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Delegation and Information Revelation

by

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Delegation and information revelation*

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Abstract

This paper addresses the question of delegation in a partial contracting set-up, where only the control over actions is contractible. We consider an organization that should take two decisions, affected by a common state of the world parameter only known by the agent. We show that, if the principal gives up the control over the first decision, to the better informed agent, the decision of the agent signals his private information to the principal. The revelation of information, associated with delegation, is valuable for the principal if she retains control over the second decision. Hence, this paper provides a new rational for partial delegation: a transfer of control to the better informed party can be used by the supervisor to elicit the agent's private information. We establish this result by using the properties of signalling game. Finally, we show that, even if there are loss of control associated with delegation, the benefits of information revelation outweights these costs and delegation could dominate centralization of all decisions by the principal, even in the case where she uses messages from the agent to acquire information; because those messages could be noisy.

Keywords: Delegation, Asymmetric information, Transferable control action, Signalling game

JEL codes: D23,D82, L22

1 Introduction

In this paper, we address the question of delegation and revelation of information in a partial contracting set-up. We consider an organization composed of one agent and one principal.[1] The organization should take a sequence of two decisions affected by a common state of the world parameter. There is an initial asymmetry of information between the principal and the subordinate agent: the agent knows the state of the world parameter while the principal does not. Moreover, we assume that the agent and the principal have diverging interests: they do not agree on the optimal decisions that the organization should implement.

In a complete contract set-up, this problem would be solved by a revelation contract that specifies the actions that should be undertaken by the agent and the corresponding payment as a function of a revelation of the state of the world by the agent.[2] Nevertheless, in repeated relations, information revelation in the contract is not always feasible (ratchet effect).[3]

In our framework, we consider the case in which the decisions and the state of the world parameter cannot be contracted for, neither ex-ante nor ex-post. It corresponds to the standard assumption in incomplete contract models[4] of observable but non-verifiable decisions. However, control over actions can be contracted for.

In this setting, the only feasible contract is to decide who is in charge of each decision. At the beginning of the game, the principal allocates the "right" to take decision(s) either to herself or to the agent. This kind of contract is called "partial contracting" by Aghion Dewatripont and Rey (2001). It refers to a situation in which some actions are non-verifiable ex-post, therefore not contractible but the control over actions is contractible.

This paper studies, with these simple contracting forms, the possibilities of transferring information from the agent to the principal. There are two possible ways to transfer information. First, the agent could communicate part of his information to the principal and let the principal decides which decisions should be implemented. We call centralization this organizational form in which the principal retains control rights over decisions. Second, the principal could transfer control and delegate the choice of some decisions to the agent. As the agent is better informed, the decision(s) he takes depend on his superior knowledge. Then, by observing the agent´s decision, the principal might be able to acquire (part of) the agent's superior information. Of course, this information transfer is valuable for the principal only if she could use the information to take subsequent decisions. Hence, in this model delegation will only be partial: the principal gives up control over one decision to the agent and keeps control over the other. We will refer to

[1] We will refer as "she" for the principal and "he" for the agent.

[2] Baron and Myerson (1982).

[3] Laffont and Tirole (1988), Freixas *et al.* (1985).

[4] Grossman and Hart (1986), Hart and Moore (1988), Hart (1995) and Tirole (1999).

this second mechanism of partial transfer of control rights to the agent as delegation.

In organizations, the projects' choices could be left to the supervisor, who could rely on some information communicated by his subordinate or it could be partially delegated to the subordinate. The choice this latter made reflects his preferences for a particular kind of project but also the information he has.[5] From the observation of the project choice, the supervisor can infer information and uses it to take other decisions.

When decisions are centralized by the principal, before the principal implements decisions, the agent can transmit a message containing information about the state of the world. But the principal cannot commit to her future decisions. Then, the communication of the agent is only strategic. The agent wants to communicate not the true information, but the information that, when it is used by the principal to take decisions, fits the best to his interests. Communication under centralization is a cheap-talk game and we know from Crawford and Sobel (1982) that this kind of communication is noisy.

In our framework, in which the state of the world parameter could only take two values, either the messages truly reveal the state of the world to the principal or the messages contain no information at all. In the former case, the principal can implement her preferred decision while in the latter, centralized decisions are based on the principal's prior beliefs.

When the agent does not reveal his information in the cheap-talk game, the alternative to learn the agent's hidden information is to give him the power to decide. When the agent has right to decide, the decision he takes has an informational content. The decision of the agent signals the state of the world to the principal. After observing the agent's decision, the principal revises her prior beliefs about the state of the world and uses this new information to take subsequent decisions. Using an appropriate equilibrium refinement, Cho and Kreps (1987) intuitive criterion, we can show that delegated decisions completely reveal the state of the world to the principal. Therefore the principal can extract agent's information by giving up the control right over some decisions.[6] As the organization takes a sequence of decisions, the information learned by the principal can be used for the other decisions. It results that delegation is only partial, the principal never gives up control over all decisions. Our central result is to show that delegation is a mechanism to transfer information from the better informed party to the principal.

But this delegated mechanism is costly. When the principal gives up the right to decide to the agent, he does not implement the principal's preferred decision. Diverging interests between the parties creates loss of control when the principal delegates. The principal's lack of commitment implies that the agent cannot be punished for these loss

[5] Armstrong (1994) has a model of delegation in which the supervisor ignores both the state of the world and the agent's preferences.

[6] If the agent does not use his private information to take the decision, i.e. the decision he takes is independent of the value of the state of the world parameter, the principal is better off if she retains the control rights over decisions. Information revelation is a necessary condition to have delegation.

of control.

Delegation, despite the associated loss of control, can be the optimal organizational structure. For this, it needs that information is not revealed in a message game and that the loss of control are small relative to the benefits of transferring information.

The two mechanisms the principal can use to transfer information work and succeed differently. When the agent receives power, his decision always signals his private information to the principal while when the principal retains the power to decide, the message transmitted to the principal could contain no information at all.

To illustrate that, suppose that there are two states of the world L and H. In state H, the agent prefers an informed principal while in state L, the agent prefers a non-informed principal. In the message game under centralization, the agent in state L can mimic the behavior of the agent in state H and ensure that the principal remains non-informed. While under delegation, if in state L the agent wants to mimic the behavior of the agent in state H, he has to take the same decision. But this has an impact on the agent's utility. Keeping the principal non-informed is costly for the agent in state L. Moreover, the agent in state H could decrease the utility of agent in state L by taking a decision that the agent in state L dislike more. When it is too costly for the agent in state L to keep the principal ignorant, the agent takes a decision that reveal the state of the world parameter. The possibility, for the agent in state H to change the cost of keeping the principal non-informed make separation of type feasible. While in cheap talk games, by the virtue of being cheap, the agent cannot make this costly move to signal his information to the principal.

In the literature[7], the trade off between delegation[8] and centralization is often a simple trade off between loss of control associated with delegation and informational benefits when the delegated is better informed than his supervisor.

Benefits of a delegated structure could be a better communication (Melumad, Mookherjee and Reichelstein 1992), a better ability to prevent collusion (Laffont and Martimort 1998 and Felli 1996), an informed decision maker (Legros 1993, Dessein 2002) or increased incentives provided to the agent (Aghion and Tirole 1997).

This paper presents a new rational for delegation. Delegation to a better informed

[7] In the standard principal agent theory, following the revelation principle (Myerson, 1982), delegation is always weakly dominated by a grand contract between the principal and all the agents. To speak about delegation in a principal agent setting, one needs to relax some assumption of the revelation principle. Melumad, Mookherjee and Reichelstein (1992) relax the assumption of perfect communication between the principal and the agent, Felli (1996) relaxes the assumption of infinitely costly communication between agents, in order to allow collusion. Laffont and Martimort (1998) assume that communication between the principal and the agents is imperfect and that side contracting between agents is feasible. Aghion and Tirole (1997) and this paper assume that the contracts are incomplete.

[8] Delegation refers to a situation in which the subordinates has some discretion in the choice of his action. In the complete contract setting, even if the agent is in charge of a given decision, he has no discretion, as everything is specified in the contract.

subordinate agent increase the information of the supervisor. When revelation contract cannot be used, delegation is an alternative to extract information from the agent. But opposed to the complete contract framework in which the principal can control the rents she gives up to the agent, there are loss of control in this delegated mechanism as soon as the principal gives power to the agent. Nevertheless, delegation is useful to reduce the initial asymmetry of information between the principal and the agent when communication is not successful.

There are several other papers related to this work. Aghion and Tirole (1997), study the rational for delegation in an incomplete contract setting where the asymmetry of information between the principal and the agent is endogenous. They show that giving authority to the subordinate increases his incentive to be informed, which in turn increases his effective control over decisions (sometimes at the expense of the principal). Aghion Dewatripont and Rey (2001) shows that giving up control over some non contractible decisions enhances the incentives to cooperate in the future of both parties. With shared-control contract, none of the party is able to implement his preferred actions at all stages and cooperation may be the efficient action.

The framework and the ideas of this model are similar to Dessein (2002). In a similar setup in which decisions and state of the world cannot be contracted upon, he compares delegation to a better informed agent with communication (cheap talk).[9] The difference with these papers is that we consider delegation as a mechanism to transfer information to the principal.

In Riordan and Sappington (1987) and Legros (1993), the principal acquires information by observing the action of a better informed delegate. Then, the principal decides, given her knowledge, how performs the second task. When performing the first task, the agent decides the amount of information he transfers to the principal. In these two papers, information revelation is partial as the principal could allocate the second task to the same agent. Hence an agent has no incentive to reveal too much information. In our model, it is not possible to have such an implicit contract in which the agent is rewarded (the agent receives control in period two) or punished (no control in period two).

The paper is organized as follow: the model is presented in section 2. The decisions under delegation and centralization are described in sections 3 and 4. Section 5 compares the two organizational structures and section 6 concludes. The appendices contain complementary material and proofs of propositions.

[9] See also de Garidel-Thoron and Ottaviani (2000).

2 Model

We model an organization composed of one principal and one agent. This organization chooses two projects (d_1 and d_2) at time $t = 1$ and $t = 2$. We call respectively d_1 and d_2 the first and second period decisions. These decisions affect the welfare of both organization's members. The utility of the principal and the agent are also affected by a common environmental parameter θ. This parameter is constant over periods.[10,11]

Environmental parameter We assume that the agent knows the "state of the world". This environmental parameter affects the utility of both the principal and the agent. The state of the world is drawn out of a set Θ from a common knowledge distribution $F(\theta)$. For simplicity, we assume that $\Theta = \{\theta_L, \theta_H\}$, with $\theta_L < \theta_H$ and we call $\Delta\theta = \theta_H - \theta_L$. The probability that θ equals θ_L is denoted v_L, the probability of $\theta = \theta_H$ equals $v_H = 1 - v_L$.

Decisions The decision represents the choice of a project implemented by the organization. The project is one dimensional. We suppose that there is a continuum of possible decisions given by $]0, +\infty[$.

Allocation of decision rights We assume that the decisions can be observed by both parties but can not be contracted for. In the terminology of Tirole (1999) it means that the decisions are observable but not verifiable. The only contracting variable is, then, the allocation of decision rights over d_1 and d_2. These decision rights are allocated by the principal at the beginning of the first period either to herself (centralization) or delegated to the agent.[12]

These contractual restrictions are consistent with the incomplete contract view of organizations. Giving authority to a subordinate agent is giving the right to select a decision from an allowed set (see Simon 1958, Grossman and Hart 1986, Hart and Moore 1988, Aghion and Tirole 1997).

There are four possible allocations of decisions right. Either the principal keeps control over both decisions, or she delegates both decisions, or the control rights are split between

[10] This is a simplification. We can alternatively assume that the state of the world changes over periods and that there is some correlation between the state of the world in the two periods. In this case, the results of the paper remains qualitatively the same. The important assumption is that the observation of the first decision (under delegation) improves the information about the state of the world in the second period.

[11] This is a common assumption in dynamic models of incentive contracts. For example Laffont and Tirole (1988).

[12] The fact that the principal initially possess decision rights over both decisions can be justified by ownership of physical assets that confers the right to decide about their use (Grossman and Hart 1986) or by institutional agreement, as it is the case in political decisions (Aghion and Tirole 1997).

the principal and the agent (d_1 or d_2 is delegated). We call *delegation* the case in which the better informed agent receives control over d_1 (but not d_2).

Timing of events The timing of events is as follow:

- The principal allocates decision rights.
- The agent observes the state of the world.
- The first decision d_1 is taken (and observed).
- The second decision d_2 is taken.
- Payoffs are realized and collected.

Message Game When the agent has observed the state of the world, he could transmit information through a message to the principal. The message may change the prior's beliefs of the principal and therefore affects the decisions she implements.[13] In our framework, the agent could send a message before each decision taken by the principal.

Preferences The principal and the agent derive private benefits from each project. We suppose that they have a preferred project d_t and their utility is a quadratic function of the distance between their preferred project and the actual project implemented within the organization[14]. More specifically, we will assume that the utility associated with each project d_t; $t = 1, 2$ is $U_t^A(d_t, \theta) = \alpha_t d_t - \frac{(\theta - d_t)^2}{2}$ for the agent and $U_t^P(d_t, \theta) = \beta_t d_t - \frac{(\theta - d_t)^2}{2}$ for the principal. In this case, the preferred project of the agent is $d_t = \max_{d_t} U_t^A = \alpha_t + \theta$ and the preferred project of the principal is $d_t = \max_{d_t} U_t^P = \beta_t + \theta$.

The distance between α_t and β_t is a measure of how the interests of the agent and the principal diverge over project d_t. The greater is $|\alpha_t - \beta_t|$, the greater is the distance between the agent and the principal preferred project.

The preferred project of the agent and the principal depends also on the state of the world θ. A change in the environment (θ) changes by the same amount the ideal point of both the principal and the agent. So the interest of the two members are not completely divergent.

We do not assume that both projects affect the utility in the same way: α_1 and α_2 do not need to be the same (idem for β_1 and β_2).

[13] It makes no difference whether messages are be verifiable or not, as we do not consider that the case in which the allocation of control right could be contingent on messages.

[14] A similar utility function is used in Crawford and Sobel (1982) and Dessein (2002).

To sum up, the utility of the agent is:

$$U^A(d_1, d_2, \theta) = U_1^A(d_1, \theta) + U_2^A(d_2, \theta) = \alpha_1 d_1 - \frac{(\theta - d_1)^2}{2} + \alpha_2 d_2 - \frac{(\theta - d_2)^2}{2}.$$

and the utility of the principal is:

$$U^P(d_1, d_2, \theta) = U_1^P(d_1, \theta) + U_2^P(d_2, \theta) = \beta_1 d_1 - \frac{(\theta - d_1)^2}{2} + \beta_2 d_2 - \frac{(\theta - d_2)^2}{2}.$$

These utility functions satisfy the single crossing property.

Agent's participation: individual rationality After learning θ and the allocation of decision rights, the agent has the possibility of quitting the organization. We assume that the agent has an outside opportunity that gives him a utility level normalized to zero. The agent is necessary in the organization. If he refuses to participate, the organization shuts down and both the principal and the agent get a zero payoff. A simple way to force the participation of the agent when d_1 and d_2 are such that $U^A(d_1, d_2, \theta) < 0$ is to pay to the agent an unconditional wage W such that: $U^A(d_1, d_2, \theta) + W = 0$. For the remaining of the paper we assume that the private benefits associated with decisions are large enough and we ignore participation constraints.

3 Delegation

This section describes the decisions taken by the agent and the principal when d_1 is delegated. Under delegation, the principal observes the agent's decision before choosing d_2. As the agent is better informed, his decision d_1 may have an informational content. Therefore, the principal should revise her prior beliefs about θ before taking the second decision and the agent should take into account that his decision contains information that will be used by the principal (sometimes at his disadvantage).

The decision of the agent signals the state of the world to the principal. The equilibrium concept used in signaling games is the Bayesian-Nash equilibrium (BNE).

Definition 1 *A Bayesian-Nash equilibrium is a strategy profile for each player*

$$d_1^*(.) \in BR(d_2^*) \equiv \underset{d_1}{\operatorname{argmax}}\, U_1^A(d_1, \theta) + U_2^A(d_2^*, \theta)$$

$$d_2^*(.) \in BR(d_1^*, \Theta) \equiv \underset{d_2}{\operatorname{argmax}} \sum_{i=1}^{2} \mu^*(\theta_i | d_1^*) U_2^P(d_2, \theta_i)$$

and posterior beliefs $\mu^*(\theta_i | d_1^*)$ consistent with the Bayes rule.

This kind of game usually has multiple equilibria. We use the intuitive criterion (Cho-Kreps 1987) to select among all the possible equilibria.

Definition 2 *Define* $U^{A^*}(\theta) = U^A(d_1^*, d_2^*, \theta)$ *the equilibrium payoff of the agent in state* θ*. A BNE fails the intuitive criterion if in state* θ_i*,* $\forall\, d_1$

$$U^{A^*}(\theta_i) > \max_{d_2 \in BR(d_1, \Theta)} U^A(d_1, d_2, \theta_i) \tag{1}$$

And in state θ_j*, there is some* d_1 *such that*

$$U^{A^*}(\theta_j) < \operatorname*{Min}_{d_2 \in BR(d_1, \Theta \backslash \theta_i)} U^A(d_1, d_2, \theta_j) \tag{2}$$

A BNE fails the intuitive criterion if the equilibrium payoff of the agent in one state of the world (θ_i) is greater with the equilibrium strategy d_1^* than with any other strategy (condition (1)). And it exists a d_1 such that the equilibrium payoffs in the other state of the world (θ_j) are smaller than those with the strategy d_1 once the principal is convicted that d_1 could not have been chosen by the agent in state θ_i (condition (2)).

In the remaining of this section, we describe the outcome of the signalling game played by the principal and the agent when the principal delegates d_1. The difficulty of this task comes from the fact the game is a non standard one and incentive constraints can go in both directions. We start by describing the separating equilibria, after we analyze the pooling equilibria. For convenience, part of the analysis has been relegated to an appendix. Results are summarized in proposition 1.

Separating equilibria If the equilibrium is separating, the principal 'knows' θ by observing $d_1^*(.)$. And hence, she selects her preferred project $d_2^*(\theta)$:

$$d_2^*(\theta) = \beta_2 + \theta. \tag{3}$$

Under delegation, if the agent's decision signals θ to the principal, she is able to implement her preferred project $d_2 = \beta_2 + \theta$.

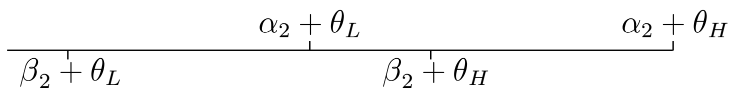
To construct the set of separating equilibria, we have first to identify in which state of the world, the agent has an incentive to lie. The agent has an incentive to lie in state θ_i if the second decision $d_2^*(\theta_j)$ gives a higher utility than $d_2^*(\theta_i)$, $j \neq i$:

$$U_2^A(d_2^*(\theta_j), \theta_i) \geq U_2^A(d_2^*(\theta_i), \theta_i). \tag{4}$$

Three different cases should be distinguished. In the first case (S1), the agent has an incentive to lie in state θ_L. In case (S2), the agent has an incentive to lie in state θ_H and in the last case (S3), no agent has an incentive to misrepresent his type.[15]

[15] The single crossing property of the utility function rules out the case in which the agent has an incentive to lie in both states of nature.

Consider the case S1. Equation (4) is satisfied in state $\theta_i = \theta_L$, if $\alpha_2 - \beta_2 \geq \frac{\Delta\theta}{2}$. This simply means that the distance between the agent's preferred project in state θ_L ($= \alpha_2 + \theta_L$) and the project implemented by the principal in state θ_L ($=\beta_2 + \theta_L$) is greater than the distance between the agent's preferred project and the project implemented by the principal in state θ_H ($=\beta_2 + \theta_H$). As the utility is a quadratic function of the distance between the preferred project and the actual project, it means that the agent has an incentive to lie in state θ_L. The single crossing property implies that if equation (4) is satisfied for $\theta_i = \theta_L$, it is not satisfied for $\theta_i = \theta_H$. The case S1 is illustrated by the following picture:



The benefits for the agent in state θ_L of misrepresenting his type are:

$$U_2^A(d_2^*(\theta_H), \theta_L) - U_2^A(d_2^*(\theta_L), \theta_L) > 0. \tag{5}$$

In case S1, given that the agent has an incentive to lie in state θ_L, the separating equilibrium will be supported by pessimistic beliefs: $\mu(\theta_L | d_1) = 1, \forall\ d_1 \neq d_1^*(\theta_H)$ and $\mu(\theta_L | d_1^*(\theta_H)) = 0$.

In addition, the following incentive constraint should be satisfied:

$$U_1^A(d_1(\theta_H), \theta_L) - U_1^A(d_1(\theta_L), \theta_L) \geq U_2^A(d_2^*(\theta_H), \theta_L) - U_2^A(d_2^*(\theta_H), \theta_L). \tag{6}$$

This constraint states that the costs, for agent in state θ_L, of mimicking the behavior of the agent in state θ_H should be greater than the benefits of lying. Benefits are given by (5). There are costs of lying for the agent in state θ_L has he should select a decision which is not is preferred one and hence, the utility $U_1^A(d_1, \theta_L)$ is smaller. The costs of lying are given by the right-hand-side of equation (6).

Then, given the beliefs supporting the separating equilibrium, the agent selects his preferred project in state θ_L and the set of separating equilibria is:

$$d_1^*(\theta_L) \quad = \quad \alpha_1 + \theta_L. \tag{7}$$

$$d_1^*(\theta_H) \quad \in \quad D \equiv \{d_2(\theta_H) \,|\, (6)\,\text{is satisfied}\}. \tag{8}$$

Now we us the intuitive criterion to select one equilibrium in D. Consider a deviation by θ_H from $d_1^*(\theta_H)$ to $d_1 \in D$. By definition of the set D, such a deviation can benefit the agent only in state θ_H. Therefore, the intuitive criterion imposes that the beliefs associated with $d_1 \in D$ should be updated to $\mu(\theta_L | d_1 \in D) = 0$.

Hence, a rational agent θ_H will select his preferred decision within D. The only equilibrium surviving the intuitive criterion is: $d_1^*(\theta_H) = \alpha_1 + \theta_H$ if $\alpha_2 - \beta_2 \leq \Delta\theta$ and

$d_1^*(\theta_H) = \alpha_1 + \theta_L + \sqrt{K_1} = \alpha_1 + \theta_H + (\sqrt{K_1} - \Delta\theta)$ otherwise. Where $K_1 = (2\alpha_2 - 2\beta_2 - \Delta\theta)\Delta\theta$. In the first case, $\alpha_1 + \theta_H \in D$, in the second case, $d_1^*(\theta_H)$ is the decision closest to $\alpha_1 + \theta_H$ within D.

The cases S2 and S3 are similar and treated in appendix A.1.

Pooling equilibria Before going to the issue of pooling equilibria, it is important to note that in the absence of information transfer from the agent to the principal, the rational for delegation disappears and the principal is better off if she takes herself both decisions.

By applying the intuitive criterion, we can suppress all the pooling equilibria. Therefore, we establish that there is an information transfer under delegation and this organizational structure should be considered.

If the agent plays a pooling equilibrium, the principal does not learn any information by observing d_1^* and her second decision corresponds to the decision of an non-informed principal:

$$d_2^* = \max_{d_2} EU^P = \beta_2 + E\theta. \tag{9}$$

Where $E\theta = v_L\theta_L + v_H\theta_H$.

As in the case of separating equilibria, we have to identify in which state, the agent has no incentives to reveal information. The agent prefers an uninformed principal in state θ_i if:

$$U_2^A(d_2^* = \beta_2 + E\theta, \theta_i) \geq U_2^A(d_2(\theta_i) = \beta_2 + \theta_i, \theta_i). \tag{10}$$

Again, there are three different cases, P1, where the agent prefers an uninformed principal in state θ_L, P2, where the agent prefers an uninformed principal in state θ_H and P3 in which the agent always prefers an informed principal. Identifying the state of nature in which the agent that has no interest to transfer information is important to define the out-of-equilibrium beliefs that support the pooling equilibrium.

Consider the case P1. The agent prefers an uninformed principal in state θ_L when the distance between $\alpha_2 + \theta_L$ and $\beta_2 + E\theta$ is smaller than the distance between $\alpha_2 + \theta_L$ and $\beta_2 + \theta_L$. This condition is met when (i) $\alpha_2 + \theta_L \geq \beta_2 + E\theta \geq \beta_2 + \theta_L$ or when (ii) $\alpha_2 + \theta_L \leq \beta_2 + E\theta$ and $\alpha_2 - \beta_2 \geq \frac{v_H\Delta\theta}{2}$. The following picture illustrates the case (ii).

Conditions (i) or (ii) could be satisfied only if $\alpha_2 > \beta_2$. But then $\alpha_2 + \theta_H > \beta_2 + \theta_H > \beta_2 + E\theta$ and the agent prefers an informed principal in state θ_H. Again, this comes from the single crossing property.

To support the pooling equilibrium, the out-of-equilibrium beliefs should be $\mu(\theta_L|d_1 \neq d_1^*) = 1$.

We can now define the set of pooling equilibria as the set of d_1^* such that the equilibrium payoffs for the agent in both states are greater than the payoffs the agent could have if he deviates from the equilibrium. The only deviations we have to consider are deviations to the agent's preferred project $d_1 = \alpha_1 + \theta$.

The set of pooling equilibria is the set of d_1^* such that:

$$U^A(d_1^*, d_2^*, \theta_L) \geq U^A(d_1 = \alpha_1 + \theta_L, d_2 = \beta_2 + \theta_L, \theta_L). \tag{11}$$

$$U^A(d_1^*, d_2^*, \theta_H) \geq U^A(d_1 = \alpha_1 + \theta_H, d_2 = \beta_2 + \theta_L, \theta_H). \tag{12}$$

Now we apply the intuitive criterion to suppress all the pooling equilibria.

Lemma 1 *$\forall\, d_1^*$, $\exists\, \tilde{d}_1$ such that:*
(i) θ_L prefers the pooling equilibrium d_1^* to $\tilde{d}_1$, whatever the beliefs associated with $\tilde{d}_1$.
(ii) θ_H prefers $\tilde{d}_1$ to the pooling equilibrium if the principal is convicted that $\mu(\theta_L|\tilde{d}_1) = 0$.

The proof of this lemma is relegated to appendix B.1.

Then, if θ_L will never deviate to $\tilde{d}_1$, the beliefs associated with $\tilde{d}_1$ should be (according to the intuitive criterion): $\mu(\theta_L|\tilde{d}_1) = 0$. But with these updated beliefs, the agent θ_H prefers to quit the pooling equilibrium (part (ii) of the lemma). Hence, the initial equilibrium d_1^* does not survive the intuitive criterion.

Cases P2 and P3 are identical to P1 and relegated to appendix A.2.

We can now establish that under delegation, the decision of the agent signals his private information to the principal.

Proposition 1 *Under delegation, the only equilibrium that survives the intuitive criterion is the least costly separating (LCS) equilibrium*[16]*.*

The LCS equilibrium is:

$$d_2(\theta) = \beta_2 + \theta. \tag{13}$$

If $\Delta\theta \geq |\alpha_2 - \beta_2|$

$$d_1(\theta) = \alpha_1 + \theta. \tag{14}$$

If $\alpha_2 - \beta_2 \geq \Delta\theta$

$$d_1(\theta_L) = \alpha_1 + \theta_L. \tag{15}$$

$$d_1(\theta_H) = \alpha_1 + \theta_H + (\sqrt{K_1} - \Delta\theta). \tag{16}$$

[16] This equilibrium is often referred to the Riley (1979) outcome.

Where $K_1 = (2\alpha_2 - 2\beta_2 - \Delta\theta)\Delta\theta$.

If $\beta_2 - \alpha_2 \geq \Delta\theta$

$$d_1(\theta_L) = \alpha_1 + \theta_L - (\sqrt{K_2} - \Delta\theta). \quad (17)$$

$$d_1(\theta_H) = \alpha_1 + \theta_H. \quad (18)$$

Where $K_2 = (2\beta_2 - 2\alpha_2 - \Delta\theta)\Delta\theta$.

In the remaining of the paper we will call the first case 'free lunch' signal and the others 'costly signaling' cases.

This first proposition is the central result of the paper. It establishes that using the properties of signalling games, delegation is going together with a transfer of information from the agent to the principal. When the contracts are incomplete, the principal can still extract information from the agent by delegating. Observing delegated decision is enough for the principal to learn agent's hidden information. When the principal allocates decision rights to the agent, he reveals his information through decisions. Proposition 1 establishes that delegating d_1 suppress the asymmetric information between the principal and the agent.

Given that the only surviving equilibrium is a separating equilibrium, in the case of delegation the principal does not need to rely on messages to become informed. Hence, cheap talk game will be used only in the case of centralization which is developed in the next section.

4 Centralization

We have established, in proposition 1, that the agent transfers information when the principal delegates the first decision. But, for the principal, the drawback of delegation is a loss of control, as the agent doesn't implement her preferred project d_1.

To avoid these loss of control the principal could centralize all the decisions. In a centralized mechanism, the principal can still acquire information by asking to the agent to communicate it. Given that the decisions and the state of the world cannot be contracted for, the principal cannot reward or punish the agent if he does not transmit the true information. Hence under centralization, communication is a cheap talk game.

The agent could have different incentives to transmit information at different periods of time. Therefore, to maximize the information transfer, the principal could require that the agent transmits his private information twice, before she takes the first decision and, eventually, before she takes the second one. Obviously, if the agent transfers the information at $t = 1$, the second message game is useless.

In these message games, the agent send a message to the principal, who revises her beliefs about θ before taking a decision. The update of beliefs is done according to the Bayes rule. We represents the principal's knowledge of the state of the world by posterior beliefs η_L and η_H. Given that the agent's private information could take only two values, we consider message games in which the set of possible message has two elements (m_L, m_H).

In the centralized mechanism, the principal maximizes her utility given knowledge. At time t, the principal's utility is maximized for:

$$d_t^* = \max_{d_t} EU^P = \beta_t + \eta_L \theta_L + \eta_H \theta_H \tag{19}$$

Before each decision taken by the principal (according to (19)), the agent decides which message he sends to the principal.

For expositional simplicity, we first consider a one period game in which the agent sends first a message, and second, the principal selects a decision. In this non repeated game, to describe the equilibrium, we need to identify the state of the world in which the agent prefers to keep the principal ignorant.

Given the principal's prior beliefs v_L and v_H, the agent prefers a completely informed principal in state θ if:

$$EU_t^A(d_t = \beta_t + \theta, \theta) \geq EU_t^A(d_t^* = \beta_t + v_L \theta_L + v_H \theta_H, \theta). \tag{20}$$

Condition (20) is not satisfied in state θ_L if:

$$\alpha_t - \beta_t \geq \frac{v_H \Delta\theta}{2} \tag{21}$$

The single crossing property implies that if the agent prefers a non informed principal in state θ_L, the agent prefers an informed principal in the other state θ_H i.e. if condition (20) is not satisfied for $\theta = \theta_L$, it is necessarily true for $\theta = \theta_H$.

Conversely, condition (20) is not satisfied in state θ_H if:

$$\beta_t - \alpha_t \geq \frac{v_L \Delta\theta}{2} \tag{22}$$

Again in this case, the single crossing property implies that in this case,condition (20) is true for $\theta = \theta_L$.

Last, when (21) and (22) are not true, the agent prefers an informed principal in both states of the world.

We have identified the incentives for the agent to reveal information in a one period game. The equilibrium of this game is described in the next lemma.

Lemma 2 *In a one period game, no information is reveled if condition (21) or (22) holds, and all the information is revealed otherwise.*

Proof of lemma 2 is relegated to appendix B.2.

Lemma 2 is simple to understand: in a one period message game, if in one state the agent prefers to keep the principal non-informed, in that state, the agent mimics the behavior he has in the other state; hence keeping the principal ignorant. When (21) or (22) holds, in one state of the world the dominant strategy of the agent is to mimic the message sends in the other state, hence the principal cannot acquire information in the message game. It is only when in both states the agent wants to have an informed principal that truthful communication takes place. In a message game, keeping the principal ignorant is costless for the agent that prefers a non-informed principal. It just requires to send the same message than in the other state.

Lemma 2 has the following implications:

1. If for $t = 1, 2$ condition (21) holds, there is no information transfer neither at $t = 1$ nor at $t = 2$. In this case, the agent in state θ_L has a dominant strategy of no communication at $t = 1$ and at $t = 2$.

2. With a similar argument, if for $t = 1, 2$ condition (22) holds, there is no information transfer neither at $t = 1$ nor at $t = 2$.

3. If for $t = 1, 2$, (21) and (22) do not hold, there is a complete information transfer at $t = 1$. Again, the agent has a dominant strategy of telling the truth at $t = 1$.

4. If for $t = 1$ either (21) or (22) holds, and for $t = 2$, (21) and (22) do not hold, there is no information transfer at $t = 1$ and a complete information transfer at $t = 2$.

To complete our description of the equilibria in the message games, we need to consider the last two possibilities: first the cases in which the agent wants to disclose information at $t = 1$ (conditions (21) and (22) do not hold for $t = 1$) but at $t = 2$, in state θ_i, the agent does not want to disclose information ((21) or (22) holds for $t = 2$). Second, the cases in which the agent prefers not to disclose information at $t = 1$, in state θ_i, while at $t = 2$, in the other state θ_j, $j \neq i$, the agent prefers a non-informed principal.

Consider the first cases: suppose that (21) holds for $t = 2$; hence in state θ_L the agent prefers an informed principal only in the first period. But it is not possible to cancel the information transmitted in first period, and therefore the message game in period one will be informative only if the agent in state θ_L prefers an informed principal in both periods to an non-informed principal in both periods (we know from lemma 2 that if information is not disclosed at $t = 1$, it will not be disclosed at $t = 2$). The agent in state θ_L prefers an informed principal in both periods if for $\theta = \theta_L$:

$$U_1^A(d_1 = \beta_1 + \theta, \theta) + U_2^A(d_2 = \beta_2 + \theta, \theta) \geq U_1^A(d_1 = \beta_1 + E\theta, \theta) + U_2^A(d_2 = \beta_2 + E\theta, \theta) \quad (23)$$

$$\Leftrightarrow \alpha_1 + \alpha_2 - \beta_1 - \beta_2 \leq v_L \Delta\theta \tag{24}$$

If (24) holds, there is information transfer at $t = 1$ and no information transfer at all if it does not hold.

Similarly, if (22) holds for $t = 2$ while neither (21) or (22) holds for $t = 1$, there is information transfer at $t = 1$ if (23) is satisfied for $\theta = \theta_H$ or equivalently if:

$$\beta_1 + \beta_2 - \alpha_1 - \alpha_2 \leq v_H \Delta\theta \tag{25}$$

Consider the last cases in which (i) (21) holds for $t = 1$ and (22) for $t = 2$ or (ii) (22) holds for $t = 1$ and (21) for $t = 2$. In this case, there will be information revelation in period one if the agent in both states prefers an informed principal for the two periods to a non informed principal for the two periods. This statement is true if (24) and (25) hold. And this terminates our description of the equilibria in the message game. Proposition 2 summarizes the results:

Proposition 2 *Under centralization, the message game equilibrium has one of the following characteristic:*

1. *The agent transmits is private information in the first period.*
2. *The agent delays the information transfer to period two.*
3. *The agent does not transmit any information.*

The following table summarizes what differentiate these three cases:

$t = 2 \backslash\, t = 1$	(21) holds	(22) holds	(21) and (22) do not hold
(21) holds	Never	If (24) and (25) hold	If (24) holds
(22) holds	If (24) and (25) hold	Never	If (25) holds
(21) and (22) do not hold	Only in period 2	Only in period 2	Always

Table 1: When the principal becomes informed with message game.

Compared to the case of delegation, under centralization the principal will not become informed in all the circumstances. Using costless communication from the agent is not sufficient to guarantee that the principal learns the state of the world. The difference is that communication is cheap, sending a message costs nothing to the agent. Hence, in the state in which the agent prefers the informed principal, he has no possibility of opposing the dominant strategy of no communication the agent has in the other state. While with delegation, if in one state the agent prefers to keep the principal non informed, it is costly for the agent: he should mimic the decision of the agent in the other state, which costs in term of utility.

When the message games produce valuable information for the principal, it certainly dominates delegation, because the principal implements her preferred projects. If communication is not informative, it does not mean that delegation is optimal. The principal trades-off the loss of control with the cost of remaining uninformed. The optimal organizational structure is the object of the next section. Before going to this point, the following interesting case should be mentioned.

Corollary 1 *When $\alpha_1 = \alpha = \alpha_2$ and $\beta_1 = \beta = \beta_2$, if $\alpha - \beta \geq \frac{v_H \Delta\theta}{2}$ or if $\beta - \alpha \geq \frac{v_L \Delta\theta}{2}$, there is no information revelation in the message games. Otherwise, the agent transmits the true state of the world to the principal before the choice of d_1.*

When preferences over the two decisions are identical, the message game has a simple equilibrium which is identical to the one period message game. Either all the information is transmitted at $t = 1$ or no information is transmitted.

5 Comparisons

The goal of this section is to determine if (and when) delegation is efficient within an organization.

Delegation is associated to loss of control and information transfer, while there are no loss of control under centralization but information could not be revealed or revealed with a delay.

If through the message game the Principal can extract agent's information[17] in the first period, centralization clearly dominates delegation. In that case, the principal keeps the control over all the actions and implements her preferred decisions.

To have delegation, it needs that, through communication, the principal can not extract the agent's information or only in second period.

Let us first compare delegation with centralization with informative messages at time 2 only. For expositional simplicity, we suppose that under delegation, signals are free i.e. taking his preferred decision is sufficient to signal the information to the principal. This corresponds to the condition $|\alpha_2 - \beta_2| \leq \Delta\theta$.

Lemma 3 *Delegation is preferred to centralization, with revelation of the information in $t = 2$, if*

$$(\alpha_1 - \beta_1)^2 \leq v_L v_H \Delta\theta^2 \tag{26}$$

[17] See table 1 for the particular conditions to have information transfer in period one.

If through centralization, the principal learns the agent's private information in $t = 2$, the principal decision is the same at $t = 2$, in both centralization and delegation. Hence, loss and gains associated to delegation come exclusively from the first decision.

Equation (26) could be interpreted as follow, the left hand side represents the loss of control, the right hand side, the benefit of information. The left hand side is, indeed, the difference between the utility of the principal when he implements her preferred decisions and the utility of the principal under delegation. Given that in both cases, the preferred project is implemented at time 2, it only depends on the divergence of preferences for d_1. $(\alpha_1 - \beta_1)^2$ measures how much it costs to give control to the agent under complete information.

The right hand side represents the benefits associated with an informed decider. It measures the extra utility of having a decider informed at time t. Again, if we take the difference between the utility of the principal, when under centralization, she receives the informative message at $t = 1$ and when she receives the message at $t = 2$, we found that the difference equals $v_L v_H \Delta\theta^2$. Hence, it could be interpreted as the benefits of being informed at time t. The right hand side measures the benefits of delegating to a better informed agent, abstracting from loss of control.

Next, we compare delegation with centralization without transfer of information:

Lemma 4 *Delegation is preferred to uninformed centralization if*

$$(\alpha_1 - \beta_1)^2 \leq 2 v_L v_H \Delta\theta^2 \tag{27}$$

When the principal remains non-informed under centralization, the costs associated with delegation are the same, but the benefits are double. In this case, delegation is valuable because the decider is informed in period one, like in the previous case, but also because information is transmitted to the principal and therefore, she can implement her preferred project at time 2, which is not possible under centralization when no message is transmitted.

If, to signal his information, the agent does not selects his preferred decision $\alpha_1 + \theta$ when he has control over decision 1, there is an extra loss of control that could be positive or negative. It is positive when the principal prefers larger (resp. lower) decisions than the agent and the agent decreases (resp. increases) his decision to signal the state of the world. Otherwise, the loss of control are reduced compare to the case $|\alpha_2 - \beta_2| \leq \Delta\theta$.

We have defined the conditions under which delegation dominates centralization, if the information is not or partially transmitted in the message game. Last, we show that there is a parameter space in which (i) the information is not revealed in the message game and (ii) delegation is optimal.

We start by a simple case (proposition 3), and generalize the results afterward in proposition 4.

Proposition 3 *When $\alpha_1 = \alpha = \alpha_2$, $\beta_1 = \beta = \beta_2$, the optimal organization structure is delegation if $\frac{(\alpha-\beta)^2}{2v_L v_H} \leq \Delta\theta^2 \leq 4\frac{(\alpha-\beta)^2}{v_K}$ (where $v_K = v_H$ if $\alpha > \beta$ and $v_K = v_L$ if $\beta > \alpha$).*

Otherwise, centralization is efficient..

Proof: in Appendix B.3

Proposition 3 establishes that, when the preferences over the two decisions are identical, delegation can be the optimal organizational structure. Delegation dominates when $\Delta\theta$ is not sufficiently large to have revelation of information in the message game but sufficiently large to have the benefits of information larger than the loss of control.

Proposition 4 *For all possible preferences $\alpha_1, \alpha_2, \beta_1, \beta_2$, it exists a structure of the agent's private information v_L, v_H, θ_L and θ_H, such that delegation is optimal.*

Proof: in Appendix B.4

In proposition 1, we have shown that delegation is a tool to transfer information from the agent. Proposition 4 shows that there are circumstances in which communication fails and the principal optimally transfers the control over the first decision to the agent. This result means that when the agent does not communicate, the loss of control associated with delegation can be smaller than the benefits of information. In technical terms, it means that the conditions to have delegation are less strong than the conditions to have communication.

In this model, the main reason for a transfer of control is not the fact that the agent is better informed but the fact that the information will be transmitted if the agent has control. Proposition 3 and 4 explain why different organizations with different structure of the agent's private information will organize differently and also succeed differently; some could manage to acquire information at no cost, some should delegate and support loss of control to acquire information and some prefers to stay non-informed.

To be complete, we mention the two other possible allocations of decision rights: the complete delegation of d_1 and d_2 and the delegation of d_2 only. These cases have in common that there is no problem of information transmission from the agent to the principal.[18] We show in appendix C that complete delegation is never optimal, while delegation of d_2 is efficient only in very particular circumstances, when there is a large divergence of interests for the first decision and a small one for the second.

6 Conclusion

In our framework, the principal has two conflicting objectives: she has to acquire the agent's private information to improve the decisions and she should retain control over

[18] These two cases are equivalent to a one period model à la Dessein (2002), where information transfers play no role.

decisions to avoid loss of control. A partial transfer of control to the agent could partially meet both objectives: she keeps some control over the actions taken by the organization and she becomes informed. However, the delegated mechanism is costly, the agent should receive power to reveal his information and the principal then suffers a loss of control. There is a trade-off between giving up power and learning information.

In this paper, we provided a new rational for delegation: in repeated interaction, transferring control to the agent implies a transfer of information from the agent to the principal. Hence, delegation is a tool to transfer information within an organization. We establish this result in three steps. First, we show that information is indeed transferred when the agent gets control. This first result is constructed using the properties of signaling games. Second, we show that alternative ways to transfer information, message games, could fail. Last, we show that when communication fails, there is room for delegation, i.e. the costs associated with are smaller than the benefits of being informed.

Proposition 1 contains the most important result of the paper: delegation forces the agent to reveal his private information to the principal. This result should be contrasted with the results of the literature on dynamic incentive contracts: in multi-periods adverse selection models, a separating equilibrium in which the agent reveals his private information does not always exist. To achieve self-selection in adverse selection models, the principal pays a rent to the so-called efficient type. With repeated interaction, even if the efficient type gets a rent if he reveals his information, it is costly as the information is used at his disavantage in second period. There is a second period implicit punishment associated with information revelation and this might destroys the incentives to disclose information.[19] In our framework, the principal cannot punish the agent that does not disclose properly his private information and hence, it eases the revelation of information by the agent. The agent reveals his information under delegation because some type prefers to have an informed principal. In the delegated mechanism, this type could separate him-self for the other and information is disclosed to the principal. If this type would have been punished by lowering his second period payoff, it would destroy the incentives to disclose information; which is exactly what happen in dynamic incentive contracts.

The paper examinated the problem of information transfers assuming that the state of the world could take two values only. If we consider a model with more than two types, we could extend the results of proposition 1, only the Riley outcome survives the intuitive criterion, if the signals are free i.e. if the agent's preferred decision belongs to the set of separating equilibria. When signals are costly, the intuitive criterion is not sufficient to eliminate all the pooling equilibria[20] and the equilibrium under delegation may involve some degree of pooling. Nevertheless, with N types, our reasoning is similar, even if there is some pooling. We have shown that a rational for delegation is information transfer

[19] In Riordan and Sappington (1987) and Legros (1993), there is also an implicit punishment associated with revealing information in first period.

[20] To eliminate the pooling equilibria, criterion such as divinity (Bank and Sobel, 1987) should be used.

and as long as there is some information transfer[21], there are still benefits associated with delegation. In these cases, the information received by the principal is not perfect but she can still use it to decide in second period. There is some noise in the information send by the agent, but as long as there is information transfer, delegation needs to be considered. Moreover, with N types, communication is noisy, and the principal should no expect that the agent communicate his private information in the cheap-talk game (Crawford and Sobel, 1982 and Dessein, 2002). Hence, when communication fails or is imperfect, delegation is still an alternative to acquire the agent's hidden information.

References

[1] Aghion, P. M. Dewatripont & P. Rey (2001), 'On Partial Contracting', mimeo University of Toulouse.

[2] Aghion, P. & J. Tirole (1997), 'Formal and Real Authority in Organizations', *Journal of Political Economy*, 105(1), 1-29.

[3] Armstrong, M. (1994), 'Delegation and Discretion', University of Southampton, Department of Economics, Discussion Papers in Economics and Econometrics no 9421.

[4] Banks, J. & J. Sobel (1987), 'Equilibrium Selection in Signaling Games', *Econometrica*, 55(3), 647-61.

[5] Baron, D. & R. Myerson (1982), 'Regulating a Monopolist with Unknown Costs', *Econometrica*, 50(4), 911-30.

[6] Cho, I. K. & D. Kreps (1987), 'Signaling Games and Stable Equilibria', *Quarterly Journal of Economics*, 12(2), 179-221.

[7] Crawford, V. & J. Sobel (1982), 'Strategic Information Transmission', *Econometrica*, 50(6), 1431-52.

[8] de Garidel-Thoron, T. & M. Ottaviani (2000) 'The Economics of Advice', mimeo UCL, London.

[9] Dessein, W. (2002), 'Authority and Communication in Organizations' forthcoming *Review of Economic Studies.*

[10] Felli, L. (1996), 'Preventing Collusion through Discretion', London School of Economics, STICERD Discussion Paper Series TE/96/303.

[21] A situation that happens when not all the N types pool on the same decision.

[11] Freixas, X., R. Guesnerie & J. Tirole (1985) 'Planning under Incomplete Information and the Ratchet Effect', *Review of Economics Studies*, 52(2), 173-91.

[12] Grossman, S. & O. Hart (1986), 'The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration', *Journal of Political Economy*, 94(4), 691-719.

[13] Hart, O. (1995), *Firms, Contracts and Financial Structure*, Clarendon Lectures in Economics, Oxford & New York: Oxford University Press, Clarendon Press.

[14] Hart, O. & J. Moore (1988), 'Incomplete Contracts and Renegotiation', *Econometrica*, 56(4), 755-86.

[15] Laffont, J. J. & D. Martimort (1998), 'Collusion and Delegation', *Rand Journal of Economics*, 29(2), 280-305.

[16] Laffont, J. J. & J. Tirole (1988), 'The Dynamics of Incentive Contracts', *Econometrica*, 56(5), 1153-75.

[17] Legros, P. (1993), 'Information Revelation and Repeated Delegation', *Games and Economic Behavior*, 5(1), 98-117.

[18] Melumad, N., D. Mookherjee & S. Reichelstein (1992), 'A Theory of Responsibility Centers', *Journal of Accounting and Economics*, 15(4), 445-84.

[19] Myerson, B. (1982), 'Optimal Coordination Mechanisms in Generalized Principal-Agent Problems', *Journal of Mathematical Economics*, 10(1), 67-81.

[20] Riley, J. (1979), 'Informational Equilibrium', *Econometrica*, 47(2), 331-59.

[21] Riordan, M. & D. Sappington (1987), 'Information, Incentives, and Organizational Mode', *Quarterly Journal of Economics*, 102(2), 243-63.

[22] Simon, H. (1958), 'A Formal Theory of the Employment Relationship', *Econometrica* 19(2), 293-305.

[23] Spence, M. (1973), 'Job Market Signaling', *Quarterly Journal of Economics*, 87(3), 355-74.

[24] Tirole, J. (1999), 'Incomplete Contracts: Where do we stand?', *Econometrica*, 67(4), 741-81.

A Complement to section 3

A.1 Separating equilibria: cases S.2 and S.3

Consider the case S2. Equation (4) is satisfied for $\theta_i = \theta_H$ if $\beta_2 - \alpha_2 \geq \frac{\Delta\theta}{2}$. In this case, the separating equilibrium is supported by pessimistic beliefs: $\mu(\theta_L|d_1) = 0, \forall\ d_1 \neq d_1^*(\theta_L)$ and $\mu(\theta_L|d_1^*(\theta_L)) = 1$. In addition, the following incentive constraint (similar to (6)) should be satisfied:

$$U_1^A(d_1(\theta_L), \theta_H) - U^A(d_1(\theta_H), \theta_H) \geq U_2^A(d_2^*(\theta_L), \theta_H) - U_2^A(d_2^*(\theta_H), \theta_H). \tag{28}$$

The set of separating equilibria is then:

$$d_1^*(\theta_L) \in D \equiv \{d_1(\theta_L) \,|\, (28)\, is\, satisfied\}. \tag{29}$$

$$d_1^*(\theta_H) = \alpha_1 + \theta_H. \tag{30}$$

Again, we use the intuitive criterion. It refines all the beliefs associated with D to $\mu(\theta_L|d_1 \in D) = 1$ and the surviving equilibrium is $d_1^*(\theta_L) = \alpha_1 + \theta_L$ if $\Delta\theta \leq \beta_2 - \alpha_2$ and $d_1^*(\theta_L) = \alpha_1 + \theta_L + \sqrt{K_2} - \Delta\theta$ otherwise, where $K_2 = (2\beta_2 - 2\alpha_2 - \Delta\theta)\Delta\theta$.

In case S3 (when $|\alpha_2 - \beta_2| \leq \frac{\Delta\theta}{2}$), equation (4) is never satisfied for $\theta_i = \theta_L$ and $\theta_i = \theta_H$.

A possible separating equilibrium is[22]:

$$d_1^*(\theta_L) = \alpha_1 + \theta_L. \tag{31}$$

$$d_1^*(\theta_H) \in D \equiv \{d_1(\theta_H) |\, (6)\, is\, satisfied\}. \tag{32}$$

With beliefs $\mu(\theta_L|d_1) = 1,\ \forall\ d_1 \neq d_1^*(\theta_H)$ and $\mu(\theta_L|d_1^*(\theta_H)) = 0$ We use the intuitive criterion to refine beliefs and the only surviving equilibrium is: $d_1^*(\theta_L) = \alpha_1 + \theta_L$, $d_1^*(\theta_H) = \alpha_1 + \theta_H$.

A.2 Pooling equilibria: cases P.2 and P.3

In case P2, when the agent prefers an non-informed principal in state θ_H, the equilibrium is supported by beliefs: $\mu(\theta_L|d_1 \neq d_1^*) = 0$ and $\mu(\theta_L|d_1 = d_1^*) = v_L$. The set of pooling equilibria is the set of d_1^* such that: $\forall\ d_1 \neq d_1^*$,

$$U^A(d_1^*, d_2^*, \theta_L) \geq U^A(d_1 = \alpha_1 + \theta_L, d_2 = \beta_2 + \theta_H, \theta_L). \tag{33}$$

$$U^A(d_1^*, d_2^*, \theta_H) \geq U^A(d_1 = \alpha_1 + \theta_H, d_2 = \beta_2 + \theta_H, \theta_H). \tag{34}$$

We use the following lemma, similar to lemma 1:

[22] There is another separating equilibrium where $d_1^*(\theta_H) = \alpha_1 + \theta_H$. The reasoning in this case is similar.

Lemma 5 $\forall\, d_1^*$, $\exists\, \tilde{d}_1$ *such that:*
(i) θ_H prefers the pooling equilibrium d_1^* to $\tilde{d}_1$, whatever the beliefs associated with $\tilde{d}_1$.

(ii) θ_L prefers $\tilde{d}_1$ to the pooling equilibrium if the principal is convicted that $\mu(\theta_L|\tilde{d}_1) = 1$.

The proof is similar to lemma 1, and with this lemma, we can show that in case P.2, no equilibrium survives the intuitive criterion.

In case P3, when the agent prefers an informed principal in both states of the world, the equilibrium is supported by passive beliefs and should satisfy: $\forall\, d_1 \neq d_1^*$,

$$U^A(d_1^*, d_2^*, \theta_L) \;\geq\; U^A(d_1, d_2 = \beta_2 + v_L\theta_L + v_H\theta_H, \theta_L). \tag{35}$$

$$U^A(d_1^*, d_2^*, \theta_H) \;\geq\; U^A(d_1, d_2 = \beta_2 + v_L\theta_L + v_H\theta_H, \theta_H). \tag{36}$$

and we use the intuitive criterion in the same way as before to eliminate all the pooling equilibria.

B Proofs

B.1 Proof of lemma 1

To each d_1^*, we can associate a $\tilde{d}_1$ defined as:

$$U^A(\tilde{d}_1, d_2 = \beta_2 + \theta_H, \theta_H) = U^A(d_1^*, d_2^* = \beta_2 + E\theta, \theta_H). \tag{37}$$

$$\tilde{d}_1 > \alpha_1 + \theta_H.$$

$\tilde{d}_1$ is the decision d_1 that left the agent θ_H indifferent between the pooling equilibrium (d_1^*, d_2^*) and $(\tilde{d}_1, \beta_2 + \theta_H)$. So part (ii) of the lemma is satisfied[23]. As θ_H prefers to signal his type, the function on the right hand side of (37) is a vertical translation of the function on the left hand side. Therefore, $\tilde{d}_1$ always exist (actually two values $\tilde{d}_1$ satisfies (37) by the single peak assumption but we select those on the right of $\alpha_1 + \theta_H$).

Now we concentrate on part (i) of the lemma. It is satisfied if, whatever the beliefs associated with the observation of $\tilde{d}_1$:

$$U^A(d_1^*, d_2^*, \theta_L) > U^A(\tilde{d}_1, d_2, \theta_L). \tag{38}$$

If the beliefs associated with $\tilde{d}_1$ are $\mu(\theta_L|\tilde{d}_1) = 1$, the condition (38) is satisfied. In that case, the agent θ_L looses on both sides: the first decision is greater than d_1^*[24] and θ_L prefers d_2^* to $d_2 = \beta_2 + \theta_L$, by definition of case P.1.

[23] To have strict preference take $\tilde{d}_1 + \epsilon$.
[24] Whatever the initial d_1^* even those smaller than $\alpha_1 + \theta_L$.

If the beliefs associated with $\tilde{d}_1$ are $\mu(\theta_L|\tilde{d}_1) = v_L$, the condition (38) is also satisfied. $\tilde{d}_1$ is greater than d_1^* and the second decision is identical. Therefore, θ_L prefers the initial equilibrium.

If the beliefs associated with $\tilde{d}_1$ are $\mu(\theta_L|\tilde{d}_1) = 0$, there is as in the previous case a cost of taking a decision greater than d_1^*, but there may be benefits if the agent prefers the second decision $d_2 = \beta_2 + \theta_H$ to d_2^*. There are benefits if:

$$U_2^A(d_2 = \beta_2 + \theta_H, \theta_H) - U_2^A(d_2^* = \beta_2 + v_H\theta_H + v_H\theta_H, \theta_L) > 0. \tag{39}$$

Which is the case if $2\alpha_2 - 2\beta_2 - (1 + v_H)\Delta\theta \geq 0$. And we will now concentrate on these cases. For the reasoning, it is important to note that these benefits are constant, i.e. independent of the initial equilibrium d_1^* and equals to $\frac{v_L\Delta\theta}{2}(2\alpha_2 - 2\beta_2 - (1 + v_H)\Delta\theta)$. Therefore, we have to look at the cost of switching from d_1^* to $\tilde{d}_1$ for θ_L and check if they exceed the benefits. The costs being:

$$U_1^A(d_1 = d_1^*, \theta_L) - U_1^A(d_1 = \tilde{d}_1, \theta_L) \tag{40}$$

For simplicity, we first concentrate on pooling equilibria $d_1^* \geq \alpha_1 + \theta_H$.

We use the following lemma:

Lemma 6 *$\forall\ d_1^* \geq \alpha_1 + \theta_H$, the cost of switching from d_1^* to the associated $\tilde{d}_1$ increases with d_1^*.*

Proof: Solving (37) for $\tilde{d}_1$ and taking the value greater than $\alpha_1 + \theta_2$, we have $\tilde{d}_1$ as a function of the equilibrium d_1^*:

$$\tilde{d}_1 = \alpha_1 + \theta_H + \sqrt{(d_1^*)^2 - 2d_1^*(\alpha_2 + \theta_H) + C} \tag{41}$$

where $C = (\alpha_1 + \theta_H)^2 + 2v_L\Delta\theta(\alpha_2 - \beta_2) + v_L^2(\theta_L + \theta_H)^2$.
With some algebra, we can show that $\frac{\partial \tilde{d}_1}{\partial d_1^*} \geq 0$ and $\frac{\partial\partial \tilde{d}_1}{\partial\partial d_1^*} > 0$ for all $d_1^* \geq \alpha_1 + \theta_H$.
On the other hand, the derivative of $U_1^A(d_1, \theta_L)$ with respect to d_1 is equal to $\alpha_1 + \theta_L - d_1$. For all $d_1 > \alpha_1 + \theta_L$, the impact (on utility) of a given change in d_1, is greater the greater d_1 is. Combining these two elements: the impact of a change in d_1^* on $\tilde{d}_1$ and the impact of a change in $\tilde{d}_1$ on U^A, it is straightforward to show that the cost of switching from $d_1^* \in D'$ to $\tilde{d}_1$ is greater, the greater the initial equilibrium is. And this proves the lemma.

Therefore, the condition (38) is satisfied for all $d_1^* \geq \alpha_1 + \theta_H$ if it is satisfied for $d_1^* = \alpha_1 + \theta_H$ (remember that the benefits of switching are constant). Replacing d_1^* by $\alpha_1 + \theta_H$ and $\tilde{d}_1$ by (41), (38) becomes (after simplifications):

$$\Delta\theta(v_L\Delta\theta + \sqrt{\Delta\theta v_L(2\alpha_2 - 2\beta_2 + v_L\Delta\theta)}) > 0$$

which is always positive since we considered cases in which $\alpha_2 > \beta_2$ and hence, for all $d_1^* \geq \alpha_1 + \theta_H$, $\exists\, \tilde{d}_1$ satisfying the conditions of lemma 1.

Now consider the other pooling equilibria. If θ_H switch from d_1^* to $\tilde{d}_1 = \alpha_1 + \theta_H + \sqrt{2v_L\Delta\theta(\alpha_2 - \beta_2) + v_L^2(\theta_L + \theta_H)^2}$, such a deviation increases (strictly) his utility if the beliefs associated with $\tilde{d}_1$ are $\mu(\theta_1|\tilde{d}_1) = 0$. For θ_1, the cost of switching from d_1^* to $\tilde{d}_1$ is the sum of the cost of switching from d_1^* to $\alpha_1 + \theta_H$ plus the cost of switching from $\alpha_1 + \theta_H$ to $\tilde{d}_1$. Then the costs of switching from any $d_1^* \in D$, $d_1^* < \alpha_1 + \theta_H$ are greater than the costs associated with $d_1^* = \alpha_1 + \theta_H$ and therefore greater than the benefits. And this prove lemma 1.

B.2 Proof of lemma 2

Consider the case in which (21) holds. It implies that $\alpha_t > \beta_t \Rightarrow \alpha_t + \theta_H > \beta_t + \theta_H$ Hence in state θ_H, the agent strictly prefers an informed principal and will send a unique message, say m_H.

In the other state θ_L, if the agent sends a unique message, given (21), the agent strictly prefers to send the same message m_H and keep the principal non-informed.

Alternatively, the agent in state θ_L could send the message m_L with probability p and the message m_H with probability $(1-p)$. With this combination, the agent's utility in state θ_L is

$$EU_t^A = pU_t^A(d_t^* = \beta_t + \theta_L, \theta_L) + (1-p)U_t^A(d_t^* = \beta_t + \eta_L\theta_L + \eta_H\theta_H, \theta_L) \qquad (42)$$

where $\eta_L = \frac{v_L(1-p)}{v_L(1-p)+v_H}$ and $\eta_H = \frac{v_H}{v_L(1-p)+v_H}$.

Expression (42) is maximized for $p = 0$. This statement is proved as follow: (i) the function EU_t^A is single peaked (ii) the derivative of EU_t^A with respect to p, evaluated at $p = 0$ is negative.

$$\left.\frac{\partial EU_t^A}{\partial p}\right|_{p=0} = U_t^A(d_t = \beta_t + \theta_L, \theta_L) - U_t^A(d_t = \beta_t + v_L\theta_L + v_H\theta_H, \theta_L) + \left.\frac{\partial U_t^A}{\partial d_t}\frac{\partial d_t}{\partial p}\right|_{p=0} < 0$$

After simplifications, the sign of the derivative is given by: $\beta - \alpha + \frac{v_H\Delta\theta}{2} - \frac{v_L\Delta\theta}{2}$ which is negative by (21). Hence, the function has a unique maximum in $p \in [0,1]$ for $p = 0$.

Mimicking the behavior of the agent in state θ_H is then a dominant strategy for the agent in state θ_L and therefore, the principal will not become informed if (21) holds.

Similar, if (22) holds, it is a dominant strategy for the agent in state θ_H to mimic the behavior of the agent in state θ_L.

Last, when neither (21) or (22) holds, telling the true state of the world gives to the agent a higher utility than keeping the principal not informed. There is one state in which the agent strictly prefers to tell the truth and therefore sends a unique message. Given that, the best reply of the agent in the other state is to send a unique and different message, hence information is revealed to the principal.

B.3 Proof of proposition 3

Suppose $\alpha > \beta$. From corollary 1, we know that communication is not successful if: $\alpha - \beta \geq \frac{v_H \Delta\theta}{2} \Leftrightarrow 4\frac{(\alpha-\beta)^2}{(v_H)^2} \geq \Delta\theta^2$. From lemma 4, we know that delegation dominates centralization when $\frac{(\alpha-\beta)^2}{2v_L v_H} \leq \Delta\theta^2$. Provided that $v_H \leq \frac{8}{9}$, we have $\frac{(\alpha-\beta)^2}{2v_L v_H} \leq 4\frac{(\alpha-\beta)^2}{(v_H)^2}$, hence if $\Delta\theta^2 \in [\frac{(\alpha-\beta)^2}{2v_L v_H}; 4\frac{(\alpha-\beta)^2}{(v_H)^2}]$, delegation is optimal.

A similar argument holds for $\alpha \leq \beta$.

B.4 Proof of proposition 4

For all possible preferences $\alpha_1, \alpha_2, \beta_1, \beta_2$, it exists a structure of the agent's private information v_L, v_H, θ_L and θ_H, such that delegation is optimal.

To proof that delegation could be optimal, we first define the space in which the agent does not communicate or communicates only in period 2, and we show that the intersection between the no-communication space and the space in which delegation is optimal (defined in lemmas 3 and 4) is non empty.

We limit our proof to the cases in which $\alpha_1 > \beta_1$ and $\alpha_2 > \beta_2$. The other cases are symmetric.

From the table 1, we can easily find the following results:

- The agent transmits is private information in the first period if

$$\Delta\theta \geq \frac{2(\alpha_1 - \beta_1)}{v_H}; \frac{2(\alpha_2 - \beta_2)}{v_H}. \tag{43}$$

  or if

$$\frac{2(\alpha_1 - \beta_1)}{v_H} \leq \Delta\theta \leq \frac{2(\alpha_2 - \beta_2)}{v_H}. \tag{44}$$

  and

$$\Delta\theta \geq \frac{\alpha_1 + \alpha_2 - \beta_1 - \beta_2}{v_L}. \tag{45}$$

- The agent delays the information transfer to period two if

$$\frac{2(\alpha_2 - \beta_2)}{v_H} \leq \Delta\theta \leq \frac{2(\alpha_1 - \beta_1)}{v_H} \tag{46}$$

- The agent does not transmit any information if

$$\Delta\theta \leq \frac{2(\alpha_2 - \beta_2)}{v_H}; \frac{2(\alpha_1 - \beta_1)}{v_H}. \tag{47}$$

If $\alpha_1 - \beta_1 > \alpha_2 - \beta_2$, conditions (43) to (47) resumes into (we have putt all the values on square): if $\Delta\theta^2 \geq \frac{4(\alpha_1-\beta_1)^2}{v_H^2}$, there is communication at time one, if $\frac{4(\alpha_2-\beta_2)^2}{v_H^2} \leq \Delta\theta^2 \leq \frac{4(\alpha_1-\beta_1)^2}{v_H^2}$, there is communication at time two and if $\Delta\theta^2 \leq \frac{4(\alpha_2-\beta_2)^2}{v_H^2}$, there is no communication.

From the Lemma 3, we know that Principal prefers delegation to centralization, with revelation of the information in $t = 2$, if $\Delta\theta^2 \geq \frac{(\alpha_1-\beta_1)^2}{v_L v_H}$. Hence, delegation is optimal for $\Delta\theta^2 \in [\frac{(\alpha_1-\beta_1)^2}{v_L v_H}, \frac{4(\alpha_1-\beta_1)^2}{v_H^2}]$. This space is non empty if:

$$\frac{4(\alpha_1 - \beta_1)^2}{v_H^2} \geq \frac{(\alpha_1 - \beta_1)^2}{v_L v_H} \Leftrightarrow v_L \geq \frac{1}{3} \tag{48}$$

From the Lemma 4, we know that Principal prefers delegation to centralization, with no revelation of the information, if $\Delta\theta^2 \geq \frac{(\alpha_1-\beta_1)^2}{2v_l v_h}$. Delegation is optimal for $\Delta\theta^2 \in [\frac{(\alpha_1-\beta_1)^2}{2v_L v_H}, \frac{4(\alpha_2-\beta_2)^2}{v_H^2}]$. This space is non empty if:

$$\frac{4(\alpha_2 - \beta_2)^2}{v_H^2} \geq \frac{(\alpha_1 - \beta_1)^2}{2v_L v_H} \Leftrightarrow \frac{v_L}{v_H} \geq \frac{(\alpha_1 - \beta_1)^2}{8(\alpha_2 - \beta_2)^2} \tag{49}$$

And this prove that for $(\alpha_1 - \beta_1) > (\alpha_2 - \beta_2) > 0$, it is possible to find an non-empty space in which delegation is optimal.

Next, suppose that: $\alpha_1 - \beta_1 < \alpha_2 - \beta_2$. In this case, information is never revealed in period two (condition (46) is never satisfied) and the agent transmits his private information in the first period if (see conditions (43) to (45))

$$\Delta\theta \geq \frac{2(\alpha_2 - \beta_2)}{v_H}$$

or if

$$\frac{\alpha_1 + \alpha_2 - \beta_1 - \beta_2}{v_L} \leq \Delta\theta \leq \frac{2(\alpha_2 - \beta_2)}{v_H}$$

Otherwise, there is no communication.

Following the same reasoning as before, we find that

if $\frac{\alpha_1+\alpha_2-\beta_1-\beta_2}{v_L} > \frac{2(\alpha_2-\beta_2)}{v_H}$, delegation is optimal if $\Delta\theta^2 \in [\frac{(\alpha_1-\beta_1)^2}{2v_L v_H}, \frac{4(\alpha_2-\beta_2)^2}{v_H^2}]$; this space is non-empty if:

$$\frac{(\alpha_1 - \beta_1)^2}{2v_L v_H} \leq \frac{4(\alpha_2 - \beta_2)^2}{v_H^2} \Leftrightarrow \frac{v_L}{v_H} \geq \frac{(\alpha_1 - \beta_1)^2}{8(\alpha_2 - \beta_2)^2}$$

if $\frac{\alpha_1+\alpha_2-\beta_1-\beta_2}{v_L} < \frac{2(\alpha_2-\beta_2)}{v_h}$, delegation is optimal if $\Delta\theta^2 \in [\frac{(\alpha_1+\alpha_2-\beta_1-\beta_2)^2}{v_L^2}, \frac{4(\alpha_2-\beta_2)^2}{v_H^2}]$ which is non-empty if:

$$\frac{(\alpha_1+\alpha_2-\beta_1-\beta_2)^2}{v_L^2} \leq \frac{(\alpha_1-\beta_1)^2}{2v_L v_H} \Leftrightarrow \frac{v_L}{v_H} \geq \frac{2(\alpha_1+\alpha_2-\beta_1-\beta_2)^2}{8(\alpha_1-\beta_1)^2}$$

Again, for $(\alpha_2-\beta_2) > (\alpha_1-\beta_1) > 0$, we have found an non-empty space in which delegation is optimal.

Then, for all $\alpha_1 > \beta_1$ and $\alpha_2 > \beta_2$, it is possible to find a structure of the agent's private information v_L, v_H, θ_L and θ_H such that delegation is optimal. The reasoning can be extended for the other structures of preference. The proof being similar, it is omitted.

C Complement to section 5

If the principal delegates $d_1$and d_2 to the agent, he implements his preferred project $\alpha_t+\theta$ in both periods. The complete delegation is dominated by delegation of d_1 as long as the associated loss of control are at most $(\alpha_1-\beta_1)^2$. Suppose that loss of control are larger. A necessary condition for this is $\Delta\theta \leq |\alpha_2-\beta_2| \Rightarrow \Delta\theta^2 \leq (\alpha_2-\beta_2)^2$. When this necessary condition holds, it is impossible to have:

$$(\alpha_1-\beta_1)^2+(\alpha_2-\beta_2)^2 \leq 2v_L v_H \Delta\theta^2$$

which is the condition that guarantee that complete delegation dominates centralization.

Consider next the delegation of d_2 only. This structure dominates both delegation and centralization, provided that communication fails if:

$$(\alpha_2-\beta_2)^2 \leq v_L v_H \Delta\theta^2 \leq \frac{(\alpha_1-\beta_1)^2}{2}$$

Which can be the case when the principal and the agent strongly disagree about d_1 and not about d_2.