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ABSTRACT

Delegation versus Authority

by Daniel Krähmer*

The paper studies the role of delegation and authority within a principal-agent relation in which a non-contractible action has to be taken. The agent has private information relevant for the principal, but has policy preferences different from the principal. Consequently, an information revelation problem arises. We contribute to the literature by assuming transferable utility and contractibility of messages and decision rights. While delegation leads to loss of control, it facilitates the agent's participation and leads to an informed decision. Moreover, message-contingent delegation creates incentives for information revelation. We derive the optimal contract for the principal and investigate when delegation outperforms authority.

Keywords: Delegation, Partial Contracting, Mechanism Design, Imperfect Commitment, Transferable Utility
JEL classification numbers: C72, D82, L22

ZUSAMMENFASSUNG

Delegation versus Autorität

Das Papier untersucht die Bestimmungsgründe für die Delegation von Entscheidungen in Organisationen. Wir betrachten eine Prinzipal-Agent Beziehung, in der eine Entscheidung getroffen werden muss, die vertraglich nicht festgeschrieben werden kann. Der Agent verfügt über für den Prinzipal relevante private Information, hat aber andere Entscheidungspräferenzen als der Prinzipal. Im Unterschied zur bisherigen Literatur betrachten wir den Fall, dass Nutzen transferierbar ist, und dass der Prinzipal sein Entscheidungsrecht in Abhängigkeit eines Berichtes des Agenten an diesen abtreten kann. Delegation führt einerseits zu einem Kontrollverlust für den Prinzipal. Andererseits erleichtert sie die Partizipation des Agenten und führt zu einer informierten Entscheidung. Darüber hinaus schafft Delegation Anreize zur Informationsoffenlegung, wenn dem Agenten das Entscheidungsrecht in Abhängigkeit seines Berichtes übertragen wird. Wir untersuchen, wann es für den Prinzipal optimal ist, die Entscheidung zu delegieren.

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1 Introduction

Decision making in firms and organizations typically affects different members in different ways. At the same time, the information relevant for decision making is often widely spread through the organization. A conflict arises if those in charge of the decision have policy preferences different from those who hold the relevant information.

An example is installing a new production technology (e.g. computers) in a firm. The employer/procurer may prefer the technology suited best for a given task but, not being a worker, may not know the best technology. In contrast, the worker, being an expert, may privately know the best technology but may prefer technologies with additional features that enhance only his private benefit from working (e.g. flat screens etc.). Another example is a principal who hires an agent to perform a project (e.g. housebuilder and architect). The agent may be specialized in running particular projects where only the agent knows his specialization. While the principal may prefer projects in which the agent is specialized, the agent may rather prefer prestigous or reputation enhancing projects or projects that improve the agent's human capital. Further examples arise in patient-doctor, client-lawyer, or lender-borrower relations.

The general problem is one of communication. An agent may be unwilling to reveal relevant information because he wants to prevent the principal from pursuing a policy contrary to his private interests. This information revelation problem is particularly severe when the principal cannot credibly pre-commit not to take an action detrimental to the agent. Indeed, it is well known from the cheap talk literature that the commitment problem generally prevents the principal from making a decision in which all of the agent's information is used (see *Crawford/Sobel* (1982)[1]).

If the principal cannot commit to an action, a simple way to use the agent's information is to decentralize decision making away from the principal to the agent.[2] However, by

[1] For a review of the cheap talk literature see *Farrell/Rabin* (1996). Two recent contributions that extend the Crawford/Sobel model to the case with two agents and a multi-dimensional action space, respectively, are *Krishna/Morgan* (2000) and *Battaglini* (2001).

[2] If the principal *can* commit to an action, then decentralizing cannot improve centralized decision structures. For the classical revelation principle implies that the outcome of delegation can be imple-

giving away control, the principal may be hurt by the agent's discretion. This trade-off between loss of information and loss of control is the basis for an extensive discussion of the information revelation problem both in political science[3] and in economics[4]. The general lesson from this literature is that if differences in policy preferences are not too large, the informational benefits of delegation may outweigh the benefits of control under cheap talk.

While cheap talk models capture situations in which contracts essentially cannot be written, this paper considers the communication problem when contracts are only partially incomplete. Particularly, we consider a situation where, on the one hand, the principal's commitment is limited by non-contractibility of actions, but, on the other hand, messages from the agent to the principal and decision rights are contractible. We refer to *authority* when the principal has the decision right and to *delegation* when the agent has that right. Since decision rights are contractible, the principal can transfer control to the agent on a contingent basis, depending on a report by the agent. We call this case *contingent delegation*.

In this contracting environment, delegation serves three purposes: first, because the agent always benefits from delegation, delegation can be used as a reward for the agent. It therefore facilitates participation of the agent. Second, as in environments with non-contractible messages, it is a cheap way to make use of the agent's information. Finally, by rewarding the agent by delegation, contingent delegation provides the principal with an additional instrument to structure the agent's incentives to reveal information.

The optimal contract trades off these benefits of delegation against the costs accompanied by loss of control. The contribution of the paper is to find and analyze the optimal contract.[5] The difficulty in finding the optimal contract stems from the principal's limited

mented through a complete incentive compatible contract in which the principal has control over the action (see *Holmström* (1984), *Szalay* (2001)).

[3]This literature asks whether a legislature should adopt an open rule (control of the principal) or a closed rule (delegation) when it consults specialized commitees in the legislation process. See for example *Gilligan/Krehbiel* (1987, 1989), *Austin-Smith* (1990, 1993), *Epstein* (1998), *Krishna/Morgan* (2001). For a review see *Bendor/Glazer/Hammond* (2001).

[4]See for example *Aghion/Tirole* (1997), *Garidel-Thoron/Ottaviani* (2000), *Dessein* (2002).

[5]We restrict attention to mechanisms with one-shot face-to-face communication. We therefore refer to

commitment. For with imperfect commitment, the standard revelation principle generally fails because a rational agent anticipates that the principal will not comply with the (non-verifiable) contract provisions when the agent reveals his information truthfully.

To take into account imperfect commitment, we therefore apply a generalized version of the revelation principle as developed in *Bester/Strausz* (2001). Bester/Strausz show that for a principal with imperfect commitment the best contract, as with the classical revelation principle, is still a direct contract, that is, the message space coincides with the state space. But, as opposed to the classical revelation principle, it may be optimal for the principal to induce the agent to lie with positive probability.

The optimal contract highlights the mentioned purposes of delegation: if preferences are sufficiently aligned, there is no incentive problem. The principal optimally unconditionally delegates the decision if she is less interested in the decision than the agent since this is a cheap way to induce participation of the agent.

As preferences become more disaligned, an incentive problem arises. If the principal's interest in the decision is small, it is still optimal to unconditionally delegate the decision since this leads to an informed decision at relatively small costs. Conversely, if the principal's interest is sufficiently large, it is optimal to unconditionally keep control over the action, as costs of delegation are large.

Finally, contractible messages together with transferable utility imply that contingent delegation may be optimal. For with contingent delegation, the participation constraint of the agent type to whom the decision is delegated is weakened. Thus, the monetary transfer to this type can be reduced. This, in turn, raises the opportunity cost of lying for the other type to whom the decision is not delegated and, consequently, weakens this type's incentive constraint. Therefore, under contingent delegation incentive compatibility is achieved at lower cost than when the principal unconditionally retains control. As a consequence, if the principal's interest is only moderately larger than that of the agent such that costs of delegation are still moderate, contingent delegation becomes optimal.

the optimal contract as the optimal contract in this restricted class. However, the principal can possibly improve by using more general mechanisms, e.g., with a mediator (see *Myerson* (1991), chapter 6.7, or *Mitusch/Strausz* (1999, 2000)) or with back-and-forth face-to-face communication (see *Forges* (1995)).

Related Literature

Our paper is most closely related to the literature that studies the abovementioned information revelation problem. We contribute to that literature by considering a partially incomplete contract environment. Closest to our setup are the papers by *Dessein* (2002), *Garidel-Thoron/Ottaviani* (2000), and *Baron* (2000). In contrast to us, Dessein focuses on non-transferable utility and assumes that control can be transferred on a non-contingent basis only. Also Garidel-Thoron/Ottaviani do not allow for contingent delegation, but, as we, they do consider monetary transfers. Yet, they restrict attention to linear payment-contracts but do not show that they are optimal. Baron, in a political science context, also considers monetary transfers, but his notion of delegation differs from ours. In his approach, the agent may or may not propose a policy to the principal. Under authority (open rule), the principal chooses an action after the agent has or has not proposed a policy. Under delegation (deference), if a proposal is made, the principal is committed to enact the proposal, while if no proposal is made, the principal chooses an action by discretion. Baron shows that deference generally dominates open rule, but he does not derive the optimal contract.

Similar to us, also *Aghion et al.* (2002) study information revelation in an environment with partially incomplete contracts. The main difference is that Aghion et al. consider a two-stage scenario where the principal can delegate control only in the first but not in the second period. Delegation may then serve as a means to "test" the agent.

Our model is also related to the literature in which the allocation of authority interacts with the agent's optimal effort choice. In contrast to these papers, in our model the agent's choice of action (under delegation) is independent from the allocation of authority. In *Aghion/Tirole* (1997) transfering authority strengthens the incentives for an initially uninformed agent to search for promising projects, but is accompanied with loss of control for the principal. *Bester* (2002) considers how the optimal allocation of authority is affected when the agent chooses his work effort only after a project has been selected. *Baker/Gibbons/Murphy* (1999) derive conditions under which delegation and high effort can be supported as an equilibrium in a repeated game when decision rights are not contractible.

The information revelation problem is also studied by *Mitusch/Strausz* (1999, 2000. Rather than on delegation, they focus on mediation. They consider a mediator who communicates with the agent and afterwards makes a policy proposal to the principal. The proposal rule is optimally designed by the principal. Mediation can improve pure cheap talk provided that the agent's incenctive to lie under cheap talk is not too large.

Finally, we mention a rationale for delegation as pointed out by social psychologists and as modelled in *Benabou/Tirole* (2000). There, delegating decisions to the agent may boost the agent's self-confidence and thereby stimulate effort.

The paper is organized as follows. Section 2 describes the model. In section 3 the optimal contract is derived. Section 4 discusses the robustness of our results, some possible extensions, and the relation of the model to the theory of the firm. Section 5 concludes.

2 The Model

A principal, P (she), hires an agent, A (he), to work on a project. The principal's and the agent's payoff from a project depends on some *action* y that is (irreversibly) chosen before the project is actually conducted.[6] E.g., y may represent the production technology the agent has to use. Actions can be chosen either by the principal or by the agent, but only the agent is able to work on the project. We assume that $y \in Y = \mathbb{R}$.

In addition, payoffs depend on a state of the world, t. E.g., the agent may be suited better or worse to work with a particular technology. We assume that there are two states of the world, t_0 and t_1, with ex-ante probabilities γ_0 and γ_1, respectively. Without loss of generality, $t_0 = 0, t_1 = 1$.

The agent has perfect private information about the true state of the world. By contrast, the principal is entirely ignorant. (Hence, A is an expert.) We identify the state of the world with an agent's type and denote an agent of type t by A_t.

Payoffs from projects are as follows. If in state t action $y \in Y$ is taken, the principal's

[6] After project choice, the agent has no discretion when working on the project, that is, there is no ex-post moral hazard.

and the agent's utility—gross of potential transfers—are respectively given as

$$v(y,t) = -\lambda (y-t)^2, \tag{1}$$

$$u(y,t) = -(y-(t+b))^2. \tag{2}$$

The parameter $b \geq 0$ measures the extent to which incentives are disaligned and is called *bias.* The larger is b, the more differ the parties' preferences with respect to action $y \in Y$. The parameter $\lambda > 0$ captures the idea that decisions may affect players differently and is called the principal's *interest* relative to the agent's. If $\lambda > 1$, deviations from a player's most preferred action entail more serious losses for the principal than for the agent. In this case the principal has a stronger interest in the decision than the agent. If $\lambda < 1$, the reverse holds. Which case is the relevant one depends on the application in question. Throughout we assume that *utility is transferable.*

Most Preferred Actions

The principal's most preferred action in state t is $y_t^P = t$, and agent A_t's most preferred action is $y_t^A = t+b$. Notice that agent A_1 prefers the principal's most preferred action in state 1 to the action most preferred by the principal in state 0. This implies that if the principal had the decision right and was naive such that she believed any reports sent by the agents about their types, agent A_1 would not have an incentive to lie. We call an agent with this property *compatible*[7]. Formally, agent A_t is called compatible if and only if $u\left(y_t^P, t\right) \geq u\left(y_s^P, t\right)$ for $t \neq s$.

Note that agent A_0 may or may not be compatible depending on the size of b. Indeed, agent A_0 is compatible if and only if $b \leq 1/2$. The communication problem arises if agent A_0 is not compatible. In this case, if the principal had the decision right and was naive, agent A_0 would not communicate his type truthfully but pretend to be agent A_1.

Contracts and Decision Rights

Disaligned preferences in combination with asymmetric information give rise to the mentioned conflict between the principal and his agent. To mitigate this conflict, parties write

[7] This term is borrowed from *Mitusch/Strausz* (1999).

an explicit contract. We shall look for the contract that, from the principal's perspective, optimally resolves this conflict.

We assume that contracts are partially incomplete. More specifically, we assume that actions are non-contractible. By contrast, decision rights and monetary transfers are contractible. Moreover, the assignment of the decision right and payments can be made contingent on messages sent from the agent to the principal, that is, we assume contractibility of messages.

More precisely, the contracting game is as follows. The principal designs a message space M and offers the agent a contract $\Gamma = (M, \alpha_m, w_m)$. If the agent accepts the contract, the agent sends a message $m \in M$ to the principal. Then, contingent on message m, the principal either delegates the decision or keeps control over the action. If $\alpha_m = 1$, the principal chooses an action (*authority*). If $\alpha_m = 0$, the agent chooses an action (*delegation*).[8] Finally, the principal pays the agent a message-contingent transfer w_m.

If the agent rejects, the project cannot be conducted, and both players receive their reservation utility.[9] We normalize the agent's reservation utility to 0. The principal's reservation utility is $\overline{v} \in \mathbb{R}$. The size of $\overline{v}$ reflects benefits from trade: the smaller is $\overline{v}$, the higher are the benefits from trade.[10]

Remark (Screening): The size of $\overline{v}$ determines whether the principal benefits from the relation at all. If $\overline{v}$ is very large, the best the principal can do is simply to offer a contract that is rejected by both agent types. If $\overline{v}$ is moderate, the principal may optimally screen between the agents by making an offer that is rejected by exactly one agent type. To illustrate this, consider the contract that offers a wage b^2 and gives the principal the decision right. Then it is an equilibrium that A_1 rejects, and A_0 accepts. For in this case,

[8] The restriction to deterministic assignments $\alpha \in \{0, 1\}$ is made for computational simplicity.

[9] This assumption is similar to Aghion et al. (2002). In contrast, Dessein (2002) and Baron (2000) assume that the principal can choose an action without the agent's consent. This is appropriate if, e.g., the agent provides only pure advice but is not needed to work on the project.

[10] Of course, we could equivalently specify the principal's utlity as $v(y, t) - \overline{v}$, and normalize her reservation utility to 0.

P beliefs that $t = 0$, if the agent accepts and chooses action $y = 0$. Agent A_0 would therefore get $-(1+b)^2 + b^2 < 0$ from accepting, while agent A_1 gets 0. Ex ante, this contract gives the principal expected utility of $-\gamma_0 b^2 + \gamma_1 \overline{v}$. However, if $\overline{v}$ is small, screening of this kind can never be optimal since P can guarantee herself a payoff of at least $-\lambda b^2$ by unconditionally delegating the decision and paying a wage of 0. To set aside screening issues, we assume in the sequel that $\overline{v} \leq -\lambda b^2$. This makes sure that the principal will optimally make contract offers that are accepted by both agent types.

3 Delegation and Authority

Before characterizing the optimal incomplete contract of the form $\Gamma = (M, \alpha_m, w_m)$, we shall first consider two benchmark cases: the case with complete information and the case with contractible actions.

3.1 Benchmark 1: Complete Information

Under complete information, the principal knows the type of the agent, that is, $\gamma_0 = 1$ or $\gamma_1 = 1$. Thus, messages are obsolete, and the principal unconditionally chooses either $\alpha = 1$ (authority) or $\alpha = 0$ (delegation) and a wage w.

Under authority, the principal chooses her most preferred action $y_t = t$ and receives gross utility 0. Thus, the agent obtains gross utility $-b^2$. Accordingly, the principal optimally chooses wage $w = b^2$ to induce participation of the agent. Hence, the principal's utility is $-b^2$.

Under delegation, the agent chooses his most preferred action $y_t^A = t + b$ in state t. This leaves him with gross utility of 0 in either state. Therefore, the principal optimally chooses $w = 0$. Moreover, the principal receives utility $-\lambda b^2$ in either state. Thus, the principal's utility is $-\lambda b^2$. This implies the following result.

Proposition 1 *With complete information, the principal optimally delegates the decision, if, and only if,* $\lambda \leq 1$.

This simply says that under complete information the party with the higher stake in the decision should be given the decision right. Though simple, this result is not completely trivial. For it illustrates the participation purpose of delegation. The principal has to reward the agent for working on the project also if the latter has no informational expertise. He may do this either by monetary compensation or by transfering control. If the principal's interest is small, she prefers the latter.[11]

3.2 Benchmark 2: The Complete Contract with Perfect Commitment

If the action is contractible, the principal can perfectly pre-commit to an action ex ante. In particular, she can commit to the action the agent would take if he had the decision right. Therefore, any contract in which the agent has the decision right can as well be implemented through a contract in which the principal has the decision right. Thus, without loss of generality, $\alpha_t = 1$.

Moreover, since the principal can perfectly pre-commit to a mechanism, we can apply the classical revelation principle to find the optimal contract for the principal. The principal's problem writes

$$\max_{y,w} \sum_{t\in\{0,1\}} \left[-\lambda \left(y_t - t\right)^2 - w_t\right] \gamma_t \tag{3}$$

s.t.

$$\text{IC}_t : -\left(y_t - (t+b)\right)^2 + w_t \geq -\left(y_s - (t+b)\right)^2 + w_s \qquad \text{for } t \neq s \tag{4}$$

$$\text{IR}_t : -\left(y_t - (t+b)\right)^2 + w_t \geq 0. \tag{5}$$

Here, y_t and w_t denote message-contingent actions and transfers (wages), respectively. The solution of the program is as follows. The proof is in the appendix.

Proposition 2 *Define*

$$\widehat{b} = \frac{1+\lambda}{2\lambda}, \quad \widetilde{b} = \frac{2+\gamma_1(\lambda-1)}{2\gamma_1\lambda}. \tag{6}$$

[11] That delegation facilitates participation is also pointed out in *Aghion/Tirole* (1997), section IV.B.

Then with perfect commitment optimal actions are given by

$$y_0 = \frac{b}{1+\lambda}, \tag{7}$$

$$y_1 = \begin{cases} 1 + \frac{b}{1+\lambda} & \text{if } b \le \widehat{b} \\ \\ \frac{1}{2} + b & \text{if } \widehat{b} < b \le \widetilde{b} \\ \\ \frac{\gamma_1\lambda+1}{\gamma_1(1+\lambda)} + \frac{b}{1+\lambda} & \text{if } b > \widetilde{b}. \end{cases} \tag{8}$$

Furthermore, A_1 gets just his reservation utility and A_0 gets an information rent if b is sufficiently large, that is,

$$w_0 = \begin{cases} (y_0 - b)^2 & \text{if } b \le \widetilde{b} \\ \\ (y_0 - b)^2 + 1 + 2b - 2y_1 & \text{if } b > \widetilde{b}, \end{cases} \tag{9}$$

$$w_1 = (y_1 - (1+b))^2 . \tag{10}$$

Unsurprisingly, the results exhibits familiar features of standard adverse selection models. There is no distortion at the top. That is, y_0 equals the efficient action under complete information. Also, agent A_1 is kept at his reservation utility. Notice however that for small bias ($b \le \widehat{b}$) also y_1 equals the efficient action under complete information, and also A_0 only gets his reservation utility. Particularly, agency costs are 0. However, as b increases, it is no longer optimal to implement the efficient action in state 1 since this can only be done at the price of a large w_0 so as to ensure incentive compatibility for A_0. Rather, it is cheaper to provide incentives for A_0 by deviating from the efficient action in state 1 and thus to pay agent A_0 a smaller information rent.

3.3 The Incomplete Message-Contingent Contract with Imperfect Commitment

We analyze now the contract with imperfect commitment. If the principal cannot commit to an action ex ante, the classical revelation principle fails. This is because the agent anticipates that the principal, under authority, will use her discretion and thereby hurt the agent if he reports his type truthfully. In other words, the contract of Proposition 2 is not feasible with limited commitment. To find the optimal contract, we can apply the generalized version of the revelation principle of *Bester/Strausz* (2001). As shown there, the optimal contract, as with the classical revelation principle, is still a direct contract. That is, the message space, as with the classical revelation principle, coincides with the type space. Thus, $M = \{0,1\}$. A contract Γ then induces a Bayesian game with the following strategies and payoffs.

Strategies: The agent's strategy consists of a probability distribution over messages and an action that he takes if the decision is delegated. For $s,t \in \{0,1\}$ denote by σ_{st} the probability that agent A_t sends message $m = s$, that is,

$$\sigma_{st} = P\left[m = s \mid A_t\right]. \tag{11}$$

Denote by $y_t^A \in Y$ agent A_t's action in case of delegation.

The principal's strategy is a function that maps messages into actions. For $s \in \{0,1\}$ denote by $y_s \in Y$ the principal's action contingent on having received message $m = s$. Moreover, the principal holds a belief about the state of nature conditional on the message received. Denote by μ_{ts} the principal's belief that the agent is of type t conditional on having received message $m = s$, that is,

$$\mu_{ts} = P\left[A_t \middle| \, m = s\right]. \tag{12}$$

Payoffs: For given contract $\Gamma = (\alpha_t, w_t)$ and strategies $\left(\sigma_{st}, y_t^A\right)$, y_s the principal receives message s in state t with probability $\gamma_t \sigma_{st}$. In this case, she obtains gross utility $-\lambda\left(y_s - t\right)^2$ if $\alpha_s = 1$, and $-\lambda\left(y_t^A - t\right)^2$ if $\alpha_s = 0$. Furthermore, she pays the agent the transfer w_s. Thus, P's expected utility is given by

$$V = \sum_{t,s \in \{0,1\}} \gamma_t \sigma_{st} \left[\alpha_s \left(-\lambda\left(y_s - t\right)^2\right) + (1-\alpha_s)\left(-\lambda\left(y_t^A - t\right)^2\right) - w_s\right]. \tag{13}$$

Likewise, agent A_t's expected utility from sending message $m = s$ is given by

$$U(s;t) = \alpha_s\left(-\left(y_s - (t+b)\right)^2\right) + (1-\alpha_s)\left(-\left(y_t^A - (t+b)\right)^2\right) + w_s. \tag{14}$$

In a Perfect Bayesian Nash Equilibrium, actions have to be optimal given beliefs. Accordingly, whenever the decision is delegated, agent A_t chooses his most preferred action $y_t^A = t + b$. Thus,

$$V = \sum_{t,s\in\{0,1\}} \gamma_t \sigma_{st} \left[\alpha_s \left(-\lambda \left(y_s - t\right)^2\right) + \left(1 - \alpha_s\right)\left(-\lambda b^2\right) - w_s\right], \tag{15}$$

$$U\left(s;t\right) = \alpha_s \left(-\left(y_s - \left(t + b\right)\right)^2\right) + w_s. \tag{16}$$

Intuitively, because the agent anticipates that the principal will use revealed information in a way detrimental to the agent, it might be very expensive for the principal to induce truthful revelation by the agent. It may therefore be optimal to induce the agent to misrepresent his type with positive probability. In this case, the agent has to be kept indifferent between messages. Formally, the generalized revelation principle states that the optimal contract for the principal is given as the solution to the following program.

$$\max_{\sigma,y,\alpha,w} V \tag{17}$$

s.t.

$$\text{IC}_t: \quad U\left(t;t\right) \geq U\left(s;t\right) \qquad \text{for } t \neq s \tag{18}$$

$$\text{IR}_t: \quad U\left(t;t\right) \geq 0 \tag{19}$$

$$\text{IND}: \quad \left[U\left(t;t\right) - U\left(s;t\right)\right]\sigma_{st} = 0 \quad \text{for } \sigma_{st} \in (0,1) \tag{20}$$

$$\text{OPT}: \quad y_s \in \arg\max_y \sum_{t\in\{0,1\}} \mu_{ts}\left[-\lambda\left(y_s - t\right)^2\right] \tag{21}$$

$$\text{BayR}: \quad \mu_{ts} = \frac{\sigma_{st}\gamma_t}{\sigma_{st}\gamma_t + \sigma_{ss}\gamma_s} \tag{22}$$

Conditions IC and IR are the usual incentive compatibility and (interim) individual rationality constraints[12]. The three additional constraints account for limited commitment. Condition IND says that an agent has to be indifferent between messages if he actively mixes between messages. Moreover, in a Perfect Bayesian equilibrium, the principal must choose an optimal action given her beliefs, and these beliefs must be consistently derived

[12] Following *Garidel-Thoron/Ottaviani* (2000), the interim individual rationality constraint can be interpreted as limited liability of the agent. The case with an ex-ante individual rationality constraint, or unlimited liability, is similarly dealt with.

by Bayes rule given the agent's strategy. These are conditions OPT and BayR. Notice that OPT implies

$$y_s = \mu_{1s}. \tag{23}$$

The principal has two instruments to induce information revelation and participation: wages and decision rights. Raising w_t or reducing α_t, ceteris paribus, increases the incentive to report message $m = t$ and the participation incentive of agent A_t. The two instruments are accompanied with different costs. Raising monetary incentives goes along with a higher wage bill. Transfering the decision right leads to a suboptimal action for the principal. The costs of transfering the decision right are reflected by the term $(1-\alpha_s)(-\lambda b^2)$ in the principal's objective. Thus, the larger is λ, the larger is the cost of delegation.

To find the optimal contract, we proceed as follows. We first compute an upper bound for the principal's utility. We then show that for $b \leq 1/2$ or $\lambda \leq 1$, this upper bound is achieved by unconditional authority and unconditional delegation, respectively. Finally, we characterize the optimal contract for the case $b > 1/2$ and $\lambda > 1$.

To compute the upper bound for the principal's utility, suppose that the agent is honest and reports his type truthfully even if incentive constraints do not hold and that the principal only has to make sure participation of the agent. This would give the principal a higher utility than when she has to respect incentive constraints. In this case, the principal would optimally choose $y_t = t$ and set $w_t = \alpha_t b^2$ for given α. The resulting utility for the principal would be

$$\overline{V} = -\gamma_0\alpha_0 \cdot 0 - \gamma_0(1-\alpha_0)\lambda b^2 - \gamma_0 w_0 - \gamma_1\alpha_1 \cdot 0 - \gamma_1(1-\alpha_1)\lambda b^2 - \gamma_1 w_1 \tag{24}$$

$$= -\lambda b^2 - b^2(1-\lambda)(\gamma_0\alpha_0 + \gamma_1\alpha_1). \tag{25}$$

Hence, if $\lambda \leq 1$, α is optimally set to $\alpha_0 = \alpha_1 = 0$, resulting in $\overline{V} = -\lambda b^2$. If $\lambda > 1$, α is optimally set to $\alpha_0 = \alpha_1 = 1$, resulting in $\overline{V} = -b^2$. Hence, we have the following result.

Lemma 1 *An upper bound on the principal's utility is given by*

$$\overline{V} = \begin{cases} -\lambda b^2 & \text{if} \quad \lambda \leq 1 \\ \\ -b^2 & \text{if} \quad \lambda > 1. \end{cases} \tag{26}$$

With this, it follows immediately that unconditional delegation is optimal whenever the principal's interest is smaller than the agent's.

Proposition 3 *Let $\lambda \leq 1$, then unconditional delegation is optimal. That is, the optimal contract has $\alpha_0 = \alpha_1 = 0$ and $w_0 = w_1 = 0$. P's expected utility is*

$$V(0,0) = -\lambda b^2. \tag{27}$$

Proof: By backward induction, under $\alpha_0 = \alpha_1 = 0$ agent A_t chooses his most preferred action $y_t^A = t + b$. This leaves A_t with utility $u = 0$ in state t. Therefore, P optimally chooses $w_t = 0$. Moreover, the principal receives gross utility $-\lambda b^2$ in either state. Thus, P's expected utility is $-\lambda b^2$. Since this coincides with the upper bound $\overline{V}$ in Lemma 1, unconditional delegation is optimal. □

The upper bound in in Lemma 1 is also assumed under unconditional authority when the principal's interest is larger than the agent's and when both agents are compatible.

Proposition 4 *Let $\lambda > 1$ and $b \leq 1/2$. Then unconditional authority is optimal. That is, the optimal contract has $\alpha_0 = \alpha_1 = 1$ and $w_0 = w_1 = b^2$. P's expected utility is*

$$V(1,1) = -b^2. \tag{28}$$

Proof: We show that $y_0 = 0, y_1 = 1$ is an equilibrium for the contract $(\alpha, w) = (1, b^2)$. Indeed, since $b \geq 1/2$, both incentive constraints IC_t hold with strict inequality for $y_0 = 0, y_1 = 1$. Thus, both agents report their type truthfully with probability 1. However, given truthful revelation, the principal optimally chooses $y_0 = 0, y_1 = 1$. This shows that $y_0 = 0, y_1 = 1$ is an equilibrium.

In this equilibrium, the principal receives gross utility 0 and pays wage b^2 in either state. Thus, P's expected utility is $-b^2$. If $\lambda > 1$, this coincides with the upper bound $\overline{V}$ in Lemma 1. Thus, unconditional authority is optimal. □

We now characterize the optimal contract for the remaining parameters $b > 1/2$ and $\lambda > 1$. For this, we define

$$\widehat{\lambda}(b) = 1 + \frac{\gamma_0}{\gamma_1}\frac{2b-1}{b^2}. \tag{29}$$

Proposition 5 *Let $b > 1/2$ and $\lambda > 1$.*

(i) Let $\lambda \geq \widehat{\lambda}$. Then unconditional authority is optimal. That is, the optimal contract has $\alpha_0 = \alpha_1 = 1$. Moreover, agent A_0 receives an information rent of $2b - 1$, that is, optimal wages are given by

$$w_0 = b^2 + 2b - 1 \quad \textit{and} \quad w_1 = b^2. \tag{30}$$

P's expected utility is

$$V(1,1) = -b^2 - \gamma_0 (2b - 1). \tag{31}$$

(ii) If $\lambda < \widehat{\lambda}$, then contingent delegation is optimal where the decision is delegated contingent on announcement of type $t = 1$. That is, the optimal contract has $\alpha_0 = 1, \alpha_1 = 0$. Moreover, no agent receives an information rent, that is, optimal wages are given by

$$w_0 = b^2 \quad \textit{and} \quad w_1 = 0. \tag{32}$$

P's expected utility is

$$V(1,0) = -\gamma_0 b^2 - \gamma_1 \lambda b^2. \tag{33}$$

The proof is in the appendix. The proof also shows that in our specification it is always optimal for the principal to induce perfect truthtelling.[13] As a consequence, if the principal has the decision right, she implements her most preferred action.

Proposition 6 *Irrespectively of b and λ the principal optimally induces agents to report truthfully and chooses the corresponding action if she keeps the decision right, that is,*

$$\sigma_{00} = 1, \sigma_{11} = 1, \tag{34}$$

$$y_0 = 0, y_1 = 1. \tag{35}$$

Figure 1 portrays the optimal contract in λ-b-space.

[13] This results from the assumption that both interest and bias are state-independent. If this is relaxed, the computational effort rises considerably.

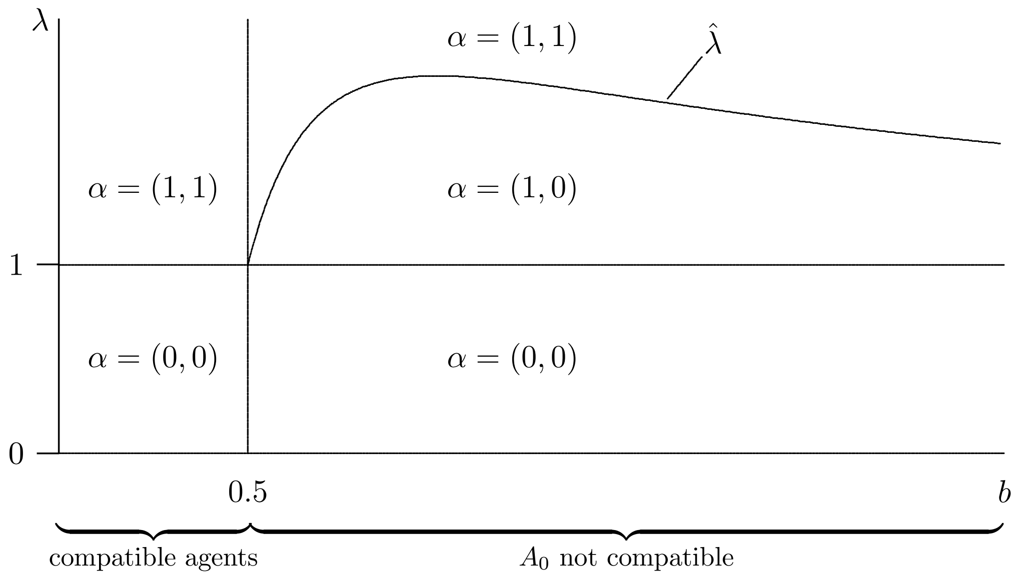

Figure 1: Decision Rights, Interest, and Bias

The intuition for the optimal contract is as follows. In general, if the principal retains control, she has to pay the agent a monetary wage to induce both participation and information revelation. This wage reflects the loss she inflicts on the agent by her discretion. On the other hand, the cost of delegation is the loss the principal incurs by the agent's discretion.

Now, if the principal's interest is smaller than the agent's, the principal's loss through the agent's discretion is smaller than the agent's loss through the principal's discretion. Therefore, if $\lambda \leq 1$, the principal always prefers to delegate control.

For $b \leq 1/2$, both agents are compatible, and there is no incentive problem. Both agents reveal their type without being paid an information rent. Therefore, whether to delegate or not is motivated exclusively by participation considerations.

Yet, as b increases, an incentive problem arises since agent A_0 becomes incompatible. Therefore, if the principal retains control, the principal not only has to compensate the agent to participate, but she also has to pay the agent so as to induce information revelation. By contrast, delegation saves the principal to pay this cost. In this sense, if $\lambda \leq 1$, delegation is a cheap way to make use of the agent's information.

As λ becomes large, the cost of delegation rises. If $\lambda \geq \widehat{\lambda}$, the costs of delegation dominate the monetary costs for information revelation under authority, and unconditional authority is optimal.

For moderate interest ($1 < \lambda < \widehat{\lambda}$) contingent delegation is optimal. Delegating the decision to the agent who announces to be type A_1 mitigates the incentive problem with respect to agent A_0. The reason is as follows. Delegating the decision to agents who report to be type A_1 weakens the participation constraint for agent A_1. Thus, the wage w_1 can be reduced as compared to authority ($\alpha_1 = 1$). This affects agent A_0 in two ways. On the one hand, with respect to transfers, lying becomes less attractive for agent A_0. On the other hand however, with respect to actions, lying becomes more attractive for agent A_0 because he is given the decision right if he misrepresents his type. Yet, with state-independent bias the first effect always dominates the second effect. That is, contingent delegation creates incentives for information revelation.[14] For the principal contingent delegation is beneficial, as monetary transfers can be reduced. However, it is also costly, as agent A_1 is granted the decision right. The balance depends on the principal's interest. If the principal's interest is only moderately larger than that of the agent such that costs of delegation are still moderate, contingent delegation becomes optimal.[15]

Note further that the effect requires both contractibility of messages and transferable utility. It does not appear in cheap talk models such as *Dessein* (2000), and *Garidel-Thoron/Ottaviani* (2000).

To sum up, the optimal contract highlights three purposes of delegation: it facilitates participation and leads to an informed decision. Moreover, contingent delegation creates incentives for information revelation.

There are several further noteworthy points. For fixed λ with $1 < \lambda < \widehat{\lambda}$, there is

[14] This incentive effect is different from the incentive view in *Aghion/Tirole* (1997) where delegation stimulates the agent's effort.

[15] Notice that the incentive effect requires that the participation constraint for A_1 is sufficiently weakened when switching from authority to delegation. This is not necessarily the case for state-dependent bias, for instance, if A_1 is not biased at all.

no monotone relation between (unconditional) authority and (contingent) delegation for increasing bias b. This may appear counterintuitive because for fixed λ the principal's loss under delegation increases b, and it may therefore seem that control should be in the principal's hands for larger bias. But this is not true. For also the monetary transfers necessary for information revelation under authority rise in b, since also the agent's loss under authority increases for larger bias. In particular, if the agent is equally interested in the decision as the principal, that is, if $\lambda = 1$, then it is never optimal for the principal to unconditionally remain in charge of the decision.

Finally, the optimal contract illustrates the role of contractible messages. If $\lambda \leq 1$ or $b \leq 1/2$, the optimal contract can be implemented as a contract which unconditionally specifies a decision right and a transfer, that is, a contract which does not make use of messages. If $\lambda \leq 1$, the principal's interest in the decision is so small that she optimally delegates to both agents. If both agents are compatible, there is no need to give agents different incentives. Only if $\lambda > 1$ and $b > 1/2$, the optimal contract makes use of messages. In this case, the principal wants to keep at least some authority and therefore has to treat agents differently so as to achieve incentive compatibility.

4 Discussion

We now discuss the robustness of our results and some possible model extensions. Finally, we shall discuss the relation of our model to the theory of the firm.

Most of our specifications are made so as to keep the model tractable. As mentioned above, a state-independent bias is important to generate the incentive effect of contingent delegation. Implicit in our loss specification is also that properties like slope or curvature of the loss functions are state-independent. It is an open question how more general loss functions would affect our results.

The two-type assumption leads to the result that there is no incentive problem for small bias. Indeed, it can be easily seen that in our model pure cheap talk gives rise to perfect information transmission for small bias. While this is a general fact for a model with discrete types, in models with a continuum of types cheap talk typically gives rise only to intermediate degrees of information transmission (for instance in *Crawford/Sobel* (1982)). Therefore, our results might change with a continuum of types, and it would be desirable to allow for a higher number of types. However, it is not clear how the generalized revelation principle in *Bester/Strausz* (2001) carries over to a continuum of types. Further, the difficulty with a higher number of discrete types is that the computational effort considerably increases in the number of types.

The model can be extended along several lines and raises a series of questions for future research. First of all, it would be interesting how the allocation of decision rights affects incentives for information acquisition or specialization when the agent is initially uninformed.

To get an interesting problem, one needs to assume that the principal can neither observe effort nor whether the agent is informed or not. In this case the principal faces a moral hazard problem on part of the agent. In addition to incentives for information revelation the principal then has to provide incentives to induce effort. Delegation may be a cheap way to motivate the agent, as he can use the information gained according to his own preference. Notice however that a thorough analysis of this case amounts to solving our model for the case with three agent types. For the uninformed agent corresponds to an agent of type $t = \gamma_1 + b$ with most preferred action $y = \gamma_1 + b$.

A further extension concerns the number of agents. The Crawford/Sobel model has only recently been extended to the case with two agents (*Krishna/Morgan* (2000), *Battaglini* (2001)), and the comparison with delegation under non-transferable utility is investigated in *Krishna/ Morgan* (2001). As for transferable utility however, the extension is not straightforward, as it is not clear whether and how the generalized revelation principle under imperfect commitment carries over to multiple agents (see *Bester/Strausz* 2000).

Relation to the Theory of the Firm

Our model is related to the theory of the firm. We can interpret the principal as a buyer and the agent as a seller who produces an intermediate good and delivers it to the buyer. The agent comes in two types (states) which refer to his specialization. The action concerns the implementation of a production technology to produce the good. The principal's utility may be state-dependent because the agent's type may affect the quality of the product.

Under unconditional authority the buyer installs the technology and hires the seller as a worker to produce the good. The utility transfer from the principal to the agent corresponds then to the worker's wage. This is suggestive of an integrated firm. Under unconditional delegation the seller decides on the technology, then produces the good, and delivers it to the buyer. The utility transfer corresponds then to the product's price. This is suggestive of a market relation. (In the parlance of the theory of the firm, authority corresponds to "make" whereas delegation corresponds to "buy".) Contingent delegation corresponds to an intermediate form where the mode of transaction is determined conditional on exchange of information prior to the actual decision.

As in transaction cost economics (*Coase* (1937), *Williamson* (1985)) and in the property rights approach (*Grossman/Hart* (1986), *Hart/Moore* (1990), *Hart* (1995)), in our model the key element to make the distinction between firms and markets is incompleteness of contracts. In fact, analogous to the property rights view, in our agency view the notion of vertical integration is one of control rights. However, as opposed to the property rights theory, in our model it is asymmetric information rather than relation-specificity of investments which is the source of inefficiencies. Notice also the differences between our and the transaction cost approach.[16] Transaction cost economics starts from asking "Why do firms exist?". For it maintains that in a world without transaction costs "buy" always dominates "make". By contrast, our model rather provides an answer to the question "Why do markets exist?". For in a world of complete contracts, in our model "make" would always dominate "buy", and we could not explain the existence of markets. In this sense, our theory can be seen as dual to transaction cost economics.

[16] For a discussion of the differences between the transaction cost and the property rights approach see *Whinston* (2000).

5 Conclusion

The paper studies the role of delegation and authority within a principal-agent relation in which a non-contractible action has to be taken. The agent has private information relevant for the principal's best policy, but at the same time has policy preferences different from the principal. We analyze the information revelation problem under the assumption of transferable utility and contractibility of messages and decision rights and derive the optimal contract for the principal. This has not been thoroughly done in the literature and is therefore our main contribution.

Our results show that delegation serves three purposes. As in environments with non-contractible messages, delegation facilitates participation of the agent and may be a cheap way to make use of the agent's information. More interestingly, we show that contractibility of messages together with transferable utility give rise to an incentive effect. Contingent delegation creates incentives for information revelation in that it weakens the incentive constraint for the agent to whom the decision is not delegated.

Appendix

Proof of Proposition 2: We show first that IR_1 is always binding. Notice that it cannot be optimal for the principal to have both IR constraints hold with strict inequality. For whether the IC constraints are satisfied depends only on the wage differential $\Delta w = w_0 - w_1$. Hence, both wages could be reduced without violating the IC constraints.

Suppose now that IR_1 is not binding. This implies that IR_0 is binding, thus $w_0 = (y_0 - b)^2$. Assume for a moment that $y_0 \leq 1/2 + b$ in the optimum. Then, the right hand side of IC_1 writes

$$-\left(y_0 - (1+b)^2\right) + (y_0 - b)^2 = 2y_0 - 1 - 2b \tag{36}$$

$$\leq 1 + 2b - 1 - 2b \tag{37}$$

$$= 0. \tag{38}$$

Hence, w_1 can be reduced until IR_1 binds without violating IC_1.

We show now that indeed $y_0 \leq 1/2 + b$. Suppose the contrary. Then

$$-\left(y_1 - (1+b)^2\right) + w_1 \geq -\left(y_0 - (1+b)^2\right) + w_0 \tag{39}$$

$$\geq -\left(y_0 - (1+b)^2\right) + (y_0 - b)^2 \tag{40}$$

$$= 2y_0 - 2b - 1 \tag{41}$$

$$> 0, \tag{42}$$

where the first inequality follows by IC_1 and the second by IR_0. Hence, IR_0 holds with strict inequality which implies that IR_0 must be binding, that is, $w_0 = (y_0 - b)^2$. However, P can improve by replacing y_0 by $\widehat{y}_0 := 2b - y_0$ and setting $\widehat{w}_0 = (\widehat{y}_0 - b)^2$. For notice that for A_0 nothing changes as $(y_0 - b)^2 = (\widehat{y}_0 - b)^2$. Furthermore, IC_1 still holds as

$$-\left(\widehat{y}_0 - (1+b)\right)^2 + w_0 = 2b - 1 - 2y_0 \leq 0. \tag{43}$$

However, $\widehat{y}_0$ is closer to 0 than is y_0, and therefore P's utility increases. Thus, IR_1 is binding.

Since IR_1 is binding it follows that $w_1 = (y_1 - (1+b))^2$. Moreover, IC_0, IC_1, and IR_0 imply that Δw must satisfy

$$y_0^2 - y_1^2 - 2b\,(y_0 - y_1) + \max\{0, 2y_1 - (1+2b)\} \tag{44}$$

$$\leq \Delta w \tag{45}$$

$$\leq y_0^2 - y_1^2 - 2\,(1+b)\,(y_0 - y_1)\,. \tag{46}$$

Thus the principal's problem is to choose $y_0, y_1, \Delta w$ so as to maximize

$$-\gamma_0 \lambda y_0^2 - \gamma_1 \lambda\,(y_1 - 1)^2 - (y_1 - (1+b))^2 - \gamma_0 \Delta w \tag{47}$$

subject to (45). Since Δw enters negatively in the objective, it must be that in the optimum $\Delta w = y_0^2 - y_1^2 - 2b\,(y_0 - y_1) + \max\{0, 2y_1 - (1+2b)\}$. Thus, the objective becomes

$$-\gamma_0 \lambda y_0^2 - \gamma_1 \lambda\,(y_1 - 1)^2 - (y_1 - (1+b))^2 \tag{48}$$

$$-\gamma_0\left(y_0^2 - y_1^2 - 2b\,(y_0 - y_1) + \max\{0, 2y_1 - (1+b)\}\right). \tag{49}$$

The first order condition with respect to y_0 yields

$$y_0 = \frac{b}{1+\lambda}, \tag{50}$$

as was claimed.

For y_1, since the objective has a kink in $y_1 = b + 1/2$, we need to distinguish the case $y_1 < b + 1/2$ (case A) and the reverse $y_1 \geq b + 1/2$ (case B). In case A the first order condition yields

$$y_1^A = \frac{\gamma_1 (\lambda + b) + 1}{\gamma_1 (1+\lambda)}. \tag{51}$$

Notice that $y_1^A < b + 1/2$ if and only if $b > (2 + \gamma_1 (\lambda - 1)) / (2\gamma_1 \lambda) = \widetilde{b}$. Thus, the optimal y_1 under the constraint $y_1 < b + 1/2$ is given as

$$y_1^A 1_{\{b>\widetilde{b}\}} + (b + 1/2 - \varepsilon) 1_{\{b \leq \widetilde{b}\}}, \tag{52}$$

where ε is thought to be arbitrarily small. In case B the first order condition yields

$$y_1^B = 1 + \frac{b}{(1+\lambda)}. \tag{53}$$

Notice that $y_1^B \geq b + 1/2$ if and only if $b \leq (1+\lambda) / (2\lambda) = \widehat{b}$. Thus, the optimal y_1 under the constraint $y_1 \geq b + 1/2$ is given as

$$y_1^B 1_{\{b \leq \widehat{b}\}} + (b + 1/2) 1_{\{b > \widehat{b}\}}. \tag{54}$$

Observe now that $\widehat{b} < \widetilde{b}$. This implies that, if $b \leq \widehat{b}$, then y_1^B is optimal. If $\widehat{b} < b \leq \widetilde{b}$, then the kink point $b + 1/2$ is optimal. And if $b > \widetilde{b}$, then y_1^A is optimal. Hence, the claimed optimality of actions is shown.

As for wages, since IR_1 is always binding, $w_1 = (y_1 - (1+b))^2$. As for w_1 notice that for $b \leq \widetilde{b}$ it holds that $y_1 \geq b + 1/2$, thus $\Delta w = y_0^2 - y_1^2 - 2b (y_0 - y_1) + 2y_1 - (1 + 2b)$ and IR_0 is binding, that is, $w_0 = (y_0 - b)^2$. If $b > \widetilde{b}$, then IC_0 holds with equality, thus $\Delta w = y_0^2 - y_1^2 - 2b (y_0 - y_1)$. This yields

$$\begin{aligned} w_0 &= w_1 + \Delta w && (55) \\ &= (y_1 - (1+b))^2 + y_0^2 - y_1^2 - 2b (y_0 - y_1) && (56) \\ &= (y_0 - b)^2 + 1 + 2b - 2y_1. && (57) \end{aligned}$$

This shows the claim. □

Proof of Proposition 5: Notice first that for given (α_0, α_1) it cannot be optimal to have both IR constraints hold with strict inequality. The reason is that the feasibility of actions y and truthtelling probabilities σ depends only on the wage differential $\Delta w = w_0 - w_1$. Thus, in such a case wages w could be at least slightly reduced without changing actions and truthtelling probabilities.

However, in contrast to standard contracting problems with perfect commitment, under imperfect commitment it is generally not possible to say ex ante which of the constraints must be binding. Therefore, to find the optimum we have to go through all possible cases and then compare the resulting utilities.

We first rewrite the IC-constraints. Define Δw_t the wage differential such that IC_t is binding. That is, $\Delta w_t = \alpha_0 (y_0 - (t+b))^2 - \alpha_1 (y_1 - (t+b))^2$. With this, the IC-constraints write

$$\Delta w_0 \overset{\text{IC}_0}{\leq} \Delta w \overset{\text{IC}_1}{\leq} \Delta w_1. \tag{58}$$

Define further $\widetilde{\Delta w} = \alpha_0 (y_0 - b)^2 - \alpha_1 (y_1 - (1+b))^2$.

Now, suppose first that it is optimal to have IR_0 binding. We show that there is no feasible contract with $\alpha_1 > 0$. Indeed, IR_0 binding implies $w_0 = \alpha_0 (y_0 - b)^2$. Hence, IR_1 implies that $\Delta w \leq \alpha_0 (y_0 - b)^2 - \alpha_1 (y_1 - (1+b))^2 = \widetilde{\Delta w}$. Thus, by IC_0, feasibility requires $\Delta w_0 \leq \widetilde{\Delta w}$. If $\alpha_1 > 0$, this is equivalent with $(y_1 - b)^2 \leq (y_1 - (1+b))^2$, or with $y_1 \geq 1/2 + b$. Since $y_1 \leq 1$ by OPT and since $b > 1/2$, this is a contradiction. Hence, $\alpha_1 = 0$.

Now, $\alpha_1 = 0$ implies that $\Delta w_0 = \widetilde{\Delta w} = \alpha_0 (y_0 - b)^2$. Because we must have that $\Delta w_0 \leq \Delta w \leq \widetilde{\Delta w}$, it follows that $\Delta w = \alpha_0 (y_0 - b)^2$. Since $w_0 = \alpha_0 (y_0 - b)^2$, this implies that $w_1 = 0$. Moreover, for $\alpha_0 > 0$, $\Delta w_1 > \Delta w$, because $b > 1/2$. Therefore, by IND, A_1 reports truthfully, thus, by BayR and OPT, $y_0 = 0$. Hence, $w_0 = \alpha_0 b^2$.

Therefore, P's expected utility is

$$V = \gamma_0 \alpha_0 \lambda \cdot 0 - \gamma_0 (1 - \alpha_0) \lambda b^2 - \gamma_0 \alpha_0 b^2 \tag{59}$$

$$- \gamma_1 \cdot 0 - \gamma_1 \lambda b^2 - \gamma_1 \cdot 0 \tag{60}$$

$$= -\gamma_0 \lambda b^2 - \gamma_1 \lambda b^2 + \gamma_0 (\lambda - 1) b^2 \alpha_0. \tag{61}$$

Since $\lambda > 1$, α_0 is optimally set to 1, and the resulting utility is

$$V^{IR_0} (1, 0) = -\gamma_0 b^2 - \gamma_1 \lambda b^2. \tag{62}$$

For $\alpha_0 = 0$, we are in the case of unconditional delegation which yields utility $-\lambda b^2$. Since $\lambda > 1$, this is thus worse than $\alpha_0 = 1$.

Suppose next that it is optimal to have IR_1 binding. This implies that $w_1 = \alpha_1 (y_1 - (1 + b))^2$. With this, IR_0 requires $\Delta w \geq \widetilde{\Delta w}$. Moreover, by IC_0, $\Delta w \geq \Delta w_0$. We have seen above that, since $b > 1/2$, $\Delta w_0 \geq \widetilde{\Delta w}$. That is, IR_0 is implied by IC_0, and it is enough to have $\Delta w \geq \Delta w_0$. Feasibility then requires that $\Delta w_1 \geq \Delta w_0$ which can easily be seen to be equivalent to

$$- (1/2 + b - y_1) \alpha_1 + (1/2 + b + y_0) \alpha_0 \geq 0. \tag{63}$$

There are now four possible cases: it may be optimal that no, exactly one, or both incentive constraints are binding. We consider all cases in turn.

If no incentive constraint is binding, then $\Delta w_0 < \Delta w < \Delta w_1$. This cannot be optimal since in this case w_0 could be reduced slightly without changing the inequality, that is, without changing the truthtelling probabilites (which equal 1 in this case) and the resulting actions.

Suppose next that IC_0 is binding, and IC_1 holds with strict inequality, that is, $\Delta w_0 = \Delta w < \Delta w_1$ Then, by IND, $\sigma_{11} = 1$, and hence, by BayR and OPT, $y_0 = 0$. With this, P's objective becomes

$$V = -\gamma_0 \sigma_{00} \lambda \left[\alpha_0 \cdot 0 + (1 - \alpha_0) b^2 \right] \tag{64}$$

$$- \gamma_0 \sigma_{10} \lambda \left[\alpha_1 y_1^2 + (1 - \alpha_1) b^2 \right] \tag{65}$$

$$- \gamma_1 \lambda \left[\alpha_1 (y_1 - 1)^2 + (1 - \alpha_1) b^2 \right] \tag{66}$$

$$- \gamma_0 \sigma_{00} w_0 - \gamma_0 \sigma_{10} w_1 - \gamma_1 w_1. \tag{67}$$

Notice that the wage bill $-\gamma_0\sigma_{00}w_0 - \gamma_0\sigma_{10}w_1 - \gamma_1 w_1$ can be written as $-\gamma_0\sigma_{00}\Delta w - w_1$, where, by IR$_1$, $w_1 = \alpha_1 (y_1 - (1+b))^2$, and, by IC$_0$, $\Delta w = \Delta w_0 = \alpha_0 b^2 - \alpha_1 (y_1 - (1+b))^2$. Moreover, with $\sigma_{11} = 1$, BayR and OPT imply

$$\sigma_{10} = \frac{\gamma_1 (1 - y_1)}{\gamma_0 y_1}. \tag{68}$$

With this, P's problem is to choose α_0, α_1, and $y_1 \in [\gamma_1, 1]$ so as to maximize V evaluated at $w_1, \Delta w, \sigma_{10}$ subject to (63). Tedious but straightforward algebra yields that V evaluated at $w_1, \Delta w, \sigma_{10}$ can be written as

$$V = \alpha_0 (\lambda - 1) b^2 \left(1 - \frac{\gamma_1}{y_1}\right) \tag{69}$$

$$- \alpha_1 (\lambda - 1) b^2 \left(1 - \frac{\gamma_1}{y_1}\right) \tag{70}$$

$$+ y_1 \alpha_1 [(\lambda - 1) \gamma_1 + 2] \tag{71}$$

$$+ \alpha_1 \left(-\gamma_1 \lambda + \lambda b^2 + 2\gamma_1 b - 1 - 2b\right) - \lambda b^2. \tag{72}$$

Since all terms in the first line are positive, it follows that α_0 is optimally set to 1. Notice that this is consistent with (63), and that with $\alpha_0 = 1$ and $y_0 = 0$, (63) becomes redundant. It can then be easily seen that V is monotonically increasing in y_1. Thus, $y_1 = 1$ in the optimum. With this, V can be written as

$$V = \alpha_1 \left[\gamma_1 \lambda b^2 - \gamma_1 b^2 + \gamma_0 (2b - 1)\right] - \gamma_0 (\lambda - 1) b^2. \tag{73}$$

Hence, α_1 is optimally set to 1, if, and only if,

$$\lambda \geq 1 + \frac{\gamma_0}{\gamma_1} \frac{2b - 1}{b^2} = \widehat{\lambda}. \tag{74}$$

In this case, $V^{IR_1, IC_0}(1,1) = -b^2 - \gamma_0 (2b - 1)$. In the other case, $V^{IR_1, IC_0}(1,0) = -\gamma_0 \lambda b^2 - \gamma_1 b^2$.

Suppose next that IC$_1$ is binding, and IC$_0$ holds with strict inequality, that is, $\Delta w_0 < \Delta w = \Delta w_1$ Then, by IND, $\sigma_{00} = 1$, and hence, by BayR and OPT, $y_1 = 1$. With this,

P's objective becomes

$$V = -\gamma_0 \lambda \left[\alpha_0 y_0^2 + (1-\alpha_0) b^2\right] \tag{75}$$

$$- \gamma_1 \sigma_{01} \lambda \left[\alpha_1 (y_0 - 1)^2 + (1-\alpha_1) b^2\right] \tag{76}$$

$$- \gamma_1 \lambda \left[\alpha_1 \cdot 0 + (1-\alpha_1) b^2\right] \tag{77}$$

$$- \gamma_0 \sigma_{00} w_0 - \gamma_0 \sigma_{10} w_1 - \gamma_1 w_1. \tag{78}$$

With the same steps as in the previous paragraph it follows that V can be written as

$$V = \alpha_1 b^2 (\lambda - 1) \frac{\gamma_1 - y_0}{1 - y_0} \tag{79}$$

$$- \alpha_0 \left[2b + 1 + (\lambda - 1)\left(y_0 - \frac{1}{1-y_0} b^2\right)\right] \tag{80}$$

$$- \lambda b^2. \tag{81}$$

Notice that, by (63), $\alpha = (0,1)$ and $\alpha = (0,0)$ is not feasible. Further, it is easy to see that for the other cases V is increasing in y_0. Thus, $y_0 = 0$ in the optimum. V thus computes to $V^{IR_1,IC_1}(1,0) = -\gamma_0 \lambda b^2 - \gamma_1 b^2$, and $V^{IR_1,IC_1}(1,1) = -b^2 - \gamma_0 (2b+1)$. Hence, this is (weakly) dominated by V^{IR_1,IC_0}, and it cannot be optimal that IC_1 is binding and IC_0 holds with strict inequality.

Suppose finally, that both incentive constraints are binding, then $\Delta w_0 = \Delta w = \Delta w_1$, hence by (63)

$$-(1/2 + b - y_1)\alpha_1 + (1/2 + b + y_0)\alpha_0 = 0. \tag{82}$$

But since $b > 1/2$ and $y_1 \leq 1$, this equality can only hold for $\alpha_0 = \alpha_1 = 0$, or $\alpha_0 = \alpha_1 = 1$. Indeed, for $\alpha_0 = 0, \alpha_1 = 1$ the l.h.s. of (82) is equal to $-(1/2 + b - y_1) < 0$, and for $\alpha_0 = 1, \alpha_1 = 0$ the l.h.s. of (82) is equal to $(1/2 + b - y_0) > 0$. Now, for $\alpha_0 = \alpha_1 = 0$, we have unconditional delegation which, as seen above, is dominated by $V^{IR_0}(1,0)$, and thus cannot be optimal. For $\alpha_0 = \alpha_1 = 1$, 82 implies that $y_0 = y_1$. By OPT, it follows that $\mu_{10} = \mu_{11}$. Thus, by BayR,

$$\frac{\sigma_{01}\gamma_1}{\sigma_{01}\gamma_1 + \sigma_{00}\gamma_0} = \frac{\sigma_{11}\gamma_1}{\sigma_{11}\gamma_1 + \sigma_{10}\gamma_0}. \tag{83}$$

This is equivalent to $\sigma_{00} = 1 - \sigma_{11} = \sigma_{01}$. Hence

$$y_0 = \mu_{10} = \frac{\sigma_{01}\gamma_1}{\sigma_{01}\gamma_1 + \sigma_{00}\gamma_0} = \gamma_1. \tag{84}$$

Moreover, since $y_0 = y_1$, $\Delta w = 0$. And since IR_1 is binding, $w_1 = w_0 = (\gamma_1 - (1+b))^2$. Using this in P's objective yields

$$V^{IR_1,IC_0,IC_1}(1,1) = -\gamma_0\sigma_{00}\lambda\gamma_1^2 - \gamma_0\sigma_{10}\lambda\gamma_1^2 - \gamma_1\sigma_{01}\lambda(\gamma_1 - 1)^2 - \gamma_1\sigma_{11}\lambda(\gamma_1 - 1)^2 \tag{85}$$

$$- (\gamma_1 - (1+b))^2 \tag{86}$$

$$= -\gamma_0\lambda\gamma_1^2 - \gamma_1\lambda(\gamma_1 - 1)^2 - (\gamma_1 - (1+b))^2 \tag{87}$$

$$= -\gamma_0\gamma_1\lambda - \gamma_0^2 - 2b\gamma_0 - b^2. \tag{88}$$

Now, this is dominated by $V^{IR_1,IC_0}(1,1)$, and thus it cannot be optimal to have both incentive constraints binding.

In summary, we have shown that it is optimal that IR_1 and IC_0 are binding, and that IC_1 holds with strict inequality. In this case $\alpha = (1,1)$, if, and only if, $\lambda \geq \widehat{\lambda}$, and $\alpha = (1,0)$ otherwise. □

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