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# Deliberation, Information Aggregation and Collective Decision Making

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# Deliberation, Information Aggregation, and Collective Decision Making

by

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We study a model of collective decision making with endogenous information collection. Agents collect information about the consequences of a project, communicate, and then vote on the project. We examine under what conditions communication may increase the probability that good decisions are made. Our most surprising result is that when there are no direct cost of communication and communication can only help to identify the truth, more communication may reduce the probability that a correct decision is made. The reason for this result is that communication may aggravate the free-rider problem associated with collecting information. (JEL: D78, D83)

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# 1 Introduction

Almost all economic models describe a silent world. In the real world people talk. McCloskey and Klamer [1995] have assessed that in 1993 in the United States about a quarter of working time was spent on talk. Talk, or more specifically, arguing or debate, takes place especially when collective choices are made. Often collective decision procedures leave plenty of room for debate. A rationale for debate is learning. Different individuals often have different pieces of information about the consequences of alternative choices. Debate is a means of revealing private information (Fearon, [1998]). In addition, debate may reveal the strength of arguments. Sometimes arguments are decisive. Sometimes they are weak or even plainly wrong. Debate may contribute to distinguishing wrong from strong arguments.

Not everybody holds an optimistic view of debate. In ancient Greece, people already worried about the possibility that eloquent speakers could convince individuals of false opinions. Moreover, debate takes time, while in practice decisions often have to be reached sooner rather than later. An obvious cost of debate is therefore postponement of reaching decisions.

This paper is concerned with the consequences of engaging in debate for agents' incentives to collect information. We analyze a model in which two agents with the same preferences have to make a binary decision about a public project under uncertainty. The agents follow a decision procedure which consists of three stages. In the first stage, each agent acquires information about the consequences of the project. The quality of the collected information depends on the effort an agent has put in acquiring information. Thus, information is endogenous in our model. In the second stage of the decision process the agents communicate. We do not model how agents communicate. Instead, we model one possible consequence of communication: communication may change an agent's opinion about which policy alternative is optimal. We model two views of communication, an optimistic and a pessimistic view. In the optimistic view, an agent who has incorrect information may learn from the other agent who has correct information. The idea behind this view is that people make mistakes, and that debate sometimes reveals mistakes. We refer to this case as the "optimistic" view of communication: given the quality of information, communication can only help to identify the truth. In the pessimistic view, communication may also lead to deception: an agent with incorrect information may mislead an informed agent. The idea behind this view is that arguments are sometimes won by eloquence rather than logic. After the two agents have communicated they vote on the project in the third stage of the decision process.

The punch line of this paper is that the possibility of communication affects the effort an agent puts into acquiring information. When information is cheap or easy to obtain, the possibility of communication reduces effort. When information is expensive or difficult to obtain, communication increases effort. To see why, suppose that information is almost free. Then agent 1 considers it very likely that agent 2 has received correct information. This reduces agent 1's incentives to collect information. When information is expensive, it is far less likely that agent 2 has received correct information. Since communication makes it possible to inform agent 2, this increases agent 1's incentive to collect information. We show that even if we take the optimistic view of communication and abstract from direct costs of debate, increasing the scope of communication may be sub-optimal from a welfare point of view.

Our paper is related to the literature on strategic information transmission. There the emphasis has been on the conditions under which messages can be trusted. The basic insight is that communication between individuals requires a certain amount of common interest (Crawford and Sobel [1982], Farrell and Rabin [1996], and Banerjee and Somanathan [2001]). Schultz [1996], Letterie and Swank [1997], Martinelli [2001], and Heidhues, and Lagerlöf [2003] study information transmission in a political setting. Our paper deviates from this literature in two ways. First, we do not assume a given distribution of information. Agents must be motivated to collect information. Second, we assume a common interest. We emphasize the consequences of communication rather than the possibility of communication.

Our paper is also related to the literature on jury and committee decision making (Nitzan and Paroush [1982, 1985], Sah and Stiglitz [1988], Austen-Smith and Banks [1996], and Persico [2000]). This literature analyzes the informational efficiency of alternative voting rules. As in this literature, in our analysis agents sometimes make mistakes. These mistakes form the rationale for collective decision making. However, in the literature on jury and committee decision making agents are usually explicitly assumed not to communicate. We examine the conditions under which communication among agents increases the mean quality of accepted projects.

Finally, this paper is inspired by the recent literature on deliberative democracy (see Elster [1998] for a recent survey of interesting articles). This literature reminds us what ordinary people already know: people talk for various reasons. We have modeled one of these reasons: communication as a means of correcting mistakes.

Our paper is organized as follows. The next section presents the model. Section 3 analyzes the model when agents cannot communicate. The outcomes serve as a benchmark for analyzing the consequences of communication. Section 4 allows for the optimistic view of communication. In Section 5, we add a pessimistic view. Section 6 concludes the paper.

## 2 The Model

Two agents, $i \in \{1, 2\}$ have to decide whether to implement a project, $X = 1$, or to reject it, $X = 0$. There are two states of the world, $S \in \{-h, h\}$. The expected benefit of the project is denoted by $p$. We assume that $p < 0$.[1] The two agents have identical preferences over decisions and states. They

[1] The analysis of the case where $p > 0$ is analogous.

are represented by:

$$
\begin{aligned}
u_i(X &= 1 \mid S = h) = p + h \\
u_i(X &= 1 \mid S = -h) = p - h \\
u_i(X &= 0 \mid S = h) = u_i(X = 0 \mid S = -h) = 0.
\end{aligned} \tag{1}
$$

We assume that $p + h > 0$. Eq. (1) thus implies that both agents prefer implementation to rejection if $S = h$ and rejection to implementation if $S = -h$.

Agents do not know the state of the world, however. Both states have equal prior probability. Each agent receives a private signal, $s_i \in \{-h, h\}$, about the true state. A signal is fully informative, that is a signal reveals the state of the world, with probability $\pi(e_i)$, where $e_i$ denotes the effort agent $i$ has put in collecting information. If $s_i$ is informative, then $\Pr(S = h \mid s_i = h) = 1$ and $\Pr(S = -h \mid s_i = -h) = 1$. If both $s_1$ and $s_2$ are informative, then $s_1 = s_2$. A signal is uninformative with probability $1 - \pi(e_i)$. An uninformative signal does not contain information about the state of the world. Thus, if a signal is uninformative, then $s_i$ is randomly drawn from $\{-h, h\}$ with $\Pr(-h) = \frac{1}{2}$. The function $\pi(e_i)$ shows the relationship between effort and the quality of a signal. We assume that $\pi(0) = 0$, $\pi'(e_i) > 0$, and $\pi''(e_i) < 0$. Effort is costly. Agent $i$'s payoff is given by $u_i(\cdot) - c(e_i)$, where $c(e_i)$ denotes the costs of effort. We assume that $c(0) = 0$, $c'(e_i) > 0$, and $c''(e_i) > 0$. When an agent has received a signal, he does not know whether the signal is informative or uninformative. He knows, however, the relationship between effort and the probability of receiving an informative signal.

After the agents have received their signal, they can deliberate which decision should be made. We do not model how agents deliberate. Instead, we model possible consequences of deliberation. We assume that deliberation may affect an agent's perception of the state of the world. We first take an optimistic view of deliberation. In this view, an agent who has received an informative signal may affect the beliefs of an agent who has received a wrong signal. Next, we add a pessimistic view. An agent who has received a wrong signal may affect the beliefs of the other agent who has received an informative signal.

At the end of the game, each agent votes on the project, $v_i \in \{N, Y\}$. With two individuals there are two sensible voting rules: implementation requires that both individuals vote for implementation, $(v_1, v_2) = (Y, Y)$, and status quo requires that both agents vote for status quo, $(v_1, v_2) = (N, N)$. In the main text we restrict attention to the first voting rule. The Appendix deals with the second voting rule. Table 1 gives a formal description of the game without deliberation.

**Table 1**: The Timing of the Model

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**Players**: $i \in \{1, 2\}$.
**Timing**:

- Nature randomly chooses $S \in \{-h, h\}$, with $\Pr(S = h) = \frac{1}{2}$.
- Each player $i$ chooses $e_i > 0$.
- Each player $i$ observes $s_i \in \{-h, h\}$: $\Pr(s_i = S) = \frac{1}{2}[1 + \pi(e_i)]$

  and $\Pr(s_i \neq S) = \frac{1}{2}[1 - \pi(e_i)]$.
- Each player $i$ chooses $v_i \in \{N, Y\}$.

**Payoffs**:
If $(v_{1,} v_2) = (Y, Y)$, then $U_i(S = h) = p + h - c(e_i)$ and
$U_i(S = -h) = p - h - c(e_i)$.
If $(v_{1,} v_2) \neq (Y, Y)$, then $U_i = -c(e_i)$.
**Assumptions**:
$p < 0$; $\pi_i(0) = 0$, $\pi'(e_i) > 0$, and $\pi''(e_i) \leq 0$; $c(0) = 0$, $c'(e_i) > 0$, and $c''(e_i) > 0$.

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As usual in voting games, our game has many equilibria. We restrict attention to symmetric Nash equilibria in which players follow pure strategies. We are aware that "nonsymmetric Nash equilibria" exist. Specifically, agent 1 may always vote "yes", thereby delegating the decision to agent 2. Models of delegation abound. We instead focus our attention on communication rather than on delegation.

# 3 A Benchmark: No Deliberation

In this section, we assume that no deliberation takes place. Agents vote on the project immediately after they have received their signal. The model of Section 2 then reduces to a conventional two-person model without communication. Each agent makes two decisions. First, each agent chooses how much effort to put in collecting information. Second, each agent chooses how to vote.

First consider agents' vote decisions. Lemma 1 presents the condition under which it is optimal for agent 1 (2) to vote in line with his signal, given that the other agent also votes in line with his signal.

**Lemma 1** *Suppose a level of effort $e = e_1 = e_2$ so that $\frac{1}{2}\left[1 + (\pi(e))^2\right]p + \pi(e)\,h > 0$. Then, it is optimal for agent 1 to vote in line with his signal, given that the other agent votes in line with his signal.*

**Proof.** Suppose $e_1 = e_2$, and that agent 2 follows his signal. It is easy to see that if agent 1 has received $s_1 = -h$, $v_1 = Y$ weakly dominates $v_1 = N$. If agent 1 has received $s_1 = h$, $v_1 = Y$ yields an expected payoff equal to $\frac{1}{2}\left[1 + (\pi(e_1))^2\right]p + \pi(e_1)\,h - c(e_1)$. Voting $v_1 = N$ yields a payoff equal to $-c(e_1)$. Hence, given $s_1 = h$, agent 1 votes $v_1 = Y$ if $\frac{1}{2}\left[1 + (\pi(e))^2\right]p + \pi(e)\,h > 0$. The analogous argument applies to agent 2. ■

Now consider agents' decisions how much effort to put in collecting information. When the agents vote in line with their signal, the project will be rejected unless both agent receive a positive signal. Consequently, when choosing effort agent 1's expected payoff equals:

$$(2)\quad \frac{1}{2}\{\pi(e_1)\pi(e_2)+\frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right]+\frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right]+\frac{1}{4}\left[1-\pi(e_1)\right]$$
$$\left[1-\pi(e_2)\right]\}(p+h)+\frac{1}{2}\{\frac{1}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right]\}(p-h)-c\left(e_1\right).$$

We can write an analogous expression for agent 2. Differentiating (2) with respect to $e_1$ yields the first-order condition:

$$(3)\qquad \frac{1}{4}\frac{\partial\pi\left(e_1\right)}{\partial e_1}\left[h+\pi\left(e_2\right)p\right]-\frac{\partial c\left(e_1\right)}{\partial e_1}=0.$$

Eq. (3) implicitly defines agent 1's effort as a function of $h$, $p$, and $e_2$. Application of the implicit function theorem yields the intuitive result that effort $e_1$ is increasing in $h$ and $p$ and decreasing in $e_2$.

We can now characterize an equilibrium of the game. Let $e_1^*$ solve (3). Furthermore, suppose that for $e_1^*=e_2^*$, the condition in Lemma 1 holds. Then, the equilibrium exists, in which (i) each agent chooses effort $e_{ND}^*=e_1^*(h,p)=e_2^*(h,p)$ and (ii) each agent votes informative.

Apart from this equilibrium, there exists an uninformative equilibrium. In the uninformative equilibrium, each agent does not exert effort and always votes for rejection. If the condition in Lemma 1 is violated, an equilibrium may exist in which the decision about the project is delegated to an agent, say agent 1. Clearly, without communication, delegation raises a coordination problem.

Using the equilibrium strategies of the two players it is easy to calculate the expected total surplus, that is the sum of the expected payoff to the two agents:

$$(4)\qquad S_{ND}=\frac{1}{2}p\{1+[\pi(e_{ND}^*)]^2\}+\pi(e_{ND}^*)h-2c\left(e_{ND}^*\right).$$

It is worth noting that from a social point of view, the agents exert too little effort. Thus, $e_{ND}^*$ does not maximize (4). The reason is a positive externality. When agent 1 increases his effort to receive an informative signal, agent 2 also benefits. The social benefits of collecting information thus exceed the private benefits.

# 4 Taking an "Optimistic" View of Deliberation

In this section, we take an optimistic view of deliberation. We assume that if an agent has received an informative signal, say agent $i$, and the other agent has received a wrong signal, say agent $j$, then with probability $\alpha$ agent $j$ learns that his signal is wrong. The idea is that through communication a wrongly informed agent may learn from an informed agent the true state of the world. Formally, we add a stage to the basic model presented in Table 1. After the agents have received their signal, but before they vote, the agents communicate. If the agents have received conflicting signals, they may learn the true state through communication. Specifically: suppose that the agents have received conflicting signals and that an agent has received an informative signal and the other agent has received an uninformative signal, then with probability $\alpha$ both agents learn the true state.[2]

As the model of Section 3, the present model has two symmetric Nash equilibria: an informative and uninformative one. As before and for the same reason, we ignore the uninformative equilibrium.

A direct consequence of deliberation is that agents do not always vote in line with their signal. An agent may vote against his signal when he has

[2] A similar assumption could be made for the case where the agents receive the same signal. However, we assume that if $\{s_1, s_2\} = \{h, h\}$, then the agents choose implementation anyway.

learned that his signal is wrong. Agent 1 votes as follows:[3,4]

(a) he votes for implementation with probability one if he has received signal $s_1 = h$ and the state of the world is $S = h$;

(b) he votes for rejection with probability one if he has received signal $s_1 = -h$ and the state of the world is $S = -h$;

(c) he votes with probability $\alpha$ for implementation if he has received the wrong signal $s_1 = -h$ and agent 2 has received an informative signal;

(d) he votes with probability $\alpha$ for rejection, if he has received the wrong signal $s_1 = h$ and agent 2 has received an informative signal.

Because of symmetry, agent 2 votes in a similar way as agent 1. How much effort do the agents put into collecting information, given that they will vote as described above? When agent 1 chooses effort, his expected payoff is:

$$(5)\qquad \frac{1}{2}\{\pi(e_1)\pi(e_2) + \frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right](1+\alpha) + \frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right] \\ (1+\alpha) + \frac{1}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right]\}(p+h) + \frac{1}{2}\{\frac{1}{4}\left[1-\pi(e_1)\right] \\ \left[1-\pi(e_2)\right]\}(p-h) - c\left(e_1\right).$$

Differentiating (5) with respect to $e_1$ yields the first-order condition:

$$(6)\qquad \frac{1}{4}\frac{\partial\pi\left(e_1\right)}{\partial e_1}\left\{h + \pi\left(e_2\right)p + 2\alpha\left[\frac{1}{2} - \pi\left(e_2\right)\right](p+h)\right\} - \frac{\partial c\left(e_1\right)}{\partial e_1} = 0.$$

An analogous condition can be derived for $e_2$. Eq. (6) implicitly defines $e_1$ as a function of $h$, $\alpha$, $p$, and $e_2$.

[3]Through deliberation, information can be shared. Since there is no conflict of interest, agents may always prearrange to vote in the same way. One may even expect that the agents will vote in the same way. In case of conflicting signals (ex post), each agent prefers rejection of the project to implementation. It is important to note that allowing for agreements on voting behavior does not affect our results. The reason is that implementation requires two agents to vote for implementation. Furthermore, note that if an agent has learned from the other agent, agents know the state of the world.

[4]Throughout this section we assume that $\pi(e_i)h > |p|$.

**Proposition 1** *Suppose that the level of effort is sufficiently high to induce sincere voting. Then, effort is a decreasing function of* $\alpha$ *if and only if* $\frac{1}{2} < \pi(e_2^*) < 1$.

**Proof.** Immediate from application of the implicit function theorem to (6). ■

Proposition 1 implies that the opportunity of deliberation may reduce agents' effort to collect information. The intuition behind this result is straightforward. When choosing effort, an agent compares the costs and benefits of effort. In our model, there are two types of benefits. First, by exerting more effort, the agent reduces the probability that he receives a wrong signal. Second, through the opportunity of deliberation, exerting more effort reduces the probability that the other agent bases his vote on a wrong signal. However, deliberation also reduces the cost of receiving a wrong signal. The reason is that deliberation makes it possible that a wrong signal will be corrected.

Using (5), it is easy to calculate the total expected surplus in the present model:

(7)

$$S_{OV} = \frac{1}{2}p\left\{1 + [\pi(e_{OV}^*)]^2\right\} + \pi(e_{OV}^*)h + \pi\left(e_{OV}^*\right)\left[1 - \pi\left(e_{OV}^*\right)\right]\alpha\left(p + h\right) - 2c\left(e_{OV}^*\right).$$

where $e_{OV}^*$ denotes the equilibrium effort level in the game with an optimistic view of deliberation. Does deliberation always improve social welfare? To answer this question, compare (4) with (7). Allowing for deliberation has two effects. First, given effort, deliberation increases the probability that the correct decision will be made (if $e_{ND}^* = e_{OV}^*$, then the third term of the right-hand side of (7) implies that $S_{OV} > S_{ND}$). Second, as discussed above the opportunity of deliberation affects effort. If effort increases, the opportunity of deliberation unambiguously enhances expected social welfare. If effort decreases, the welfare effect of deliberation is ambiguous. A higher value of $\alpha$, which can be interpreted as giving more room for communication, may decrease expected social welfare.

We illustrate the effect of deliberation on total expected social surplus with a numerical example. Let $\pi(e_i) = 0.8e_i$, $c(e_i) = \frac{1}{2}\lambda e_i^2$ with $\lambda > 0$, $h = 2$, and $p = -1$. Figure 1 and 2, illustrate the effect of $\alpha$ on the total expected social surplus in the case of $\gamma = 0.5$ and 0.17, respectively. In Figure 1, an increase in $\alpha$ leads to an increase in the total expected social surplus. The reason is that $0 < \pi(e^*) < \frac{1}{2}$ holds for all values of $\alpha$. Figure 2 shows that an increase in $\alpha$ may lead to a decrease in the total expected social surplus. The parameter values now ensure that $\frac{1}{2} < \pi(e^*) < 1$.

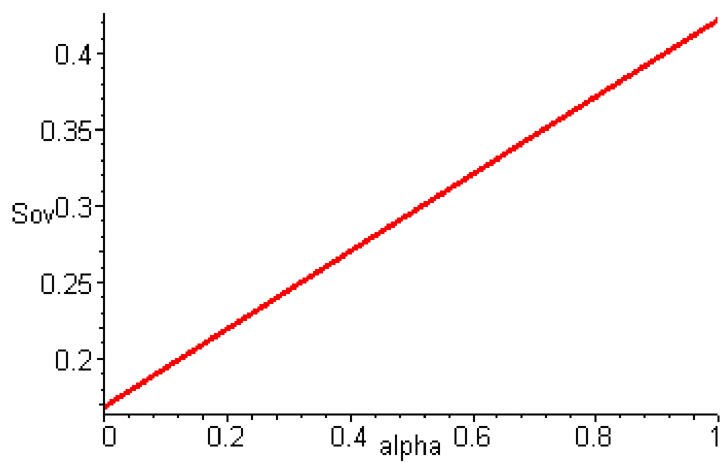


*Figure 1* $0 < \pi(e^*) < \frac{1}{2}$; $\gamma = 0.8$, $\lambda = 0.5$, $p = -1$, $h = 2$.

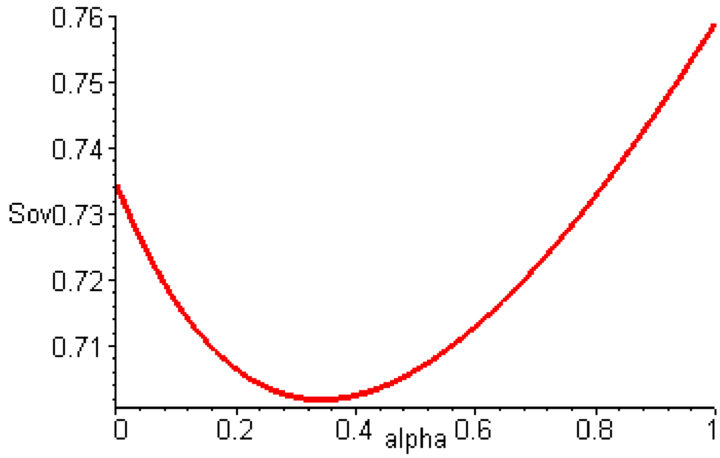


*Figure 2* $\frac{1}{2} < \pi(e^*) < 1$; $\gamma = 0.8$, $\lambda = 0.17$, $p = -1$, $h = 2$.

# 5 Adding a "Pessimistic" View of Deliberation to the Model

We now add a more sceptical view of deliberation to our model. We assume that with probability $\beta$ an agent, say agent $i$, who has received a wrong signal, convinces an agent, say agent $j$, who has received a different, possibly informative, signal that $j$'s signal is wrong. We maintain $\alpha$ in the model. We exclude the possibility that $i$ convinces $j$ and $j$ convinces $i$ simultaneously.[5]

Throughout the remaining part of this section we assume that it is optimal for each agent to vote in line with his (posterior) perception of the true state of the world. Agent 1 thus votes as follows:

(a) when he receives the same signal as agent 2 he always votes in line with his signal;

(b) when he receives a correct signal and agent 2 receives a wrong signal, he votes in line with his own signal with probability $1 - \beta$;

[5] Excluding this possibility does not affect our main results.

(c) when he receives a wrong signal and agent 2 receives an informative signal, he votes with probability $1-\alpha$ in line with his own signal.

The expected payoff to agent 1 when he chooses effort equals:

$$\begin{aligned}(8)\qquad & \frac{1}{2}\{\pi(e_1)\pi(e_2)+\frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right](1+\alpha)+\frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right] \\ & (1+\alpha)+\frac{1}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right](1+2\beta)\}(p+h)+ \\ & \frac{1}{2}\{\frac{1}{2}\pi\left(e_1\right)\left[1-\pi\left(e_2\right)\right]\beta+\frac{1}{2}\pi\left(e_2\right)\left[1-\pi\left(e_1\right)\right]\beta+\frac{1}{4}\left[1-\pi(e_1)\right] \\ & \left[1-\pi(e_2)\right](1+2\beta)\}(p-h)-c\left(e_1\right).\end{aligned}$$

Differentiating (8) with respect to $e_1$ yields the first-order condition:

$$(9)\quad \frac{1}{4}\frac{\partial\pi(e_1)}{\partial e_1}\{h+\pi(e_2)p+(p+h)(\alpha-\beta)+2\pi(e_2)[h\beta-\alpha(p+h)]\}-\frac{\partial c(e_1)}{\partial e_1}=0.$$

Eq. (9) implicitly defines $e_1$ as a function of $h$, $p$, $\alpha$, $\beta$, and $e_2$. By application of the implicit function theorem, it is easy to show that $e_1$ is a decreasing function of $\beta$ if and only if $\pi\left(e_2^*\right)<\frac{h+p}{2h}$. The total expected social surplus is:

$$\begin{aligned}(10)\qquad S_{PV} \;=\; & \frac{1}{2}p+[\pi\left(e_{PV}^*\right)]^2[\frac{1}{2}p+\alpha(-p-h)+h\beta]+ \\ & \pi\left(e_{PV}^*\right)[(\alpha-\beta)(p+h)+h]+p\beta-2c\left(e_{PV}^*\right).\end{aligned}$$

where $e_{PV}^*$ denotes the equilibrium level of effort in the present game. Analogous to the results of the previous section we can show that for small values of $\pi\left(e_{PV}^*\right)$, the welfare effect of an increase in $\beta$ is ambiguous. Hence, if more communication implies a higher probability that a person who has wrong information convinces a person who has good information, then more communication does not always increase the probability of good public decisions. The main reason for this result is that agents may respond to the adverse consequences of communication by putting more effort in collecting information.

# 6 Conclusion

Correcting mistakes and sharing information are two well-known rationales for deliberation. In this paper, we have examined the conditions under which deliberation improves collective decision making. Our most surprising result is that when there are no direct cost of communication and communication can only convince uninformed or wrongly informed agents of the truth, more communication may reduce the probability that a correct decision is made. The reason for this result is that communication may aggravate the free-rider problem associated with collecting information. Especially, when information is cheap, or good information is easy to acquire, more communication reduces agents' incentives to collect information. When collecting information is expensive, more communication usually increases the probability of good collective decisions.

We are aware that our results are derived from a highly stylized model based on many restrictive assumptions. Some assumptions were made for simplicity and are innocuous. Relaxing them does not affect the main results qualitatively. For instance, the assumption that there are only two states and that they occur with the same prior probability is not important. Adding individuals to the group is not likely to affect our main results either. Of course, the free-rider problem aggravates. This reduces the probability that an individual receives an informative signal. On the other hand, the probability that some individual receives an informative signal may rise. A complication is that the probability of learning may depend on the number of individuals in the group. A less innocuous assumption is that individuals have the same preferences. We conjecture that introducing conflict of interest into our model may jeopardize communication among agents.

# Appendix

This Appendix analyzes deliberation under the alternative voting rule: implementation requires one vote. Again we focus on symmetric equilibria in pure strategies. We focus on agent 1. As the results are qualitatively the same as in the main text, we hardly comment on our results.

**Case I: A Benchmark: No Deliberation**

As implementation requires one vote, the expected payoff to agent 1 is given by:

$$\text{(A1)}\quad \frac{1}{2}\left\{1-\frac{1}{4}[1-\pi(e_1)][1-\pi(e_2)]\right\}(p+h)+\frac{1}{2}\{\frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right] \\ +\frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right]+\frac{3}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right]\}(p-h)-c\left(e_1\right).$$

Differentiating (A1) with respect to $e_1$ yields the first-order condition:

$$\text{(A2)}\qquad \frac{1}{4}\frac{\partial\pi\left(e_1\right)}{\partial e_1}[h-\pi\left(e_2\right)p]-\frac{\partial c\left(e_1\right)}{\partial e_1}=0.$$

Eq. (A.2) implicitly defines $e_1$ as a function of $h$, $p$, and $e_{2,}$. As in the main text, effort is increasing in $h$ and decreasing in $p$ and in $e_2$.

The total expected social surplus is:

$$\text{(A3)}\qquad S_{ND'}=\frac{1}{2}p\left\{3-\left[\pi\left(e^*_{ND'}\right)\right]^2\right\}+h\pi\left(e^*_{ND'}\right)-2c\left(e^*_{ND'}\right).$$

where $e^*_{ND'}$ denotes the equilibrium effort level with no deliberation.

**Case II: Taking an Optimistic View of Deliberation**

The expected payoff to agent 1 when he chooses effort equals:

$$\text{(A4)}\frac{1}{2}\left\{1-\frac{1}{4}[1-\pi(e_1)][1-\pi(e_2)]\right\}(p+h)+\frac{1}{2}\{\frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right](1-\alpha) \\ \frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right](1-\alpha)+\frac{3}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right]\}(p-h)-c(e_1).$$

Differentiating (A4) with respect to $e_1$ yields the first-order condition:

$$\text{(A5)} \qquad \frac{1}{4}\frac{\partial \pi\left(e_1\right)}{\partial e_1}\left\{h - p\pi\left(e_2\right) + \alpha(p-h)[2\pi\left(e_2\right) - 1]\right\} - \frac{\partial c\left(e_1\right)}{\partial e_1} = 0.$$

An analogous condition can be derived for $e_2$. Eq. (A5) implicitly defines $e_1$ as a function of $e_2$, $p$, $h$, and $\alpha$. Application of the implicit function theorem shows that $e_1$ is a decreasing function of $\alpha$ if and only if $\frac{1}{2} < \pi\left(e_2^*\right) < 1$. The result is analogous to that of Section 4.

By using Eq. (A5), the total expected social surplus is:

(A6)

$$S_{OV'} = \frac{1}{2}p\left\{3 - \left[\pi\left(e^*_{OV'}\right)\right]^2\right\} + h\pi\left(e^*_{OV'}\right) + \pi\left(e^*_{OV'}\right)\left[1 - \pi\left(e^*_{OV'}\right)\right]\alpha(h-p) - 2c\left(e^*_{OV'}\right).$$

where $e^*_{OV'}$ denotes the equilibrium effort level in the game with an optimistic view. As in Section 4, the total expected social surplus may decrease in $\alpha$.

**Case III: Adding a Pessimistic View of Deliberation to the Model**

The expected payoff to agent 1 when he chooses effort is given by:

(A7)

$$\begin{aligned}
&\frac{1}{2}\{1 - \frac{1}{4}[1-\pi(e_1)][1-\pi(e_2)](1+2\beta) - \frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right]\beta \\
&-\frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right]\beta\}(p+h) + \frac{1}{2}\{\frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right] + \frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right] \\
&+\frac{3}{4}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right] - \frac{1}{2}\pi(e_1)\left[1-\pi(e_2)\right]\alpha - \frac{1}{2}\pi(e_2)\left[1-\pi(e_1)\right]\alpha \\
&-\frac{1}{2}\left[1-\pi(e_1)\right]\left[1-\pi(e_2)\right]\beta\}(p-h) - c(e_1).
\end{aligned}$$

Differentiating (A7) with respect to $e_1$ yields the first-order condition:

(A8)

$$\frac{1}{4}\frac{\partial \pi(e_1)}{\partial e_1}\left\{h - p\pi(e_2) - (p-h)(\alpha-\beta) + 2\pi(e_2)\left[h\beta + \alpha(p-h)\right]\right\} - \frac{\partial c(e_1)}{\partial e_1} = 0.$$

Eq. (A8) implicitly defines $e_1$ as a function of $e_2$, $p$, $h$, $\alpha$, and $\beta$. Application of the implicit function theorem shows that $e_1$ is an decreasing function of $\beta$ if and only if $\pi(e_2^*) < \frac{h-p}{2h}$.

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