model, W is explicitly taken into account and both parameters are endogenized. The parameters R and W determine the expected punishment, conditional on the agent's action choice. Assume that his utility depends on his effort and the expected punishment. Denote the utility from choosing low effort as L, and the utility from choosing high effort as H. High effort creates a positive externality to the benefit of the principal, but imposes effort cost C on the agent. Let us consider first a situation without monitoring. Then, low effort is preferred by the agent if $L > H\text{-}C$. In this case, there is a conflict between agent and principal which requires a solution. Implementing high effort is socially efficient if the principal's benefit is greater than $L+C\text{-}H$. The agent does not have the incentive to create the positive externality to the benefit of the principal. Monitoring, combined with a punishment that amounts to $S > 0$, motivates a risk-neutral agent to choose high effort if, and only if

$$H - C - W*S > L - R*S \quad \Leftrightarrow \quad (R-W)*S > C+L-H \qquad (1)$$

The second inequality in expression (1) can be interpreted in the following way: $(L-H)$ is the difference in utility the agent internalizes by choosing low instead of high effort, C represents the cost saved when doing so. Thus, $C+L-H$ is his net benefit from choosing low instead of high effort in a world without monitoring. For simplification, let me define this net benefit as N, with $N=C+L-H$.

$(R-W)*S$ is the incremental expected punishment imposed by the monitoring system when the agent chooses low instead of high effort. If this is greater than N, then he is deterred from choosing low effort, thus he chooses high effort instead. Condition (1) is fulfilled in a trivial way with an infinite (or very high) sanction S. This corresponds with the "maximum-fine-result" of *Becker* (1968): the expected punishment can be increased by an increase of S, or by an increase of R, in order to fulfill condition (1). Becker did not explicitly discuss the parameter W (so it was set equal to zero implicitly). While increasing R would require resources, like employing better monitoring devices, S can be increased without cost for the principal. Thus, it is technically efficient to set S as high as possible in order to keep R relatively low as long as condition (1) is fulfilled. However, the absolute punishment is constrained due to three reasons:

- S needs to be enforceable, which is a problem if the agent's wealth is limited. If the sanction cannot be imposed, then it fails to deter the agent from low effort even if monitoring is perfect.
- The threat to impose a sanction must be credible. Capital punishment for minor deviations, e.g., would face a credibility problem. The agent would perhaps not expect an excessive sanction to actually be carried out.
- The participation in the organization has to remain attractive for potential employees. If an applicant has to be afraid of severe punishment for a minor offense (or even in case of compliance) then she will prefer her outside option.

If condition (1) is satisfied with a realistic value of S, then the monitoring and sanction system implements the desired behavior. Condition (1) is equivalent to

$$R > N/S + W \qquad (2)$$

This expression is visualized in figure 2 which shows the parameter *R* on the vertical and the parameter *W* on the horizontal axis. The combinations of *R* and *W* (above the diagonal line representing **R = N/S + W**) fulfill condition (1) for given values of *N* and *S*. Condition (1) and figure 2 make clear, that $N/S < 1$ (hence $S > N$) is a necessary condition for an incentive compatible monitoring and punishment system. With $N > S$ the agent could never be deterred, due to $R \leq 1$. Furthermore, condition (1) implies that a trade-off between *R* and *W* exists. A higher probability of the second type error (a higher *W*) can be compensated by a lower probability of the probability of the first type error (a higher *R*) in order to maintain the incentive compatibility of the monitoring system.

Insert Figure 2 about here

Detection Skill and Incentives of the Monitor

Two reasons are obvious that may lead to errors of the first and the second type in monitoring systems: the ability of the monitor, and his incentives. The ability of the monitor to detect the true action chosen by the monitored agent can be limited, since the monitor may not have been present at the time when the agent made his choice. Consider a large organization in which one team member complains about the behavior of one of his colleagues. Such a complaint can be justified, or it can be opportunistic. The monitor who is supposed to supervise this team then faces a problem similar to the one of a judge in a civil court. A judge, too, has to decide whether a suit is legitimate or opportunistic. *Kirstein & Schmidtchen* (1997) have demonstrated that the ability to do so, called “positive detection skill”, is a necessary condition for a court system to induce contractual compliance.

The incentive compatibility of a monitoring system depends on three parameters, as demonstrated in the previous section: the probability of a legitimate and a wrongful sanction (*R* and *W*), and the size of the punishment (*S*). In this section, it is shown that the two conditional probabilities depend on the detection skill of the monitor as well as on his incentives. Detection skill is the ability of the monitor to distinguish between situations in which a sanction is legitimate (i.e., the monitored agent has actually chosen low effort), and those situations where a sanction is unjustified (the effort was actually high).

However, even if the monitor is perfectly able to observe the actual choice of the agent, she can base her decision to impose a punishment on the toss of a coin. In such a case, the monitor would not make use of her detection skill when deciding about sanctions (or when reporting to the instance that actually sanctions the respective agent). From the viewpoint of information economics, the detection skill of a monitor can be interpreted as the ability to distinguish between two signals, one of which indicates high effort, while the other one indicates low effort. These signals may be external or internal: the monitor examines the case, does research, and comes to an opinion (internal signal) or finds evidence (external signal). When processing such a signal, the monitor might commit two types of errors. Let denote r the probability of a signal indicating high effort, given the effort was actually high:

$$r = prob(signal=\text{"high"} | effort=high)$$

Furthermore, let w denote the probability that the realization of the signal is “high”, even though the agent’s actual effort choice was low:

$$w = prob(Signal=\text{"high"} | effort=high)$$

Then, w is the probability of a diagnosis error of type one, and $1-r$ is the probability of a type two diagnosis error. A diagnosis system is called “informative” if r>w: the probability of the “high” signal is greater in case the effort was actually high than in case the effort was low. Three constellations of the parameters r and w are reasonable to distinguish:

- $r = w$: the monitor has zero detection skill.
- $0 < w < r < 1$: the monitor has imperfect, but positive detection skill.
- $r = 1, w = 0$: the detection skill is perfect (thus positive).

Now it is demonstrated that the ability of a monitor to implement incentive compatible sanctions does not only require detection skill, but also incentives to make use of this ability. Let me first examine the case of a firm owner who exerts the monitoring task. This case is in line with the idea of Alchian & Demsetz (1972) according to which the monitoring agent should be put in the position of the sole residual claimant, in order to implement incentives for him to use his detection skill. As to the parameters r and w, Alchian and Demsetz seem to have (implicitly) assumed that a team member who specializes in monitoring and assumes the position of the residual claimant has perfect detection skill. Thus, the problem of imperfect detection skill is excluded.

Insert Table 1 about here

Table 1 shows the incentive situation of a monitor who is in the position of a residual claimant. His payoffs depend on his own decision (to sanction the agent or to pay no bonus on the one hand, not to sanction him or to pay a bonus on the other hand). Furthermore, his payoff depends on the effort choice of the agent. Assume that the owner-monitor has a prior distribution concerning the actual (but unknown) effort. Let q be the probability of high effort, thus $1-q$ is the probability of low effort. Denote the state-contingent payoffs of the owner-monitor as A, B, C, and D. I assume the owner-monitor to prefer the imposition of a sanction (or: to pay no bonus) if it is justified, hence $A > B$. And she prefers not to impose the sanction (or: to pay a bonus) if it is unjustified, hence $C < D$.
Finally, assume that the monitor is risk-neutral. First, consider the case in which the monitor receives no diagnosis signal at all. Then his optimal choice is to sanction the agent if

$$qA+(1-q)C>qB+(1-q)D \iff q(A-B)+(1-q)(C-D) > 0 \qquad (3)$$

Without loss of generality, the exposition can be simplified by introducing $G=(A-B)>0$, the gain from a justified sanction, and $L=(C-D)<0$, the loss from an unjustified sanction. Then, condition (3) is equivalent to $qG+(1-q)L>0$. Let me define, for further simplification, the "tolerance threshold" T as

$$T = -L(1-q)/qG. \qquad (4)$$

Then condition (3) implies $T>1$. Note that, due to $G>0>L$ and $0<q<1$, the threshold T is always positive. With $T<1$, the optimal decision of an owner who does not receive a diagnosis signal would be to not sanction the agent. Now consider an owner-monitor who is able to generate an informative diagnosis signal. Assume that this can be done without cost. His optimal punishment decision depends on the realization of the diagnosis result, as it is shown in Proposition 1 (the proof of which can be found in the Appendix).

Proposition 1: *Assume a prior distribution (q, 1-q) over the two possible states of the word (Agent has chosen low or high effort) and positive, imperfect detection skill ($0<w<r<1$). Assume furthermore that the preferences of the monitor are characterized by $G>0$ and $L<0$. Then his optimal decision is to punish the agent if*

- *the diagnosis result is "low" and $T > r/w$, or*
- *the diagnosis result is "high" and $(1-r)/(1-w) > T$.*

Otherwise the optimal decision of the monitor is not to sanction the agent, respectively.

Given the incentives of a monitor with positive detection skill, the value of *T* can be derived. Now it only depends on the ratio of *r/w* whether the observation of "low" should lead to the consequence that a sanction is imposed. If $r/w > T$, thus the ratio of the detection parameters exceeds the threshold, then it is optimal for the monitor to follow the "low" signal and punish the agent. However, if $r/w < T$, then the diagnosis result "low" should not lead to a punishment. A symmetric result can be derived if the observed signal realization is "high". If the threshold value *T* is greater than the ratio *(1-r)/(1-w)*, then the monitor should follow the diagnosis result, thus abstain from punishment. If, on the other hand, *T* is smaller than this ratio, then she should punish the agent despite the friendly diagnosis result.

The concept of "reaction strategies" helps to reformulate the above result. A reaction strategy (xy) embodies the plan to choose action x if the diagnosis result is "low" and the action y in case the diagnosis result is „high", with $x, y \in \{s ; n\}$ and s = sanction, n = not sanction. Hence, four (pure) reaction strategies exist: (sn), (ns), (ss), (nn). The former two are called "contingent" reaction strategies, since the action which is actually carried out depends on the diagnosis result. The latter two are "non-contingent" reaction strategies since the action to be carried out is independent of the diagnosis result. A non-contingent reaction strategy can be interpreted as a rule of thumb or as a standard operating procedure.

A decision-maker who chooses such a reaction strategy relies on rule-governed behavior rather than on his ability to analyze the situation and on his diagnosis results. The definition of reaction strategies and Proposition 1 imply the next result, which is presented without further proof:

Proposition 2: *Given the assumptions made in Proposition 1, then*

1. *(sn) is the optimal reaction strategy* $<=> r/w > T > (1-r)/(1-w)$
2. *(ss) is the optimal reaction strategy* $<=> r/w > T < (1-r)/(1-w)$
3. *(nn) is the optimal reaction strategy* $<=> r/w < T > (1-r)/(1-w)$

It is easy to demonstrate that $r>w$ implies that (ns) can never be optimal. Furthermore, mixed reaction strategies are not optimal: maximization of the monitor's linear expected payoff functions always leads to corner solutions, thus only pure strategies are candidates for optimality.

Agent's Incentives and the Detections Skill of the Monitor

The agent's incentives to spend high effort depend on the expected sanction, which is determined by two factors: the nominal sanction (S) and the supervision quality (represented by the parameters *R* and *W*). The supervision quality also depends on two factors: on the one hand, the monitor's detections skill (represented by the parameters *r* and *w*), and on the other hand, his incentives to actually make use of his detection skill. The relation between the supervision quality parameter and the detection skill parameters depends on the chosen reaction strategy:

Proposition 3: *Given the assumptions of Proposition 1. If the monitor chooses the reaction strategy*

- *(nn), then* $R=0=W$;
- *(ss), then* $R=1=W$;
- *(sn), then* $R=r$ *and* $W=w$.

According to Proposition 3, the supervision quality parameters (*R, W*) depend on the detection skill parameters (*r, w*) of the monitor and on his incentives to choose the non-contingent reaction strategy (*sn*). If $r/w > T$ is fulfilled, then a monitor with positive detection skill produces positive supervision quality. If the monitor's incentives are such that she chooses a non-contingent reaction strategy, then the supervision quality is zero ($R = W$) even if the monitor's detection skill is positive ($r > w$).

Recall the condition for the implementation of high effort on the side of the agent. Proposition 3 makes it obvious that a monitoring system is not incentive compatible if the monitor's incentives make him choose a non-contingent reaction strategy, as long as $N > 0$ is fulfilled. $R = W$ would create no obstacle for the implementation of high effort only if $N \leq 0$ is true, i.e., the net benefit from choosing high effort exceeds the benefit from choosing low effort. In such a situation, no conflict between owner and agent exists, and there is no need for monitoring at all. In other words: if a conflict exists ($N > 0$), then the incentive compatibility of a monitoring and sanction system requires that the monitor has incentives to choose a contingent reaction strategy. Furthermore, condition (2) has to be fulfilled.

If the monitor has an incentive to choose the contingent reaction strategy, then $R=r$ and $W=w$. Thus, the detection skill parameters of the monitor do also have to fulfill condition (2), in addition to the condition that motivates the monitor to choose the contingent reaction strategy. Proposition (4) comprises the conditions that have to be fulfilled by r and w so that a monitoring system has the desired impact on the incentives of the agent:

Proposition 4: *Given the assumptions of Proposition 1. Assume furthermore that the agent's payoff from choosing low effort amounts to* $N > 0$*, and a sanction for detected low effort is* $S > 0$*. Then, the agent chooses high effort if, and only if,*

$$r > N/S + w \quad \wedge \quad r/w > T > (1-r)/(1-w)$$

These conditions are summarized in figure 2 for the case $T > 1$ (the case $T < 1$ could be demonstrated in a modified figure). The diagonal line starting in $r = w = 0$ represents the conditions $r/w > T$ (with $T > 1$ and $r > w$, this part of the condition in proposition 4 is binding). Combinations of *(r, w)* above this diagonal motivate the monitor to choose the contingent reaction strategy *(sn)*. The diagonal line in the upper left corner of figure 2 represents condition (2); above this line, there are the (r, w) combinations that motivate the agent to choose high effort (provided the monitor chooses his contingent reaction strategy). The intersection of both parameter subsets is labeled "a". In this incentive "compatibility field", the parameter combinations *(r, w)* can be found that implement high effort.

Insert Figure 3 about here

Consider the opposite case: if, for a given threshold value $T > 1$ the *r-w*-combination is situated in area “b”, then the agent prefers low effort even though the monitor chooses the contingent reaction strategy. With a r-w-combination from area “d”, the agent would choose high effort if the monitor would choose the contingent reaction strategy. However, the monitor prefers to choose a non-contingent reaction strategy and therefore the agent chooses low effort. In the remaining area (“c”), the agent would prefer low effort even if the monitor would choose contingently, but even worse, the monitor chooses a non-contingent reaction strategy.

MONITORING OF SEVERAL AGENTS

Based on the previous results, this section presents a reason why hierarchical structures can be superior, compared to “lean” organizations. In a large organization with a large number of agents, much more monitoring is required than in a small firm. If the organization resembles a network rather than a hierarchy, then the number of interactions is increasing faster than the number of employees. With two agents, there is only one relation, with three agents, we have three relations, among four agents, there are six relations, and five agents interact in ten relations in which cheating may occur. In a tree-like hierarchy, this effect is avoided.

Monitoring-agents (M) and firm-owner (Principals, denoted as P) can be distinguished with respect to their degree of specialization in monitoring. In the context of the model introduced above, this means that specialized monitoring agents may have better detection skills than the principal. Thus, the error probabilities of specialized monitors are smaller. This difference can be due to training and specialization. If an employed monitor has better detection skill than the owner, then the detection skill parameters of the two fulfill the following condition:

$$r_M / w_M > r_P / w_P \qquad (5)$$

Recall that the r/w-ratio needs to exceed the threshold value T so that an agent is motivated to choose the contingent reaction strategy. Inequality (5) indicates that, for a given threshold value between the two ratios (i.e., $r_M / w_M > T > r_P / w_P$), the specialized monitor will react contingent on the diagnosis signal, while the non-specialized principal reacts non-contingently.

There are several reasons for the assumption that principals may have lower detection skills than specialized monitoring agents. A prominent one reflects the idea that detection skill is influenced by the number of persons to be supervised. If a monitor with limited resources has to supervise several agents, then the probability of an examination is smaller than one, and tends to be decreasing with the number of cases. Employing several monitoring agents allows for increasing the probability of examination. A single monitor, like the principal, can assign only a small portion of his scarce resources to each of the supervised agents.

Assume for each person that the detection skill parameters (r, w) depend on the number of agents to be observed, denoted as *n*. Hence,

$$\partial r/\partial n < 0 < \partial w/\partial n. \qquad (6)$$

This implies that the effective *r/w* ratio is decreasing in *n*. The incentives of the monitoring person, however, which are embodied in the threshold value *T*, are independent of *n*. Assume furthermore the incentives of the supervised agents (*N* and *S*) to be independent of *n*. Figure 3 demonstrates that a monitor (be it an owner or a monitoring agent) who is capable of motivating one agent may fail to provide selective incentives if he is in charge of supervising more than one agent. An increase of *n* leads to a shift of the effective *r*-*w*-combination towards the south-east, as it is indicated by the arrow in figure 4.

Insert Figure 4 about here

A small increase in *n* may imply only a small shift of the *r*-*w*-vector. As long as the effective r-w-combination is still in area “a”, then the monitor would still induce all supervised agents to choose high effort. However, as soon as this shift leads beyond only one of the two diagonal lines, then this monitor would become unable to provide selective incentives.

In the process of growth of a firm, there will be a point from which on the Principal will become unable to effectively monitor the number of agents employed. Then it is beneficial to employ one or several monitoring agents. Even if the monitoring agents have equal or worse detection skill than the owner, this can make sense since they can concentrate on a small number of cases. If the monitoring agents specialize in monitoring, they may even have better detection skill than the owner, so they would be able to supervise an even greater number of agents than the owner himself. However, effective monitoring by monitoring agents requires them to have incentives to make use of their detection skill, i.e., to choose a contingent reaction strategy. If the employed monitors are closely linked with the owner, like family members, then this problem may be solved. If they are independent, then the principal has to find a way to influence the incentives of the monitoring agents. In a hierarchy, this could be achieved by monitoring the monitoring agents. The principal could limit his monitoring activities to the supervision of only a small number of monitoring agents; these would monitor a larger number of monitoring agents, which in turn supervise the productive agents. This structure could guarantee that the effective detection skill parameters for each supervised employee are in the respective area "a". Each monitor is motivated to perform his monitoring task and thereby provides selective incentives for the next layer of agents. The genuine incentives of the principal are thereby transferred to all members of the hierarchy. Table 3 demonstrates this kind of division of labor in a large hierarchy.

Insert Table 2 about here

In the light of diagnosis theory (or: imperfect decision making) a hierarchy serves to transfer selective incentives to all agents. Intermediate monitors are required to compensate the limited detection skill of the owner, who is the only person with genuine incentives.

Let me introduce a numerical example. Assume that one principal is able to supervise three agents effectively. From the fourth agent on, the principal's detection skill parameters are shifted out of the incentive compatibility field. Under lean management, the maximum firm size thus is limited to four if all agents should be motivated to choose high effort. Assume now that a specialized monitoring agent can effectively monitor 20 agents. If the principal employs one monitor, the maximum firm size is 24: the principal can supervise 2 agents and the monitoring agent, who in turn supervises 20 agents. If the principal employs three monitors, the maximum firm size is 64 (P, 3 M, 60 A). For even larger organizations, effective monitoring would require several layers of monitoring agents. E.g., with four layers the maximum firm size would already grow to 1264 (P, 3 higher M, 60 lower M, 1200 Agents).

Given the detection skill of the persons who perform monitoring tasks, and given the costs incurred by monitoring agents, the optimal number of layers can be derived for a firm of a given size. In other words: the model points out that the detection skill and incentives of the monitors in a firm provide an additional constraint when deriving the optimal number of layers in a hierarchy, and the optimal number of supervised agents in a division.

CONCLUSION

The paper has analyzed the impact of a monitoring system on the incentives of agents. Two factors determine the effectiveness of monitoring: the sanction for undesired behavior and the supervision quality. The latter is governed by two factors: the detection skill of the monitor and his incentives (which determine whether the monitor makes use of his detection skill or not). If the incentives of the monitor are such that he follows a rule of thumb rather than making use of his detection skill, this has a fatal effect on the incentives of the supervised agent: she expects to be treated independently of his actual effort choice. Therefore, she has no selective incentives that implement the choice of high effort.

The incentives of a monitor to use his detection skill do not impose a problem as long as the monitoring is performed by the owner, since he is the residual claimant. Several problems may keep the owner from doing so:

- often he has to monitor several agents, which would force him to assign his monitoring capacity to a large number of cases;
- the effective detection skill might then be too small to create selective incentives;
- or the owner is less able than a specialized agent to do the monitoring.

Making use of specialized agents, however, requires him to solve the incentive problem of the monitoring agents. Division of labor in a hierarchy may turn out to be helpful in achieving a solution. Let the owner monitor only a small number of specialized monitoring agents, who in turn are able to supervise a large number of agents each. Then the imperfect diagnosis skill of the owner can be sufficient to transfer selective incentives through all layers of the hierarchy, providing motivation for all productive agents to choose high effort.

The model provides an explanation for hierarchies and argues against the inconsiderate introduction of “lean management” when firms are reorganized. A normative interpretation is the derivation of an optimal number of levels in a hierarchy, which depends on the detection skills of the owner and of the monitors, respectively.

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APPENDIX

Proof of Proposition 1:

Assume that values are given for the parameters r, w, q, G and L,
with $G=A-B>0$ and $L=C-D<0$. For proving the proposition, two situations have to be distinguished: the monitor may have received the signal realization “low” or the realization “high”. After having received the signal “low”, it is optimal to choose punishment (or: no bonus) if, and only if, the following condition holds:

$$rqG + w(1-q)L > 0$$

Rearranging yields $r/w > T$.
In the other possible situation, after having received the signal “high”, it is optimal to sanction if, and only if,

$$(1-r)qG + (1-w)(1-q)L > 0$$

is true. Rearranging yields $(1-r)/(1-w)>T$, and the proposition is proven: q.e.d.

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TABLE 1
State-contingent incentives of the owner-monitor

The agent has chosen...	**....low effort**	**...high effort**
prior of M	q	1-q
M’s payoff when choosing...		
...sanction/no bonus	A	C
...no sanction/bonus	B<A	D>C

TABLE 2
Division of labor in large organizations

	Detection skill	Incentives
Principal (P)	low	genuine
Monitor (M)	high (due to specialization)	from P
Agent (A)	-	from M

FIGURE 1
General monitoring-model

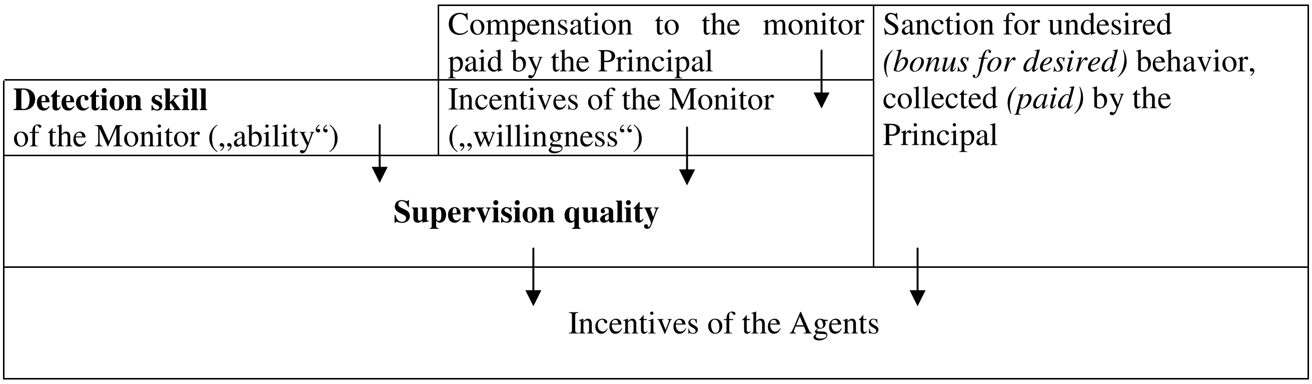

FIGURE 2
Incentive compatible R-W-combinations

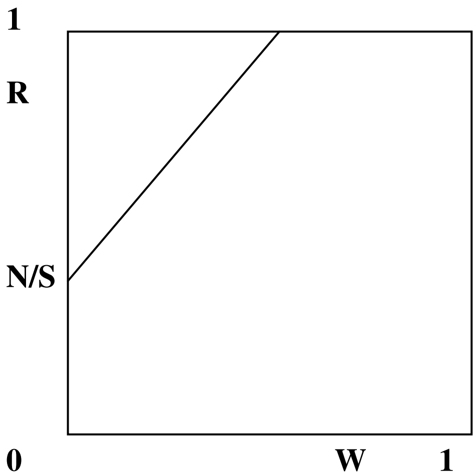

FIGURE 3
Incentive compatibility conditions, case *T > 1*

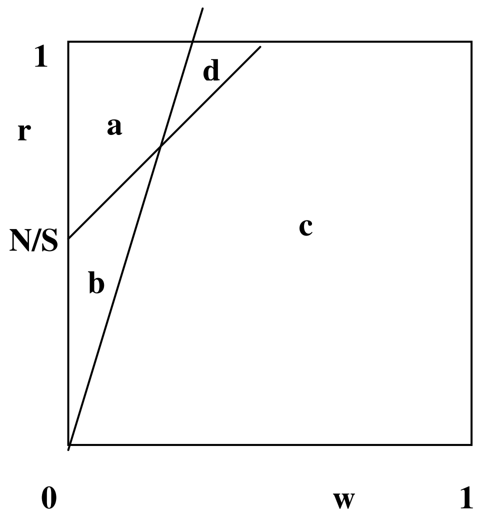

FIGURE 4
Increase in the number of supervised agents *n*