Centre de Recherche en Économie et Statistique

CREST

Série des Documents de Travail

n° 2013-50

# Communication and Binary Decisions : Is it Better to Communicate ?

F. LOSS[1] – E. MALAVOLTI[2]
T. VERGÉ[3]

September 2013



1 CNAM (LIRSA [*corresponding author]*

2 ENAC (LEEA).

3 CREST, Laboratoire d'Economie Industrielle.

# Communication and Binary Decisions: Is it Better to Communicate?*

Frédéric Loss† Estelle Malavolti‡ Thibaud Vergé§

September 2013

**Abstract**

We study information transmission between an informed expert and an uninformed decision-maker when the decision is binary and the expert does not have a systematic bias. Whenever, an equilibrium exists where the decision is delegated to the expert, it is ex-ante Pareto-dominant. Adding a round of multilateral communication does not improve information transmission. The decision-maker can however improve information transmission by communicating sequentially with two experts. However, introduce multiple rounds of communication (i.e., allowing for rebuttal) does not help. (JEL: C72, D82, D83)

*We would like to thanks Anne-Marie Tauzin, the Editor and an anonymous referee, as well as seminar participants at Ecole Polytechnique, CNAM, CREST, and the 2012 Royal Economic Society Annual Conference (Cambridge) for helpful comments and discussions. All remaining errors are our own.

†CNAM(LIRSA) [corresponding author]

‡ENAC(LEEA)

§CREST(LEI)

# 1 Introduction

In many instances, decisions are limited to a yes/no choice: CEOs have to decide whether or not to realize a project, politicians must choose to approve or reject a reform, competition authorities have to decide to clear or block a merger, or whether a practice is pro- or anti-competitive. In many of those cases, the decision-maker does not initially know the optimal decision and often has to seek advice from informed experts.[1] It is however often the case that the informed experts have their own agenda that may differ from the decision-maker's preferences. They can thus be tempted to withhold information from or transmit false information to the decision-makers in order to influence them. How they reveal their privileged information to the decision-maker will also depends on the impact of their decisions on their payoffs. In some situations, they will be engaged in a contractual relationship with the decision-maker. However, in many instance, there is no direct financial incentives for the expert who only gets "paid" (i.e., derives some utility) from the actual outcome.[2]

This raises a number of questions concerning the interactions between the decision-maker and the informed experts. A first question is whether decision-maker should simply delegate the decision process to one expert (i.e., letting her decide), or try to obtain advice from one or several experts keeping for himself the power to decide. If the decision-maker decides to seek advice, the next question is to decide how sophisticated the communication mechanism should be. We try to answer these questions by adapting the standard cheap-talk model à la Crawford and Sobel (1982) to binary decisions. Cheap-talk models have often been used by political scientists to analyze how legislative rules influence information transmission.[3] They however usually assume continuous choices whereas we are interested by much simpler contexts where the decision cannot be fine-tuned and choices are binary.

[1]For example, CEOs routinely seek advice from marketing specialists, investment bankers or management consultants; politicians rely on advisers; competition authorities rely on case handlers but also on firms' counsels to decide on each case.

[2]The way to model the interactions between the expert and the decision-maker is totally different when side-payments can be made. See for instance Gromb and Martimort (2007) who analyze similar situations but in a principal-agent context with direct monetary transfers.

[3]See for instance Gilligan and Krehbiel (1987), Gilligan and Krehbiel (1989), Austen-Smith (1993), Krishna and Morgan (2001a) and Mylovanov (2008).

In such a simple setting in which the expert is not systematically biased, we show the only information that the decision-maker can extract is whether the expert would prefer to implement the project or not. Therefore, the most informative equilibrium (if such an equilibrium exists) yields the same outcome as delegating the decision to the expert. Krishna and Morgan (2004), building on the long cheap-talk literature initiated by Aumann and Hart (2003), show that adding a face-to-face meeting help the decision-maker to extract more information from the single expert. We show that when decision is binary, adding such multistage bilateral communication does not improve information transmission. Thus, when using a single expert, the decision-maker does not really need to communicate with her since the ex-ante Pareto-dominant equilibrium is either equivalent to letting the expert decide or not listen to her. The result that delegation is preferred to communication (at least when the expert is not too biased), derived by Dessein (2002) in the continuous decision model continues to hold in the binary case, although delegation and communication are now equivalent.

We then move on to the multiple experts case and show, in a simple game where the experts sequentially send one message each before the decision is taken, that communication with both experts may then improve information transmission. Indeed, although a babbling equilibrium and delegation-like equilibria again exist, there may also exist additional equilibria that rely on the messages sent by both experts. Moreover, any of these new equilibria, namely a veto-power equilibrium where a project is rejected unless both experts advise to implement it, and an implementation-power equilibrium where a project is implemented unless both experts advise against it, may well be the decision-maker's preferred outcome. Finally, we also study the possibility that experts engage in an extended back-and-forth debate and consider a rebuttal game. Krishna and Morgan (2001b) have shown in the continuous decision case, that an extended back-and-forth debate could lead to full information revelation when the two experts have opposite biases as long as they are not "extremists".[4] We show in this paper that multiple rounds of communication do not induce the experts to reveal more useful information than a simple one round of communication in which each expert speaks only once.

The paper proceeds as follows. We start with the single expert case, looking at

[4] In a setting in which the decision-maker does not observe the experts' biases, Li and Madaràsz (2008) show (in a continuous decision setting) that nondisclosure may then dominate mandatory disclosure.

unilateral as well as multilateral communication (Section 2). We then move on to the multiple experts case, and consider games with a single round of communication as well as with multiple rounds (Section 3). Section 4 concludes. Formal proofs are relegated in the Appendix.

# 2 Seeking Advice from One Expert

We first focus on the interactions between an uninformed decision-maker ($DM$, he) and a perfectly informed expert ($E$, she). In contrast to the standard cheap-talk literature (à la Crawford and Sobel (1982)) that considers continuous decisions, we envisage binary decisions, that is, situations in which $DM$ can only decide whether to implement a project or not.

$E$ perfectly observes the project's "type", $\theta \in \Theta$, while $DM$ only knows the distribution from which this type is drawn. If the project is implemented, it generates private net benefits $u_{DM}(\theta)$ and $u_E(\theta)$ for the decision-maker and the expert respectively. Contrary to the literature on multi-dimensional cheap-talk (see for instance Battaglini (2002) and Levy and Razin (2007)) in which the "dimension of conflict" influences the decision-maker's ability to extract information from the expert, in our setting, dimensionality does not matter and we thus allow $\theta$ to be multi-dimensional. This is because, choices being binary, what really matters is the utility derived by the players from the decision-making process and therefore it all boils down to a one-dimensional problem. We define the following subsets of $\Theta$:

- $DM^+ = \{\theta \in \Theta \mid u_{DM}(\theta) > 0\}$ and $DM^- = \{\theta \in \Theta \mid u_{DM}(\theta) < 0\}$.
- $E^+ = \{\theta \in \Theta \mid u_E(\theta) > 0\}$ and $E^- = \{\theta \in \Theta \mid u_E(\theta) < 0\}$.

For the sake of simplicity, we only consider generic versions of the game.[5]

## 2.1 Unilateral Communication, Delegation and Centralization

We start with a standard unilateral communication game $G(\Theta)$ in which $E$ sends a message $m(\theta)$ to $DM$, who then chooses his strategy, i.e., chooses, for each message

[5] In particular, the sets of values of $\theta$ for which $u_{DM}(\theta) = 0$ or $u_E(\theta) = 0$ are of measure 0, and $E_\theta(u_{DM}(\theta) \mid \theta \in E^+) \neq 0$, $E_\theta(u_{DM}(\theta) \mid \theta \in E^-) \neq 0$ and $E_\theta(u_{DM}(\theta)) \neq 0$.

$m$, the probability $\delta(m)$ that the project is implemented. As it is common in cheap-talk games, there always exists a babbling (i.e., non-informative) equilibrium: anticipating that $DM$ never listens to her messages, transmitting a non-informative signal is an optimal strategy for $E$; and, given that the messages are non-informative, it is indeed optimal for $DM$ to base his decision on his prior beliefs. This non-revealing equilibrium thus yields the same outcome as *centralization* (i.e., not using any expert).

We now focus on equilibria in which some information is revealed which requires that there exist at least two messages for which $DM$'s decision differ. We denote $m^+$ (resp., $m^-$) a message for which the probability that the project is implemented is the highest (resp., lowest). When $E$ wants the project to be implemented (i.e., $\theta \in E^+$) sending the message $m^+$ is an optimal strategy as it maximizes the chances that the project goes through. Similarly, when she prefers not to implement the project (i.e., $\theta \in E^-$), sending $m^-$ is an optimal strategy.[6] Given that we focus on generic versions of the game, $DM$'s optimal strategy must be a pure strategy, and, we must therefore have $\delta(m^+) = 1$ and $\delta(m^-) = 0$. This is indeed $DM$'s optimal strategy if and only if:

$$E_\theta\left(1_{\{\theta\in E^+\}} u_{DM}(\theta)\right) > 0 \text{ and } E_\theta\left(1_{\{\theta\in E^-\}} u_{DM}(\theta)\right) < 0. \qquad (C)$$

This partially-revealing equilibrium thus yields the same outcome as delegating the decision-power to the expert (in this equilibrium $DM$ always chooses $E$'s preferred action). Moreover, this *delegation*-like equilibrium ex-ante Pareto-dominates – whenever condition $(C)$ is satisfied – the centralization-like equilibrium: it is obvious that $E$ prefers the delegation-like equilibrium since her optimal action is always selected. Moreover, when "centralization" implies that no project is implemented, $DM$ also prefers "delegation" in which projects in $E^+$ are implemented and $E_\theta\left(1_{\{\theta\in E^+\}} u_{DM}(\theta)\right) > 0$. Similarly, when centralization implies that all projects are implemented, delegation ensures that projects in $E^-$ are not implemented, which is better for $DM$ since $E_\theta\left(1_{\{\theta\in E^-\}} u_{DM}(\theta)\right) < 0$. The next proposition summarizes the previous results.[7]

[6] For the projects such that $u_E(\theta) = 0$, $E$ is indifferent while $DM$'s might not be indifferent. However, since we only consider generic versions of the game, we can abstract from considering such projects.

[7] Note that there always exist many equilibria where $E$ plays mixed strategies, but these are all outcome-equivalent to either centralization-like or delegation-like equilibria. Indeed, whenever there exist multiple signals for which the probabilities that $DM$ implements the project are identical, $E$ can

**Proposition 1** *When conditions* ($C$) *hold, any perfect Bayesian equilibrium of the unilateral communication game* $G(\Theta)$ *is outcome-equivalent either to centralization (DM never listens to E) or to delegation (DM always follows E's advice), and delegation is ex-ante Pareto-dominant. Otherwise, all equilibria are outcome-equivalent to centralization.*

Because decisions are binary ("yes/no"), $E$ always splits the projects in two groups: those she would like to implement, and the others. It is thus impossible to obtain more information than that and sophisticated messages are useless. Besides, communication is not needed: either $DM$ does not listen to the expert's advice (non-revealing equilibrium) or he follows the expert's advice and could as well let her decide. As in Crawford and Sobel (1982), the most informative equilibrium (delegation when conditions ($C$) hold) is also ex-ante Pareto-dominant. In a model with continuous decisions, Dessein (2002) showed that delegation always outperforms informative communication whenever the expert's bias is sufficiently small to ensure that an informative equilibrium exists. This result still holds in our binary setting – although in a less extreme form since the most informative equilibrium is equivalent to delegation. Therefore, whether decisions are binary or continuous, communication is not needed: the decision-maker can just ex-ante decide whether to take a decision without any advice or delegate the decision to the expert. To eliminate any communication and still achieve the same outcome, the decision-maker only needs to be able to commit on a very simple mechanism, either not using an expert at all, or delegating the decision-power to the expert. The game is obviously very different if the decision-maker can credibly commit to more sophisticated strategies, for instance to take decisions that depend on the signal he receives.

## 2.2 Face-to-Face Communication

Krishna and Morgan (2004) have shown in a setting à la Crawford and Sobel (1982) that active participation by the decision-maker along with multiple stages of communication yields more information disclosure by the expert.[8] They introduced an additional stage of simultaneous exchange of cheap-talk messages (i.e., a face-to-face meeting between $DM$ and $E$) before the unilateral communication game. Even though $DM$ is initially uninformed, this meeting can improve information

always randomize over those signals.

[8]See Koessler and Forges (2008) for an extensive literature review of multistage communication games.

transmission and thus increase the ex-ante expected utility of both $DM$ and $E$. Nevertheless, the outcome of this additional stage has to be random, otherwise the expert would be able to anticipate $DM$'s action and would, *in fine*, have no incentives to reveal more information. An uncertain relationship between $E$'s message and $DM$'s strategy reduces the incentives of a risk-averse expert to strategically withhold information from $DM$ because revealing more information reduces uncertainty.

Following Krishna and Morgan (2004), we adapt our model and consider a simple multistage bilateral communication game. Formally, we assume that a face-to-face meeting occurs before the unilateral communication game, in which $E$ and $DM$ simultaneously send messages. As in Krishna and Morgan (2004), if information is revealed during the face-to-face meeting, it must be the case that it generates a random outcome in at least one of the subgames, otherwise the overall equilibrium is necessarily equivalent to one of the equilibria of the simple game $G(\Theta)$. For instance, suppose that the first stage reveals whether $\theta$ belongs to one of two subsets $\Theta_1$ and $\Theta_2$, and that $DM$ and $E$ anticipate, that in both subgames, they will coordinate on the centralization-like equilibrium (of the game $G(\Theta_i)$, with $i = 1, 2$) in which no project is ever implemented. In this case, revealing the information during the first stage does not affect the overall outcome, i.e., no project is implemented. Moreover, for centralization-like equilibria (without implementation) to exist, we must have: $E_\theta\left(1_{\theta\in\Theta_i} u_{DM}(\theta)\right) < 0$ for any $i = 1, 2$. But this implies that $E_\theta\left(u_{DM}(\theta)\right) < 0$, and centralization without implementation is an equilibrium of the simple game $G(\Theta)$. Obtaining more "information" is therefore useless. A similar argument applies if $DM$ and $E$ coordinate on the same outcome (centralization with implementation or delegation) in both subgames. Suppose instead, that they anticipate that they will coordinate on the centralization-like equilibrium with implementation if $\theta \in \Theta_1$, but on centralization without implementation if $\theta \in \Theta_2$. In this case, it would be optimal for $E$ to transmit a different message when $\theta \in E^+$ and when $\theta \in E^-$. The overall outcome is therefore the same than in a delegation-like equilibrium. Moreover, the existence conditions of the two centralization equilibria for $\Theta_1 = E^+$ and $\Theta_2 = E^-$, imply that delegation is also an equilibrium of $G(\Theta)$. In the same vein, any certain combination of different equilibria for the two subgames generate an outcome equivalent to delegation and the existence conditions imply that delegation is also an equilibrium of $G(\Theta)$.

In order to generate a new outcome (and not only a new equilibrium), it must be the case that, in at least one of the subgames, say following a signal that $\theta \in \Theta_i$, delegation is a possible equilibrium of $G(\Theta_i)$, and that $DM$ and $E$ will "randomize" over the two equilibria (centralization and delegation) of this game $G(\Theta_i)$.[9] Formally, this can be done in a similar way than the "partition equilibrium" of Krishna and Morgan (2004): during the face-to-face meeting, $E$ and $DM$ send messages $(i, A_E)$ and $A_{DM}$ respectively. The first part of $E$'s message $(i)$ transmits information revealing that $\theta$ belongs to the subset $\Theta_i$, whereas $A_E$ and $A_{DM}$ are used to determine the outcome of a jointly-controlled lottery à la Aumann and Maschler (1995). More specifically, whenever the game $G(\Theta_i)$ admits a delegation-like equilibrium, the jointly-controlled lottery determines on which of the two equilibria, $E$ and $DM$ coordinate. The crucial element of this additional stage is that none of the two players can unilaterally influence the outcome of this lottery. An equilibrium of this multistage communication game is thus characterized by a series of subsets $\Theta_i$ (with $i = 1, \ldots, N$) and probabilities $\beta_i$ that $E$ and $DM$ coordinate on the centralization-like equilibrium of $G(\Theta_i)$ in the continuation subgame.

Consider, for simplicity, an equilibrium in which $E$ initially reveals whether $\theta$ belongs to one of the two subsets $\Theta_1$ and $\Theta_2$.[10] Suppose first that the centralization equilibria are different for the two continuation subgames $G(\Theta_1)$ and $G(\Theta_2)$. Whether one or both of these subgames admits a delegation-like equilibrium does not matter, since $E$ can always ensure that her preferred outcome is chosen: it suffices that she initially sends messages that reveal whether $\theta$ belongs to $E^+$ or to $E^-$. Since the existence conditions of the relevant centralization equilibria then correspond to the two conditions that guarantee that $G(\Theta)$ admits a delegation-like equilibrium, the face-to-face meeting does not generate an outcome that could not be generated in the simple unilateral communication game.

Suppose now the centralization equilibria are the same (say, projects are always implemented[11]) for the two continuation subgames. Therefore, it must be the case, that at least one of subgames (say, $G(\Theta_1)$) admits a delegation-like equilibrium.

[9] The unilateral communication game $G(\Theta_i)$ always has multiple equilibria. However, there are all outcome-equivalent to either centralization or delegation (when such an equilibrium exists). We thus restrict our attention to these two "outcomes".

[10] The reasoning easily extends to any number of subsets.

[11] It is easy to adapt the argument to the case where the centralization equilibria are both such that no project is ever implemented.

The equilibria in the two continuation games are going to be different only if $\beta_1 < \beta_2 \leq 1$.[12]

In this case, the expert is willing to report that $\theta$ belongs to $\Theta_2$ only if she wants the project to be implemented (i.e., $\theta \in E^+$). Therefore, this equilibrium is simply equivalent to randomizing between centralization and delegation with respective probabilities $\beta_1$ and $1 - \beta_1$. Moreover, the existence conditions of the various equilibria in the two subgames ensure that the game $G(\Theta)$ already admits a delegation-like equilibrium. Since centralization is always ex-ante Pareto-dominated by delegation, randomizing between the two types of equilibria must also be ex-ante Pareto-dominated.

Moreover, we show in Appendix that a delegation-like equilibrium always exist in the unilateral communication game when other informative equilibria exist in the multistage communication game, and that using mixed strategies does not allow to generate other equilibria. This leads us to the following proposition.

**Proposition 2** *If conditions* $(C)$ *do not hold, any perfect Bayesian equilibrium of the two-stage multilateral communication game is outcome-equivalent to centralization. Otherwise, any equilibrium is ex-ante Pareto-dominated by delegation which can arise as an equilibrium of this two-stage multilateral communication game.*

As in the continuous decision case analyzed by Krishna and Morgan (2004), the multilateral communication stage may help to generate new equilibria. The equilibrium outcome of the first stage of this more sophisticated communication game is simply a "commitment" by $DM$ and $E$ to randomize over the different equilibrium outcomes of the one-round game $G(\Theta)$. Since one of the equilibria of the simple one-round of communication game, is always Pareto-dominant, the new outcomes generated by the additional stage of communication are necessarily dominated. More information may be transmitted through the face-to-face meeting but it is irrelevant information. In the continuous decision case, one way to improve the outcome is to introduce noisy communication (see for instance Blume, Board, and Kawamura (2007)). Since the expert is risk-averse, adding noise will convince her to reveal more information to reduce uncertainty. In the binary case, it is however unlikely that this would improve information transmission. If communication is noisy, the expert will be tempted to significantly distort her message to the decision-maker

[12] When the game $G(\Theta_2)$ does not admit a delegation-like equilibrium, we must have $\beta_2 = 1$.

to induce him to accept or reject the project. When decision is continuous such a distortion is extremely costly because it affects the decision-maker's choice.

# 3 Communication with Multiple Experts

We now extend the model and allow the decision-maker to use several experts, and analyze whether using multiple sources of information can improve information transmission. We adapt the setting of Krishna and Morgan (2001b) to the binary decision case. $DM$ can now seek advice from two perfectly informed experts, $E_1$ and $E_2$. Expert $E_k$'s net gain of implementing a project of type $\theta$ is denoted $u_k(\theta)$. As in the single expert case, we divide the state-space $\Theta$, in subsets on the basis of the expert's preferred actions, that is, for $k = 1, 2$:

$$E_k^+ = \{\theta \in \Theta \mid u_k(\theta) > 0\} \text{ and } E_k^- = \{\theta \in \Theta \mid u_k(\theta) < 0\}.$$

We also define the following four subsets of projects:

$$\Theta^{++} = E_1^+ \cap E_2^+,\ \Theta^{+-} = E_1^+ \cap E_2^-,\ \Theta^{-+} = E_1^- \cap E_2^+ \text{ and } \Theta^{--} = E_1^- \cap E_2^-,$$

and assume that none of these subsets is empty. Therefore, although the experts have different preferences, they do not always disagree on the action to be taken. We also assume that when the experts agree, $DM$ also agrees with them (that is, $u_{DM}(\theta) > 0$ for any $\theta \in \Theta^{++}$, and $u_{DM}(\theta) < 0$ for any $\theta \in \Theta^{--}$). Although this is not the most general case, we consider it is a reasonable assumption that would apply when $DM$ aggregates the views of various lobbying groups (e.g., $u_{DM}$ is a convex combination of $u_1$ and $u_2$).

Finally, for any $T \in \{++, +-, -+, --\}$, we denote $U^T = E_\theta\left(1_{\{\theta \in \Theta^T\}} u_{DM}(\theta)\right)$. Under our assumptions, $U^{++} > 0$, $U^{--} < 0$ while $U^{+-}$ and $U^{-+}$ can be either positive or negative. In order to simplify the presentation, we suppose that $U^{+-} \neq 0$ and $U^{-+} \neq 0$.

## 3.1 Single Round of Communication

We first consider a simple sequential message game adapted from Krishna and Morgan (2001b) in which the two experts sequentially send publicly observable messages to the decision-maker who then decides on his best strategy.[13] Without loss of generality, we assume that $E_1$ is the first expert to transmit a message.

Part of the analysis done with one expert only still applies. In particular, a non-revealing, centralization-like, equilibrium always exists, and delegation-like equilibria may also exist. Consider for instance an equilibrium where $DM$ always follows $E_1$'s advice ("delegation to $E_1$"). Anticipating that $DM$ never listens to her, it is optimal for $E_2$ to send non-informative messages. $DM$ is then in the same situation as when dealing with one expert only, and this delegation-like equilibrium thus exists whenever:

$$E_\theta\left(1_{\{\theta\in E_1^+\}}u_{DM}(\theta)\right)=U^{++}+U^{+-}>0 \text{ and } E_\theta\left(1_{\{\theta\in E_1^-\}}u_{DM}(\theta)\right)=U^{-+}+U^{--}<0.$$

Similarly, an equilibrium equivalent to delegating the decision to $E_2$ exists whenever $U^{++}+U^{-+}>0$ and $U^{+-}+U^{--}<0$.

We now look for other (partially) informative equilibria. Since the decision is binary, each expert only cares about the messages that induce $DM$ either to implement or to reject the project. For the purpose of the discussion, let us assume in what follows that the message-space is also binary, i.e., experts can only send one of two messages $m^+$ and $m^-$. We also focus here on pure-strategy equilibria. We show however in Appendix that allowing for more sophisticated messages and/or mixed strategies does not affect the outcome. Given that we do not look for "babbling equilibria", there must exist two pairs of messages that induce different decisions. Thus, the four possible pairs of messages need to be separated into two non-empty subsets.

One possibility to "pool messages" is to have one singleton. Given that we can rename the messages if necessary, there are only two such possibilities. The first one is to give a *"veto-power"* to the experts, that is, to have $\delta(m^+,m^+)=1$ and $\delta(m_1,m_2)=0$ for all other pairs of messages. In that case, each expert can always ensure that the project will not be implemented. Given this decision rule, each expert has a (weakly) dominant strategy which is to reveal her preferred action, i.e., sending the message $m^+$ (resp., $m^-$) if $\theta\in E_i^+$ (resp., $E_i^-$). This constitutes an equilibrium if $DM$'s strategy is optimal given the experts' strategies, that is, if

[13] Assuming that messages are sent sequentially rather than simultaneously is a simple way to limit chances that multiple equilibria co-exist. It simply serves as a first selection mechanism but does not affect the final results.

and only if $U^{-+}+U^{+-}+U^{--}<0$. The second possibility is to grant each expert an *"implementation-power"*, that is, to have $\delta(m^-,m^-)=0$ and $\delta(m_1,m_2)=1$ for all other pairs of messages. Once again, revealing her preferred action is a (weakly) dominant strategy for each expert, implying that an implementation-power equilibrium exists whenever $U^{++}+U^{-+}+U^{+-}>0$.

The other possibilities to "pool messages" are to have two subsets containing two elements each, which can be done in three different ways. The first one is such that $\delta(m^+,m^+)=\delta(m^+,m^-)$ and $\delta(m^-,m^+)=\delta(m^-,m^-)$, and is equivalent to delegating the decision to $E_1$. The second one is such that $\delta(m^+,m^+)=\delta(m^-,m^+)$ and $\delta(m^-,m^-)=\delta(m^+,m^-)$, and is equivalent to delegating the decision to $E_2$. The third possibility is such that $\delta(m^+,m^+)=\delta(m^-,m^-)$ and $\delta(m^-,m^+)=\delta(m^+,m^-)$. However, since message are sent sequentially, this is equivalent to delegating the decision to $E_2$, because she can always adapt her message to the decision rule once she has observed the message sent by $E_1$.

The following lemma summarizes these results:

**Lemma 1** *Any perfect Bayesian equilibrium of the sequential-message game is outcome equivalent to either centralization, delegation to one expert, veto- or implementation-power.*

- *A "babbling" equilibrium (centralization) always exists.*
- *An equilibrium equivalent to delegation to $E_1$ (resp., $E_2$) exists if and only if $U^{++}+U^{+-}>0$ and $U^{-+}+U^{--}<0$ (resp., $U^{++}+U^{-+}>0$ and $U^{+-}+U^{--}<0$).*
- *The veto-power equilibrium exists whenever $U^{-+}+U^{+-}+U^{--}<0$.*
- *The implementation-power equilibrium whenever $U^{++}+U^{-+}+U^{+-}>0$.*

Consider the "babbling" equilibrium when $DM$'s priors are pessimistic ($E_\theta(u_{DM}(\theta))<0$), equilibrium in which all projects are rejected independently of the experts' messages. Since $U^{++}>0$ by assumption, the veto-power equilibrium also exists and is preferred to this non-revealing equilibrium, both by the two experts (since only projects that generate a net benefit for each of the two experts are implemented) and by $DM$. Similarly, when $E_\theta(u_{DM}(\theta))>0$, the "babbling" equilibrium (in which all projects are implemented) is ex-ante Pareto-dominated by the implementation-power equilibrium, which exists since $U^{--}<0$ by definition. Therefore, the "babbling" equilibrium is always ex-ante Pareto-dominated.

Let us now consider the three other types of equilibria. Since conflicts exist between the two experts (i.e., when $\theta \in \Theta^{+-} \cup \Theta^{-+}$), it is impossible to Pareto-rank these equilibria. We thus only focus on $DM$ and look for his preferred equilibrium. When $U^{+-}$ and $U^{-+}$ are both positive (resp., negative), $DM$ would like to implement a project whenever it is supported by at least one expert (resp., by both experts) and his preferred equilibrium is therefore the implementation-power (resp., veto-power) equilibrium. When $U^{+-}$ and $U^{-+}$ have opposite signs, $DM$'s best option is to delegate the decision to one expert, $E_1$ (resp., $E_2$) whenever $U^{+-} > 0$ (resp., $< 0$). This discussion is summarized in the following proposition.

**Proposition 3** *$DM$ prefers a delegation-like equilibrium when $U^{+-}$ and $U^{-+}$ have opposite signs, with delegation to $E_1$(resp., $E_2$) when $U^{+-} > 0$ (resp., $< 0$), while he favors the implementation-power (resp., veto-power) equilibrium when $U^{+-}$ and $U^{-+}$ are both positive (resp., negative). Moreover, the "babbling" equilibrium is always ex-ante Pareto-dominated.*

The existence of multiple experts may improve communication. Because the decision is binary, the experts only try to convince the decision-maker that the project has either a positive or a negative value. Therefore, their messages do not need to convey more precise information and it is a (weakly) dominant strategy for the experts to "tell the truth", i.e., inform the decision-maker truthfully on whether they would prefer to implement the project or not. $DM$ thus faces a difficulty only when the experts disagree and cannot identify, from the two conflicting messages, to which of the two subsets $\Theta^{+-}$or $\Theta^{-+}$ the project belongs. If his priors are such that $U^{+-}$ and $U^{-+}$ have the same sign, say both are positive (resp. negative), $DM$'s will decide to implement (resp. reject) them all. Given that he always follows the experts' advice when they agree, this is then equivalent to give each expert the power to implement (resp. to veto). $DM$ thus uses the experts to identify projects on which they disagree and communication with the two experts is useful. When, $U^{+-}$ and $U^{-+}$ have opposite signs, $DM$'s priors coincide with one of the expert's preferred decision and using that expert is therefore sufficient to elicit the best information.

## 3.2 Several Rounds of Communication: Rebuttal Game

Krishna and Morgan (2001b) have shown that using several rounds of communication may help to generate a fully revealing equilibrium when experts have opposite biases. The intuition is simple: using a second expert forces the first one to reveal more information. In turn, allowing the first expert to rebutt the second message forces the second expert to reveal more information. By playing one expert against the other, it then becomes possible to "convince" the experts to truthfully transmit information to the decision-maker. As we will show now, this result no longer holds when decisions are binary. We consider the following rebuttal game in which experts sequentially send $N$ messages each:

(1.1) $E_1$ publicly sends her first message $m_1^1(\theta)$.

(1.2) $E_2$ publicly sends her first message $m_2^1(m_1^1;\theta)$.

...

(N.1) $E_1$ publicly sends her $N^{th}$ message $m_1^N\left(m_1^1, m_2^1; ...; m_1^{N-1}, m_2^{N-1}; \theta\right)$.

(N.2) $E_2$ publicly sends her $N^{th}$ message $m_2^N\left(m_1^1, m_2^1; ...; m_1^{N-1}, m_2^{N-1}; m_1^N; \theta\right)$.

(D) $DM$ decides whether to implement the project or not.

The only interesting question is whether adding multiple rounds of communication generates new equilibria or make existing equilibria easier to sustain (i.e., increase the set of parameter values for which such equilibria exist). Obviously, the equilibrium outcomes of the single-round game are still equilibrium outcomes of the $N$-round game: indeed, experts can always send uninformative messages during the first $N-1$ rounds ("babbling") and communicate only during the final round.

We now look for equilibria that generate new outcomes, i.e., new probabilities of implementation. As in the single-round game, when experts agree they select (pairs of) messages that generate either the highest (whenever $\theta \in \Theta^{++}$) or the lowest (whenever $\theta \in \Theta^{--}$) probability of implementation. If adding extra rounds of communication generates new outcome, these outcome must lead to subdivisions of either $\Theta^{+-}$ or $\Theta^{-+}$, i.e., more relevant information must be transmitted by the experts. Suppose that there exist two projects, $\theta_1$ and $\theta_2$, which both belong to $\Theta^{+-}$ and for which the equilibrium probabilities of implementation differ, say $d_1 > d_2$.[14] In equilibrium it must be impossible for expert $E_1$ to deviate at any time in order to increase the probability that project $\theta_2$ is implemented above $d_2$. In particular, this

[14]Whereas $\delta(m_1, m_2)$ denotes $DM$'s strategy given the messages he has received, $d$ denotes the outcome, i.e., the probability that a given project will be implemented, given the equilibrium messages sent by the expert and $DM$'s equilibrium strategies.

has to be true for any possible deviation at stage (1.1), including trying to mimic the message that $E_1$ sends in equilibrium for project $\theta_1$. But this would then imply, that $E_2$ could ensure that the probability to implement project $\theta_1$ is at most $d_2 < d_1$, a contradiction. Therefore, in any equilibrium of the $N$-round communication game, the equilibrium probability of implementation should be identical for all projects in $\Theta^{+-}$. A similar argument applies to $\Theta^{-+}$.

Even with additional rounds of communication, the information transmitted by the two experts does not allow $DM$ to subdivide $\Theta^{+-}$ or $\Theta^{-+}$ in more subsets. Therefore, $DM$ is in the same situation as in the single-round communication game. Therefore, the equilibria are identical in the two games, as are their existence conditions. This leads to the following proposition.

**Proposition 4** *With binary decisions, additional rounds of communication do not generate transmission of more relevant information.*

In the continuous-action model, Krishna and Morgan (2001b) show that multiple rounds of communication help generating a fully-revealing equilibrium when experts have opposing biases. The idea is in some sense the following: with one round of communication, playing one expert against the other already allows to generate a semi-revealing equilibrium for which the project's true type will be revealed for some subset of types. However, the order of play is important: for instance depending on which expert goes first, the equilibrium will be such that either high or low values of $\theta$ ($\theta$ is uni-dimensional in the Crawford and Sobel (1982) basic setting) will be revealed. Adding a second round of communication in essence patches together two semi-revealing equilibria, one where low values are revealed, the other where high values are revealed. Depending on the expert's biases (i.e., if there are not too extreme so that each semi-revealing equilibrium reveals enough information), this rebuttal game (it suffices that each expert has two opportunities to talk) yields a fully-revealing equilibrium. In our case, this "patching effect" cannot work since the order of play does not matter in the basic sequential unilateral communication game.

# 4 Conclusion

This paper shows that, with a single expert, delegation always ex-ante Pareto-dominates centralization. Moreover, delegation is outcome-equivalent to the best informative perfect Bayesian equilibrium of the simplest unilateral communication game. Moreover, adding a round of multilateral communication does not lead to outcomes which ex-ante Pareto-dominate delegation. With multiple experts, the decision-maker can sometimes increase his expected welfare by communicating with the two experts. However, multistage communication, i.e., with rebuttal à la Krishna and Morgan (2001b) does not lead to the revelation of more relevant information than with the simplest communication game.

The settings discussed in this paper remain quite simple. One possibility to extend our analysis would be looking for the optimal mediation mechanism as in Golstman et al. (2009) or Ganguly and Ray (2011) who compare mediated and unmediated negotiations (as well as the possibility to use an arbitrator). As already discussed in the paper when analyzing face-to-face communication, we believe that adding noise to the communication process (as in Blume, Board, and Kawamura (2007)) which is often associated to the use of a mediator is unlikely to improve the outcome in our binary-decision setting. Adding a possibility for the decision-maker to acquire hard information, either through the expert (as in Glazer and Rubinstein (2006)) or directly (as in Glazer and Rubinstein (2004)) may help the expert(s) to persuade the decision-maker in our context. However, as long as the hard information available to the principal (or the expert(s)) is not too precise in this sense that conflicts may still exist, our results should at least partially extend.

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# Appendix

## Proof of Proposition 2

As in the standard cheap-talk games, there exist equilibria in which the first stage of communication ("face-to-face meeting") is uninformative. Therefore, the equilibria of the game $G(\Theta)$ remain part of an equilibrium (in addition the first stage is totally uninformative) of the face-to-face game and the existence conditions remain unchanged.

We now consider other equilibria which may exist with a face-to-face meeting. Without loss of generality, suppose that these equilibria are such that $\beta_1 < \beta_2 < ... < \beta_N$ and $N \geq 2$.[15]

If $\beta_1 = 0$, $E$ can always ensure that her preferred action is implemented by initially reporting $i = 1$. Any such equilibrium is therefore outcome-equivalent to delegation. Suppose from now on that $\beta_1 > 0$. When $E$ initially reports $i$, her expected utility is:

$$U_E(\theta, i) = \beta_i d_i u_E(\theta) + (1 - \beta_i) \max[0, u_E(\theta)],$$

where $d_i$ denotes the probability that a project in $\Theta_i$ is implemented) in the non-revealing equilibrium of $G(\Theta_i)$, that is:

$$d_i = \begin{cases} 1 & \text{if } E_\theta\left(1_{\{\theta\in\Theta_i\}} u_{DM}(\theta)\right) > 0, \\ 0 & \text{if } E_\theta\left(1_{\{\theta\in\Theta_i\}} u_{DM}(\theta)\right) < 0. \end{cases}$$

Let us denote $I_0 = \{i | d_i = 0\}$ and $I_1 = \{i | d_i = 1\}$. If $I_0$ and $I_1$ are both non-empty, the expert can always ensure that her preferred action is implemented. Indeed, it suffices to report $i \in I_1$ (resp., $I_0$) whenever $\theta \in E^+$ (resp., $\theta \in E^-$). Any such equilibrium is therefore outcome-equivalent to delegation and exists if and only if for each $i \in I_1$ (resp., $I_0$), all projects are implemented (resp., no project is ever implemented) in the (pure-strategy) non-revealing equilibrium of $G(\Theta_i)$, that is, for any $i \in I_1$ (resp., $I_0$), $E_\theta\left(1_{\{\theta\in\Theta_i\}} u_{DM}(\theta)\right) > 0$ (resp., $< 0$). This implies that the

[15] It is always possible to divide a subset $\Theta_i$ into several subsets, $(\Theta_{i,j})_{j=1,\ldots,J}$, with $\beta_{i,j} = \beta_i$ for all $j = 1, ..., J$. For all values of $\theta \in \Theta_i$, the expert is indifferent between messages revealing that $\theta$ belongs to any of the subsets $\Theta_{i,j}$ since this does not affect the final outcome. We can thus aggregate these subsets into the initial subset $\Theta_i$ without affecting the equilibrium outcome. We thus only focus on equilibria for which all the probabilities are different.

following two conditions are satisfied:

$$\sum_{i\in I_1} E_\theta\left(1_{\{\theta\in\Theta_i\}}u_{DM}(\theta)\right) > 0 \text{ and } \sum_{i\in I_0} E_\theta\left(1_{\{\theta\in\Theta_i\}}u_{DM}(\theta)\right) < 0,$$

that is:

$$E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right) > 0 \text{ and } E_\theta\left(1_{\{\theta\in E^-\}}u_{DM}(\theta)\right) < 0;$$

which in turn implies that $G(\Theta)$ admits a delegation-like equilibrium.

If $I_1$ is empty, $DM$ rejects all projects whenever the non-informative equilibrium of $G(\Theta_i)$ is played in the continuation game (i.e., with probability $\beta_i$). Any project $\theta \in E^-$ is thus rejected. For any $\theta \in E^+$, $E$ reports $i = 1$ in order to minimize the probability that the project is rejected (i.e., in order to minimize $\beta_i$). Such an equilibrium exists if and only if:

$$E_\theta\left(1_{\{\theta\in\Theta_i\}}u_{DM}(\theta)\right) < 0 \text{ for any } i,\ E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right) > 0 \text{ and } E_\theta\left(1_{\{\theta\in\Theta_1\cap E^-\}}u_{DM}(\theta)\right) < 0.$$

Since for any $i > 1$, $\Theta_i \cap E^- = \Theta_i$, we must also have:

$$E_\theta\left(1_{\{\theta\in E^-\}}u_{DM}(\theta)\right) = E_\theta\left(1_{\{\theta\in\Theta_1\cap E^-\}}u_{DM}(\theta)\right) + \sum_{i>1} E_\theta\left(1_{\{\theta\in\Theta_i\}}u_{DM}(\theta)\right) < 0,$$

which implies that $G(\Theta)$ admits a delegation-like equilibrium, and moreover this equilibrium is ex-ante Pareto-dominant. Indeed, delegation is always preferred by $E$, and $DM$'s expected payoff in this equilibrium is equal to $\beta_1 E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right)$ which is lower than his expected payoff in the delegation-like equilibrium (i.e., $E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right)$).

A similar argument holds when $I_0$ is empty, inverting the roles played by $E^+$ and $E^-$. Besides, $DM$'s expected payoff is then:

$$E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right) + (1-\beta_1)\, E_\theta\left(1_{\{\theta\in E^-\}}u_{DM}(\theta)\right) \leq E_\theta\left(1_{\{\theta\in E^+\}}u_{DM}(\theta)\right),$$

and delegation is again ex-ante Pareto-dominant.

We only focused until now on pure-strategy equilibria. Considering mixed-strategies is now more complex than in the one-round case since the subsets $\Theta_i$ are endogenously defined and the game $G(\Theta_i)$ may well be non-generic. For instance, if $\Theta_i$ is such that $E_\theta\left(1_{\{\theta\in\Theta_i\cap E^+\}}u_{DM}(\theta)\right) = 0$ and $E_\theta\left(1_{\{\theta\in\Theta_i\cap E^-\}}u_{DM}(\theta)\right) < 0$, centralization (no project is implemented) and delegation are equilibria of the game $G(\Theta_i)$. However, there also exist multiple mixed-strategy equilibria: for any $d^+ \in ]0,1[$, there is an equilibrium such that projects in $E^-$ are never implemented and projects in $E^+$ are implemented with probability $d^+$. But such an equilibrium generates the same outcome as randomizing over centralization and delegation with probabilities $1-d^+$ and $d^+$. Therefore, allowing mixed strategies is equivalent to redefining the probabilities of the jointly-controlled lotteries ($\beta_i$) to take into account the fact that a mixed-strategy equilibrium of $G(\Theta_i)$ is already a randomization over centralization and delegation.

## Proof of Lemma 1

A strategy for $DM$ is a function $\delta(m_1, m_2)$ that takes its values in the interval $[0,1]$. Let $d^+ = \max \delta(m_1, m_2)$ and $d^- = \min \delta(m_1, m_2)$. Any equilibrium for which $d^+ = d^-$ must be centralization-like. Indeed, anticipating that their messages will never be taken into consideration, it is optimal for the experts to send non-informative messages. In return, it is optimal for $DM$ to make his decision based on his priors. Given that we only look at generic versions of the game, such an equilibrium must lead to all projects being implemented (whenever $E_\theta(u_{DM}(\theta)) > 0$) or none of them being implemented (whenever $E_\theta(u_{DM}(\theta)) < 0$).

We now focus on equilibria in which $d^+ > d^-$. There must exist two different pairs of messages $(m_1^+, m_2^+) \neq (m_1^-, m_2^-)$ such that $\delta(m_1^+, m_2^+) = d^+$ and $\delta(m_1^-, m_2^-) = d^-$. For any $\theta \in \Theta^{++}$, the two experts agree to implement the project and will therefore want to maximize the chances that it gets through. Therefore, sending messages $m_1^+$ and $m_2^+$ is an optimal strategy and, in equilibrium it must be the case that any project in $\Theta^{++}$ is implemented with probability $d^+$. Similarly, any project in $\Theta^{--}$ must be implemented with probability $d^-$.

Consider now two projects, $\theta_1$ and $\theta_2$, which both belong to $\Theta^{+-}$ and are such that the equilibrium probabilities that they are implemented differ. This imply that there must exist two differ pairs of equilibrium messages such that:

$$\delta(m_1^*(\theta_1), m_2^*(\theta_1)) = d_1 \text{ and } \delta(m_1^*(\theta_2), m_2^*(\theta_2)) = d_2 < d_1.$$

Since $E_2$ wants to minimize the probability that $\theta_1$ is implemented, it must be the case that for any $m_2$, $\delta(m_1^*(\theta_1), m_2) \geq d_1$. Similarly, since $E_1$ wants to maximize the probability that $\theta_2$ is implemented, we must have that for any $m_1$, there exists $\overline{m}_2(m_1)$ such that $\delta(m_1, \overline{m}_2(m_1)) < d_2$. However, this last condition must also hold for $m_1 = m_1^*(\theta_1)$ and this thus contradicts the first set of conditions. Therefore, $DM$'s optimal strategy (given the experts' reports) must be the same for all $\theta \in$

$\Theta^{+-}$, and we denote the equilibrium probability of implementation $d^{+-}$. A similar argument applies for $\Theta^{-+}$. Moreover, given that we consider only generic versions of the game, we must have pure-strategy equilibria only: $d^{+} = 1$, $d^{-} = 0$, $d^{+-} \in \{0, 1\}$ and $d^{-+} \in \{0, 1\}$. There are therefore four possible equilibria:

| | $d^{-+} = 1$ | $d^{-+} = 0$ |
|---|---|---|
| $d^{+-} = 1$ | Implementation-power | Delegation to $E_1$ |
| $d^{+-} = 0$ | Delegation to $E_2$ | Veto-power |

which exist under the following conditions:

1. "Implementation-power" exists if and only if $d^{-} = 0$, $d^{+} = d^{+-} = d^{-+} = 1$ are $DM$'s optimal strategies, that is, if and only if $U^{++} + U^{+-} + U^{-+} \geq 0$.
2. "Veto-power" exists if and only if $d^{-} = d^{+-} = d^{-+} = 0$, $d^{+} = 1$ are $DM$'s optimal strategies, that is, if and only if: $U^{--} + U^{+-} + U^{-+} < 0$.
3. "Delegation to $E_1$" exists if and only if $d^{-} = d^{-+} = 0$, $d^{+} = d^{+-} = 1$ are $DM$'s optimal strategies, that is, if and only if: $U^{++} + U^{+-} \geq 0$ and $U^{--} + U^{-+} < 0$.
4. "Delegation to $E_2$" exists if and only if $d^{-} = d^{+-} = 0$, $d^{+} = d^{-+} = 1$ are $DM$'s optimal strategies, that is, if and only if: $U^{++} + U^{-+} \geq 0$ and $U^{--} + U^{+-} < 0$.