# Authority in Complex Organizations*

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**Abstract**

I study organizational design under informational interdependence—the fact that a single piece of information affects many decisions. In the model, a principal must decide on the allocation of authority over two decisions in order to aggregate information dispersed among biased agents. Under centralization, an agent reveals information depending on how it influences decisions and on his decision-specific biases. The principal prefers to centralize if there are sufficiently many agents with small 'aggregate bias'—which may include agents with extreme biases in both dimensions. Under delegation, any information transmitted to a decision maker only affects the decision he controls. I find the principal prefers to delegate a high-conflict decision if that improves communication with her in the other dimension. I also analyse how interdependence affects information acquisition. Agents can specialize, which signals commitment not to manipulate information and, hence, enhances credibility. Finally, I show that delegation reduces the incentives to acquire information: it is lower overall and concentrated on states that are more important for the decision at hand.

**Keywords:** Multidimensional Cheap Talk, Industrial Organization, Delegation, Organizational Design.
**JEL:** D21, D83.

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## 1 Introduction

When a principal in charge of many decisions needs to aggregate information from agents, incentives for communication depend on their preferences over decisions and on how information affects these decisions. In some cases, a single piece of information affects many decisions: there is *informational interdependence*. The allocation of authority—who decides what—alters the interaction between interdependence and preferences: the number of decisions a player controls, together with his preferences, shape other players' communication incentives. Hence, making dispersed information available for decision-making requires an appropriate organizational structure. This paper studies the allocation of authority under informational interdependence.

If decisions were independent, the principal would delegate authority to a better informed, but biased agent only if the informational gains compensate for the loss of control (Aghion and Tirole, 1997; Dessein, 2002). When information is dispersed among many agents, the informational gains depend on how much information the decision maker expects to receive from other agents in equilibrium (Austen-Smith, 1990; Dewan and Squintani, 2015). Informational interdependence alters this trade-off because incentives to transmit information depend on the number of decisions a player controls. Hence, depending on how interdependence aggregates preferences, the principal may have higher or lower incentives to delegate than when decisions are independent. To see this, consider how multinational corporations create knowledge. These firms locate some activities close to economic and technological agglomerates in order to gain access to specific knowledge (Ghoshal and Bartlett, 1990; Andersson and Forsgren, 2000). For subsidiaries to be able to identify and assimilate new knowledge, they must forge close relationships with local business partners, which can create conflict with organizational goals (Andersson et al., 2005; Ecker et al., 2013). Despite the conflicts, some of these relationships are especially important for the firm. As the management literature puts it, the degree of autonomy over product decisions granted to subsidiaries (product mandate) is positively correlated with the degree to which knowledge spills over to sister units (Andersson et al., 2007; Boutellier et al., 2008).[1]

In this paper, I construct a model of authority under informational interdependence. A principal in charge of two decisions needs information about two state variables. There are $n$ biased agents, each of whom observes noisy signals about the two states and can communicate them through costless, non-verifiable messages. Before any communication takes place, the principal allocates decision rights among all members of the organization. Incentives for communication are shaped by the degree of preference misalignment (conflict of interest) between each agent and each decision maker, depending

[1] Andersson et al. (2007) identify that "*on the one hand, a high degree of external embeddedness is important for the development of a subsidiary's competence, with some competence spilling over to other subsidiaries; and, on the other, a high degree of external embeddedness indicates that the subsidiary is largely involved in long-term business interactions with local partners, resulting in issues external to the MNC being prioritized.*"

on the decision(s) the latter controls. When authority is centralized, information about each state affects both decisions such that informational interdependence aggregates decision-specific biases.

The optimal organizational structure resolves a trade-off between informational gains and loss of control. Informational gains can be of two types. Direct gains refer to the additional information a decision maker receives in equilibrium when the principal delegates authority to him. These gains reflect the traditional argument: the principal delegates to an agent with sufficiently large 'informational advantage' (see Dessein, 2002; Dewan et al., 2015).[2] Indirect gains, by contrast, refer to the additional information *the principal* receives when she delegates one decision and retains authority on the other (partial delegation). These gains occur when there are agents whose biases are large in one dimension and low in the other. Delegation of the high-conflict decision thus allows the principal to restrict these agents' communication with her to the low-conflict decision.

Interdependence can lead to informational spillovers. An agent's preferences feature negative informational spillovers when extreme bias in one dimension prevents communication under centralization, despite the bias in the other dimension being small (Levy and Razin, 2007). There can also be positive spillovers in this context. Suppose an agent has extreme biases in both dimensions but any information he transmits influences one decision towards his bias and the other against it. In such cases, the utility gains in one dimension compensate the losses in the other and, hence, the aggregate conflict of interest is small. This notion of positive spillovers is present in many real-world situations. For instance, the idea that merging public bodies once in charge of separate policies can lead to synergies that improve policy outcomes (Baughman, 2006; Baumgartner and Jones, 2009; White and Dunleavy, 2010), or the fact that issue linkage constitutes an elemental strategy for reaching agreements in international negotiations (Morgan, 1990; Davis, 2004; Trager, 2011).[3]

I find that organizational design plays a crucial role in cases of informational spillovers. Proposition 2 shows negative spillovers require delegation of high-conflict decisions and retaining authority over low-conflict ones. The optimal organizational structure is thus partial delegation. On the contrary, agents whose preferences are affected by positive spillovers reveal more information to the principal under centralization. Therefore, if the number of such agents is sufficiently large, the principal prefers to centralize decision making. The mechanism behind this result is similar to 'mutual discipline' in public communication with multiple audiences (Farrell and Gibbons, 1989; Goltsman and Pavlov, 2011), and 'persuasive cheap talk' in multidimensional communication (Chakraborty and Harbaugh, 2010): information affects decisions in a way such that decision-specific conflicts of interest compensate each other.

[2]Informational advantage conducive to delegation arises ex-post and on path, as in Dewan et al. (2015).

[3]More specifically, "an agreement leading to the peaceful resolution of an international crisis often becomes possible when an issue, not originally in contention, is brought into the bargaining for linkage purposes" (Morgan, 1990).

Informational interdependence not only affects communication, it also affects information acquisition. In the second part of the paper, I introduce endogenous information acquisition. After the allocation of decision rights, each agent decides whether to observe information at a given cost. This investment is worth making only if it is cost-effective, i.e. the expected utility gains from revealing the acquired information must compensate its cost. Because agents can only acquire signals with a fixed amount of noise, expected utility gains are decreasing in the amount of information the decision maker receives on-path.[4] This limits the amount of information any decision maker can have in equilibrium.

Agents decide on information acquisition about two state variables and they can specialize. I show that if an agent acquires information about one state, truthful revelation is incentive compatible for a larger set of biases. When an agent observes information about both states, there are some realizations for which one part of the information favours him and the other part does not. In such a case, he has incentives to follow the favourable information, which involves deviations from truth-telling. These incentives impose a penalty on credibility: incentive compatibility constraints are tighter than if he observes only one signal. But, then, these perverse incentives are absent when he specializes, a sort of commitment not to manipulate information. In other words, a principal benefits from restricting her advisers' access to information they are not expected to reveal.

Finally, I study how the organizational structure affects incentives to acquire information. I find that, under delegation, the expected investment in information is both lower overall and more concentrated on the state that is more important for the decision at hand. The first of these results—lower overall investment—stems from the fact that agents typically influence one decision under delegation. Hence, the expected marginal utility from any piece of information is smaller than when it affects both decisions. The second result—unbalanced investment—relates to the fact that information about each state affects decisions differently. Under delegation, then, agents expect to derive higher marginal utility when they acquire information about the state that is most important for each decision. These results represent a qualification on the informational benefits from delegation and could be interpreted as part of the 'long run' informational effects from organizational design.

**Related Literature.** The paper builds upon the literature on multidimensional cheap talk. In a seminal paper, Battaglini (2002) shows that multidimensionality allows a receiver to extract all the information from perfectly informed senders, by restricting the influence of each of them to the dimension of common interest. When there are as many senders as decisions, the receiver can commit to ignore part of the information provided by each sender because it is provided (in equilibrium) by the

[4] I assume signals have a fixed amount of noise and agents can acquire at most one such signal per state. As a consequence, individual incentives for communication are decreasing in the amount of information the decision maker is expected to have in equilibrium (see Morgan and Stocken, 2008; Galeotti et al., 2013).

others. Note that, as a consequence, the receiver does not need delegation. Dewan and Hortala-Vallve (2011) apply this result to explain the design of jurisdictions in parliamentary cabinets. They argue that a Prime Minister uses her prerogatives on ministerial appointments and allocation of portfolios to limit each minister's influence to decisions for which preferences are somewhat aligned. This way, there is no need for effective delegation of authority. But the argument above relies on the assumption that ministers are perfectly informed. When this is not the case and decisions are interdependent, the receiver loses her equilibrium commitment power. Levy and Razin (2007) show this leads to communication breakdown if the conflict of interest in one dimension is sufficiently large: senders' incentives depend on how information affects decisions.[5] My paper shows delegation substitutes for the principal's ability to ignore information in Battaglini (2002) and, more generally, analyses how the allocation of authority helps to manage informational spillovers.

The main contribution of the paper is to organizational design, in which strategic communication has important consequences for the allocation of decision rights. In unidimensional decision problems with a perfectly informed sender, Dessein (2002) shows that delegation dominates cheap talk communication for all conflicts of interest for which there is transmission of information in the latter. The benefits from delegation are increasing in the sender's informational advantage. Similar intuitions underlie the organization of legislative debate (Gilligan and Krehbiel, 1987; Austen-Smith, 1990; Krishna and Morgan, 2001a), policy-making cabinets (Dewan and Hortala-Vallve, 2011; Dewan et al., 2015), political parties (Dewan and Squintani, 2015), and multi-divisional firms (Alonso et al., 2008; Rantakari, 2008). Introducing informational interdependence represents a step towards a more realistic understanding of the underlying forces.

Multi-divisional firms trade off the need for adaptation to local shocks with the need for coordination between divisions. Communication frictions may lead to inefficiencies in terms of giving up benefits from the specialization of production (Dessein and Santos, 2006) or the need for coordination through scheduled tasks instead of using communication (Dessein et al., 2016). When divisional managers' information is not verifiable, the allocation of decision rights—along with non-separability of preferences and divisional conflict of interest—shapes incentives for communication (Alonso et al., 2008, 2015; Rantakari, 2008). But the trade-off between adaptation and coordination is not the relevant problem in many applications. Product design in multinational corporations, for instance, relies on innovations over different attributes that appeal to consumers. Because 'knowledge clusters' for the different attributes are dispersed around the world, firms need organizational structures that allow subsidiaries to assimilate knowledge and make it available for the rest of the organization (see

[5] In a complementary paper, Chakraborty and Harbaugh (2007) show that, in two-player games, the sender can credibly communicate any ranking of the decision dimensions that reflects (at least partially) the order of the realization of the states across dimensions.

Andersson et al., 2007; Boutellier et al., 2008). My framework isolates the effects of informational interdependence on communication and shows how the organization can be designed to produce and aggregate information effectively.

The allocation of decision rights also affects incentives to acquire information. Aghion and Tirole (1997) show that delegation of real authority motivates an agent to acquire information, resulting in a loss of control for the principal. But delegation may discourage information acquisition in this context, either because the agent prefers to put more effort into information that benefits him personally (Rantakari, 2012), or because he no longer has to convince a principal with divergent opinion about the best course of action (Che and Kartik, 2009). When the agent has access to imperfect (non-verifiable) information, the principal induces him to over-invest in information gathering if punishments upon deviations are credible (Argenziano et al., 2016); in such cases, centralization dominates. My paper shows that informational interdependence has meaningful consequences for incentives to acquire information. By allowing information acquisition about multiple states, my framework also captures different drivers of specialization.

More recently, Deimen and Szalay (2019) have also integrated the ideas of information acquisition and strategic communication. In their framework, a principal and an agent face a uni-dimensional problem that depends on information about two states. Players disagree on the state upon which the decision has to be calibrated, such that the conflict of interest is decreasing in the correlation between states. The principal's benefits from delegation are thus increasing in the correlation. In my paper, the effect of interdependence (correlation) on communication is not monotonic because conflicts of interest are state independent (as in Crawford and Sobel, 1982). Besides, the multidimensionality of the decision problem plays a central role in shaping incentives for information acquisition under different organizational structures.

The next section presents the baseline model with no information acquisition and the results for optimal allocation of decision-rights. In section 4 I integrate the allocation of decision-rights with endogenous information acquisition. In section 5 I discuss some extensions and conclude.

## 2 Baseline Model

**Players and preferences.** An organization consists of a principal, $P$, and $n$ agents.[6] There are two decisions to be made, $\mathbf{y} \in \Re^2$, but the outcome of each of them depends on two state variables $\theta_1$ and $\theta_2$ (to be defined later). Optimal decisions thus require information about these states. The decision-specific uncertainty is represented by two composite states $\delta_1(\theta_1, \theta_2)$ and $\delta_2(\theta_1, \theta_2)$. Preferences for

[6] As usual in this literature, I use female pronouns to refer to the principal and male pronouns for each agent.

player $i = \{P, 1, \ldots, n\}$ are given by:

$$U^i(\boldsymbol{\theta}, \mathbf{y}, \mathbf{b}^i) = -\left(y_1 - \delta_1(\theta_1, \theta_2) - b_1^i\right)^2 - \left(y_1 - \delta_2(\theta_1, \theta_2) - b_2^i\right)^2$$

Where $\mathbf{b}^i \in \Re$ represents $i$'s bias vector, which is normalized to $\mathbf{b}^P = (0, 0)$ for the principal.

**Information structure.** Pay-off relevant states, $\theta_1$ and $\theta_2$, are uniformly distributed with support in the interval $[0, 1]$, and $\theta_1 \perp \theta_2$. Information about each of these states affects both decisions, that is, there is *informational interdependence*. In the example of multinational corporations, the states can be interpreted as different technological attributes relevant for many products the firm produces. Decisions would represent the different product lines using these technologies; arguably, each technology is a salient attribute for a different product. In a policy-making example, states can be interpreted as the different goals of a policy intervention, while decisions represent the different policy instruments that address those goals; arguably, different instruments address goals with different degrees of success. The composite states $\delta_1$ and $\delta_2$ capture informational interdependence:

$$\begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} \equiv \begin{bmatrix} w_{11}\,\theta_1 + w_{12}\,\theta_2 \\ w_{21}\,\theta_1 + w_{22}\,\theta_2 \end{bmatrix}$$

The uniform distribution of states represents the canonical example in Crawford and Sobel (1982) and has been extensively used in the cheap talk literature.Assuming independent states allows me to isolate the effect of informational interdependence through $\boldsymbol{\delta}$. The elements of the weighting matrix W are indexed by $w_{dr}$, for $y_d = \{y_1, y_2\}$ and $\theta_r = \{\theta_1, \theta_2\}$ ($d$ represents decisions and $r$ represents states). All the weights are weakly positive and I normalize them as $w_{d1} + w_{d2} = 1$. Without loss, I also take $w_{11}, w_{22} > \frac{1}{2}$, so that the index corresponding to the state also reflects which decision that state is more important for. As a consequence, the informational interdependence between decisions is linear, and captured by the ex-ante correlation between the composite states.

$$\text{Corr}(\delta_1, \delta_2) = \frac{(w_{11}w_{12} + w_{21}w_{22})}{[(w_{11}^2 + w_{21}^2)(w_{12}^2 + w_{22}^2)]}$$

**Agents' signals and communication.** Agents have access to noisy, non-verifiable information about both states. Each agent observes one signal associated with each state (two in total). Let $\mathbf{S}^i = (S_1^i, S_2^i) \in \mathcal{S} \equiv \{0, 1\}^2$ be $i$'s signals, and $\tilde{\mathbf{S}} \in \mathcal{S}$ be the vector of realizations. Signals are independent across players, conditionally on $\boldsymbol{\theta}$. The prior probability distribution for each signal is characterized by $\Pr(\tilde{S}_1^i = 1) = \theta_1$ and $\Pr(\tilde{S}_2^i = 1) = \theta_2$.[7]

Each agent sends private, non-verifiable (cheap talk) messages to decision maker $j = \{P, 1, .., n\}$. Let $\mathbf{m}_j^i\left(\mathbf{S}^i\right) \in \{0,1\}^2$ denote agent $i$'s message to decision maker $j$, in charge of $y_d = \{y_1, y_2\}$. Note that $i$'s (pure) message strategies associated with each signal can take one of two forms (up to relabelling messages): the truthful one, $m_j^i(S_r^i) = \tilde{S}_r^i$ for all $S_r^i$, and the babbling one, $m_j^i(\tilde{S}_r^i = 0) = m_j^i(\tilde{S}_r^i = 1)$. Besides, the complete set of message strategies is not just based on babbling or revealing information on separate dimensions independently. An agent could, for instance, truthfully reveal both signals for some realizations and send the babbling message for others. Such message strategies arise because states are orthogonal and information about one state does not reveal information about the other. I call these strategies 'dimensional non-separable' (DNS).

Let $\mathbf{m}_j = \{..., \mathbf{m}_j^i, ...\}$ denote the matrix containing all the messages decision maker $j$ receives from agents (including himself if applicable). The updated expectation and variance for each state depend on the number of agents revealing the corresponding signal truthfully, $k_r(j) \leq n$, and the the number of those agents who report a 1, $\ell_r(j)$, for $\theta_r = \{\theta_1, \theta_2\}$, as follows.

$$E\left(\theta_r|\mathbf{m}_j\right) = \frac{(\ell_r(j)+1)}{(k_r(j)+2)} \qquad \mathrm{Var}\left(\theta_r|\mathbf{m}_j\right) = \frac{(\ell_r(j)+1)(k_r(j)-\ell_r(j)+1)}{(k_r(j)+2)^2(k_r(j)+3)}$$

**Allocation of decision rights.** Decision-rights are allocated before each agent learns his information. Formally, the principal decides on a set of assignments that grants decision making authority over the set of decisions. The assignment grants complete jurisdiction over the delegated decision, such that authority over each decision is granted to a unique individual. Decision makers are also granted the possibility of private communication with each agent. I assume decision makers cannot communicate the information transmitted to them by other agents. Different allocations of decision-rights lead to different organizational structures. I group these structures into three categories: under *centralization* the principal decides on both issues; under *full delegation* the principal grants authority to two different agents, each of them assigned to a different decision; under *partial delegation* the principal retains authority over one issue and delegates the other to an agent.

At this point two clarifications are necessary. First, I am not considering the case of delegation of both decisions to a single agent. Incentives for communication in such a case use the same measure of conflict of interest as under centralization. Hence, interdependence plays no role beyond the basic trade-off between informational gains and loss of control. On the contrary, the two forms of delegation considered in the paper involve different measures of conflict of interest. The second clarification relates to the distinction between delegation of decision authority and decentralization on the access

[7] A similar information structure, for unidimensional problems with one state variable, has been used in Austen-Smith and Riker (1987); Morgan and Stocken (2008); Galeotti et al. (2013) among others.

to information. In my framework, authority can be centralized or decentralized, the latter is called 'delegation' throughout the paper. Information, on the contrary, is always decentralized because it is dispersed among agents.

**Equilibrium concept** The equilibrium concept is pure-strategies Perfect Bayesian Equilibria (equilibrium, henceforth). A full characterization including mixed strategies is cumbersome and does not provide much insight beyond the pure-strategies case. Because communication is cheap talk, there typically exist multiple equilibria. I select among equilibrium message strategies on the basis of the decision maker's ex-ante expected utility.[8]

In the following section I analyse optimal organizational design when agents observe one signal associated with each state.

## 3 Organizational Design and Information Transmission

In this section I characterize the role of informational interdependence in organizational design. I first describe incentives for communication under each organizational structure (the formal analysis is left to the appendix). I then analyse the optimal organizational structure. The figure below outlines the timing of the game.

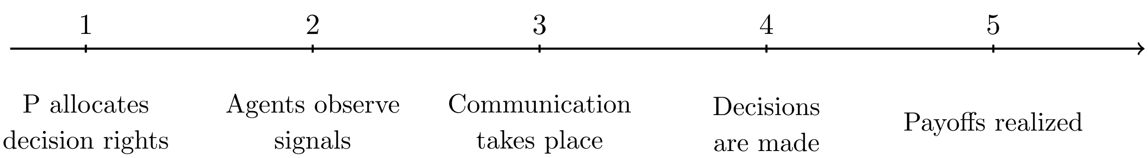



Figure 1: Timing of the Organizational Structure Game

Before describing the incentives for communication, I introduce some notation. Let $k_r^*(j) \equiv k_r(\mathbf{m}_j^*)$ and $\ell_r^*(j)$ denote the number of truthful messages and 'ones' decision maker $j$ receives in equilibrium, respectively. Also, let $k_r(j)$ be an agent's conjecture about the number of agents other than him who reveal information about state $\theta_r$ to decision maker $j$ (on path).[9] To keep track of who decides what, let $j', j'' \in \{P, 1, ..., n\}$ be the decision makers for $y_1$ and $y_2$, respectively (the number of apostrophes coincides with the index on the decision).

An equilibrium of the game defined by the allocation of authority is characterized by the triple $\left(\mathbf{y}^*, \mathbf{m}_{j'}^*, \mathbf{m}_{j''}^*\right)$, representing the vector of decisions and the vectors of message strategies to $j'$ and $j''$,

[8]See Crawford and Sobel (1982); Farrell (1993); Chen et al. (2008). Also, given the focus on pure strategies, it can be shown that this criterion satisfies neologism proofness (Farrell, 1993).

[9]Note that $i$'s conjecture will be correct in equilibrium, and whenever his message strategy involves revealing the corresponding signal then $k_r^*(j) = k_r(j) + 1$, otherwise $k_r^*(j) = k_r(j)$.

respectively. Optimal actions satisfy:

$$y_1^* = w_{11}E(\theta_1|\mathbf{m}_{j'}^*) + w_{12}E(\theta_2|\mathbf{m}_{j'}^*) + b_1' \qquad y_2^* = w_{21}E(\theta_1|\mathbf{m}_{j''}^*) + w_{22}E(\theta_2|\mathbf{m}_{j''}^*) + b_2''$$

Where $b_1'$ represents the bias of decision maker $j'$ with respect to $y_1$, and similarly for $b_2''$, $j''$, and $y_2$. Note that centralization means $j' = j'' = P$, such that the biases are equal to zero. From the principal's perspective, delegation of decision-rights has two payoff-relevant consequences. On the one hand, it implies a biased agent decides on behalf of the principal, resulting in a biased decision. On the other hand, individual incentives for communication depend on the conflict of interest between the agent and each decision maker. Different organizational structures (and decision makers) then result in different communication incentives. Agent $i$'s optimal message strategy to decision maker $j$ solves:

$$\mathbf{m}_j^{i*}(\mathbf{S}^i, \mathbf{b}^i, b_1', b_2'') = \arg\max_{\mathbf{m}_j^i} \left\{ E\Big[ -\left(y_1\left(m_{j'}^i, \mathbf{m}_{j'}^{\text{-}i}\right) - \delta_1 - b_1^i\right)^2 - \left(y_2\left(m_{j''}^i, \mathbf{m}_{j''}^{\text{-}i}\right) - \delta_2 - b_2^i\right)^2 \Big| \mathbf{S}^i \Big] \right\}$$

To simplify notation, let $k_r^{\mathrm{C}} \equiv \{k_r(j) |\, j' = j'' = P\}$ denote the number of truthful messages about $\theta_r = \{\theta_1, \theta_2\}$ the principal receives under centralization; let $k_r^{\mathrm{P1}} \equiv \{k_r(P) |\, j' = P\}$ be the number of messages received when she decides on $y_1$ only, and $k_r^{\mathrm{P2}} \equiv \{k_r(P) |\, j'' = P\}$ when she decides on $y_2$ only. For when $P$ does not decide at all, let $k_r' \equiv k_r^*(j')$ and $k_r'' \equiv k_r^*(j'')$ refer to the number of truthful messages for decision makers of $y_1$ and $y_2$, respectively, while keeping $k_r^j \equiv k_r^*(j)$ for a generic decision maker.

Note that the principal's expected utility from different allocations of decision rights depends on the amount of information the different decision makers are expected to receive on the equilibrium path. I first analyse incentives for communication for a typical agent under different organizational structures, then I study the role of informational interdependence in the principal-optimal structure.

**Incentives for communication under delegation.** I first describe agent $i$'s incentives to reveal information to decision maker $j$ in charge of $y_d$. Because communication between $i$ and $j$ is private, incentives depend on the conflict of interest between them, represented by $|b_d^i - b_d^j|$. But since $i$ is imperfectly informed, communication also depends on how many other agents are expected to be truthful to $j$ on the equilibrium path. If $j$ receives information from many agents other than $i$, he conjectures the decision will be 'too close' to $j$'s ideal, and far away from his. These two determinants constitute the traditional mechanism determining communication of imperfect information via cheap talk (Austen-Smith and Riker, 1987; Morgan and Stocken, 2008; Galeotti et al., 2013). In my framework, agents observe signals about two independent states, which introduces a third determinant.

Informational interdependence implies that information about the two states affect each decision.

When $i$ observes signals $\mathbf{S}^i = \{(0,1)\}$, for instance, his influence depends on which signal he is expected to reveal to $j$. Because the conflict of interest between them is unidimensional, one of these signals always moves the decision towards his bias. Therefore, $i$ has higher incentives to follow the favourable signal, for all possible message strategies. These deviation incentives lead to a *credibility loss*, which depends on $i$'s conjecture about the influence of the favourable signal, given the equlibrium behaviour of the other agents. As a consequence, incentives for communication now depend on how much information *about both states* other agents are expected to reveal on path.

Lemma A1 and Proposition A1 characterize the equilibrium communication between agent $i$ and decision maker $j$; here I describe the intuitions behind it. When $i$ is expected to reveal one signal on path, his incentives depend on the conflict of interest with $j$, on how many agents reveal the same information, and how many of them reveal the other signal (due to the credibility loss). When $i$ is expected to reveal both signals on path, his influence on the decision depends on whether the signals realizations coincide or not. If they coincide, $\mathbf{S}^i = \{(0,0),(1,1)\}$, the signals' influences reinforce each other; $i$'s expected marginal utility from revealing such signals will be larger than revealing each of them individually (conditional on $k_1^j$ and $k_2^j$). Agent $i$ would have, in principle, higher incentives to reveal both signals than revealing either of them individually. But signals may not coincide, $\mathbf{S}^i = \{(0,1),(1,0)\}$, in which case their influences counteract each other and $i$ has incentives to follow the most favourable of them. An implication of this is that incentive compatiblity constraints for revelation of one signal and full revelation coincide, meaning that these constraints hold for the same set of bias vectors. As a result, the equilibrium under delegation involves only two message strategies: full revelation, $\mathbf{m}_j^{i*} = \{\{(0,0)\};\{(1,1)\};\{(1,0)\};\{(0,1)\}\}$, and babbling, $\mathbf{m}_j^{i*} = \{\{(0,0);(1,1);(1,0);(0,1)\}\}$.[10]

**Incentives for communication under centralization.** Interdependence means that information transmitted to the principal under centralization affects both decisions. But an agent's influence on decisions depend on the type and amount of information he transmits. To see this, note that revealing $S_1^i$ has a larger influence on $y_1$ and, thus, the bias on the first dimension weighs more heavily in determining $i$'s incentives. If he reveals both signals, on the contrary, the overall influence is more balanced and so are the weights of $b_1^i$ and $b_2^i$ on the IC constraints. This leads to different measures of conflict of interest depending on the information revealed by different message strategies.

The possibility of different measures of conflict of interest results in two main differences with respect to delegation. First, revealing information about one state only constitutes the equilibrium message strategy for a non-empty set of bias vectors. The relevant measure of conflict of interest

[10] One could think that $i$ may want to fully reveal signals when they coincide and announce the corresponding babbling message when they do not—i.e. $\mathbf{m}_j^i = \{\{(0,0)\};\{(1,1)\};\{(1,0);(0,1)\}\}$. In Appendix A I show the set of bias vectors for which this is incentive compatible is a strict subset of that for which full revelation is.

for revealing $S_1^i$ is given by $\beta_1 = b_1^i w_{11} + b_2^i w_{21}$, while that for revealing $S_2^i$ is $\beta_2 = b_1^i w_{12} + b_2^i w_{22}$ (Lemma A2 and Proposition A2). The second difference with delegation relates to the effects of ambiguous information, i.e. $\mathbf{S}^i = \{(0,1),(1,0)\}$. Under centralization, revealing both signals has a balanced overall influence on decisions. Note that truthful revelation of $\mathbf{S}^i = \{(0,1)\}$ or $\mathbf{S}^i = \{(1,0)\}$ move decisions in opposite directions. If, for instance, $i$ credibly announces $\mathbf{m}_P^i = \{(0,1)\}$, he would influence $y_1$ towards 0 and $y_2$ towards 1. If $i$'s biases have the same sign, such a message leads to utility gains in one dimension and losses in the other. For some set of bias vectors $i$'s equilibrium message strategy consists of revealing ambiguous signals and sending non-influential messages otherwise. The most informative equilibrium features the following message strategies are: full revelation, revelation of information about one state, full revelation of some signal realization and nothing otherwise, and babbling.[11] I now focus on the analysis of the optimal organizational structure.

**Optimal Organizational Structure.** In this subsection I characterize the optimal organizational structure and present the main result of the communication game: the optimal allocation of decision-rights depends on the existence and the extent of informational spillovers.

The profile of preferences, $\mathbf{B} = \{\mathbf{b}^1, ..., \mathbf{b}^n\}$, determines the amount of equilibrium information for each possible organizational structure. By allocating decision rights the principal affects agents' equlibrium message strategies; effectively, she chooses among the different equilibria induced by $\mathbf{B}$. Let $\text{Var}(\theta_r|\mathbf{m}_j)$ denote the ex-ante expected variance associated to state $\theta_r = \{\theta_1, \theta_2\}$ in the equilibrium in which decision maker $j = \{P, 1, ..., n\}$ receives messages characterized by $\mathbf{m}_j$.[12] The definition below characterizes the principal's ex-ante expected utility, for two generic decision makers $j'$ and $j''$.

**Definition 1** (principal's ex-ante expected utility)**.** *Consider an equilibrium* $(\mathbf{y}, \mathbf{m})$ *in which* $j', j'' = \{P, 1, ..., n\}$ *decide on* $y_1$ *and* $y_2$*, respectively. Denote by* $\mathbf{m}_j = \{\mathbf{m}_{j'}, \mathbf{m}_{j''}\}$ *the equilibrium messages for* $j'$ *and* $j''$ *under delegation, for* $j', j'' = \{P, 1, 2, ...\}$*. Then, the principal ex-ante expected utility is given by:*

$$\begin{aligned} \hat{U}^{\mathrm{P}}(\mathbf{B}, \mathbf{m}_{j'}, \mathbf{m}_{j''}) = &- \left[(b_1')^2 + (w_{11})^2\ Var(\theta_1|\mathbf{m}_{j'}) + (w_{12})^2\ Var(\theta_2|\mathbf{m}_{j'})\right] \\ &- \left[(b_2'')^2 + (w_{21})^2\ Var(\theta_1|\mathbf{m}_{j''}) + (w_{22})^2\ Var(\theta_2|\mathbf{m}_{j''})\right] \end{aligned} \tag{1}$$

Equation (1) is derived in Appendix A. The first term in square brackets represents the principal's ex-ante expected utility associated with delegation of $y_1$ to decision maker $j'$. Because his decision will be biased, the principal's utility is decreasing in $b_1'$. But her utility also depends on her expectations about the decision maker's posterior beliefs in equilibrium. The principal thus delegate authority to a

[11]For a more thorough discussion of communication incentives under centralization see Habermacher (2018).

[12]Formally, $\text{Var}(\theta_r|\mathbf{m}_j) \equiv E\left[\left(E(\theta_r|\mathbf{m}_j) - \theta_r\right)^2; \mathbf{m}_j\right] = \frac{1}{6(k_r^j+2)}$.

player whose preferences on the associated decision are sufficiently close to other agents' preferences. This is the trade-off in the literature: informational gains must compensate for the loss of control.

But informational interdependence can lead to a different source of informational gains for the principal. Because delegation breaks the interdependence, there may be agents willing to reveal information under delegation but not under centralization. This happens when, for instance, agents' biases are very large in one dimension and small in the other. If the principal delegates the high-conflict decision and retains authority over the low-conflict decision, these agents will reveal information to her. I call these informational gains *indirect*, since they do not arise because the new decision maker aggregates more information, but is a by-product of delegation. Indeed, indirect informational gains arise because some agents are affected by *negative informational spillovers*—under centralization, a high-conflict dimension impedes communication in a dimension of low conflict of interest (Levy and Razin, 2007).[13] The proposition below defines both types of informational gains arising in this game, and characterizes the necessary conditions for each of them.

**Proposition 1.** *Consider the equilibrium under centralization, characterized by* $\mathbf{m}^*_{\mathrm{C}}$*; and the equilibrium in which the principal delegates* $y_1$ *to agent* $j'$ *and retains authority on* $y_2$*, characterized by* $\mathbf{m}^*_{j'}$ *and* $\mathbf{m}^*_{\mathrm{P}2}$*. Utility gains from delegation consist of:*

- ***Direct Informational Gains*** *if:*

$$DIG_{j'}(y_1) \equiv (w_{11})^2\big[\mathit{Var}(\theta_1|\mathbf{m}^*_{\mathrm{C}}) - \mathit{Var}(\theta_1|\mathbf{m}^*_{j'})\big] + (w_{12})^2\big[\mathit{Var}(\theta_2|\mathbf{m}^*_{\mathrm{C}}) - \mathit{Var}(\theta_2|\mathbf{m}^*_{j'})\big] \geq (b'_1)^2$$

  *Moreover, such direct informational gains require that there exists an agent* $i$ *whose preferences satisfy:*

$$|b^i_1 - b'_1| < \left|b^i_1 + b^i_2\,\frac{w_{21}}{w_{11}}\right| \tag{2}$$

- ***Indirect Informational Gains*** *if:*

$$IIG(y_2) \equiv (w_{21})^2\big[\mathit{Var}(\theta_1|\mathbf{m}^*_{\mathrm{C}}) - \mathit{Var}(\theta_1|\mathbf{m}^*_{\mathrm{P}2})\big] + (w_{22})^2\big[\mathit{Var}(\theta_2|\mathbf{m}^*_{\mathrm{C}}) - \mathit{Var}(\theta_2|\mathbf{m}^*_{\mathrm{P}2})\big] \geq 0$$

  *Moreover, such indirect informational gains require that there exists an agent* $i$ *whose preferences satisfy:*

$$|b^i_2| < \left|b^i_1\,\frac{w_{12}}{w_{22}} + b^i_2\right| \tag{3}$$

*Moreover, whenever the optimal allocation of decision rights involves delegation of* $y_1$ *to* $j'$*, then either* $DIG_{j'}(y_1) > b'_1$*, or* $IIG(y_2) > 0$*, or both.*

[13] Levy and Razin describe negative informational spillovers as the case when $i$'s bias with respect to $y_1$ is so large that he would not reveal any information under centralization, even though $|b^i_2|$ is very small.

*Proof.* See Appendix A □

Direct informational gains arise when more agents transmit information to the new decision maker under delegation than to the principal under centralization. Such gains arise only if $j'$ has more central preferences on $y_1$; that is, if there is at least one agent who is willing to reveal information to $j'$ but not to the principal under centralization. Equation (2) reflects this condition: it shows that the relevant conflict of interest between $i$ and $j'$ (left-hand side) is lower than that between $i$ and the principal under centralization (right-hand side).

Indirect informational gains arise when more agents transmit information to the principal upon delegation of one decision, as compared to centralization. For this to take place there must be at least one agent who reveals more information to the principal when she decides on $y_2$ only. Equation (3) shows that the conflict of interest with the principal under partial delegation must be lower than the aggregate conflict of interest. In this case, the bias on the first dimension is so large that communication under centralization is less informative than when the principal only decides on $y_2$. The presence of *negative informational spillovers* is then a necessary condition for indirect informational gains.

The optimal allocation of decision rights is fully characterized in Proposition A3. Full delegation is optimal when there are two different agents with central preferences and no informational spillovers associated with retaining authority. The allocation of decision rights depends then on the different communication equilibria induced by the profile of preferences. The previous discussion made clear that the argument reduces to whether the direct and/or indirect informational gains are sufficiently large, where sufficiency involves the loss of control from delegation.

**The role of informational spillovers on organizational design.** I now present the main result of this section: how the presence of informational spillovers leads to specific organizational structures. In the previous section I showed that the presence of negative informational spillovers is a necessary condition for indirect gains, which in turn leads to partial delegation. But informational spillovers are not limited to being negative in this context. Positive spillovers occur when $i$'s decision-specific biases are both large, but the aggregate conflict of interest (associated with the information he reveals in equilibrium) is small. When $i$ is expected to reveal information about $\theta_1$ only, for instance, his incentives are maximal when $b_1^i = -\frac{w_{12}}{w_{11}} b_2^i$. Intuitively, if there were many agents whose preferences are affected by positive spillovers, the principal would prefer centralization to any other organizational structure. The proposition below shows how informational spillovers affect the allocation of authority.

**Proposition 2.** *Let the triple* $(\mathbf{k}^{\mathrm{C}}, \mathbf{k}', \mathbf{k}'')$ *characterize the optimal organizational structure under the profile of biases* $\mathbf{B}^n = (\mathbf{b}^1, ..., \mathbf{b}^n)$*. Suppose that* $k_1' = k_2'$*,* $k_1'' = k_2''$*, and* $k_1^{\mathrm{C}} = k_2^{\mathrm{C}}$*. Now, consider the* *associated game consisting of $n+m$ agents, with the profile of biases for the first $n$ being $\mathbf{B}^n$, such that $\mathbf{B}^{n+m} = (\mathbf{b}^1, ..., \mathbf{b}^n, \mathbf{b}^{n+1}, ..., \mathbf{b}^{n+m})$. For a sufficiently large $\mathfrak{b} \in \Re_+$, it is true that:*

1. *For $\mathbf{b}^{n+1} = ... = \mathbf{b}^{n+m} = (\mathfrak{b}, 0)$; then, there exists a sufficiently large $m$ such that the optimal organizational structure in the game with $n+m$ agents is partial delegation of $y_1$ only.*

2. *For $\mathbf{b}^{n+1} = ... = \mathbf{b}^{\frac{2n+m+1}{2}} = (-\mathfrak{b}, \mathfrak{b})$ and $\mathbf{b}^{\frac{2n+m+1}{2}} = ... = \mathbf{b}^{n+m} = (\mathfrak{b}, \mathfrak{b})$; then, there exists a sufficiently large $m$ such that the optimal organizational structure in the game with $n+m$ agents is centralization.*

*Proof.* See Appendix A $\square$

If negative spillovers are sufficiently large with respect to one dimension, the principal's optimal organizational structure is partial delegation. If positive spillovers are sufficiently large, the principal's optimal organizational structure is centralization. Informational spillovers in Proposition 2 are captured by the preferences of the 'additional' agents, such that $m$ reflects the intensity of these spillovers.

Negative spillovers lead to partial delegation because the principal finds optimal to delegate the controversial decision in order to induce the additional agents to reveal the information they have. Positive spillovers, on the other hand, lead to centralization because the additional agents are willing to play dimensional non-separable strategies under centralization. Agents whose decision-specific biases have different signs fully reveal their signals when $\mathbf{S}^i = \{(0,0);(1,1)\}$ and announce the babbling message for the other possible realizations; while agents whose biases have the same sign fully reveal their signals when $\mathbf{S}^i = \{(0,1);(1,0)\}$ and announce the babbling message otherwise. In both cases, the additional information the principal expects to receive from the $m$ agents brings her a higher expected utility than the optimal allocation under the original profile of preferences.

Because the choice among organizational structure depends on the trade-off between informational gains and loss of control, in the following subsection I study it in more depth.

### 3.1 Relationship between informational gains and loss of control

Proposition 3 below characterizes the relationship between informational gains and loss of control under informational interdependence, when agents are imperfectly informed.

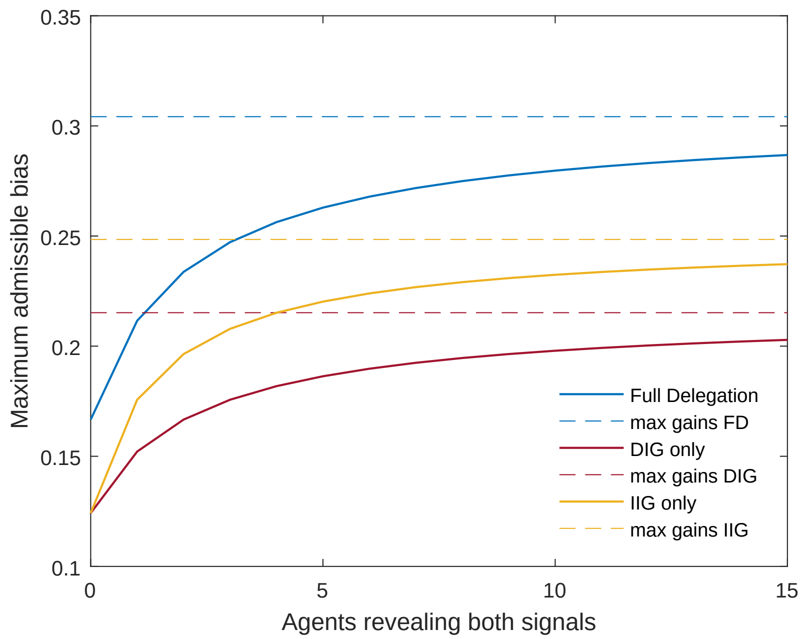
**Proposition 3** (Maximum Admissible Loss of Control)**.** *Let $\mathbf{b}^{\mathrm{D}} = (b_1', b_2'')$ be the biases of decision makers for $y_1$ and $y_2$, respectively. Then, the maximum $\mathbf{b}^{\mathrm{D}}$ for which the principal is willing to delegate* *at least one decision is given by:*

$$||\mathbf{b}^{\mathrm{D}}|| \equiv \left[\sum_{y_d}\left[w_{d1}^2\big(Var(\theta_1|\mathbf{m}_{\mathrm{C}}) - Var(\theta_1|\mathbf{m}_j)\big) + w_{d2}^2\big(Var(\theta_2|\mathbf{m}_{\mathrm{C}}) - Var(\theta_2|\mathbf{m}_j)\big)\right]\right]^{\frac{1}{2}}$$

*Proof.* See Appendix A □

There is a positive relationship between informational gains from delegation and loss of control. The expression $||\mathbf{b}^{\mathrm{D}}||$ represents the relevant measure for the loss of control: how far are both decisions from the principal's (state-dependent) ideal. Under partial delegation, one of the components of $||\mathbf{b}^{\mathrm{D}}||$ is zero, which marks the maximum bias the principal tolerates in a single decision.

Figure 2: Admissible loss of control as a function of informational gains




**Note:** $w_{11} = w_{22} = \frac{2}{3}$, $k_1^{\mathrm{C}} = k_2^{\mathrm{C}} = 0$

Figure 2 illustrates the relationship between informational gains and loss of control. It shows the maximum $||\mathbf{b}^{\mathrm{D}}||$ the principal tolerates as a function of the number of agents revealing both signals, in three cases.[14] First, when she delegates both decisions to different agents (in blue). Minimum informational gains in this case mean each decision maker decides with his own signals, but no other agent reveals any additional information. The concavity of the curve represents the decreasing marginal utility of additional information, which comes from quadratic preferences and the updating process.[15]

[14]To make the comparison clear, I assume $k_1^{\mathrm{C}} = k_2^{\mathrm{C}} = 0$.

[15]The marginal influence of an additional signal on the associated posterior belief is decreasing (see Morgan and

Maximum informational gains are represented with the dashed line, showing the maximum bias the principal tolerates when she expects each decision maker *to become perfectly informed in equilibrium.* Second, the red lines show the relationship for direct informational gains only, assuming the principal retains authority on one decision and does not receive any information from agents. Minimum informational gains thus mean the agent decides with his own information and the principal decides with no information. Hence, the maximum bias the principal tolerates is lower than the full delegation case, which holds for all possible informational gains. The same intuition applies for the maximum bias the principal tolerates (dashed line). Finally, the yellow lines show the relationship when informational gains are indirect—partial delegation results in more information being received by the principal. For the delegated decision, the agent observes his own signals, which explains in part why the principal tolerates a higher bias than for direct informational gains. Because of the quadratic preferences, this additional information has a high marginal return for the principal.

The intuitions just described assume constant information under centralization ($k_1^{\text{C}} = k_2^{\text{C}}$). I now show how the information the principal expects to receive under centralization affects the loss of control she is willing to tolerate. In summary, the principal's marginal expected utility from an additional signal is decreasing in the amount of information she expects to receive under centralization.

**Corollary 1.** *The 'marginal value' of a signal for the principal is decreasing in the amount of information she receives under centralization. Let* $\Delta\, Var(\theta_r|k_r^{\text{C}}) = Var(\theta_r|\mathbf{m}_{\text{C}}) - Var(\theta_r|\mathbf{m}_j, k_r^j = k_r^{\text{C}} + 1)$.

$$\frac{\partial \Delta\, Var(\theta_r|k_r^{\text{C}})}{\partial k_r^{\text{C}}} = \frac{1}{6}\left[\frac{1}{(k_r^{\text{C}}+3)^2} - \frac{1}{(k_r^{\text{C}}+2)^2}\right] < 0 \tag{4}$$

Equation (4) means that an additional signal represents a smaller informational gain when the principal expects to be well informed under centralization. The maximum bias she is willing to tolerate thus decreases as the profile of biases allows more agents to truthfully reveal information under centralization. The result extends Corollary 1 in Dessein (2002) to the case of imperfectly informed senders.[16]

# 4 Endogenous Information Acquisition

In this section I analyse agents' incentives to acquire information before the communication stage, but after decision-rights have been allocated. I first present the extended model. Next, I derive the

Stocken, 2008; Galeotti et al., 2013).

[16]Dessein finds that incentives to delegate depend on the magnitude of the residual variance. His paper features a single, perfectly informed sender who advises the principal on a one decision problem. He analyses incentives for delegation as a function of the ex-ante variance associated with the state, against the babbling equilibrium. The residual variance here depends on the amount of information received by the principal under centralization.

two incentive compatibility constraints involved in information acquisition decisions and show how costs impose restrictions on informational gains from delegation. I then characterize the equilibrium strategies for a generic agent, showing the cases in which he decides to specialize. Finally, I analyse how interdependence affects incentives to acquire information under different organizational structures.

**Baseline model with endogenous information acquisition.** Agents have access to imperfect information about each state. In particular, each agent has access to one binary trial per state and decides which realizations to observe (if any).[17] Formally, let $\mathfrak{s}^i \in \{\{\emptyset\}, \{\tilde{S}_1\}, \{\tilde{S}_2\}, \{\tilde{S}_1, \tilde{S}_2\}\}$ be agent $i$'s information acquisition decision. With this formulation, $i$'s type is given by the realizations of both signals but he decides the extent to which he observes his type.

**Definition 2.** *The information structure for agent $i$ in the game with endogenous information acquisition consists of the following elements: $\mathbf{S}^i = (S_1^i, S_2^i)$ are the signals available to him, $\tilde{\mathbf{S}}^i = (\tilde{S}_1^i, \tilde{S}_2^i)$ the realization of the corresponding signals (his type), and $\mathfrak{s}^i \in \{\{\emptyset\}, \{\tilde{S}_1\}, \{\tilde{S}_2\}, \{\tilde{S}_1, \tilde{S}_2\}\}$ the information he actually decides to observe.*

The costs of different information structures are captured by the function $C(\mathfrak{s})$, which satisfies $C\left(\{\tilde{S}_1, \tilde{S}_2\}\right) > C\left(\{\tilde{S}_1\}\right) = C\left(\{\tilde{S}_2\}\right) > C(\emptyset) = 0$. The principal has no direct access to information. The preferences of agent $i = \{1, \dots, n\}$ are given by:[18]

$$U^i(\boldsymbol{\theta}, \mathbf{x}, \mathbf{b}^i, \mathfrak{s}^i) = -\sum_{y_d=\{y_1,y_2\}} \left(y_d - \delta_d(\theta_1, \theta_2) - b_d^i\right)^2 - C(\mathfrak{s}^i)$$

Figure 3 shows the timing of the game. The allocation of decision rights is observed by all agents. Knowing who decides what, each agent chooses the information he will observe (if any). I assume *overt information acquisition*—individual decisions (but not information) are observable. In Section 5 I discuss the implications of relaxing this assumption.

The communication stage is similar to the previous section, so I keep the notation. Let $i$ be a generic agent and $j$ a generic decision maker, let $j', j'' \in \{P, 1, ..., n\}$ be the decision makers for $y_1$ and $y_2$, respectively, such that $i = \{1, ...n\}$ and $j = \{j', j''\}$. Let $k_r^j \equiv k_r^*(\mathbf{m}_j^*(\mathfrak{s}^*))$ be the number of truthful messages decision maker $j$ receives in equilibrium, and $k_r' \equiv k_r^*(j')$ and $k_r'' \equiv k_r^*(j'')$ refer to the number of truthful messages to decision makers $j'$ and $j''$ (respectively).

An equilibrium in this game is then characterized by the decision vector, $\mathbf{y}_d^*$, and collections of messagse and information acquisition strategies for each agent and decision maker $j$, $\mathbf{m}_j^* = \{\dots, \mathbf{m}_j^{i*}, \dots\}$

[17] In principle, agents could have the choice on how much information about each state to observe, involving information acquisition at the intensive and the extensive margins. Here, however, I focus on the extensive margin, meaning that each agent decides whether to observe at most one binary signal per state. In section 5, I discuss some implications of allowing agents to acquire information on the intensive margin.

[18] The principal's preferences are captured by $U^P(\boldsymbol{\theta}, \mathbf{x}) = -\left(y_1 - \delta_1(\theta_1, \theta_2)\right)^2 - \left(y_2 - \delta_2(\theta_1, \theta_2)\right)^2$.

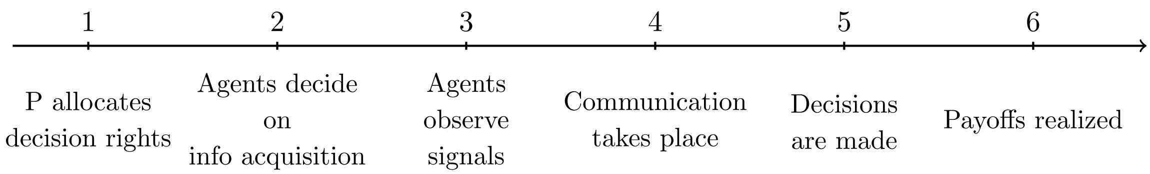



Figure 3: Timing of the Org. Structure / Info Acquisition game.

and $\mathfrak{s}^* = \{\ldots, \mathfrak{s}^{i*}, \ldots\}$. The expressions for optimal actions and messages are similar to those of the previous section, noting that $k_r^*(\mathbf{m}^*(\mathfrak{s}^*))$, $y_d^*(\mathbf{m}_j^*(\mathfrak{s}^*))$, and $\mathbf{m}_j^{*i}\left(\mathfrak{s}^i, \mathbf{m}^{-i}(\mathfrak{s}^{-i})\right)$. Agent $i$'s information acquisition strategy is given by:

$$\mathfrak{s}^{i*} = \arg\max_{\mathfrak{s}^i} \left\{ E\Big[ -\left(y_1\left(\mathbf{m}_{j'}^i(\mathfrak{s}^i), \mathbf{m}_{j'}^{-i}\right) - \delta_1 - b_1^i\right)^2 - \left(y_2\left(\mathbf{m}_{j''}^i(\mathfrak{s}^i), \mathbf{m}_{j''}^{-i}\right) - \delta_2 - b_2^i\right)^2 \Big] - C(\mathfrak{s}^i) \right\}$$

The expectation is based on equilibrium beliefs. Agent $i$'s equilibrium message strategy depends on the information he acquired in an earlier stage of the game and his conjecture about other agents' message strategies. Information acquisition are observable at the communication stage, which simplifies the beliefs space. The signals $i$ acquired thus affect his communication strategy. When he acquires information about both states, the IC constraints for communication are the same as in the previous section. When he acquires information about one state, however, the IC constraints change significantly because his incentives to reveal information are not affected by beliefs about the other state. This kills the credibility loss and truthful communication is incentive compatible for a larger set of bias vectors. Now, let me focus on the details of these arguments.

**Incentives to acquire information.** For an agent to acquire a piece of information the expected utility gains must compensate its costs. First, costly information acquisition means that each agent will invest in a signal only if he expects to benefit from it. In equilibrium $i$ only acquires signals he is willing to reveal; if he fails to reveal any piece of information (off path), no other agent will change his equilibrium message strategy.[19] The number of truthful messages does not change when $i$ acquires a signal he does not reveal, but he still bears the costs. The lemma below formalizes this intuition—incentive compatibility at the information acquisition stage requires incentive compatibility at the communication stage.

**Lemma 1.** *Let $(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$ be equilibrium strategy profiles for the principal and all agents. The equilibrium is characterized by the number of truthful messages decision makers receive, $k_1^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$ and*

[19]Formally, $i$'s incentives for communication depend on having acquired the signal, $\mathbf{b}^i$, and on his conjecture about $k_1^j$ and $k_2^j$. Then, for $i$ acquiring $S_r^i$ *off-path* to change another agent $h$'s conjecture about $k_r^j$, $b^i$ should be such that he is willing to reveal that signal. In such a case, $h$ (off-path) conjecture for $k_r^j$ should be larger than the equilibrium value, but then $i$ would be willing to reveal $S_r^i$ in equilibrium and would have acquired it.

$k_2^j\left(\mathbf{m}_j^*(\mathfrak{s}^{i*})\right)$, *for* $j=\{j',j''\}$. *Then, agent* $i$ *equilibrium information acquisition strategy,* $\mathfrak{s}^{i*}$*, satisfies:*

- $S_r \in \mathfrak{s}^{i*}$ *only if truthful revelation to* $j$ *is incentive compatible, given* $k_r^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$;
- $\{S_1, S_2\} \in \mathfrak{s}^{i*}$ *only if full revelation to* $j$ *is incentive compatible, given* $k_1^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$ *and* $k_2^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$.

*Proof.* See Appendix A. □

The main implication of Lemma 1 is that the choice of organizational structure will affect agents' incentives for information acquisition, because it determines the relevant IC constraints at the communication stage. Incentives to acquire information depend on the possibility of being influential. But credibility hinges on both the conflict of interest and the number of other agents expected to reveal similar information on path. Agents thus acquire information they expect to reveal on the equilibrium path, given the allocation of decision rights. The conclusion is similar to Di Pei (2015): information structures available to agents and the cost function satisfy assumptions 1 and 2 of his paper ("Richness" and "Monotonicity"). Both seem rather natural assumptions in my framework; for a given information structure a 'coarser' alternative means investing in less signals, which will also be cheaper than the original choice.

The second element of incentive compatibility of information acquisition relates to its costs. Utility gains from revealing any piece of information are decreasing in the number of other agents revealing the same information ($k_r^j$). Given costs are strictly positive, there is a maximum number of agents for whom the utility gains of revealing that piece of information compensate the costs. The following lemma presents the *cost-effectiveness* condition, which captures this idea.

**Lemma 2.** *Let* $k_r^j$ *denote* $i$*'s conjecture about other agents revealing* $S_r$ *truthfully to* $j$.

**Centralization:** *acquiring signal* $S_r^i$ *is cost-effective for* $i$ *under centralization if:*

$$C(S_r^i) \leq \frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^{\mathrm{C}}+2)(k_r^{\mathrm{C}}+3)} \tag{5}$$

**Delegation:** *acquiring signal* $S_r^i$ *is incentive compatible for agent* $i$ *if for at least one decision,* $y_d$*, with the corresponding decision maker* $j$ *is true that:*

$$C(S_r^i) \leq \frac{(w_{dr})^2}{6(k_r^j+2)(k_r^j+3)} \tag{6}$$

*Proof.* See Appendix A. □

The right-hand sides in equations (5) and (6) represent the ex-ante expected utility gains from revealing one signals under centralization and delegation, respectively. An agent acquires a signal if its expected influence on decision(s) is sufficiently large. The influence of revealing a signal depends on how many other agents are expected to reveal the same information, which in turn depends on the organizational structure. Under centralization, revealing a given signal influences both decisions, which is reflected in the numerator of equation (5). Under delegation, the influence depends on whether $i$ reveals the signal to one or both decision makers. The ex-ante expected utility gains of acquiring (and revealing) a given signal are thus weakly lower under delegation.

Dimensional non-separable message strategies face a more restrictive cost-effectiveness condition because $i$ expects to reveal information for half of the possible signal realizations. The costs of acquiring both signals must then be sufficiently low for such a strategy to be cost-effective. The latter does not hold if revealing one signal is also incentive compatible for $i$, in which case the most-informative equilibrium consists of acquiring and revealing information about one state.

Because the expected influence of truthful revelation is decreasing in the number of other agents revealing the same information, there exists a maximum number of agents for whom cost-effectiveness holds with respect to any signal.

**Corollary 2.** *The maximum number of agents acquiring $S_r$ in any equilibrium under centralization is given by:*

$$K_r^{\mathrm{C}} = \left\lfloor \left[\frac{1}{4} + \frac{[(w_{1r})^2 + (w_{2r})^2]}{6\,C(S_r^i)}\right]^{1/2} - \frac{5}{2} \right\rfloor + 1 \tag{7}$$

*And under delegation, the maximum number of agents acquiring $S_r$ in any equilibrium is:*

$$K_r^{\mathrm{D}} \in \left[ \left\lfloor \left[\frac{1}{4} + \frac{(\hat{w}_{dr})^2}{6\,C(S_r)}\right]^{1/2} - \frac{5}{2} \right\rfloor + 1\,;\, K_r^{\mathrm{C}} \right] \tag{8}$$

*Where* $\hat{w}_{dr} \equiv \min\{w_{1r}, w_{2r}\}$

Expressions (7) and (8) represent the maximum number of agents, other than $i$, for whom investing in a signal is cost-effective under centralization ($K_r^{\mathrm{C}}$) and delegation ($K_r^{\mathrm{D}}$), respectively. These numbers depend on whether revealing information influences both decision or only one of them. Note that under centralization any influential agent affects both decisions; while, under delegation, the same is true only for agents revealing information to both decision makers. Typically, however, many agents under delegation will reveal information to one decision maker, which would make $K_r^{\mathrm{C}} > K_r^{\mathrm{D}}$.

I now discuss the equilibrium information acquisition and message strategies and how they are affected by the allocation of decision rights. I also present the analysis on specialization.

### Equilibrium information acquisition and specialization

Equilibrium information acquisition strategies depend on the organizational structure and the cost of information. Cost-effectiveness imposes restrictions in addition to incentive compatibility at the communication stage, which can lead agents to underinvest in information—relative to what they would be willing to reveal. In the following paragraphs, I analyse how this leads to specialization, here defined as the case in which an agent decides to acquire information about one state only.

**Specialization.** Individual decisions on information acquisition are equivalent to choosing between message strategies given other agents' equilibrium behaviour. In particular, when agent $i$ acquires information about one state only, his incentives for communication do not depend on information about the other state (because he does not observe any). This eliminates the credibility loss due to ambiguous information, thus enlarging the set of biases for which revealing that signal is incentive compatible. The proposition below shows the result.

**Proposition 4.** *Let $\mathbf{k}^j = \{k_1^j, k_2^j\}$, where $k_r^j = k_r^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$ be $i$'s conjecture about other agents revealing their information about $\theta_r = \{\theta_1, \theta_2\}$ to decision maker $j = \{P, 1, ..., n\}$. There exists a set of bias vectors, $\mathfrak{B}_r^j = \mathfrak{B}_r^j(\mathbf{b}^j, \mathbf{k}^j)$, such that if $\mathbf{b}^i \in \mathfrak{B}_r^j$, then revealing information about $\theta_r$ only is incentive compatible when $\mathfrak{s}^i = \{\tilde{S}_r^i\}$, but is not incentive compatible when $\mathfrak{s}^i = \{\tilde{S}_1^i, \tilde{S}_2^i\}$. Moreover, the set $\mathfrak{B}_r^j$ depends on the organizational structure.*

*Proof.* See Appendix A ☐

Acquiring information about one state eliminates the possibility of ambiguous information. Hence, agent $i$ is not tempted to lie when information about the other state is more favourable: revealing information about that state is thus incentive compatible for a larger set of biases. In other words, *specialization* acts as a commitment device because the agent does not know when an unfavourable signal produces an excessive update against his preferences.

Proposition 4 also implies that, for a given set of biases, the principal prefers that agent $i$ specializes, even when he has free access to information.

**Corollary 3.** *Let $C(S_1^i) = C(S_2^i) = 0$. If agent $i$'s preferences satisfy:*

$$|\beta_1^i| \in \left( \frac{(w_{11})^2 + (w_{21})^2}{2} \left[ \frac{1}{(k_1^{\mathrm{C}} + 3)} - \frac{C_1}{(k_2^{\mathrm{C}} + 3)} \right] \; ; \; \frac{(w_{11})^2 + (w_{21})^2}{2\,(k_1^{\mathrm{C}} + 3)} \right]$$

*Then, in the most informative equilibrium under centralization he acquires and truthfully reveals information about $\theta_1$ only.*

The principal prefers a less informed agent because it guarantees he will not be tempted to manipulate information. Note that the two results above hinge on the assumption that information acquisition decisions are observable. In Section 5, I discuss the implications of relaxing it and show that specialization still increases credibility when the cost of information is not too low. These results have implications for how firms organize subunits' access to information, since increasing the cost of some types of information may improve the quality of communication.

I now analyse the different conditions that induce an agent to specialize, in an example with two agents. Let assume $w_{11} = w_{22} = w > \frac{1}{2}$ and $C(\mathfrak{s}^i) = c \times (\# \mathfrak{s}^i)$, and let denote the agents by $A^1$ and $A^2$. I focus on the centralization equilibrium in which $A^1$ acquires information about $\theta_1$ and $A^2$ acquires information about $\theta_2$, $\mathfrak{s}^{1*} = \{\tilde{S}^1_1\}$ and $\mathfrak{s}^{2*} = \{\tilde{S}^2_2\}$. In the equilibrium under consideration, the principal is (ex-post) more informed than each of the agents since $k^*_1 = 1$ and $k^*_2 = 1$.[20] The Proposition below formalizes the result and panel (a) in Figure 4 illustrates the set of biases for which $\mathfrak{s}^{1*} = \{\tilde{S}^1_1\}$ under centralization.

**Proposition 5** (Specialization under centralization)**.** *Suppose that there are only two agents, $A^1$ and $A^2$, and the marginal cost of each signal is linear and equal to $c$. There exist two cost thresholds, $\underline{c} < \bar{c}$, such that the most-informative equilibrium under centralization, $(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$, consists in $A^1$ acquiring and revealing information on $\theta_1$ only, and $A^2$ acquiring and revealing information about $\theta_2$ only, in the following cases:*[21]

1. *For $c \leq \underline{c}$, if and only if revealing $S^1_1$ is IC for $A^1$, revealing $S^2_2$ is IC for $A^2$, and revealing both signals is not IC for any of them; or*

2. *For $\underline{c} < c \leq \bar{c}$, if and only if revealing $S^1_1$ is IC for $A^1$ and revealing $S^2_2$ is IC for $A^2$.*

*Where* $\underline{c} = \frac{w^2+(1-w)^2}{72}$ *and* $\bar{c} = \frac{w^2+(1-w)^2}{36}$.

*Proof.* See Appendix B □

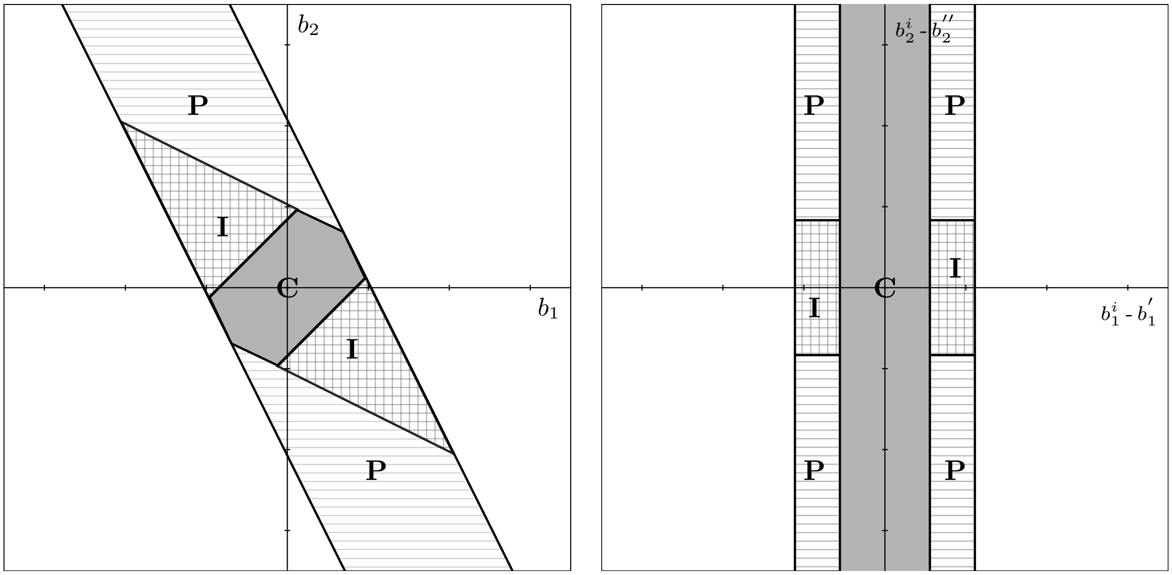
When the cost of a signal is close to zero, information acquisition does not impose restrictions on communication. Agents will then acquire any information they are willing to reveal and, thus, they specialize on different signals only if these are the only IC message strategies. The stripped region in panel (a) of Figure 4 shows specialization *driven by preferences.*

The cross-hatched region in panel (a) represents the set of biases for which $A^1$ is willing to reveal information about any state if he only observes the associate signal, but this does not hold if he observes

[20] The paper by Alonso et al. (2015) analyses a similar situation in the form of generalist-specialist information structure, where each agent specializes in a different piece of information and fully transmits it to the principal.

[21] Formally, the equilibrium consists in $\mathfrak{s}^{1*} = \{\tilde{S}^1_1\}$ and $m^{1*} = \big\{\{(0,0),(0,1)\},\{(1,0),(1,1)\}\big\}$ for $A^1$, and $\mathfrak{s}^{2*} = \{\tilde{S}^2_2\}$ and $m^{2*} = \big\{\{(0,0),(1,0)\},\{(0,1),(1,1)\}\big\}$ for $A^2$.

Figure 4: Specialization in the 2-agents model — Driven by preferences (**P**), influence (**I**), and costs (**C**).




(a) $A^1$ specializes on $\theta_1$ – Centralization (b) $A^1$ specializes on $\theta_1$ – Delegation

**Notes:** $w = \frac{2}{3}$ and $k_1^* = k_2^* = 1$

information about both states. In the equlibrium under considerantion, he expects $A^2$ to acquire and reveal information about $\theta_2$, such that the expected utility gains is larger when he specializes on $\theta_1$. This specialization decision is *driven by expected larger influence* on the principal's beliefs, given the equilibrium strategy of the other agent.[22]

Now suppose preferences of $A^1$ are such that he is willing to reveal both signals under centralization. Specialization only emerges if acquiring such information is too costly. Whether he acquires information about $\theta_1$ or $\theta_2$ depends on what $A^2$ is expected to do: $A^1$ acquires information about the state the principal is expected to be less informed on path. The solid gray region in panel (a) illustrates the case of specialization *driven by costs*.

Specialization under delegation follows the same intuitions. I describe them using Panel (b) in Figure 4. Recall that information about $\theta_1$ affects $y_1$ more than $y_2$. Therefore, $A^1$ specializes on $\theta_1$ when his preferences on the first dimension are sufficiently close to $j'$. Indeed, whenever his preferences are close to the decision maker of the second dimension, $A^1$ prefers to acquire information about $\theta_2$. The intuitions for the different drivers of specialization—preferences, influence, and costs— are the

[22] An alternative equilibrium exists when both agents' bias vectors lie on cross-hatched regions. The strategies $\mathfrak{s}^{1*} = \{\tilde{S}_2^1\}$ and $\mathfrak{s}^{2*} = \{\tilde{S}_1^2\}$ can also be sustained; agents thus face a coordination problem for which there is no clear selection criterion—the principal is ex-ante (and ex-post) indifferent between any of these. Both equilibria involve specialization mainly because no agent is willing to reveal both signals.

same as for centralization, and are illustrated in the different regions of panel (b).

In the following section, I analyse the effects of different organizational structures on incentives to acquire information.

## 4.1 Organizational Design on Incentives to Acquire Information

The optimal organizational structure depends on both the profile of biases and the cost of information. In the previous section I showed that an agent acquires a signal if the expected utility gains from revealing it compensate its cost. If information costs are small, the principal can materialize the informational gains from delegation studied in Section 3. For sufficiently large costs, however, centralization is always optimal, since at the limit no agent can aquire any signal.

In this section, I study how the allocation of decision rights affects incentives to acquire information when the exact profile of biases is not known by the principal. Abstracting from the precise profile of biases circumvents the fact that information acquisition depends on how many other agents are willing to reveal each piece of information. In other words, for sufficiently small costs, there always exists a profile of biases for which delegation outperforms centralization in terms of information acquisition. This conclusion, however, stems from the analysis in section 3 more than from new insights on the effects of organizational structure on investment. From an empirical perspective, the analysis captures the idea that institutions may have persistent informational effects on outcomes. In policy-making, for instance, the allocation of authority over a set of issues to a governmental agency effectively grants policy influence to interest groups linked to it (Baumgartner and Jones, 2009). Part of that influence is about 'feeding' the agency with information likely to be more favourable to the groups' preferences. Hence, the policy becomes too responsive to these issues but insensitive to other issues it should be taking into account.

I first analyse whether delegation affects the *expected absolute investment in information*, by focusing on the maximum number of agents for whom acquiring a signal is cost-effective. Second, I analyse whether delegation affects the *expected relative investment in information*, by assuming the bias vectors are randomly allocated within a fixed conflict of interest with the principal.

**Absolute Investment in Information** When information is costly for agents, there is a limit on the informational gains the principal can obtain from delegation (Corollary 2). Through this channel, costs affect the ability of different organizational structures to aggregate information. The following result shows that information costs impose stronger restrictions on delegation than centralization.

**Proposition 6.** *Let $\kappa$ be the maximum number of agents willing to reveal information about $\theta_r = \{\theta_1, \theta_2\}$ to both decision makers under delegation. Then, for every $\kappa < n$, there exist costs for which* *the maximum number of agents willing to acquire (and reveal) information about $\theta_r$ is strictly lower under delegation than under centralization. Formally,*

$$C(S_r) \in \left( \frac{(\hat{w}_{dr})^2}{6(\kappa+2)(\kappa+3)}, \frac{(w_{1r})^2 + (w_{2r})^2}{6(\kappa+3)(\kappa+4)} \right] \;\Rightarrow\; K_r^{\mathrm{C}} > K_r^{\mathrm{D}}$$

*Where* $\hat{w}_{dr} = \max\{w_{1r}, w_{2r}\}$.

*Proof.* See Appendix A. □

When information is costly, the maximum informational gains under delegation are weakly lower than under centralization. Under delegation, there can be agents who reveal information to one decision maker only, unless there is an agent whose preferences are central in both dimensions (and these are not too far from the principal's preferences). Under centralization, on the contrary, any information transmitted affects both decisions, and agents willing to reveal any signal have larger overall influence. The expected utility gains for such agents are thus larger under centralization and there will typically be more of them willing to invest in information.

Proposition 6 does not mean that centralization is always optimal. For a non-empty set of cost values, there exist profiles of biases, $\mathbf{b}$, for which delegation of some sort is preferred to centralization ($K_r^{\mathrm{C}} > K_r^{\mathrm{D}}$ is not binding). But for sufficiently large costs, centralization always dominates (see Corollary A1 in Appendix A). This is the case when the cost of each signal is so high that no agent acquires information under delegation.

In addition, Proposition 6 relates to the relationship between loss of control and informational gains in Proposition 3. In the previous section we learned that $||\mathbf{b}^{\mathrm{D}}||$ is increasing in the informational gains from delegation. In the present section I showed that information costs impose limits on informational gains; now I will show how $||\mathbf{b}^{\mathrm{D}}||$ is affected by costs. The maximum bias as a function of $K^{\mathrm{D}}$ (maximum informational gains) is given by:

$$||\mathbf{b}^{\mathrm{D}}|| = \left[ \frac{[w^2 + (1-w)^2]}{6} \left[ 1 - \frac{2}{(K^{\mathrm{D}}+2)} \right] \right]^{\frac{1}{2}}$$

Which together with equation (8) in Corollary 2 leads to the following result.

**Corollary 4.** *The effect of information costs on $||\mathbf{b}^{\mathrm{D}}||$ is given by:*

$$\frac{\partial ||\mathbf{b}^{\mathrm{D}}||}{\partial C(S_r)} < 0$$

The maximum admissible bias the principal tolerates decreases as the cost of information increases. Increasing costs reduces the number of agents willing to acquire any signal, decreasing the informational gains that can be achieved through delegation. This is relevant when information costs are large and the principal is not sure about the exact profile of biases at the moment of allocating decision rights. In such a case, she can expect the benefits from delegation to be low relative to centralization. This relationship between the information costs and distributional loss could be related to information acquisition on the intensive margin—the higher the costs, the lower the amount of information a single agent is expected to acquire and, thus, the lower his 'informational advantage' with respect to the principal. I explore this intuition in Section 5.

**Relative Investment in Information** I now analyse whether the allocation of decision rights affects the relative investment in information—the amount of information about each state decision makers are expected to receive. In order to isolate the mechanism, I make two assumptions. First, I assume the principal does not observe the exact distribution of biases when deciding on the allocation of decision rights. As in the previous analysis, this assumption allows me to abstract from the influence of the specific profile of biases. Second, I assume zero cost of information, which eliminates the influence of the costs on incentives to acquire information.

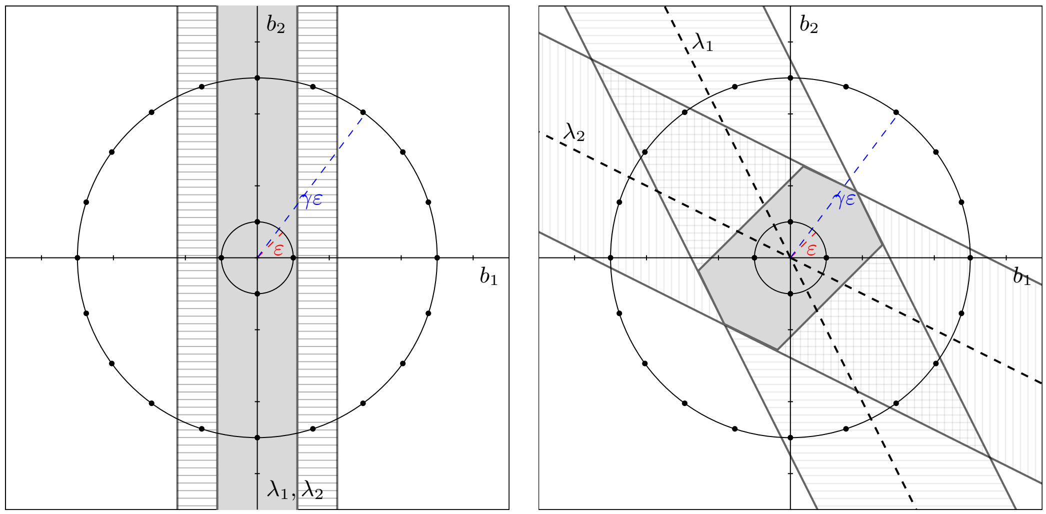
Consider the case of delegation. Agent $i$'s incentives for communication with decision maker $j'$, in charge of $y_1$, are maximal when the conflict of interest is zero, that is $b_1^i - b_1' = 0$. More generally, any conflict of interest between $i$ and $j$ can be expressed as the 'horizontal distance' between $\mathbf{b}^i$ and $\mathbf{b}^j$. Communication of a given piece of information is then incentive compatible for $i$ if this distance is small enough or, equivalently, the distance between $\mathbf{b}^i$ and the 'maximal incentives for communication' is small enough. In appendix A, I show this distance can be expressed as the projection of $\mathbf{b}^i$ onto the line that represents the maximal incentives for communication when $j'$ decides on $y_1$.

Because $\theta_1$ is more important for $y_1$ than $\theta_2$, $j'$ expects to receive more information about the former than about the latter (Lemma A4) In other words, under delegation, each decision maker expects to receive proportionally more information about the state that is more important for the decision he controls. This can be seen in Panel (a) of Figure 5, for fixed conflict of interests $\varepsilon$ and $\gamma\,\varepsilon$, and where the maximal incentives to reveal information about $\theta_1$ ($\theta_2$) are denoted by $\lambda_1$ ($\lambda_2$).

Now, consider the case of centralization. As in the case of delegation, the conflict of interest between $i$ and the principal can be measured as the distance between $\mathbf{b}^i$ and the 'maximal incentives' for communication. Here, however, the maximal incentives for communication with the principal depend on the information $i$ is expected to reveal. For instance, when expected to reveal information about $\theta_1$ only, $i$'s communication incentives are maximal when $\beta_1^i = w_{11}b_1^i + w_{12}b_2^i = 0$. Because there are different measures of 'maximal incentives', for a fixed conflict of interest, there are always agents willing to reveal information about $\theta_1$ *and* $\theta_2$. This is shown in panel (b) of Figure 5 by the two lines

$\lambda_1$ and $\lambda_2$, which represent the maximal incentives to reveal information about $\theta_1$ and $\theta_2$, respectively. The difference between $\lambda_1$ and $\lambda_2$ implies that for any agent $i$ who is willing to truthfully reveal $S_1^i$ on path, there exista an agent $h$ who is willing to reveal $S_2^h$ on path (Lemma A5).

Figure 5: Information transmission under different organizational structures




(a) Delegation of $y_2$ (b) Centralization

Full Revelation; $S_1$ only; $S_2$ only; Babbling; $(0,0)$ and $(1,1)$ only; $(0,1)$ and $(1,0)$ only

**Note:** $w_{11} = w_{22} = \frac{2}{3}$

In Section 3 I showed that negative informational spillovers can provide a just foundation for partial delegation. This argument requires that the principal knows the profile of biases of informed agents, $\mathbf{B}$. When she does not observe $\mathbf{B}$, however, delegation may lead to losing control over payoff-relevant information, well beyond the distributional loss. In particular, each decision maker under delegation is expected to receive more information on the more relevant state, becoming an *ex-post specialist*. I formalize this argument in the proposition below.

**Proposition 7.** *Let $w_{11} = w_{22} = w$. For a sufficiently large number of agents, $n$; for any conflict of interest $\varepsilon \in \Re_+$, such that the profile of biases, $\mathbf{B} = \{\mathbf{b}^1, ..., \mathbf{b}^n\}$, is uniformly distributed between $[0, \varepsilon]$ for agents $i = \{1, .., n\}$; for any integer $\kappa$. Then, the principal expects to receive more balanced information under centralization than when she delegates any decision to agent $j$; that is,*

$$|E\left[Var(\theta_1|\mathbf{m}_C^*)\right] - E\left[Var(\theta_2|\mathbf{m}_C^*)\right]| < \left|E\left[Var(\theta_1|\mathbf{m}_j^*)\right] - E\left[Var(\theta_2|\mathbf{m}_j^*)\right]\right|$$

*Proof.* See Appendix A $\square$

Because of informational interdependence, the influence of revealing any signal is larger under centralization. When a principal delegates a decision, this influence decreases and, also, varies depending on the dimension in which communication is expected to take place. For instance, the decision maker of $y_1$ expects to receive more information about $\theta_1$ because expect to have a higher influence by revealing the associated signal. This leads to decision makers being *ex-post* specialized on the issues that are more relevant for a decision. Proposition 7 shows this specialization in the form of higher expected precision of beliefs about the most important state for each decision.

Ex-post specialization of decision makers under delegation is not in itself an undesired outcome. The increased precision associated with the most important state could, in principle, compensate for the lower precision of the other. Proposition 6, however, shows that the opposite happens: the expected absolute investment in information is (weakly) lower under delegation. These two results highlight an important limitation of delegation that goes beyond the distributional loss: the negative effects on incentives to acquire information. Hence, organizational design that aims at providing incentives to invest in information must consider the negative 'long run' informational consequences of delegation.

# 5 Discussion and Conclusion

In this section I extend the model with endogenous information acquisition in two directions. First, I relax the assumption of overt information acquisition, showing that results are robust. Second, I discuss the possibility that agents observe more than one binary signal per state, offering some insights on how to approach the problem.

### Covert Information Acquisition

Suppose information acquisition decisions are private information of each agent. I focus on the centralization case, restricting the analysis to pure strategies at the information acquisition and communication stages. It can be shown that focusing on equilibria in which messages do not convey information about the acquisition decision is without loss (Lemma C6).[23] As a result, messages sent at the communication stage do not convey information about decisions on information acquisition. Also, any deviation at the information acquisition stage results in a deviation (from truth-telling) at the communication stage (see Lemma C7).

In the appendix I derive the IC constraints for a typical agent $i$ in the covert information acquisition game. There are two relevant deviations: acquiring fewer or more signals than on the equilibrium path. First, when agent $i$ deviates by *acquiring fewer signals* than on path, he saves on information costs

[23] Also, see Lemma 3 in Argenziano et al., 2016.

but he induces lower-than-optimal precision on beliefs. Suppose $i$ is expected to acquire information about both states on path; if, instead, he decides to acquire information about $\theta_1$ only, his message corresponding to $\theta_2$ will induce wrong beliefs for half of its possible realizations. Because his message strategy off-path consists of announcing the most favourable of the possible realizations of $S_2^i$, the deviation is equivalent to lying on this signal. Incentive compatibility, hence, requires that these utility gains—lying towards his bias *plus* saving on information costs— are lower than the expected utility losses from inducing a higher expected variance.[24] Incentive compatibility constraints in the covert game are thus more restrictive than in the overt game.

The second deviation consists of *acquiring more signals* than on path. When $i$ is expected to acquire and reveal information about $\theta_1$, he can profitably deviate by also acquiring information about $\theta_2$. But $i$ cannot transmit information about $\theta_2$ on path. Hence, the expected utility gains have to do with ambiguous information. This means he lies about $\theta_1$ when his information is unfavourable and that about $\theta_2$ is favourable. If information costs are sufficiently low, $i$ cannot commit himself to acquiring information about $\theta_1$ only. The result below shows when he *can* commit.

**Proposition 8.** *Let $(\mathfrak{s}^*, \mathbf{m}^*, \mathbf{y}^*)$ characterize an equilibrium in the covert game under centralization, and let $\mathbf{k}^{\mathrm{C}} = \{k_1^{\mathrm{C}}, k_2^{\mathrm{C}}\}$ be agent i's equilibrium conjecture about other agents truthfully revealing information. Denote by $\mathfrak{B}_r^i = \mathfrak{B}_r\left(C(S_1^i), C(S_2^i), \mathbf{k}^{\mathrm{C}}\right)$ the set of biases for which acquiring and revealing information about $\theta_r$ is incentive compatible for agent i, where $\theta_r, \theta_{\tilde{r}} = \{\theta_1, \theta_2\}$ such that $\theta_r \neq \theta_{\tilde{r}}$.*

1. *$\mathfrak{B}_r^i \neq \emptyset$ if and only if $\frac{(w_{1r}^2 + w_{2r}^2)}{2(k_r^{\mathrm{C}}+3)^2} - \max\left\{C(S_r^i)\,;\, \frac{(w_{1r}w_{1\tilde{r}} + w_{2r}w_{2\tilde{r}})}{2(k_r^{\mathrm{C}}+3)(k_{\tilde{r}}^{\mathrm{C}}+3)} - 2C(S_{\tilde{r}}^i)\right\} > 0$;*
2. *$\frac{\partial \mathfrak{B}^{\mathrm{i}}{}_r}{\partial C(S_r^i)} < 0$;*
3. *$\frac{\partial \mathfrak{B}_r^i}{\partial C(S_{\tilde{r}}^i)} > 0$.*

*Proof.* See Appendix C. □

Acquiring information about $\theta_1$ in the covert game is incentive compatible for $i$ if and only if the utility gains are sufficiently large. As in the overt game, these utility gains must compensate for the cost of acquiring the corresponding signal, $C(S_1^i)$. Unlike the overt game, however, the utility gains from increasing the precision of the principal's beliefs must compensate for the utlity gains associated with having ambiguous information (rightmost term inside the curly brackets). In other words, if acquiring information about $\theta_2$ is cheap for $i$, he will acquire $S_2^i$ and lie to the principal whenever this signal favours his interests and $S_1^i$ goes against them. Incentive compatibility, hence, requires that the cost of the signal associated with the state is low and the cost of that associated with the other state is sufficiently high.

[24]See equations (23), (24), and (25) in Appendix C

The relationship between incentive compatibility and the costs of the different signals is shown in the last two statements of Proposition 8. Because of the first type of deviations—acquiring fewer signals— $i$'s incentives to acquire and reveal information about $\theta_1$ decrease as the cost of $S_1^i$ increases; saving on the cost of the signal becomes more profitable for $i$. The second type of deviations—acquiring more signals—leads to an increase in credibility when the cost of $S_2^i$ increases. This effect stems from the credibility loss due to ambiguous information.

### More than one binary signal per state

Throughout the paper I assumed each agent's information consists of one binary signal associated with each state, two in total. Here I discuss how this assumption can be relaxed, in principle, by allowing each agent to observe many binary trials associated with each state. I proceed in two steps. First, I show what happens with communication incentives when *a single agent* observes $\kappa$ signals about *a single* state in an *unidimensional* cheap talk problem, based on Förster (2019). I then argue that, under the notion of informational interdependence used in this paper, incentives for communication of *perfectly informed* specialists are characterized by similar measures of conflicts of interest.

Förster (2019) studies a sender's incentives for communication to a receiver in charge of one decision, when the former observes $\kappa \geq 1$ binary signals that are independent conditional on the state $\theta \in \Theta = [0, 1]$. In the most informative equilibrium, the sender's message strategy is influential if his bias is below a threshold $\bar{b}(\kappa)$, which involves full revelation of his information for sufficiently low biases, $b \leq \underline{b}(\kappa) < \bar{b}(\kappa)$.[25] Interestingly, the threshold for influential message strategies ($\bar{b}$) is increasing in the sender's information ($\kappa$); while the threshold for fully revealing messages ($\underline{b}$) is decreasing in $\kappa$. My focus on a single binary signals associated to each state is then a conservative estimation of incentives to transmit any information.

Now, what happens when agents observe more than one binary signal in the presence of informational interdependence? In a companion paper, I analyse the case of two specialists, each of whom is perfectly informed about a single (different) state and observes no information about the other. There I show that message strategies consist of increasing partitions of the state space. Individual IC constraints are isomorphic to those in Crawford and Sobel (1982), where sender $i$'s bias is represented by $\frac{\beta_r^i}{w_{1r}^2 + w_{2r}^2}$. These IC constraints could be interpreted as the maximum bias for which an agent reveals *some* information about one state.

An additional question relates to asymmetries on agents' information. In the paper I showed that individual incentives to reveal information depend on how much information the decision maker is expected to have in equilibrium.[26] If one agent, $A^1$, observes more than one binary signal in my

[25]See Propositions 2 and 3 in Förster (2019).

[26]In Krishna and Morgan (2001b), for example, two senders are perfectly informed and individual incentives for

framework, his incentives will follow a more complex form of partitional communication equilibria (as in Förster, 2019). If agents other than $A^1$ still observe binary signals about each state, their incentives depend on conjectures about the information the decision maker receives in equilibrium, which includes $A^1$'s equilibrium message strategy. Indeed, the fact that incentives for full revelation are decreasing in the number of signals implies the principal weakly prefers to delegate any decision to $A^1$ rather than another agent with the same conflict of interest, even if the second agent is willing to fully reveal his information to $A^1$.[27] This suggests that, *ceteris paribus*, the principal prefers to delegate decisions to more informed agents. Deepening these intuitions is a subject for future work.

### Concluding remarks

Most organizations operate in complex environments: they face multi-causal problems and solutions involve many interrelated courses of action. Because actions address the causes with different degrees of success, relevant information affects many of these actions. In addition, the information is typically dispersed among the organization's members, who communicate it strategically. This paper has studied how information is acquired and aggregated under such complexity. I showed that the allocation of decision rights constitutes a key tool to govern the conflict of interests in an organization. In particular, I found a principal may want to delegate controversial decisions if that improves transmission of information on other, less controversial ones. When preferences over all decisions are extreme, centralization can 'discipline' these conflict of interests such that more information is transmitted. I have shown that complexity affects incentives to acquire information under different organizational structures. Under delegation, expected investment in information is not only lower overall but also more concentrated on issues that are salient for the corresponding decision. The analysis presented here has broad applications to the organization of policy-making bodies, advisory committees, knowledge creation in multinational corporations, and other settings where information needs to be obtained and communicated in complex environments.

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communication depend on the other sender's bias because it predicts how much information he reveals on path.

[27] If the conflict of interest between $A^1$ and $A^2$ is greater than $|\underline{b}(\kappa_1)|$, communication is less than fully revealing.

# Appendix A Complementary results and proofs

## Equilibrium communication under delegation

**Lemma A1** (Incentive Compatibility of Communication on $y_d$.). *Consider an equilibrium* $(\mathbf{y}^*, \mathbf{m}^*)$ *in which the principal delegates* $y_d$ *to agent* $j$ *(and he does not decide on the other decision).*[28] *Then, revealing any information (either* $S^i_r$ *or both signals) is incentive compatible for* $i$ *if:*

$$|b^i_d - b^j_d| \leq \frac{1}{2}\left|\frac{w_{d1}}{(k^j_1+3)} - \frac{w_{d2}}{(k^j_2+3)}\right| \tag{9}$$

*And revealing both signals when* $\tilde{\mathbf{S}}^i\{(0,0);(1,1)\}$ *and announcing the babbling message for other realizations if:*

$$|b^i_d - b^j_d| \leq \frac{1}{4}\left[\frac{w_{d1}}{(k^j_1+3)} + \frac{w_{d2}}{(k^j_2+3)}\right] \tag{10}$$

*Where* $y_d = \{y_1, y_2\}$*.*

*Proof.* See Appendix B □

The proposition below summarizes the equilibrium communication in the case of delegation.

**Proposition A1** (Equilibrium Communication for $y_d$). *Let agent* $j$ *be the decision maker of* $y_d$*. In the most-informative equilibrium* $(\mathbf{y}^*, \mathbf{m}^*_{j'}, \mathbf{m}^*_{j''})$ *between agents* $i$ *and* $j$*,* $i$ *fully reveals his information if and only if condition* (9) *hold. If the right-hand side of* (10) *is larger than that of* (9)*, then agents with* $|b^i_d - b^j_d|$ *within these two values reveal both signals when* $(\tilde{S}^i_1, \tilde{S}^i_2) = \{(0,0),(1,1)\}$ *and send the corresponding babbling message otherwise. For other values of* $\mathbf{b}^i$*,* $i$ *always send the babbling message consistent with his bias.*

*Proof.* See appendix B. □

Equilibrium communication in the case of one decision is characterized by the IC constraint in Lemma A1. As already discussed, full revelation dominates message strategies in which $i$ reveals one signal because the IC constraints are the same and the decision maker always prefer the former. The same happens with dimensional non-separable message strategies for most parameter values, so they can be overlooked in this case with little loss. Now is time to analyse communication between $i$ and the principal when she retains authority over both decisions.

## Equilibrium communication under centralization

**Lemma A2** (Incentive Compatibility of Communication under Centralization). *Consider an equilibrium* $(\mathbf{y}^*, \mathbf{m}^*)$*, truthful communication is be incentive compatible for agent* $i$ *in the following cases:*

- *Revealing* $S^i_r$*, if:*

$$|\beta^i_r| \leq \frac{(w_{1r})^2 + (w_{2r})^2}{2}\left[\frac{1}{(k^C_r+3)} - \frac{C_r}{(k^C_{\tilde{r}}+3)}\right] \tag{11}$$

[28] By assumption, communication between decision makers only involves own signals (not information transmitted by other agents). For an analysis on hierarchies as information intermediation see Migrow (2017).

- *Revealing both when* $\tilde{\mathbf{S}}^i = \{(0,0);(1,1)\}$, *if:*

$$\frac{(w_{11})^2+(w_{21})^2}{(k_1^{\mathrm{C}}+3)}\left[\frac{1}{(k_1^{\mathrm{C}}+3)}+\frac{C_1}{(k_2^{\mathrm{C}}+3)}\pm 2\beta_1\right]+\frac{(w_{12})^2+(w_{22})^2}{(k_2^{\mathrm{C}}+3)}\left[\frac{1}{(k_2^{\mathrm{C}}+3)}+\frac{C_2}{(k_1^{\mathrm{C}}+3)}\pm 2\beta_2\right]\geq 0 \tag{12}$$

- *Revealing both when* $\tilde{\mathbf{S}}^i = \{(0,1);(1,0)\}$, *if:*

$$\frac{(w_{11})^2+(w_{21})^2}{(k_1^{\mathrm{C}}+3)}\left[\frac{1}{(k_1^{\mathrm{C}}+3)}-\frac{C_1}{(k_2^{\mathrm{C}}+3)}\pm 2\beta_1\right]+\frac{(w_{12})^2+(w_{22})^2}{(k_2^{\mathrm{C}}+3)}\left[\frac{1}{(k_2^{\mathrm{C}}+3)}-\frac{C_2}{(k_1^{\mathrm{C}}+3)}\mp 2\beta_2\right]\geq 0 \tag{13}$$

*Where* $\beta_r = b_1^i w_{1r} + b_2^i w_{2r}$, $C_r = \frac{w_{11}w_{12}+w_{21}w_{22}}{w_{1r}^2+w_{2r}^2} \in [0,1]$, *and* $\pm$ *means that the condition must hold for the most restrictive of these operations, given the sign of the corresponding* $\beta$.

*Proof.* See Habermacher (2018). □

**Lemma A3** (IC constraints for dimensional non-separable strategies under centralization)**.** *In any equilibrium* $(\mathbf{y}^*, \mathbf{m}^*)$ *in which* $\mathbf{m}^{i*}$ *includes a babbling strategy; then, i's incentives to reveal both signals against this deviation are characterized by:*

- *For* $\mathbf{S}^i = \{0,0\}$ *and* $\mathbf{S}^i = \{1,1\}$, *if:*

$$\left|\frac{\beta_1^i}{(k_1+3)}+\frac{\beta_2^i}{(k_2+3)}\right| \leq \frac{1}{4}\left[\frac{(w_{11})^2+(w_{21})^2}{(k_1+3)^2}+\frac{(w_{12})^2+(w_{22})^2}{(k_2+3)^2} + \frac{2\left[w_{11}\,w_{12}+w_{21}\,w_{22}\right]}{(k_1+3)(k_2+3)}\right] \tag{14}$$

- *For* $\mathbf{S}^i = \{0,1\}$ *and* $\mathbf{S}^i = \{1,0\}$, *if:*

$$\left|\frac{\beta_1^i}{(k_1+3)}-\frac{\beta_2^i}{(k_2+3)}\right| \leq \frac{1}{4}\left[\frac{(w_{11})^2+(w_{21})^2}{(k_1+3)^2}+\frac{(w_{12})^2+(w_{22})^2}{(k_2+3)^2} - \frac{2\left[w_{11}\,w_{12}+w_{21}\,w_{22}\right]}{(k_1+3)(k_2+3)}\right] \tag{15}$$

*Proof.* See Habermacher (2018) □

**Proposition A2** (Characterization of P-Optimal equilibrium under centralization —Proposition 2 in Habermacher, 2018)**.** *The P-optimal Perfect Bayesian Equilibrium for sender i consists of the following strategies:*

1. ***Revealing both signals****, if* $\mathbf{b}^i$ *satisfies conditions* (12), (13) *and* (18) *with respect to both states.*
2. ***Revealing one signal only****, if* $\mathbf{b}^i$ *satisfies condition* (11) *for* $S_r^i$ *only.*
3. ***Dimensional non-separable message strategies*** *in the following cases:*

(a) *Fully revealing* $\mathbf{S}^i = \{(0,0);(1,1)\}$ *if* $\mathbf{b}^i$ *satisfies condition* (14) *only;*

(b) *Fully revealing* $\mathbf{S}^i = \{(0,1);(1,0)\}$ *if* $\mathbf{b}^i$ *satisfies condition* (15) *only.*

4. ***No communication*** *(babbling strategy), if none of the above holds.*[29]

*Proof.* See Habermacher (2018). □

## Proof of equation (1)

*Proof.* The principal's ex-ante expected utility in the equilibrium characterized by by $\{\mathbf{y}, \mathbf{m}_{j'}, \mathbf{m}_{j''}\}$ is given by:

$$E\left[U^{\mathrm{P}}(\boldsymbol{\delta},\mathbf{b});\mathbf{m}\right] = -E\left[(y_1-\delta_1)^2;\mathbf{m}_{j'}\right] - E\left[(y_2-\delta_2)^2;\mathbf{m}_{j''}\right]$$

Which, by definitions of equilibrium $y_d$ and $\delta_d$ yield:[30]

$$E\left[U^{\mathrm{P}}(\boldsymbol{\delta},\mathbf{b});\mathbf{m}\right] = -(b_1')^2 - (b_2'')^2 - \sum_{y_d=\{y_1,y_2\}} E\left[\Big(w_{d1}\big(E(\theta_1|\mathbf{m}_j)-\theta_1\big) + w_{d2}\big(E(\theta_2|\mathbf{m}_j)-\theta_2\big)\Big)^2\right]$$

With some rearrangement and given $\theta_1 \perp \theta_2$, I have:

$$E\left[U^{\mathrm{P}}(\boldsymbol{\delta},\mathbf{b});\mathbf{m}\right] = -\left[(b_1')^2 + (b_2'')^2\right] - \sum_{y_d=\{y_1,y_2\}} \sum_{\theta_r=\{\theta_1,\theta_2\}} \left[(w_{dr})^2\, E\left[\big(E(\theta_r|\mathbf{m}_j)-\theta_r\big)^2;\mathbf{m}_j\right]\right] \qquad (16)$$

[29] Where Full Revelation corresponds to the equilibrium message strategy $\mathbf{m}^i = \Big\{\{(0,0)\};\{(0,1)\};\{(1,0)\};\{(1,1)\}\Big\}$; revealing $S_1^i$ or $S_2^i$ only correspond to $\mathbf{m}^i = \Big\{\{(0,0);(0,1)\};\{(1,0);(1,1)\}\Big\}$ and $\mathbf{m}^i = \Big\{\{(0,0);(1,0)\};\{(0,1);(1,1)\}\Big\}$; DNS message strategies correspond to $\mathbf{m}^i = \Big\{\{(0,0)\};\{(1,1)\};\{(0,1);(1,0)\}\Big\}$ when $(0,0)$ and $(1,1)$ fully reveal their types, and $\mathbf{m}^i = \Big\{\{(0,0);(1,1)\};\{(0,1)\};\{(1,0)\}\Big\}$ the case in which $(0,0)$ and $(1,1)$ do so; and finally the babbling strategy $\mathbf{m}^i = \Big\{\{(0,0);(1,1);(0,1);(1,0)\}\Big\}$.

[30] Note that the terms $E\left(E(\delta_d|\mathbf{m}_j)-\delta_d\right)b_d^j = 0$.

Now, the expectation of the squared deviation for each state is given by:

$$
\begin{aligned}
E\left[\left(E(\theta_r|\mathbf{m}_j)-\theta_r\right)^2;\mathbf{m}_j\right] &= \int_0^1 \sum_{\ell_r=0}^{k_r^j}\left(E(\theta_r|\mathbf{m}_j)-\theta_r\right)^2 f(\ell_r^j|k_r^j,\theta_r)\,d\theta_r \\
&= \int_0^1 \sum_{\ell_r=0}^{k_r^j}\left(E(\theta_r|\mathbf{m}_j)-\theta_r\right)^2 \frac{h(\theta_r|\ell_r^j,k_r^j)}{(k_r^j+1)}\,d\theta_r \\
&= \frac{1}{(k_r^j+1)}\sum_{\ell_r^j=0}^{k_r^j}\int_0^1\left(E(\theta_r|\mathbf{m}_j)-\theta_r\right)^2 h(\theta_r|\ell_r^j,k_r^j)\,d\theta_r \\
&= \frac{1}{(k_r^j+1)}\sum_{\ell_r^j=0}^{k_r^j}\mathrm{Var}(\theta_r|\ell_r^j,k_r^j) \\
&= \frac{1}{(k_r^j+1)}\sum_{\ell_r^j=0}^{k_r^j}\frac{(\ell_r^j+1)(k_r^j-\ell_r^j+1)}{(k_r^j+2)^2(k_r^j+3)}
\end{aligned}
$$

Solving the sum and plugging the above into (16) yields:

$$
\hat{U}^{\mathrm{P}}(\mathbf{B},\mathbf{m}_{j'},\mathbf{m}_{j''}) = -\left[(b_1')^2+\frac{(w_{11})^2}{6\left(k_1'+2\right)}+\frac{(w_{12})^2}{6\left(k_2'+2\right)}\right]-\left[(b_2'')^2+\frac{(w_{21})^2}{6\left(k_1''+2\right)}+\frac{(w_{22})^2}{6\left(k_2''+2\right)}\right]
$$

Let denote by $\mathrm{Var}(\theta_r|\mathbf{m}_j)\equiv E\left[\left(E(\theta_r|\mathbf{m}_j)-\theta_r\right)^2;\mathbf{m}_j\right]$.

$$
\begin{aligned}
\hat{U}^{\mathrm{P}}(\mathbf{B},\mathbf{m}_{j'},\mathbf{m}_{j''}) = &-\left[(b_1')^2+(w_{11})^2\,\mathrm{Var}(\theta_1|\mathbf{m}_{j'})+(w_{12})^2\,\mathrm{Var}(\theta_2|\mathbf{m}_{j'})\right] \\
&-\left[(b_2'')^2+(w_{21})^2\,\mathrm{Var}(\theta_1|\mathbf{m}_{j''})+(w_{22})^2\,\mathrm{Var}(\theta_2|\mathbf{m}_{j''})\right]
\end{aligned}
$$

□

### Optimal Organizational Structure

**Proposition A3** (Optimal Organizational Structure)**.** *Given the vector of preferences,* $\mathbf{B}=\{\mathbf{b}^1,\ldots,\mathbf{b}^n\}$*, and generic agents* $i$*,* $j'$*, and* $j''$*; the organizational structure that maximizes the principal's ex-ante welfare is:*

**Full Delegation.** *That is, agents* $j'$ *and* $j''$ *decide on* $y_1$ *and* $y_2$ *(resp.) if and only if:*

1. $DIG_{j'}(y_1)-(b_1')^2>\max\left\{DIG_i(y_1)-(b_1^i)^2\,,\,IIG(y_1)\,,\,-\{DIG_{j''}(y_2)-(b_2'')^2\}\right\}$ *for any* $i\neq j'$*; and*
2. $DIG_{j''}(y_2)-(b_2'')^2>\max\left\{DIG_i(y_2)-(b_2^i)^2\,,\,IIG(y_2)\,,\,-\{DIG_{j'}(y_1)-(b_1')^2\}\right\}$ *for any* $i\neq j''$*.*

**Partial Delegation.** *That is, agent* $j$ *decides on* $y_d$ *and the principal retains decision authority over* $y_{\tilde{d}}$*; if and only if there exist both Direct and Indirect informational gains such that:*

1. $DIG_j(y_d)-(b_d^j)^2>\max\left\{DIG_i(y_d)-(b_d^i)^2\,,\,IIG(y_d)\,,\,-IIG(y_{\tilde{d}})\right\}$ *for any* $i\neq j$*; and*
2. $IIG(y_{\tilde{d}})>\max\left\{DIG_i(y_{\tilde{d}})-(b_{\tilde{d}}^i)^2\,,\,-\{DIG_j(y_d)-(b_d^j)^2\}\right\}$ *for any* $i\neq j$*.*

**Centralization.** *That is, the principal decides on both issues, if and only if there are no agent $i$ and $j$ such that:*

1. $DIG_j(y_d) - (b_d^j)^2 + IIG(y_{\tilde{d}}) > 0$*; nor*
2. $DIG_{j'}(y_1) - (b_1')^2 + DIG_{j''}(y_2) - (b_2'')^2 > 0$

*Proof.* The proof is constructive. The optimal organizational structure maximizes the principal's ex-ante expected utility. Optimality of delegation implies some informational gains, otherwise she can retain authority over both issues and decide with the information transmitted under centralization. Full Delegation is then optimal if there are two agents $j'$ and $j''$ who decide on $y_1$ and $y_2$, respectively; such that the corresponding informational gains more than compensate each decision maker's bias. These gains must be maximal among all agents, and strictly larger than if the principal retained any single decision ($IIG$).

Partial Delegation is optimal in either of two cases (non-exclusive). First, when direct informational gains from delegation are possible only on one decision, the principal prefers to retain authority on the other. If the $DIG$ are sufficiently large, she may be willing to tolerate some informational losses on the retained decision; that is, receiving less information than under centralization.

The second and most interesting case is when indirect informational gains are large. From Proposition 2 we know that the presence of negative informational spillovers under centralization is a necessary condition. Delegating $y_d$ thus breaks the interdependence between decisions and allows communication on the low-conflict dimension. This may hold even if there are no informational gains in the delegated decision, as long as the indirect ones are sufficiently large.

Finally, Centralization is optimal when any potential informational gain is small, such that it does not compensate the loss of control on the delegated decision(s). □

## Proof of Proposition 1

*Proof.* The characterization of the optimal organizational structure (Proposition A3 above) is a complement of this result. Informational gains arise when more agents reveal information to at least one decision maker, as compared to those revealing information to the principal under centralization.

Consider direct informational gains first. For every agent who would reveal information under centralization, there must exist an agent revealing at least the same amount of information to the new decision maker under delegation. Strict gains require that there also exist at least one agent revealing strictly more information to the new decision maker. Let $j'$ denote the decision maker on $y_1$ and suppose the principal decides on $y_2$. For every other agent $h \in N$ such that $\beta_1^h$ satisfies (11) there must exist a $i \in N$ such that $b_1^i$ satisfies (9); otherwise, $k_1'$ will be lower than $k_1^{\mathrm{C}}$.[31] At this point, there must also exist an agent such that:

$$|b_1^i w_{11} + b_2^i w_{21}| > \frac{1}{2}\left[\frac{(w_{11})^2 + (w_{21})^2}{(k_1^{\mathrm{C}}+3)} - \frac{w_{11}w_{12} + w_{21}w_{22}}{(k_2^{\mathrm{C}}+3)}\right]$$
$$|b_1^i - b_1^j| \leq \frac{1}{2}\left[\frac{w_{11}}{(k_1^j+3)} - \frac{w_{12}}{(k_2^j+3)}\right]$$

Multiplying the last inequality by $w_{1r}$, its right-hand side is strictly lower than that of the expression above. I thus get the condition that $|b_1^i - b_1^j| < |b_1^i + b_2^i \frac{w_{21}}{w_{11}}|$ for direct info gains from delegation.

Indirect informational gains mean that in equilibrium $k_2^{\mathrm{P}2} > k_2^{\mathrm{C}}$; the above equations must hold for $y_2$. An argument similar to the previous leads to: for every $h \in N$ such that $\beta_2^h$ satisfies (11), there

[31] Indeed, any of the agents revealing under delegation are revealing both signals.

must exist a $i \in N$ such that $b^i_2$ satisfies (9) and, in addition, there exist exists an agent $i$ such that:

$$|b^i_1 w_{12} + b^i_2 w_{22}| > \frac{1}{2}\left[\frac{(w_{12})^2 + (w_{22})^2}{(k^{\text{C}}_2 + 3)} - \frac{w_{11}w_{12} + w_{21}w_{22}}{(k^{\text{C}}_1 + 3)}\right]$$
$$|b^i_2| \leq \frac{1}{2}\left[\frac{w_{22}}{(k^j_2 + 3)} - \frac{w_{21}}{(k^j_1 + 3)}\right]$$

Again, multiplying the last inequality be $w_{22}$ evidences that its RHS is larger than that of the first one. This reduces the necessary condition for $IIG$ to $w_{22}|b^i_2| < |b^i_1 w_{12} + b^i_2 w_{22}|$. It follows that the previous is only possible when $|b^i_1|$ is sufficiently large. □

## Proof of Proposition 2

*Proof.* Let $\mathbf{B}^n = (\mathbf{b}^1, ..., \mathbf{b}^n)$ denote a given profile of biases for $n$ informed agents. The optimal organizational structure is characterized by the number of truthful messages decision makers receive in equilibrium, $\mathbf{k}'$, $\mathbf{k}''$, and the number of truthful messages the principal receives under centralization, $\mathbf{k}^{\text{C}}$, as per Proposition A3. Suppose that $k'_1 = k'_2$, $k''_1 = k''_2$, and $k^{\text{C}}_1 = k^{\text{C}}_2$. Now consider the associated game consisting of $n + m$ agents, with the profile of biases for the first $n$ agents being $\mathbf{B}^n$, that is $\mathbf{B}^{n+m} = (\mathbf{b}^1, ..., \mathbf{b}^n, \mathbf{b}^{n+1}, ..., \mathbf{b}^{n+m})$. Let $\mathfrak{b} \in \Re_+$ denote a large number.

Now, consider the following cases for the preferences of agents $n + 1$ to $n + m$:

1. $\mathbf{b}^{n+1} = ... = \mathbf{b}^{n+m} = (\mathfrak{b}, 0)$.

   Suppose first that the optimal organizational structure under $\mathbf{B}^n$ was full delegation. Under the profile $\mathbf{B}^{n+m}$, the principal prefers to retain authority over $y_2$ if and only if $IIG(y_2) \geq DIG_{j''}(y_2) - (b''_2)^2$; which by Lemma 1 and Proposition A3 translates into:

$$\frac{w^2_{21}}{6}\left[\frac{1}{(k''_1 + 2)} - \frac{1}{(k^{\text{P}2}_1 + m + 2)}\right] + \frac{w^2_{22}}{6}\left[\frac{1}{(k''_2 + 2)} - \frac{1}{(k^{\text{P}2}_2 + m + 2)}\right] \geq -(b''_2)^2$$

   Then, for any $k''_1, k''_2, k^{\text{P}2}_1, k^{\text{P}2}_2 \leq n$, there exists a $m$ for which the above holds.

   Now, suppose the optimal organizational structure under $\mathbf{B}^n$ is centralization. Then the additional information she receives with partial delegation of $y_1$ under $\mathbf{B}^{n+m}$ must also compensate the distributional loss on the delegated decision; which means:

$$\frac{w^2_{21}}{6}\left[\frac{2}{(k^{\text{C}}_1 + 2)} - \frac{1}{(k^{\text{P}2}_1 + m + 2)}\right] + \frac{w^2_{22}}{6}\left[\frac{1}{(k^{\text{C}}_2 + 2)} - \frac{1}{(k^{\text{P}2}_2 + m + 2)}\right] \geq$$
$$\geq \frac{w^2_{11}}{6}\left[\frac{1}{(k'_1 + 2)} - \frac{1}{(k^{\text{C}}_1 + 2)}\right] + \frac{w^2_{12}}{6}\left[\frac{1}{(k'_2 + 2)} - \frac{1}{(k^{\text{C}}_2 + 2)}\right] + b'_1$$

   Note that the RHS of the expression above is non-negative because of the optimality of centralization under $\mathbf{B}^n$. A sufficient condition for optimality of partial delegation is that there exists an agent $j'$ whose bias satisfies:[32]

$$(b'_1)^2 \leq \frac{w^2_{11} + w^2_{21}}{6(n + 2)} + \frac{w^2_{12} + w^2_{22}}{6(n + 2)} - \frac{w^2_{11}}{18} - \frac{w^2_{12}}{18}$$

[32]The expression reflects the case in which all $n$ agents fully reveal their signals under centralization ($k^{\text{C}}_r = n$), $j'$ does not receive any signals from other agents in equilibrium ($k'_r = 1$), and the indirect informational gains are maximal ($m = \mathfrak{b}$).

Then, there exists a finite $m$ such that Partial Delegation (of $y_1$) is preferred by the principal over centralization.

2. $\mathbf{b}^{n+1} = ... = \mathbf{b}^{\frac{2n+m+1}{2}} = (-\mathfrak{b}, \mathfrak{b})$ and $\mathbf{b}^{\frac{2n+m+1}{2}} = ... = \mathbf{b}^{n+m} = (\mathfrak{b}, \mathfrak{b})$.

   Lemma A3 implies that, for $k_1^{\text{C}} = k_2^{\text{C}}$, senders with these preferences will have maximal incentives to play equilibrium DNS strategies. In particular, those in the first group satisfy:

$$\left|\frac{\beta_1^i}{(k_1^{\text{C}}+3)} + \frac{\beta_2^i}{(k_2^{\text{C}}+3)}\right| = \left|\frac{w_{11}b_1^i + w_{12}b_2^i + w_{21}b_1^i + w_{22}b_2^i}{(k^{\text{C}}+3)}\right| = \left|\frac{b_1^i + b_2^i}{(k^{\text{C}}+3)}\right| = 0$$

   And those in the second group:

$$\left|\frac{\beta_1^i}{(k_1^{\text{C}}+3)} - \frac{\beta_2^i}{(k_2^{\text{C}}+3)}\right| = \left|\frac{w_{11}b_1^i + w_{12}b_2^i - w_{21}b_1^i - w_{22}b_2^i}{(k^{\text{C}}+3)}\right| = \left|\frac{b_1^i - b_2^i}{(k^{\text{C}}+3)}\right| = 0$$

   Then, $m = 2n$ is a sufficient condition for the principal to prefer centralization over any other organizational structure that was optimal with the original profile of biases.

□

## Proof of Proposition 3

*Proof.* Suppose the equilibrium organizational structure involve some form of delegation, and let $j', j'' \in \{P, 1, 2, ...\}$ be decision makers for $y_1$ and $y_2$, respectively. The principal's ex-ante utility gain with respect to centralization is given by:

$$\begin{aligned}(b_1')^2 + (b_2'')^2 \leq & \frac{(w_{11})^2}{6}\left[\frac{1}{(k_1^{\text{C}}+2)} - \frac{1}{(k_1'+2)}\right] + \frac{(w_{12})^2}{6}\left[\frac{1}{(k_2^{\text{C}}+2)} - \frac{1}{(k_2'+2)}\right] + \\ & \frac{(w_{21})^2}{6}\left[\frac{1}{(k_1^{\text{C}}+2)} - \frac{1}{(k_1''+2)}\right] + \frac{(w_{22})^2}{6}\left[\frac{1}{(k_2^{\text{C}}+2)} - \frac{1}{(k_2''+2)}\right]\end{aligned}$$

According to expression (1), and denoting by $\mathbf{m}_{\text{C}}$ the messages sent to the principal under centralization, the above can be expressed as:

$$\left[(b_1')^2 + (b_2'')^2\right]^{\frac{1}{2}} \leq \left[\sum_{y_d}\left[w_{d1}^2\big(\text{Var}(\theta_1|\mathbf{m}_{\text{C}}) - \text{Var}(\theta_1|\mathbf{m}_j)\big) + w_{d2}^2\big(\text{Var}(\theta_2|\mathbf{m}_{\text{C}}) - \text{Var}(\theta_2|\mathbf{m}_j)\big)\right]\right]^{\frac{1}{2}}$$

Denote by $\hat{\mathbf{b}}^{\text{D}}$ the vector whose component satisfy the above expression with equality. Because the LHS above represents the euclidean distance of a vector with components $b_1'$ and $b_2''$ to the origin, then $\hat{\mathbf{b}}^{\text{D}}$ represents the maximum conflict of interest the principal will tolerate as a function of the informational gains from delegation of the corresponding decision(s).

For the second part of the proof let assume that $k_r^j = k^{\text{C}} + 1$, and denote the reduction in variance under delegation by $\Delta\text{Var}(\theta_r|\mathbf{m}_j) = \text{Var}(\theta_r|\mathbf{m}_{\text{C}}) - \text{Var}(\theta_r|\mathbf{m}_j, k_r^j = k_r^{\text{C}} + 1)$, which then is given by:

$$\Delta\text{Var}(\theta_r|\mathbf{m}_j) = \frac{1}{6}\left[\frac{1}{(k_r^{\text{C}}+2)} - \frac{1}{(k_r^{\text{C}}+3)}\right]$$

Then, taking the derivative with respect to $k_r^{\text{C}}$ gives expression (4). □

## Proof of Lemma 1

*Proof.* The proof proceed by contradiction. I focus on the centralization case, since decentralization follows the same logic. Let $(\{\mathbf{y}^*\}, \{\mathbf{m}^*, \mathfrak{s}^*\})$ be the equilibrium strategy profiles for the receiver and all agents, respectively. Recall the equilibrium is characterized by $k_1^*$ and $k_2^*$.

**Acquisition of $S_1$.** Suppose that $i$'s equilibrium info acquisition strategy has $S_1 \in \mathfrak{s}^{i*}$ but condition (11) does not hold for $S_1$. In such a case revealing information about $\theta_1$ is not incentive compatible for $i$ despite he acquired information about it. Other agents base their message strategies on conjectures about $k_1^*$, but $i$ is not included among agents revealing $S_1$ truthfully. At the information acquisition stage, $i$'s expected payoff of $\mathfrak{s}^{i*}$ is thus given by:

$$E\left[U^i\left(\mathbf{y}^*(\mathbf{m}^*(\mathfrak{s}^*)), \delta, b^i\right)\right] = -E\left[\left(\mathbf{y}_1\left(m^{i*}(\mathfrak{s}^{i*}), \mathbf{m}^{\text{-}i*}\right) - \delta_1 - b_1^i\right)^2 + \left(\mathbf{y}_2\left(m^{i*}(\mathfrak{s}^{i*}), \mathbf{m}^{\text{-}i*}\right) - \delta_2 - b_2^i\right)^2\right] - C(\mathfrak{s}^{i*})$$

Now, consider the following deviation: $\hat{\mathfrak{s}}^i = \mathfrak{s}^{i*} \backslash \{S_1\}$. Note that this deviation does not affect $k_1^*$ or $k_2^*$, and $i$'s overall influence on $j$'s decision(s) is thus unaltered—i.e. $y_d\left(m^i(\hat{\mathfrak{s}}^i), \mathbf{m}_j^{\text{-}i}\right) = y_d\left(m^i(\mathfrak{s}^{i*}), \mathbf{m}_j^{\text{-}i}\right)$. Note also that $C(\mathfrak{s}^{i*}) > C(\hat{\mathfrak{s}}^i)$, given $\#\mathfrak{s}^{i*} > \#\hat{\mathfrak{s}}^i$. Consequently,

$$E\left[U^i\left(\mathbf{y}^*(\mathbf{m}^*(\mathfrak{s}^*)), \delta, b^i\right)\right] - E\left[U^i\left(\mathbf{y}\left(m^i(\hat{\mathfrak{s}}^i), \mathbf{m}^{\text{-}i*}\right), \delta, b^i\right)\right] = -C(\mathfrak{s}^{i*}) + C(\hat{\mathfrak{s}}^i) < 0$$

So, $\hat{\mathfrak{s}}^i$ is a profitable deviation from $\mathfrak{s}^{i*}$. $\Rightarrow\Leftarrow$

**Acquisition of both signals.** The proof is similar to the previous, with $i$'s proposed equilibrium strategy being $\mathfrak{s}^{i*} = \{S_1, S_2\}$ but conditions for Full Revelation do not hold. Then, a profitable deviation for $i$ will be to acquire the signal he is willing to reveal on the equilibrium path (if any). $\square$

## Equilibrium Information Acquisition and Cost-effectiveness condition

Before the proof of Lemma 2 I derive the information-acquisition IC constraint.

**Observation.** *Let* $k_r^{j*} \equiv k_r^j\left(\mathbf{m}_j^i(\mathfrak{s}^{i*}, \mathfrak{s}^{\text{-}i}), \mathbf{m}_j^{\text{-}i}(\mathfrak{s}^{i*}, \mathfrak{s}^{\text{-}i})\right)$ *and* $\hat{k}_r^j \equiv k_r^j\left(\mathbf{m}_j^i(\hat{\mathfrak{s}}^i, \mathfrak{s}^{\text{-}i}), \mathbf{m}_j^{\text{-}i}(\mathfrak{s}^{i*}, \mathfrak{s}^{\text{-}i})\right)$ *for* $\theta_r = \{\theta_1, \theta_2\}$. *Let* $\mathfrak{s}^{i*}$ *denote* $i$*'s information acquisition strategy in an equilibrium characterized by* $(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$. *Then,* $i$*'s ex-ante expected utility from* $\mathfrak{s}^{i*}$ *is given by:*

$$E\left[U^i\left(\mathbf{m}^*, \mathfrak{s}^{i*}, \mathfrak{s}^{\text{-}i}, \boldsymbol{\delta}, \mathbf{b}^i\right)\right] = -\left[(b_1^i)^2 + (b_2^i)^2\right] - \sum_{y_d = \{y_1, y_2\}}\left[\frac{(w_{d1})^2}{6\left(k_1^{j*} + 2\right)} + \frac{(w_{d2})^2}{6\left(k_2^{j*} + 2\right)}\right]$$

*Now, let* $(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$ *be equilibrium strategy profiles. Then,* $\mathfrak{s}^{i*}$ *is incentive compatible for agent* $i$ *if and only if, for every alternative* $\hat{\mathfrak{s}}^i$*:*

$$\sum_{y_d = \{y_1, y_2\}} \sum_{\theta_r = \{\theta_1, \theta_2\}} \frac{(w_{dr})^2}{6}\left[\frac{1}{\left(\hat{k}_r^j + 2\right)} - \frac{1}{\left(k_r^{j*} + 2\right)}\right] \geq \left[C(\mathfrak{s}^{i*}) - C(\hat{\mathfrak{s}}^i)\right] \tag{17}$$

## Proof of Proposition 4

*Proof.* Let $S_r \in \mathfrak{s}^{i*}$ and $S_{\tilde{r}} \notin \mathfrak{s}^{i*}$ for $\theta_r \neq \theta_{\tilde{r}}$, and $k_r^j\left(\mathbf{m}_j^*(\mathfrak{s}^*)\right)$ be $i$'s conjecture about other agents revealing their information about $\theta_r$ to decision maker $j$. Then, agent $i$'s IC constraint for revealing

$S^i_r$ is:

- When $j = P$ decides on both issues (centralization),

$$|\beta^i_r| \leq \frac{(w_{1r})^2 + (w_{2r})^2}{2\,(k^{\mathrm{C}}_r + 3)} \tag{18}$$

- When $j$ decides on $y_d$ only,

$$|b^i_d - b^j_d| \leq \frac{w_{dr}}{2\big(k^j_r + 3\big)} \tag{19}$$

I prove the IC constraint for case of delegation, as centralization follows the same argument but requires more algebra (see Habermacher, 2018 for a reference). Suppose agent $i$'s acquires only $S^i_1$; then strategy $\mathbf{m}^{i*} = \{m^{i*}_{j'}, m^{i*}_{j''}\}$ is preferred to any alternative $\hat{\mathbf{m}}$ iff (IC constraint in section B):

$$-\left[w_{d1}(\nu^{i*}_{d1} - \hat{\nu}^i_{d1}) + w_{d2}(\nu^{i*}_{d2} - \hat{\nu}^i_{d2})\right]\left[w_{d1}(\nu^{i*}_{d1} + \hat{\nu}^i_{d1}) + w_{d2}(\nu^{i*}_{d2} + \hat{\nu}^i_{d2}) - 2[w_{d1}\nu^i_{d1} + w_{d2}\nu^i_{d2} - (b^i_d - b^j_d)]\right] \geq 0$$

But since $i$ has information about $\theta_1$ only, then $E(\theta_2|S^i_1, \mathbf{m}^{-i}_j) = \nu^i_{d2} = \nu^{i*}_{d2} = \hat{\nu}^i_{d2}$. Moreover, the strategy space when $i$ has only one signal is degenerated, such that he can only reveal it or lie. Revealing $S^i_1$ is thus IC iff:

$$-\left[w_{d1}(\nu^{i*}_{d1} - \hat{\nu}^i_{d1})\right]\left[w_{d1}(\nu^{i*}_{d1} - \hat{\nu}^i_{d1}) - 2(b^j_d - b^i_d)\right] \geq 0$$

Following the same steps as in section B it is easy to note that the above expression becomes:

$$\begin{aligned} &\text{For } \tilde{S}^i_1 = 0: \quad && 2(b^i_d - b^j_d) \leq \frac{w_{d1}}{(k^j_1 + 3)} \\ &\text{For } \tilde{S}^i_1 = 1: \quad && -2(b^i_d - b^j_d) \leq \frac{w_{d1}}{(k^j_1 + 3)} \end{aligned}$$

Which together imply equation (19).

Now, the vector $\mathfrak{B}^j_r(\mathbf{b}^j, \mathbf{k}^j)$ results from comparing equations (9) and (19). That is, assuming $j$ decides over $y_d$ only and $k^j_r = \{k^j_1, k^j_2\}$ are $i$'s equilibrium conjectures about other agents revealing information to $j$, $\mathfrak{B}^{\mathrm{D}j}_r(\mathbf{b}^j, \mathbf{k}^j)$ can be defined as:

$$\mathfrak{B}^j_r = \left\{x : b^j_d \pm x \in \frac{1}{2} \times \left(\left|\frac{w_{d1}}{(k^j_1 + 3)} - \frac{w_{d2}}{(k^j_2 + 3)}\right|, \frac{w_{dr}}{(k^j_r + 3)}\right]\right\}$$

Under centralization, the vector $\mathfrak{B}^j_r(\mathbf{b}^j, \mathbf{k}^j)$ results from comparing equations (11) and (18). Denote by $k^{\mathrm{C}}_r$ agent $i$'s equilibrium conjectures about other agents revealing information about $\theta_r\{\theta_1, \theta_2\}$ to the principal under centralization, and $k^{\mathrm{C}}_{\tilde{r}} \neq k^{\mathrm{C}}_r$. Then, $\mathfrak{B}^{\mathrm{P}}_r(\mathbf{k}^{\mathrm{P}})$ is defined as:

$$\mathfrak{B}^{\mathrm{P}}_r = \left\{x : |x| \in \frac{(w_{1r})^2 + (w_{2r})^2}{2} \times \left(\left[\frac{1}{(k^{\mathrm{C}}_r + 3)} - \frac{C_r}{(k^{\mathrm{C}}_{\tilde{r}} + 3)}\right], 2\,(k^{\mathrm{C}}_r + 3)\right]\right\}$$

□

**Proof of Lemma 2**

*Proof.* I first derive the cost-effectiveness condition (5) and then the maximum number of agents for which acquiring a given piece of information is cost-effective –condition (7). In order to derive cost-effectiveness (CE), I consider each possible info acquisition strategy in equilibrium.

The number of agents revealing truthfully their signals in equilibrium, $k_r^*$, includes $i$'s message strategy when he acquires (and reveals) it in equilibrium.[33] Here I need to make two clarifications. Firstly, if there were agents who acquired information on $\theta_1$ but were not willing to reveal it when $\hat{k}_1 = k_1^* + 1$, then only one of them changes his message strategy because when one of these agents stop revealing, then $\hat{k}_1 = k_1^*$ again. As a consequence, $\hat{k}_1 = \{k_1^*, k_1^* + 1\}$. I take the most conservative of these approaches by making $\hat{k}_1 = k_1^* + 1$ whenever $i$ acquires $S_1$ off-path.

The second clarification relates to what happens when $i$ acquires a signal and does not reveal it. Since other agents' message strategies will depend on conjectures about $k_r$, $i$ not revealing the signal acquired off-path does not affect their equilibrium behaviour at the communication stage. In other words, Lemma 1 holds: $i$ gains nothing from acquiring a signal he will not reveal.

**Centralization.** Let first consider the acquisition of both signals in equilibrium; that is $\mathfrak{s}^{i*} = \{S_1^i, S_2^i\}$. Expression (17) for each possible alternative strategy becomes:

1) $\tilde{\mathfrak{s}}^i = \{\emptyset\}$

$$\sum_{\theta_r} \frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^* + 2)(k_r^* + 3)} \geq C(S_1^i, S_2^i)$$

When $i$ plays DNS message strategies on path, he expects to reveal information for half of the possible realizations, such that the CE conditions becomes:

$$\frac{(w_{11})^2 + (w_{21})^2}{6(k_1^* + 2)(k_1^* + 3)} + \frac{(w_{12})^2 + (w_{22})^2}{6(k_2^* + 2)(k_2^* + 3)} \geq 2\, C(S_1^i, S_2^i) \tag{20}$$

2) $\tilde{\mathfrak{s}}^i = \{S_r^i\}$

$$\frac{(w_{1\tilde{r}})^2 + (w_{2\tilde{r}})^2}{6(k_{\tilde{r}}^* + 2)(k_{\tilde{r}}^* + 3)} \geq C(S_{\tilde{r}}^i)$$

Now, when the equilibrium strategy consists of one signal only, $\mathfrak{s}^{i*} = \{\tilde{S}_r^i\}$, the IC constraints become:

3) $\tilde{\mathfrak{s}}^i = \{\emptyset\}$

$$\frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^* + 2)(k_r^* + 3)} \geq C(S_r^i)$$

4) $\tilde{\mathfrak{s}}^i = \{S_{\tilde{r}}^i\}$

$$\frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^* + 2)(k_r^* + 3)} \geq \frac{(w_{1\tilde{r}})^2 + (w_{2\tilde{r}})^2}{6(k_{\tilde{r}}^* + 2)(k_{\tilde{r}}^* + 3)}$$

5) $\tilde{\mathfrak{s}}^i = \{S_1^i, S_2^i\}$

$$\frac{(w_{1\tilde{r}})^2 + (w_{2\tilde{r}})^2}{6(k_{\tilde{r}}^* + 2)(k_{\tilde{r}}^* + 3)} < C(S_{\tilde{r}}^i)$$

[33] In equilibria in which $i$ does not acquire $S_1^i$, $k_1^*$ does not count him; but in any deviation in which he does acquire it, then $\hat{k}_1 = k_1^* + 1$.

Case 3) represents the necessary condition to acquire any individual signal $S_r^i$, since it implies case 1) (in which it holds for both signals) and case 4) (in which the agent acquires the signal that would have the highest influence). This case corresponds to equation (5).

Now I work out the expression for the maximum number of agents to acquire a given signal under centralization. According to the equation (5) as $k_r$ increases the ex-ante expected utility of acquiring $S_r$ decreases. So, the maximum number of agents who will acquire that signal is given by the largest $k^*$ for which the cost-effectiveness condition hold. Re-arranging this condition I get the following polynomial:

$$-(k_r^*)^2 - 5k_r^* - \left[6 - \frac{(w_{1r})^2 + (w_{2r})^2}{6\,C(S_r^i)}\right] \geq 0$$

Then, solving for the highest positive root I get $K_r^{\mathrm{C}}$ in (7).

**Delegation.** As before, $i$ is not willing to acquire signals he is not willing to reveal on-path (Lemma 1). But in this case there are two decision makers and IC can refer to any of them (or both). From (17) we know that acquiring $S_r^i$ requires that $i$ is willing to reveal it to at least one decision maker, say:

$$C(S_r^i) \leq \frac{(w_{dr})^2}{6(k_r^j + 2)(k_r^j + 3)}$$

For at least one $y_d$. Consider the case of acquiring both signals, which is cost-effective in two generic cases. First, when $i$ is willing to reveal at least one signal to a different decision maker, the CE condition above should hold for each decision maker. Second, when $i$ is willing to reveal both signals to a single $j$ the RHS of the above expression becomes larger. As a consequence, equation (6) is a necessary condition for investing in any individual signal.

To get the expression for the maximum number of agents to invest in $S_r$ I need to analyse also two cases. The minimal incentives to reveal are given by the case in which all agents are willing to reveal $S_r$ to decide on the dimension it is less important. This will define the minimum upper-bound, since the CE condition becomes

$$C(S_r^i) \leq \min_{w_{dr}} \left\{ \frac{(w_{dr})^2}{6(k_r^j + 2)(k_r^j + 3)} \right\}$$

Now consider the case in which all agents are willing to reveal *both signals* to *both decision makers*. This is the maximum upper-bound. In such a case, the CE condition will be just like the centralization case; that is:

$$C(S_r^i) \leq \frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^j + 2)(k_r^j + 3)}$$

Then, following the same steps as the proof of Lemma 2 (Appendix A) I have the first and the second expressions in square bracket in equation (8), respectively. □

## Agents' equilibrium strategies (endogenous information acquisition).

In this subsection I combine the results of Lemma 1 and Lemma 2 to characterize agent $i$'s equilibrium information acquisition and message strategies. I start with the case of centralization ($j' = j'' = P$) and then proceed to the case of delegated decisions. The following result summarizes the intuitions developed in the previous discussion, presenting the equilibrium acquisition and message strategies for a typical agent under centralization.

**Proposition A4** (Equilibrium under Centralization)**.** *In the most informative equilibrium under centralization* $(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$*, agent i only acquires signals that are cost-effective and incentive compatible. In particular, i's equilibrium strategies are given by:*

***Acquiring and revealing both signals:*** *if and only if conditions* (5) *and* (18) *hold for both signals, and* (13) *hold.*

***Acquiring both signals and playing a dimensional non-separable strategy:*** *if condition* (20) *hold for both signals and* (18) *does not at all, in the following cases:*

- *Fully revealing both signals when they coincide and babbling otherwise, if condition* (14) *holds;*
- *Fully revealing both signals when they do not coincide and babbling otherwise, if condition* (15) *holds.*

***Acquiring and revealing one signal only.*** *Agent i acquires and reveals* $S_1^i$ *if* (18) *and* (5) *hold with respect to* $\theta_1$ *and one of the following is true:*

- *Revealing* $S_2^i$ *is not IC —i.e.* (18) *does not hold for* $\theta_2$*; or*
- *Acquiring* $S_2^i$ *is not CE —i.e.* (5) *does not hold for* $\theta_2$*; or*
- *Acquiring* $S_2^i$ *is CE and revealing it is IC, but revealing both signals is not IC —i.e.*(11) *and* (5) *hold for both signals, but* (13) *does not and* $\frac{(w_{1r})^2+(w_{2r})^2}{(k_r^*+2)(k_r^*+3)} \geq \frac{(w_{1\tilde{r}})^2+(w_{2\tilde{r}})^2}{(k_{\tilde{r}}^*+2)(k_{\tilde{r}}^*+3)}$

*For* $r \neq \tilde{r}$*.*

***Acquiring no signal,*** *if only if any of the statements below is true:*

- *No signal is CE to acquire —i.e. condition* (5) *does not holds for any signal; and/or*
- *No signals is IC to reveal —i.e. condition* (18) *does not hold for any signal, nor* (13) *holds.*

*Proof.* See Appendix B □

As discussed earlier, the number of agents revealing the same piece of information is an important determinant of cost-effectiveness. It could lead some agents to acquire less information than what each is willing to reveal, resulting in either specialization or non-investment. The possibility of abstaining to acquire a given signal can enhance incentives for communication (for the other signal) because it kills the effects of ambiguous information.

Dimensional non-separable message strategies can arise under centralization. As in the pure communication game, these strategies take the form of full revelation for some realizations and babbling for the rest. Because any of these involves acquiring both signals and revealing them half of the time, they arise when costs are sufficiently low and only if revealing one signal is not IC. Then, agent $i$ typically prefers to reveal a single signal than play a DNS strategy, provided both are incentive compatible and cost-effective.[34]

Similar intuitions apply to the case of delegation. The result below characterizes equilibrium strategies for agent $i$ and decisions $y_d$ and $y_{\tilde{d}}$.

**Proposition A5** (Equilibrium under Delegation)**.** *When the organizational structure involves more than one decision maker, agent i only acquires signals that are cost-effective and for which communication is incentive compatible. In the most informative equilibrium ,*$(\mathbf{y}^*, \mathbf{m}^*, \mathfrak{s}^*)$*, i's equilibrium strategies are:*

[34] For a formal discussion see Appendix B.

***Acquiring and revealing both signals:*** *if and only if conditions (9) and (6) hold for both signals and at least one decision maker –and the associated decision.*

***Acquiring and revealing*** $S_1$ ***only,*** *if acquiring this signal is both cost-effective and incentive compatible for agent $i$ in the following cases:*

1. *Revealing $S_2$ is not IC for any decision —i.e. condition (19) does not hold for $S_2^i$; or*
2. *Acquiring $S_2$ is not CE for any decision —i.e. condition (6) does not hold for $S_2^i$ for any decision; or*
3. *Both $S_1$ and $S_2$ are CE and IC, but revealing both is not IC with respect to any decision maker —i.e. conditions (19) and (6) hold for both signals and at least one decision maker, but (9) does not hold for any of them and $\frac{(w_{dr})^2}{(k_r^*+2)(k_r^*+3)} \geq \frac{(w_{d\tilde{r}})^2}{(k_{\tilde{r}}^*+2)(k_{\tilde{r}}^*+3)}$*

*For $r \neq \tilde{r}$.*

***Acquiring no signal*** *if only if any of the statements below are true:*

1. *Condition (19) does not hold for any signal and any decision, nor (13) hold; and/or*
2. *Condition (6) does not holds for any signal, any decision.*

*Proof.* See Appendix B. □

In presence of two decision makers agents acquire a signal if it is cost-effective and incentive compatible to reveal it to at least one of them. As discussed in Proposition 4, the possibility of not acquiring one of the signals makes credible the strategy of revealing only one signal. When such a strategy is incentive compatible it always refers to the state the decision maker is less informed in equilibrium. In other words, the agent will acquire the signal for which the influence is larger, which in turn implies that dimensional non-separable strategies are dominated by this strategy. As a consequence, no DNS strategy can emerge in equilibrium under delegation.

**Corollary A1.** *Let $w \equiv w_{11} = w_{22}$, $\kappa = 1$, and $\frac{\hat{w}_{dr}^2}{72} < C(S_r) \leq \frac{[(w_{1r})^2+(w_{2r})^2]}{72}$ for both $\theta_r$. If there are no agents $j'$ and $j''$ whose preferences represent a conflict of interest within $||\mathbf{b}^{\mathrm{D}}|| \leq 1-2w(1-w)$, then the principal strictly prefers centralization over any form of delegation. If there where such agents, the principal still prefers centralization (strictly) as long as there is at least one agent $i$ who fully reveals his information —i.e. $\mathbf{b}^i$ satisfy conditions (11) and (13) with respect to both signals.*

*Proof.* When $\kappa = 1$, decision makers have the stronger incentives to acquire both signals under delegation. Noting that $6(\kappa+2)(\kappa+3) = 72$, from Proposition 6 I get that $\frac{\hat{w}_{dr}^2}{72} < C(S_r) \leq \frac{[(w_{1r})^2+(w_{2r})^2]}{72}$ implies $K_r^{\mathrm{C}} > K_r^{\mathrm{D}} = 1$. In addition, from Proposition 3 we know that, for $w_{11} = w_{22} = w$ and $k_r^j = 1$:

$$||\hat{\mathbf{b}}^{\mathrm{D}}|| = \left[\frac{w^2}{6}\left(1-\frac{2}{3}\right) + \frac{(1-w)^2}{6}\left(1-\frac{2}{3}\right)\right] = 1-2w(1-w)$$

If there are no agents $j'$ and $j''$ such that $||\mathbf{b}^{\mathrm{D}}|| \leq ||\hat{\mathbf{b}}^{\mathrm{D}}||$, then the distributional loss from delegation is never compensated by the maximal informational gain; as a consequence, centralization yields higher ex-ante expected utility to the principal. On the other hand, if there were agents $j'$ and $j''$ such that $(b_1', b_2'') \in ||\hat{\mathbf{b}}^{\mathrm{D}}||$ the principal prefers delegation when there is no agent $i$ whose preferences satisfy conditions (11) and (13). For if there were such an agent, he reveals both signals under centralization and, thus, delegation yields no informational gains.

Under the parameters of Corollary A1, costs are so high that the maximum number of truthful messages under delegation is zero. Having the chance to influence both decisions, $i$'s acquisition of one signal is cost-effective (provided communication is IC). The result also illustrates the restrictions imposed by information costs on the optimality of different organizational structures (Proposition A3). For sufficiently high costs the principal always prefer to retain authority over both issues, but restrictions weaken as the costs of acquiring a signal decreases. $\square$

## Proof of Proposition 6

*Proof.* Let $(\mathfrak{s}, \mathbf{m}, \mathbf{y})$ denote a generic equilibrium in which $\kappa < n$ is the maximum number of agents willing to reveal $S_r$ to both decision makers (suppose $\kappa > 0$). For any of such agents cost-effectiveness under delegation –condition (6)– is given by:

$$C(S_r^i) \leq \frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^j + 2)(k_r^j + 3)}$$

But for any other agent, the CE condition is at most:

$$C(S_r^i) \leq \frac{(\hat{w}_{dr})^2}{6(k_r^j + 2)(k_r^j + 3)}$$

Then, $C(S_r^i) \leq \frac{(w_{1r})^2+(w_{2r})^2}{6(\kappa+2)(\kappa+3)}$ implies acquiring information about $\theta_r$ is CE for agents willing to reveal it to both decision makers. But if at the same time $C(S_r^i) > \frac{(\hat{w}_{dr})^2}{6(\kappa+2)(\kappa+3)}$, agents willing to reveal $S_r$ to at most one decision maker do not acquire this signal because it is not CE.

On the other hand, the first of the above equations (7) determines the maximum number of agents for which acquiring $S_r$ is CE under centralization. But since $C(S_r^i) \leq \frac{(w_{1r})^2+(w_{2r})^2}{6(\kappa+3)(\kappa+4)}$, it should be greater or equal to $\kappa + 1$. Then, $K_r^{\mathrm{D}} = \kappa < K_r^{\mathrm{C}}$ $\square$

## Relative investment in information under delegation

Consider the case of delegation. Let $\lambda_r^d \equiv \{\mathbf{z} \in \Re^2 | \ \mathbf{z}'\mathbf{I}_d = 0\}$ be the locus of maximal incentives to reveal about $\theta_r = \{\theta_1, \theta_2\}$ when deciding on $y_d = \{y_1, y_2\}$.[35] The locus $\lambda_r^d$ captures the fact that communication depends only on the conflict of interest associated with $y_d$—coincides with either the vertical or the horizontal axis, for $\lambda_r^1$. and $\lambda_r^2$ (respectively). Condition (19) for communication with the principal can be expressed as:

$$||\mathbf{b}^i - \mathrm{Proj}_{\lambda_r^d}(\mathbf{b}^i)|| \leq \frac{w_{dr}}{2\big(k_r^{\mathrm{P}d} + 3\big)}$$

Then, the lemma below shows when the principal can expect to receive more information about one state under (partial) delegation.

**Lemma A4.** *Let $w \equiv w_{11} = w_{22}$. Given $\varepsilon \in \Re_+$ and an arbitrarily large $n_\varepsilon$, there exists an integer $\kappa$ and $i \in N_\varepsilon$ with $||\mathbf{b}^i - Proj_{\lambda_r^d}(\mathbf{b}^i)|| \leq \frac{w_{dr}}{2(\kappa+3)}$ such that $||\mathbf{b}^i - Proj_{\lambda_{\tilde{r}}^d}(\mathbf{b}^i)|| > \frac{w_{d\tilde{r}}}{2(\kappa+3)}$.*

*Moreover, this is true for the state associated with $w_{dr}$ because $w_{dr} > w_{d\tilde{r}}$*

*Proof.* Given that $\lambda_r^d = \lambda_{\tilde{r}}^d$ and $w_{dr} > w_{d\tilde{r}}$, the result holds for any $b_d^i \in \left(\frac{w_{d\tilde{r}}}{2(\kappa+3)}; \frac{w_{dr}}{2(\kappa+3)}\right]$ $\square$

[35] Where $\mathbf{I}$ is the 2-by-2 identity matrix, and $\mathbf{I}_d$ is its $d$th column, which matches the index of the decision under consideration.

Now, consider the case of centralization. Let $\varepsilon \in \Re_+$ and $N_\varepsilon = \{1, 2, ..., n_\varepsilon\}$ be a group of agents whose preferences satisfy: for all $i \in N_\varepsilon$ then $||\mathbf{b}^i|| = \varepsilon$. Now, let $\lambda_r \equiv \left\{\mathbf{z} \in \Re^2 | \ \mathbf{z}' \, \mathbf{W}_r = 0\right\}$ be the locus with slope $-\frac{w_{1r}}{w_{2r}}$ related to $\theta_r$. This locus represents maximal incentives to reveal information about $\theta_r = \{\theta_1, \theta_2\}$ to the principal ($\beta^i_r = 0$). The IC constraint for revealing one signal under centralization –equation (18)– can be expressed as:

$$||\mathbf{b}^i - \text{Proj}_{\lambda_r}(\mathbf{b}^i)|| \leq \frac{\left[(w_{1r})^2 + (w_{2r})^2\right]^{\frac{1}{2}}}{2\,(k^{\text{C}}_r + 3)}$$

Where $\text{Proj}_{\lambda_r}(\mathbf{b}^i)$ is the projection of $i$'s bias vector onto the locus $\lambda_r$. Note that agents with small conflict of interest reveal both signals. The same conclusion applies to dimensional non-separable message strategies; agents with the corresponding preferences reveal both signals for some realizations and reveal nothing otherwise. Hence, the principal expects to receive more information about one of the states when many agents acquire and reveal the associated signal and few agents acquire and reveal the other. The result below shows whether this is the case under centralization.

**Lemma A5.** *Let $w \equiv w_{11} = w_{22}$. Given $\varepsilon \in \Re_+$ and arbitrarily large $n_\varepsilon$, then for every integer $\kappa$ and $i \in N_\varepsilon$ with $||\mathbf{b}^i - \mathit{Proj}_{\lambda_1}(\mathbf{b}^i)|| \leq \frac{\left[(w)^2+(1-w)^2\right]^{\frac{1}{2}}}{2\,(\kappa+3)}$, there exists a $j \in N_\varepsilon$ with $||\mathbf{b}^j - \mathit{Proj}_{\lambda_2}(\mathbf{b}^j)|| \leq \frac{\left[(1-w)^2+(w)^2\right]^{\frac{1}{2}}}{2\,(\kappa+3)}$.*

*Proof.* See appendix B □

### Proof of Proposition 7

*Proof.* Note first that $\text{Var}(y_d|\mathbf{m}^*) = w^2_{d1}\text{Var}(\theta_1|\mathbf{m}^*) + w^2_{d2}\text{Var}(\theta_2|\mathbf{m})$ which, given $w_{11} = w_{22} = w$, implies that $\text{Var}(y_1|\mathbf{m}^*) - \text{Var}(y_2|\mathbf{m}^*) = w^2(1-w)^2 \left[\text{Var}(\theta_1|\mathbf{m}^*) - \text{Var}(\theta_2|\mathbf{m}^*)\right] = w^2(1-w)^2 \left[\frac{1}{6(\tilde{k}^*_1+2)} - \frac{1}{6(\tilde{k}^*_2+2)}\right]$.

Under centralization, the principal's expectation about her update beliefs on each state—and, thus, the residual variance— depends on how much information she expects to receive from agents on the equilibrium path. Since biases are uniformly distributed between $[0, \varepsilon]$, Lemma A5 implies that for any agent she expects to be revealing information about $\theta_1$, she expects another agent with the same conflict of interest who will be willing to reveal information about $\theta_2$. Then, in expectation, the number of agents revealing each signal coincide, that is $\tilde{k}^{\text{c}}_1 = \tilde{k}^{\text{c}} = 2$, which implies that $E\left[\text{Var}(\theta_1|\mathbf{m}^*) - \text{Var}(\theta_2|\mathbf{m}^*)\right] = 0$.

Now suppose the principal delegates $y_2$ to agent $i = 0$. Again, given the uniform distribution of biases, by Lemma A4 she expects more agents willing to reveal information about $\theta_1$ than $\theta_2$—and the opposite pattern for $i = 0$. Then, her ex-ante expectations about equilibrium information on each state satisfy: $\tilde{k}^{\text{P}1}_1 > \tilde{k}^{\text{P}1}_2$ and $\tilde{k}^0_1 < \tilde{k}^0_2$; as a consequence, $E\left[\text{Var}(\theta_1|\mathbf{m}^{\text{P}1})\right] < E\left[\text{Var}(\theta_2|\mathbf{m}^{\text{P}1})\right]$ and $E\left[\text{Var}(\theta_1|\mathbf{m}^0)\right] > E\left[\text{Var}(\theta_2|\mathbf{m}^0)\right]$. □

## Appendix B Proofs of Complementary results

### Generic IC constraints for communication

*Proof.* Let $j', j'' \in \{P, 1, ..., n\}$ be the decision makers for $y_1$ and $y_2$, respectively; and $i \in \{1, ..., n\}$ be a generic sender. Let $\mathbf{m}^{i*}_j$ denote $i$'s equilibrium message strategy with respect to $j$, and $\hat{\mathbf{m}}^i_j$ an alternative message strategy (deviations to be considered in each case). Then, $y_d(\mathbf{m}^i_j, \mathbf{m}^{-i}_j)$ represents the action $j$ takes when $i$ is expected to play $\mathbf{m}^{i*}_j$ and other senders are playing $\mathbf{m}^{-i}_j$. Given $i$'s conjectures about others' strategies are correct in equilibrium, I can simplify notation in the following way: $y_d(\mathbf{m}^{i*}_j(\mathbf{S}^i), \mathbf{m}^{-i}_j) = y_d(\mathbf{m}^{i*}_j)$ and $y_d(\hat{\mathbf{m}}^i_j(\mathbf{S}^i), \mathbf{m}^{-i}_j) = y_d(\hat{\mathbf{m}}^i_j)$.

Message strategy $\mathbf{m}^{i*} = \{m^{i*}_{j'}, m^{i*}_{j''}\}$ is then incentive compatible for sender $i$ if and only if for any alternative $\hat{\mathbf{m}}^i$:

$$-\int_0^1\int_0^1 \Bigg[\Big[\big(\delta_1 + b^i_1 - y_1(\mathbf{m}^{i*}_{j'})\big)^2 + \big(\delta_2 + b^i_2 - y_2(\mathbf{m}^{i*}_{j''})\big)^2\Big] - \\ - \Big[\big(\delta_1 + b^i_1 - y_1(\hat{\mathbf{m}}^i_{j'})\big)^2 + \big(\delta_2 + b^i_2 - y_2(\hat{\mathbf{m}}^i_{j''})\big)^2\Big]\Bigg] f(\theta_1, \mathbf{m}^{-i}|\mathbf{S}^i)\, f(\theta_2, \mathbf{m}^{-i}|\mathbf{S}^i)\, d\theta_1\, d\theta_2 \geq 0$$

By operating inside the square brackets with the identity $a^2 - b^2 = (a+b)(a-b)$, by definition of optimal decisions, $y^*_d = E(\delta_d|\mathbf{m}_j) + b^j_d$, and by denoting:

$$\Delta(\delta_1) = E(\delta_1|\mathbf{m}^{i*}_{j'}, \mathbf{m}^{-i}_{j'}) - E(\delta_1|\hat{\mathbf{m}}^i_{j'}, \mathbf{m}^{-i}_{j'}) \qquad \Delta(\delta_2) = E(\delta_2|\mathbf{m}^{i*}_{j''}, \mathbf{m}^{-i}_{j''}) - E(\delta_2|\hat{\mathbf{m}}^i_{j''}, \mathbf{m}^{-i}_{j''})$$

I get:[36]

$$-\int_0^1\int_0^1 \Bigg[\Big[\frac{E(\delta_1|\mathbf{m}^{i*}_{j'}, \mathbf{m}^{-i}_{j'}) + E(\delta_1|\hat{\mathbf{m}}^i_{j'}, \mathbf{m}^{-i}_{j'})}{2} - \delta_1 - (b^i_1 - b'_1)\Big]\Delta(\delta_1) + \\ + \Big[\frac{E(\delta_2|\mathbf{m}^{i*}_{j''}, \mathbf{m}^{-i}_{j''}) + E(\delta_2|\hat{\mathbf{m}}^i_{j''}, \mathbf{m}^{-i}_{j''})}{2} - \delta_2 - (b^i_2 - b''_2)\Big]\Delta(\delta_2)\Bigg] \\ f(\theta_1|\mathbf{m}^{-i}, S^i_1)\, f(\theta_2|\mathbf{m}^{-i}, S^i_2)\, P(\mathbf{m}^{-i}_{j'}|S^i_1)\, P(\mathbf{m}^{-i}_{j'}|S^i_2)\, P(\mathbf{m}^{-i}_{j''}|S^i_1)\, P(\mathbf{m}^{-i}_{j''}|S^i_2)\, d\theta_1\, d\theta_2 \geq 0$$

Given that the equilibrium message strategies for players other than $i$, $\mathbf{m}^{-i}$, are independent of $i$'s actual signal realizations, the expressions $P(\mathbf{m}^{-i}_j|S^i_1)$ and $P(\mathbf{m}^{-i}_j|S^i_2)$ can be taken out the double-integral.

I denote the receiver's updated beliefs with respect to $\delta_d$ from $i$'s perspective as:

$$\nu^{i*}_d = E(\delta_d|\mathbf{m}^{i*}_j, \mathbf{m}^{-i}_j) \qquad \hat{\nu}^i_d = E(\delta_d|\hat{\mathbf{m}}^i_j, \mathbf{m}^{-i}_j) \qquad \nu^i_d = E(\delta_d|\mathbf{S}^i_j, \mathbf{m}^{-i}_j)$$

Such that $\Delta(\delta_d) = \nu^{i*}_d - \hat{\nu}^i_d$. The generic IC constraint is then given by:

$$-\Bigg[\Big[(\nu^{i*}_1+\hat{\nu}^i_1)-2(\nu^i_1+b'_1-b^i_1)\Big]\,\Delta(\delta_1)+\Big[(\nu^{i*}_2+\hat{\nu}^i_2)-2(\nu^i_2+b''_2-b^i_2)\Big]\,\Delta(\delta_2)\Bigg]\, P(\mathbf{m}^{-i}|S_1)\, P(\mathbf{m}^{-i}|S_2) \geq 0 \quad (21)$$

Note that under Centralization $b'_1 = b''_2 = 0$ and we are back to the IC constraints in Habermacher (2018). More importantly, when $i$ reveals one signal only $\nu^{i*}_d$ and $\hat{\nu}^i_d$ are different from $\nu^i$. Sender $i$'s strategies in equilibrium and in the deviation under analysis do not transmit all the information he has, and the beliefs he induces on $j$ are different from what he believes are the optimal decisions (in the equilibrium under consideration). As I show later, this generates credibility losses for $i$ because of the possibility of ambiguous information —i.e. signals that move decisions in opposite directions if fully revealed. $\square$

[36]Note that $f(\theta_1, \mathbf{m}^{-i}|\mathbf{S}^i) = f(\theta_1|\mathbf{m}^{-i}, S^i_1)\, P(\mathbf{m}^{-i}|S^i_1)$ and that $f(\theta_2, \mathbf{m}^{-i}|\mathbf{S}^i) = f(\theta_2|\mathbf{m}^{-i}, S^i_2)\, P(\mathbf{m}^{-i}|S^i_2)$

## Proof of Lemma A1

*Proof.* Consider the equilibrium $(\mathbf{y}^*, \mathbf{m}^*_{\mathbf{j}'}, \mathbf{m}^*_{\mathbf{j}''})$ in which the principal delegates $y_d$ to agent $j$, who does not decide on the other decision. By the assumption on private information with each decision-maker, $i$'s messages to $j$ only affect $y_d$. The IC constraint in (21) then becomes:

$$-\Big[(\nu_d^{i*} + \hat{\nu}_d^i) - 2(\nu_d^i - b_d^i)\Big]\,\Delta(\delta_d) \geq 0$$

I denote by $\nu_{dr}^{i*} = E(\theta_r|\mathbf{m}_j)$ and $\hat{\nu}_{dr}^i = E(\theta_r|\hat{\mathbf{m}}_j)$ sender $i$'s expectations of $j$'s posterior beliefs about $\theta_r$ in equilibrium when he plays strategies $m_j^i$ and $\hat{m}_j$ (eqm and deviation), respectively. In addition, denote by $\nu_{dr}^i = E(\theta_r|S_r^i, \mathbf{m}_j^{-i})$ sender $i$'s expectation of $j$'s posterior beliefs about $\theta_r$ if $j$ knew $i$'s information about that state.

The IC constraint then becomes:

$$-\left[w_{d1}(\nu_{d1}^{i*} - \hat{\nu}_{d1}^i) + w_{d2}(\nu_{d2}^{i*} - \hat{\nu}_{d2}^i)\right]\Big[w_{d1}(\nu_{d1}^{i*} + \hat{\nu}_{d1}^i) + w_{d2}(\nu_{d2}^{i*} + \hat{\nu}_{d2}^i) - 2[w_{d1}\nu_{d1}^i + w_{d2}\nu_{d2}^i - (b_d^i - b_d^j)]\Big] \geq 0$$

When he reveals only one signal, however, the previous is true for the state associated with the signal he reveals truthfully but not for the other state. To see this recall that he is not being influential with respect to the latter, so his expectations about $j$'s beliefs in equilibrium are different from his conjectures including his own information.[37] It is easy to check that:

$$\begin{aligned}\nu_{dr}^i = E\left(\theta_r|\tilde{S}_r^i, \mathbf{m}_j^{-i}\right) &= \frac{(\ell_r^j + 1 + \tilde{S}_r)}{(k_r^j + 3)}\\ &= \frac{\left(k_r^j + 3 - (-1)^{\tilde{S}_r^i}\right)}{2(k_r^j + 3)}\end{aligned}$$

The second equality follows from taking expectation over the realization of others' signals (by the Law of Iterated Expectations); whereas $E(\theta_r|m_j^{-i}) = \nu_{dr}^{-i} = 1/2$ —i.e. what $i$ expects $j$'s beliefs on $\theta_r$ are if only considers other senders' truthful messages.

Consider the equilibrium in which $i$ reveals $S_1^i$ only, the IC constraint becomes:

$$-\left[w_{d1}(\nu_{d1}^{i*} - \hat{\nu}_{d1}^i)\right]\Big[w_{d1}(\hat{\nu}_{d1}^i - \nu_{d1}^{i*}) + 2w_{d2}(\nu_{d2}^{i*} - \nu_{d2}^i) + 2[(b_d^i - b_d^j)]\Big] \geq 0$$

When $i$'s type is given by $\tilde{\mathbf{S}}^i = (0,0)$, then $\nu_{d1}^{i*} = \nu_{d1}^i = \frac{(k_1^j+2)}{2(k_1^j+3)}$, $\hat{\nu}_{d1}^i = \frac{(k_1^j+4)}{2(k_1^j+3)}$; and $\nu_{d2}^{i*} = \hat{\nu}_{d2}^i = 1/2$, while $\nu_{d2}^i = \frac{(k_1^j+2)}{2(k_1^j+3)}$. Replacing these values on the above IC constraint I get:

$$2(b_1^i - b_1^j) \leq \frac{w_{d1}}{(k_1^j + 3)} + \frac{w_{d2}}{(k_2^j + 3)}$$

The case of $\tilde{\mathbf{S}}^i = (1,1)$ is analogous, with the LHS having negative signs. For the case of $\tilde{\mathbf{S}}^i = (0,1)$, all $i$'s conjectures about $j$'s posteriors are the same as the previous case ($i$ reveals the same realization

[37] In other words, if $i$ is expected to reveal $S_1^i$, then $\nu_{d2}^{i*} = \hat{\nu}_{d2}^i = E(\theta_s|\mathbf{m}_j^{-i})$ because $i$ is not influential with respect to $\theta_2$, and $\nu_{d2}^{i*} \neq \nu_{d2}^i$.

of the same signal), except for $\nu^i_{d2} = \frac{(k^j_1+4)}{2(k^j_1+3)}$. It can be easily checked that this leads to:

$$2(b^i_1 - b^j_1) \leq \frac{w_{d1}}{(k^j_1+3)} - \frac{w_{d2}}{(k^j_2+3)}$$

Whereas for $\tilde{\mathbf{S}}^i = (1,0)$ the LHS above has a negative sign.

Because all these IC constraints have to be satisfied in order for $i$ to be credible in the equilibrium under consideration, and given that all of them hold for the same measure of conflict of interest between $i$ and $j$, the following is a necessary and sufficient conditions for $i$ not having incentives to lie on $S^i_1$:

$$|b^i_1 - b^j_1| \leq \frac{1}{2}\left[\frac{w_{d1}}{(k^j_1+3)} - \frac{w_{d2}}{(k^j_2+3)}\right]$$

Now, in equilibria in which $i$ reveal both signals truthfully $\nu^{i*}_{dr} = \nu^i_{dr}$; that is, what he expects $j$'s beliefs to be in equilibrium is the same as what he conjectures the optimal decisions will be according to his information. The IC constraint then becomes:

$$-\left[w_{d1}(\nu^{i*}_{d1} - \hat{\nu}^i_{d1}) + w_{d2}(\nu^{i*}_{d2} - \hat{\nu}^i_{d2})\right]\left[w_{d1}(\nu^{i*}_{d1} - \hat{\nu}^i_{d1}) + w_{d2}(\nu^{i*}_{d2} - \hat{\nu}^i_{d2}) - 2(b^i_d - b^j_d)\right] \geq 0$$

Incentive compatibility in this case means $i$ prefers truthful revelation of both signals to any deviation, taking into account that any message he sends is believed to be truthful. So, for each type $\tilde{\mathbf{S}}^i = \{(0,0);(0,1);(1,0);(1,1)\}$ I consider deviations to announce a message different from his own. This leads to three generic deviations: lying in both signals,[38] lying on $S^i_1$,[39] and lying on $S^i_2$.[40] A substantial amount of algebra shows that the IC constraints for not lying in one signal are similar to those for revealing one signal, but without the negative term on the RHS (see Habermacher, 2018 for a detailed derivation of these IC). Incentives not to lie on both signals depend on whether the signals coincide or not, enthusiast readers can check that replacing the values for $\nu^{i*}_{dr}$ and $\hat{\nu}^i_{dr}$ for each type and deviation leads to the following IC constraints.

$$\text{For } \tilde{S}^i = \{(0,0);(1,1)\}: \qquad |b^i_1 - b^j_1| \leq \frac{1}{2}\left[\frac{w_{d1}}{(k^j_1+3)} + \frac{w_{d2}}{(k^j_2+3)}\right]$$

$$\text{For } \tilde{S}^i = \{(0,1);(1,0)\}: \qquad |b^i_1 - b^j_1| \leq \frac{1}{2}\left|\frac{w_{d1}}{(k^j_1+3)} - \frac{w_{d2}}{(k^j_2+3)}\right|$$

The last of the above is the necessary condition for full revelation given it is more restrictive (RHS is smaller). Note moreover that the expression is similar to that for revealing one signal only, which mean that whenever 'both' hold the decision-maker will prefer full revelation and, thus, will be the strategy arising in equilibrium.

Finally, I analyse the existence of Dimensional Non-separable (DNS) message strategies. I consider two of them:[41] revealing both signals when they coincide and no information otherwise, $m^{i*}_j = \{\{(0,0)\},\{(1,1)\},\{(0,1),(1,0)\}\}$, and full revelation when they do not coincide and nothing other-

[38] Meaning that type $(0,0)$ announces $(1,1)$ or vice-versa, and type $(0,1)$ announces $(1,0)$ or vice-versa.

[39] Meaning that type $(0,0)$ announces $(1,0)$ or vice-versa, and type $(0,1)$ announces $(1,1)$ or vice-versa.

[40] Meaning that type $(0,0)$ announces $(0,1)$ or vice-versa, and type $(1,0)$ announces $(1,1)$ or vice-versa.

[41] In the companion paper I show that full revelation of two types and babbling for the other two are the only two DNS message strategies arising in any equilibrium. The argument is based on the equilibrium selection criterion given the similarity of IC constraints, and applies to the case of one decision as well.

wise, $m_j^{i*} = \{\{(0,1)\},\{(1,0)\},\{(0,0),(1,1)\}\}$. Deviation incentives between the two influential messages translate into the IC constrains derived above. Note that this rules out the DNS in which the agent fully reveals ambiguous information because the IC constraint will be similar to that for Full Revelation.

Now I show that the strategy $m_j^{i*} = \{\{(0,0)\},\{(1,1)\},\{(0,1),(1,0)\}\}$ cannot arise in equilibrium. The argument relies on the incentives of the 'non-influential types' to announce influential messages according to their bias. When $\mathbf{S}^i = (0,1)$ does not have incentives to announce $m_j^i = \{(1,1)\}$, $\nu_{1r}^{i*} = 1/2$ and $\hat{\nu}_{1r}^i = \frac{(k_r^j+4)}{2(k_r^j+3)}$ for both signals; whereas $\nu_{11}^i = \frac{(k_1^j+4)}{2(k_1^j+3)}$ and $\nu_{12}^i = \frac{(k_2^j+2)}{2(k_2^j+3)}$. Then, solving the IC constraint I get the following:

$$(b_1^i - b_1^j) \leq \frac{1}{4}\left[\frac{w_{11}}{(k_1^j+3)} - \frac{w_{12}}{(k_2^j+3)}\right]$$

Which, solving for all the relevant cases, leads to:

$$|b_1^i - b_1^j| \leq \frac{1}{4}\left|\frac{w_{11}}{(k_1^j+3)} - \frac{w_{12}}{(k_2^j+3)}\right|$$

Note that this IC constraint is more restrictive than that for Full Revelation, and the decision maker will prefer the latter. As a consequence, no DNS strategy arises under delegation. □

## Proof of Proposition A1

*Proof.* Having derived the necessary conditions for communication (Lemma A1), getting the receiver-optimal (R-optimal) equilibrium consist of finding the system of beliefs consistent with each message strategy (if those exist). Let denote by $\mu_j^*\left(\mathbf{S}^i|m_j^{i*}\right)$ the beliefs of decision maker $j$ about $i$'s information (her type) upon receiving message $m_j^{i*}$.

A Fully Revealing message strategy means any of $i$'s messages is taken at face value, that is:

$$\begin{aligned}
&\mu^*\left((0,0)|m_j^i = \{(0,0)\}\right) = 1 \qquad && \mu^*\left((1,0)|m_j^i = \{(1,0)\}\right) = 1\\
&\mu^*\left((0,1)|m_j^i = \{(0,1)\}\right) = 1 \qquad && \mu^*\left((1,1)|m_j^i = \{(1,1)\}\right) = 1
\end{aligned}$$

From Lemma (A1) we know that if $i$'s preferences satisfy condition (9), then he truthfully announces his type and the beliefs above are consistent with that strategy in equilibrium. Because $j$ also knows that, the system of beliefs defined above are implemented only if $i$'s preferences satisfy condition (9); otherwise, there is always a deviation for which the beliefs are not consistent. Now, because the IC constraints for revealing one signal are the same and given I focus on R-optimal equilibria, fully revealing dominates.

For DNS, the Proof of Lemma A1 showed the only of such strategies emerging in equilibrium is $m_j^{i*} = \{\{(0,0)\},\{(1,1)\},\{(0,1),(1,0)\}\}$. Beliefs consistent with such a strategy are given by:

$$\begin{aligned}
&\mu^*\left((0,0)|m_j^i = \{(0,0)\}\right) = 1 \qquad \mu^*\left((1,1)|m_j^i = \{(1,1)\}\right) = 1\\
&\mu^*\left((0,1)|m_j^i = \{(0,1)\}\right) = \mu^*\left((1,0)|m_j^i = \{(0,1)\}\right) = 1/2\\
&\mu^*\left((0,1)|m_j^i = \{(1,0)\}\right) = \mu^*\left((1,0)|m_j^i = \{(1,0)\}\right) = 1/2
\end{aligned}$$

By the same argument as above, these are equilibrium beliefs if and only if $i$'s preferences satisfy (10). □

*Proof of equation* (20) *(DNS under Centralization).* For any dimensional non-separable strategy in which $i$ fully reveals some realizations and play babbling on the others, the expected payoff in equation (17) becomes.

$$\frac{[(w_{11})^2+(w_{21})^2]}{6}\left[\frac{1}{(\hat{k}_1+2)}-\frac{1}{2(k_1^*+2)}-\frac{1}{2(k_1^*+3)}\right]+ \\ +\frac{[(w_{12})^2+(w_{22})^2]}{6}\left[\frac{1}{(\hat{k}_2+2)}-\frac{1}{2(k_2^*+2)}-\frac{1}{2(k_2^*+3)}\right]\geq\left[C(\mathfrak{s}^{i*})-C(\hat{\mathfrak{s}}^i)\right]$$

Agent $i$ fully reveals his signals half of the time (in expectation), where $k_r^*$ indicates the equilibrium number of agents revealing information about $\theta_r$ apart from $i$. Then, solving for deviations as in the previous result, I get that acquiring both signals to play a DNS message strategy is cost effective if:

$$\frac{(w_{11})^2+(w_{21})^2}{6(k_1^*+2)(k_1^*+3)}+\frac{(w_{12})^2+(w_{22})^2}{6(k_2^*+2)(k_2^*+3)}\geq 2C(S_1^i,S_2^i)$$

Now, $i$ would prefer to acquire both signals and play DNS strategy to acquire only $S_r$ and reveal it for sure if:

$$\frac{(w_{1\tilde{r}})^2+(w_{2\tilde{r}})^2}{6(k_{\tilde{r}}^*+2)(k_{\tilde{r}}^*+3)}-\frac{(w_{1r})^2+(w_{2r})^2}{6(k_r^*+2)(k_r^*+3)}\geq 2C(S_{\tilde{r}}^i)$$

Which is easily shown that never holds when $w_{11}=w_{22}$ and $w_{d1}+w_{d2}=1$. □

## Proof of Proposition A4

*Proof.* We know from Lemmas 1 and 2 that any equilibrium information acquisition strategy must be CE and IC at the communication stage. Recall that the principal observes agents' choices of information, for which she knows the relevant message space for each agent. Equilibrium communication is then characterized as in Proposition A1 and its equivalent under centralization (Proposition 2 in Habermacher, 2018).

But cost-effectiveness can impose restrictions on equilibrium communication; for instance, when $i$ cannot afford to acquire all the information he is willing to reveal on-path. Consider the case in which $i$ revealing both signals is IC but acquiring only one of them is CE. Revelation of each signal individually is a necessary condition for Full Revelation, so $i$ acquires one signal if CE and reveal it in equilibrium. Now, which of those signals he actually acquires depend on the ex-ante expected utility –see case 4) in the previous proof.

Similar argument applies to any equilibria in which $i$ is willing to reveal $S_r^i$ only. If acquiring is CE, then he reveals that information in equilibrium; if not, he does not reveal any information –indeed, he has no message to send and the receiver observes that.

Finally, no information is transmitted when $i$'s preferences are such that he is not willing to reveal any information, or when acquiring any signal is not cost-effective.

For the case of delegation the same argument applies, with Lemmas A1 and 1, and Corollary 2. □

## Proof of Proposition 5

*Proof.* When costs do not impose restrictions on information acquisition, incentive compatibility at the communication stage dictates agents' equilibrium strategies (expressions in Lemma A2). In the case of two agents and linear costs, CE does not restrict agents' communication strategies if the cost of any signal is lower than the ex-ante expected utility in the equilibrium when $k_r^* = 1$; that is:

$$C(S_r^i) \leq \frac{(w_{1r})^2 + (w_{2r})^2}{6(k_r^* + 2)(k_r^* + 3)}$$
$$c \leq \frac{(w)^2 + (1-w)^2}{72}$$

Agent $A^1$ acquires and reveals $S_1^1$ in equilibrium if his preferences satisfy expression (18) associated with $\theta_1$ and with $k_1^* = 1$ (see Section B for the supporting system of beliefs on communication). But his preferences should not be such that full revelation is IC, otherwise the principal would be better-off under this equilibrium.[42] A similar argument applies for $A^2$ with respect to $S_2^2$.

When $\frac{(w)^2+(1-w)^2}{72} < c \leq \frac{(w)^2+(1-w)^2}{36}$ it is not CE to acquire both signals, so agents acquire the signal each of them is willing to reveal. In other words, the necessary and sufficient condition for specialization in this case is that (18) holds for different signals for each agent. □

## Proof of Lemma A5

*Proof.* Let $w \equiv w_{11} = w_{22}$, let $\kappa$ be an non-negative integer, and let $\varepsilon \in \Re_+$ with associated integer $n_\varepsilon$. Also, let $i \in N_\varepsilon$ be an agent whose preferences satisfy equation (18) with respect to $\theta_r$ for $k_r = \kappa$. Note that $\boldsymbol{\lambda}_r = \left(1, -\frac{w_{1r}}{w_{2r}}\right)$, the associated unit vector is $\hat{\boldsymbol{\lambda}}_r = \frac{\boldsymbol{\lambda}_r}{||\boldsymbol{\lambda}_r||} = \left(\frac{w_{1r}}{(w_{1r}^2+w_{2r}^2)^{1/2}}, \frac{w_{2r}}{(w_{1r}^2+w_{2r}^2)^{1/2}}\right)$, and that $\text{Proj}_{\boldsymbol{\lambda}_r}(\mathbf{b}^i) = (\mathbf{b}^i \cdot \hat{\boldsymbol{\lambda}}_r)\boldsymbol{\lambda}_r$. Then, careful algebra leads to condition (18) expressed as:

$$||\mathbf{b}^i - \text{Proj}_{\lambda_1}(\mathbf{b}^i)|| \leq \frac{\left[(w)^2 + (1-w)^2\right]^{\frac{1}{2}}}{2(\kappa+3)}$$

Now consider an agent $j$ with the following preferences: $b_1^j = b_2^i$ and $b_2^j = b_1^i$. I need to show 1) $j \in N_\varepsilon$, and 2) $\mathbf{b}^j$ satisfies equation (18) for $\theta_2$. Proving the first claim is straightforward, since $j$'s preference vector is just $i$'s with its components swapped. This says that both $i$ and $j$ agents have exactly the same conflict of interest with the principal.

The second part of the proof requires work out $||\mathbf{b}^j - \text{Proj}_{\lambda_2}(\mathbf{b}^j)||$, which yield:

$$\begin{aligned}
||\mathbf{b}^j - \text{Proj}_{\lambda_2}(\mathbf{b}^j)|| &= |b_1^j\,(1-w) + b_2^j\,w|\ \left[(w)^2 + (1-w)^2\right]^{-\frac{1}{2}} \\
&= |b_2^i\,(1-w) + b_1^i\,w|\ \left[(w)^2 + (1-w)^2\right]^{-\frac{1}{2}} \\
&= ||\mathbf{b}^i - \text{Proj}_{\lambda_1}(\mathbf{b}^i)||
\end{aligned}$$

□

[42] Note that if condition (18) holds for $S_2^1$ (but still not those for full revelation) he will still find optimal to acquire $S_1^1$ only, *given $A^2$ is acquiring the other signal in equilibrium.*

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# Appendix C (Online Appendix)

## Covert Information Acquisition Game

In the covert game the decision maker does not observe agents' information acquisition decisions. This implies that a Perfect Bayesian Equilibrium must also specify the decision maker's beliefs about agents' investments in information. I will focus on pure strategy equilibria at the information acquisition stage. In principle, the agent in question may try to convey information about which signals he acquired to the decision maker by means of his cheap talk message. However, a result from Argenziano et al. (2016) allows me to restrict attention to equilibria in which agents do not signal how much information each has acquired, and this is without loss of generality. Below I present the result.

**Lemma C6** (Argenziano et al., 2016)**.** *Any outcome supported in a Perfect Bayesian Equilibrium of the covert game in which an agent follows a pure strategy in the choice of information can be supported in a Perfect Bayesian Equilibrium in which the decision makers beliefs about his information acquisition decision do not vary with the agents message.*

There would be two classes of deviations available to agents if the decision maker's beliefs about information acquisition decisions could be affected by the choice of messages. First, an agent could acquire an off-path amount of information but still send the message corresponding to the equilibrium amount of information. Secondly, the agent could acquire an off-path amount information and send a message corresponding to an off-path information acquisition choice, which in turn may no be true. The lemma says that any equilibrium outcome under the second class of deviations can be supported as an equilibrium in which the agent cannot change the decision maker's beliefs about his information acquisition decision.

When an agent acquires an off-path amount of information he can choose among the equilibrium messages according to his preferences. As a consequence, any deviation at the information acquisition stage implies a deviation at the communication stage. The result below summarizes this.

**Lemma C7.** *When agent $i$ acquires fewer signals than what is expected on the equilibrium path, the messages used under the deviation are a strict subset of the equilibrium messages available. When $i$ acquires more signals than expected on path, he uses the additional information to deviate from truth-telling for some signal realizations.*

The argument of the above lemma is straightforward. When $i$ acquires fewer signals, he will not be able to condition his message on the information that has not been observed. As a consequence, the messages effectively used under the deviation will be fewer than those available on the equilibrium path, which implies that $i$ is inducing beliefs that do not reflect his signal realizations. When $i$ acquires more signals he cannot transmit that additional information on the equilibrium path (there is no way of signalling he acquired more information). Because additional information implies additional costs, $i$ must be obtaining some utility gains with respect to equilibrium communication—by inducing beliefs according to his preferences for some signals realizations. This clearly implies that he will deviate from truth-telling when he observes the corresponding realizations.

Let $(\mathfrak{s}^*, \mathbf{m}^*(\mathfrak{s}^*), \mathbf{y}^*(\mathbf{m}^*(\mathfrak{s}^*)))$ be the equilibrium information acquisition decisions, message strategies, and decisions (respectively). Then, agent $i$'s IC constraint at the information acquisition stage must consider any possible deviation $\hat{\mathfrak{s}}^i$ and the corresponding message strategy $\hat{m}^i(\hat{\mathfrak{s}}^i)$; that is,

$$E\Bigg[\int_0^1\int_0^1 -\sum_{y_d}^{\{y_1,y_2\}}\left(y_d\left(m^{i*},\mathbf{m}^{\text{-}i*}\right)-\delta_d-b_d^i\right)^2 f(\theta_1|\mathfrak{s}^{i*},\mathbf{m}^{\text{-}i*})f(\theta_2|\mathfrak{s}^{i*},\mathbf{m}^{\text{-}i*})+$$
$$+\int_0^1\int_0^1 \sum_{y_d}^{\{y_1,y_2\}}\left(y_d\left(\hat{m}^{i},\mathbf{m}^{\text{-}i*}\right)-\delta_d-b_d^i\right)^2 f(\theta_1|\hat{\mathfrak{s}}^{i},\mathbf{m}^{\text{-}i*})f(\theta_2|\hat{\mathfrak{s}}^{i},\mathbf{m}^{\text{-}i*})\Bigg]\geq C(\mathfrak{s}^{i*})-C(\hat{\mathfrak{s}}^i) \tag{22}$$

Then, given that deviations at the info acquisition stage do not affect the set of influential messages (Lemma C6) and that this deviations necessarily imply deviations at the communication stage (Lemma C7), the above expression can be solved by computing the expectation over all possible signals realizations and the corresponding messages on- and off-path. In particular, the utility gains from deviations will be given by the realizations in which the messages on- and off- path are different. Formally, let $\tilde{\mathbf{S}}^i$ represent the realization of the signals corresponding to agent $i$, independent of which of these he observes (determined by $\mathfrak{s}^i$). I can then express and compare message strategies on- and off-path as functions of $i$'s type and the information he observes. In other words, *before deciding on information acquisition* and given the equilibrium under play, he can assess the utility gains from any info acquisition strategy and the corresponding messages he expects to send conditional on each possible pair of signal realizations. Equation 22 then becomes:

$$\sum_{\tilde{\mathbf{S}}\in\mathcal{S}}\Pr(\tilde{\mathbf{S}}^i)\times\int_0^1\int_0^1 -\sum_{y_d}^{\{y_1,y_2\}}\left[\left(y_d\left(m^i(\mathfrak{s}^{i*},\tilde{\mathbf{S}}^i)\right)-\delta_d-b_d^i\right)^2-\left(y_d\left(m^i(\hat{\mathfrak{s}}^{i},\tilde{\mathbf{S}}^i)\right)-\delta_d-b_d^i\right)^2\right]\times$$
$$\times f(\theta_1|\tilde{S}_1^i,\mathbf{m}^{\text{-}i*})f(\theta_2|\tilde{S}_2^i,\mathbf{m}^{\text{-}i*})\geq C(\mathfrak{s}^{i*})-C(\hat{\mathfrak{s}}^i)$$

Now, I proceed to analyse deviations from different equilibrium info acquisition strategies.

**Agent $i$ acquires both signals in equilibrium ($\mathfrak{s}^{i*}=\mathbf{S}^i$)**

Let denote by $\nu_r^{i*}(\tilde{\mathbf{S}}^i)=E\left(\theta_r|m^i(\mathfrak{s}^{i*},\tilde{\mathbf{S}}^i),\mathbf{m}^{\text{-}i*}\right)$ the beliefs about $\theta_r=\{\theta_1,\theta_2\}$ induced by $i$ under the equilibrium information acquisition strategies and the message corresponding to the realizations given by $\tilde{\mathbf{S}}\in\mathcal{S}$. Equivalently, denote by $\hat{\nu}_r^{i}(\tilde{\mathbf{S}}^i)=E\left(\theta_r|m^i(\hat{\mathfrak{s}}^{i},\tilde{\mathbf{S}}^i),\mathbf{m}^{\text{-}i*}\right)$ be the beliefs induced under the deviation at the information acquisition stage (for the same signals realizations). Then, the IC constraint at the information acquisition stage for agent $i$ becomes:

$$\sum_{\tilde{\mathbf{S}}^i\in\mathcal{S}}\Pr(\tilde{\mathbf{S}}^i)\Bigg[-\sum_{y_d}\left[w_{d1}\left(\nu_1^{i*}(\tilde{\mathbf{S}}^i)-\hat{\nu}_1^{i}(\tilde{\mathbf{S}}^i)\right)+w_{d2}\left(\nu_2^{i*}(\tilde{\mathbf{S}}^i)-\hat{\nu}_2^{i}(\tilde{\mathbf{S}}^i)\right)\right]\times$$
$$\left[-w_{d1}\left(\nu_1^{i*}(\tilde{\mathbf{S}}^i)-\hat{\nu}_1^{i}(\tilde{\mathbf{S}}^i)\right)-w_{d2}\left(\nu_2^{i*}(\tilde{\mathbf{S}}^i)-\hat{\nu}_2^{i}(\tilde{\mathbf{S}}^i)\right)-2b_d^i\right]\Bigg]\geq C(\mathfrak{s}^{i*})-C(\hat{\mathfrak{s}}^i)$$

First consider the deviation in which $i$ only acquires information about $\theta_1$; that is, $\hat{\mathfrak{s}}^i=\{S_1^i\}$. It is straightforward to note that this deviation *per se* does not imply any difference in induced beliefs with respect to $\theta_1$, formally $\nu_1^{i*}(\tilde{\mathbf{S}}^i)=\hat{\nu}_1^{i}(\tilde{\mathbf{S}}^i)$ for all $\tilde{\mathbf{S}}^i\in\mathcal{S}$. Now, $i$'s message associated with $S_2^i$ does not depend on the signal's realization, but depends on $\mathbf{b}^i$ and may also depend on $S_1^i$.

Let consider the case in which $\hat{m}^i=\{\tilde{S}_1^i,1\}$, i.e. $i$ truthfully reveals his information about $\theta_1$ and announces always a 1 for $\theta_2$. Then, $\hat{\nu}_1^{i}(\tilde{\mathbf{S}}^i)=\frac{(k_2+4)}{2(k_2+3)}$ and it is different from $\nu_1^{i*}(\tilde{\mathbf{S}}^i)$ only when $\tilde{S}_2^i=\{0\}$

which, in turn, happens for $\tilde{\mathbf{S}}^i = \{(0,0);(1,0)\}$. The IC constraint in such a case is:

$$\Pr\left(\tilde{\mathbf{S}} = \{(0,0)\}\right)\left[\sum_{y_d}\left[w_{d2}\left[\frac{(k_2+2)}{2(k_2+3)} - \frac{(k_2+4)}{2(k_2+3)}\right]\right]\left[w_{d2}\left[\frac{(k_2+2)}{2(k_2+3)} - \frac{(k_2+4)}{2(k_2+3)} - 2b^i_d\right]\right]\right] +$$
$$\Pr\left(\tilde{\mathbf{S}} = \{(1,0)\}\right)\left[\sum_{y_d}\left[w_{d2}\left[\frac{(k_2+2)}{2(k_2+3)} - \frac{(k_2+4)}{2(k_2+3)}\right]\right]\left[w_{d2}\left[\frac{(k_2+2)}{2(k_2+3)} - \frac{(k_2+4)}{2(k_2+3)} - 2b^i_d\right]\right]\right] \geq C(S^i_2)$$

Given that $\Pr\left(\tilde{\mathbf{S}} = \{(0,0)\}\right) = \Pr\left(\tilde{\mathbf{S}} = \{(1,0)\}\right) = 1/4$, the IC constraint becomes.

$$\frac{1}{(k_2+3)}\left[\frac{(w^2_{12}+w^2_{22})}{2(k_2+3)} - \beta^i_2\right] \geq C(S^i_2)$$

That is, the expected utility gains of inducing the correct beliefs about $\theta_2$ should be greater than the extra utility from saving in the costs of becoming informed about that state. It is easy to show that the case of $\hat{m}^i = \{\tilde{S}^i_1, 0\}$ has the sign of $\beta^i_2$ reversed, for which the generic IC constraint for not acquiring signal $S^i_r$ becomes:

$$\frac{1}{(k_r+3)}\left[\frac{(w^2_{1r}+w^2_{2r})}{2(k_r+3)} - |\beta^i_r|\right] \geq C(S^i_r) \tag{23}$$

For the deviation involving no information acquisition, $\hat{\mathfrak{s}}^i = \{\emptyset\}$, the expression of the IC constraint will depend on the message $i$ decides to announce at the communication stage. On the one hand, when the message is $\hat{m)}^i = \{(0,0),(1,1)\}$, the induced beliefs will coincide with the equilibrium strategy when $\tilde{\mathbf{S}}^i = (1,1)$, but also partially for other realizations. Formally $\nu^{i*}_r(1,1) = \hat{\nu}^i_r(1,1)$ for $\theta_r = \{\theta_1,\theta_2\}$, $\nu^{i*}_1(1,0) = \hat{\nu}^i_1(1,1)$, and $\nu^{i*}_2(0,1) = \hat{\nu}^i_r(1,1)$. Following the characterization of equilibrium communication under centralization, the IC constraint becomes:

$$\left[\frac{1}{(k_1+3)}\left[\frac{(w^2_{11}+w^2_{21})}{2(k_1+3)} + \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_2+3)} - |\beta^i_1|\right] +\right.$$
$$\left. + \frac{1}{(k_2+3)}\left[\frac{(w^2_{12}+w^2_{22})}{2(k_2+3)} + \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_1+3)} - |\beta^i_2|\right]\right] \geq 2C(S^i_1,S^i_2) + \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_1+3)(k_2+3)} \tag{24}$$

Which basically is a more strict version of the IC constraint for full revelation when signals coincide (under centralization).

Similarly, when the deviation involves announcing $\hat{m)}^i = \{(0,1),(1,0)\}$ the IC constraint becomes:

$$\left[\frac{1}{(k_1+3)}\left[\frac{(w^2_{11}+w^2_{21})}{2(k_1+3)} - \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_2+3)} - |\beta^i_1|\right] +\right.$$
$$\left. + \frac{1}{(k_2+3)}\left[\frac{(w^2_{12}+w^2_{22})}{2(k_2+3)} - \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_1+3)} - |\beta^i_2|\right]\right] \geq 2C(S^i_1,S^i_2) + \frac{(w_{11}w_{12}+w_{21}w_{22})}{(k_1+3)(k_2+3)} \tag{25}$$

**Agent $i$ acquires one signal on path ($\mathfrak{s}^{i*} = \{S^i_1\}$).**

When $i$ acquires only one signal on path, his assessment of the consequences of any deviation still conditions on each possible pair of signal realizations. As I show in this section, this becomes particularly important for deviation involving acquisition of more signals. Not is necessary to distinguish between the induced beliefs on- and off-path, and the actual information $i$ has access to. Thus, in addition to the previously defined $\nu_r^{i*}(\tilde{\mathbf{S}}^i)$ and $\hat{\nu}_r^i(\tilde{\mathbf{S}}^i)$, I now denote by $\nu_r^i(\tilde{\mathbf{S}}^i) = E\left(\theta_r|\tilde{\mathbf{S}}^i, \mathbf{m}^{-i*}\right)$ the beliefs about $\theta_r$ that would result from the decision maker observing the signals available to agent $i$ (independent of his information acquisition strategy). Then, $i$'s IC constraint at the information acquisition stage becomes:

$$\sum_{\tilde{\mathbf{S}}^i \in \mathcal{S}} \Pr(\tilde{\mathbf{S}}^i)\Bigg[-\sum_{y_d}\left[w_{d1}\left(\nu_1^{i*}(\tilde{\mathbf{S}}^i) - \hat{\nu}_1^i(\tilde{\mathbf{S}}^i)\right) + w_{d2}\left(\nu_2^{i*}(\tilde{\mathbf{S}}^i) - \hat{\nu}_2^i(\tilde{\mathbf{S}}^i)\right)\right] \times$$
$$\left[w_{d1}\left(\nu_1^{i*}(\tilde{\mathbf{S}}^i) + \hat{\nu}_1^i(\tilde{\mathbf{S}}^i) - 2\nu_1^i(\tilde{\mathbf{S}}^i)\right) + w_{d2}\left(\nu_2^{i*}(\tilde{\mathbf{S}}^i) + \hat{\nu}_2^i(\tilde{\mathbf{S}}^i) - 2\nu_2^i(\tilde{\mathbf{S}}^i)\right) - 2b_d^i\right]\Bigg] \geq C(S_1^i) - C(\hat{\mathfrak{s}}^i)$$

When $i$ considers the deviation of not acquiring any signals and decides to announce $\hat{m}_1^i = \{1\}$, he induces incorrect beliefs as compared to the equilibrium in two cases, namely $\tilde{\mathbf{S}} = \{(0,0);(0,1)\}$. The ex-ante expected utility losses of such strategy depends on the signal realizations, as can be noted in the expression for the IC constraint below:

$$\Pr\left(\tilde{\mathbf{S}}^i = (0,0)\right)\Bigg[-\sum_{y_d}\left[w_{d1}\left(\frac{(k_1+2)}{2(k_1+3)} - \frac{(k_1+4)}{2(k_1+3)}\right)\right] \times$$
$$\left[w_{d1}\left(\frac{(k_1+2)}{2(k_1+3)} + \frac{(k_1+4)}{2(k_1+3)} - \frac{2(k_1+2)}{2(k_1+3)}\right) + w_{d2}\left(\frac{1}{2} + \frac{1}{2} - \frac{2(k_2+2)}{2(k_2+3)}\right) - 2b_d^i\right]\Bigg] +$$
$$\Pr\left(\tilde{\mathbf{S}}^i = (0,1)\right)\Bigg[-\sum_{y_d}\left[w_{d1}\left(\frac{(k_1+2)}{2(k_1+3)} - \frac{(k_1+4)}{2(k_1+3)}\right)\right] \times$$
$$\left[w_{d1}\left(\frac{(k_1+2)}{2(k_1+3)} + \frac{(k_1+4)}{2(k_1+3)} - \frac{2(k_1+2)}{2(k_1+3)}\right) + w_{d2}\left(\frac{1}{2} + \frac{1}{2} - \frac{2(k_2+4)}{2(k_2+3)}\right) - 2b_d^i\right]\Bigg] \geq C(S_1^i)$$

Which, after some algebra gives:

$$\frac{1}{(k_1+3)}\left[\frac{(w_{11}^2 + w_{21}^2)}{2(k_1+3)} - \beta_1^i\right] \geq C(S_1^i) \tag{26}$$

It is straightforward to note that the generic IC constraint involves the absolute value of $\beta_r^i$.

Deviations involving the acquisition of more information have the issue that $i$ cannot signal this to the decision maker. This additional information will thus be used to identify situations (i.e. signal realizations) under which $i$ will deliberately lie to the decision maker. Such deviations are thus related to the credibility loss, because $i$ would like to induce beliefs about the signal he is not expected to acquire on path by means of messages on the signal he is believed on path.

As analysed in the communication game, the credibility loss takes place when signals do not coincide, $\tilde{\mathbf{S}}^i = \{(0,1);(1,0)\}$, so any deviation at the communication stage will take place in one of these cases. Moreover, given that $\beta_1^i$ is typically not zero, $i$'s incentives to lie will always be in a single direction, that is either when $\tilde{\mathbf{S}}^i = (0,1)$ or when $\tilde{\mathbf{S}}^i = (1,0)$ but not in both. The IC constraint for the deviation of acquiring both signals and announcing $\hat{m}_1^i = 0$ when $\tilde{\mathbf{S}}^i = (1,0)$ will be given by:

$$-\Pr\left(\tilde{\mathbf{S}}^i = (1,0)\right)\sum_{y_d}\left[\left[w_{d1}\left(\frac{(k_1+4)}{2(k_1+3)} - \frac{(k_1+2)}{2(k_1+3)}\right)\right]\times\right.$$
$$\left.\left[w_{d1}\left(\frac{(k_1+4)}{2(k_1+3)} + \frac{(k_1+2)}{2(k_1+3)} - \frac{(k_1+4)}{(k_1+3)}\right) + w_{d2}\left(1 - \frac{(k_2+2)}{(k_2+3)}\right) - 2b_d^i\right]\right] \geq C(S_2^i)$$

Which yields:

$$\left[\frac{(w_{11}^2 + w_{21}^2)}{2(k_1+3)^2} - \frac{(w_{11}w_{12} + w_{21}w_{22})}{2(k_1+3)(k_2+3)} - \beta_1^i\right] \geq -2C(S_2^i) \tag{27}$$

Which is equivalent to say that the cost of acquiring the second signal is too large with respect to the utility gain from deviating under ambiguous information.

Incentive compatibility then depends on $|\beta_1^i|$ being within the limits imposed by equations (18), (26), and (27). Note that equation (26) implies (18), meaning that if $i$ is willing to acquire $\tilde{S}_1^i$ instead of acquiring no signal, then he will certainly reveal it. Incentive compatibility thus is captured by equations (26), and (27), which lead to:

$$\frac{|\beta_1^i|}{(k^{\mathrm{C}}+3)} \leq \min\left\{\frac{(w_{11}^2 + w_{21}^2)}{2(k_1^{\mathrm{C}}+3)^2} - C(S_1^i)\,;\, \frac{(w_{11}^2 + w_{21}^2)}{2(k_1^{\mathrm{C}}+3)^2} - \frac{(w_{11}w_{12} + w_{21}w_{22})}{2(k_1+3)(k_2+3)} + 2C(S_2^i)\right\} \tag{28}$$

Now, let define $\mathfrak{B}_1\left(C(S_1), C(S_2), \mathbf{k}^{\mathrm{C}}\right) = \{\mathbf{b} : \mathbf{b}\,\text{satisfies equation (28)}\}$. Then, the LHS in equation (28) is weakly positive and, thus, $\mathfrak{B}_1 \neq \emptyset$ when the RHS is strictly positive, that is,

$$\frac{(w_{11}^2 + w_{21}^2)}{2(k_1^{\mathrm{C}}+3)^2} - \max\left\{C(S_1^i)\,;\, \frac{(w_{11}w_{12} + w_{21}w_{22})}{2(k_1^{\mathrm{C}}+3)(k_2^{\mathrm{C}}+3)} - 2C(S_2^i)\right\} > 0 \tag{29}$$

Moreover, it is evident from the above expression that $\frac{\partial \mathfrak{B}_1}{\partial C(S_1)} < 0$ and $\frac{\partial \mathfrak{B}_1}{\partial C(S_2)} > 0$.

## Information acquisition on the intensive margin

This subsection tries to convey a sense of how restrictive is the assumption that sender can acquire at most one signal associated with each state. Despite the question relates to the model with information acquisition (Section 4), throughout this analysis I will 'endow' agents with different amount of information and study their communication incentives. The analysis with information acquisition on the intensive margin, and its consequences for optimal organizational design will be subject of future work.

I focus in a one-decision, one-state cheap talk model between a sender and a receiver, much in the spirit of the uniform-quadratic example in Crawford and Sobel (1982). I perform two exercises. First, I compare the uniform-quadratic case with the beta-binomial model in which infinitely many senders with the same bias receive a binary signal. Since each of these virtual senders will truthfully reveal his signal when the expected precision of the decision is sufficiently low, the exercise allows me to understand how much the *receiver* gains from allowing a single sender to partition the message space. I show that the receiver strictly prefers to have a single, perfectly-informed sender than infinitely many of them having noisy information, for each possible bias.

In order to gain further intuition, in the second analysis I parametrize the sender's information as a finite number of iid binary trials correlated to the state. I borrow this information structure from Argenziano et al. (2016), but I extend their work by characterizing the maximum number of partitions as a function of the number of signals available to the sender (and his bias). I show the maximum number of partitions in any influential equilibria converges to the perfectly informed case in Crawford and Sobel (1982) when the number of binary experiments goes to infinity. So far I cannot compare the receiver's ex-ante expected utility under centralization and delegation as a function of the sender's information, due to not being able to find a closed form solution for the residual variance under communication.