Decision Making and Implementation in Teams

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Abstract

We consider a team whose members make a joint decision and exert individual efforts to implement it. Since efforts are non–contractible, incentives depend on the members' beliefs about the appropriateness of the team's decision, i.e. their "motivation". We identify an important inefficiency in the team's decision making. In the presence of asymmetric information about the right course of action, members have an incentive to manipulate their private information in order to increase their colleagues' motivation. As a consequence the team is unable to aggregate information efficiently and decision making becomes distorted. The team design that minimizes these distortions can be characterized as follows: (1) There exists an optimal team size which is increasing in the importance of making the right decision. (2) Better informed members should be provided with stronger incentives, i.e. larger shares of the team's revenue. (3) Access to better information should be assigned to members with higher ability, i.e. lower costs of effort.

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1 Introduction

In his seminal paper on moral hazard in teams, Holmstrom (1982) states that “the members of an organization may be seen as providing two kinds of services: they supply inputs for production and process information for decision making”. Indeed there are many examples of organizations whose members make joint decisions and subsequently exert individual efforts in order to implement them. For instance, political parties choose candidates or laws and individual politicians spend time into their advertisement or promotion. In joint ventures firms choose the characteristics of their common product and then make investments into its development and marketing. Co-workers in teams first decide the course of action and later implement it through individual efforts. Expert committees agree on a recommendation and then spend resources justifying it. Finally, member states of multinational organizations negotiate treaties and then separately undertake their ratification and enforcement.

In these examples implementation efforts are often unverifiable and hence non contractible and it is well known that this moral hazard leads to free riding amongst the members of the organization. However, contributions to our understanding of team environments have so far neglected the members' dual task of information processing and input supply, instead studying these two issues separately. In this paper we show that in the presence of asymmetric information decision making and implementation are interconnected. Our starting point is the observation that a team's decision making may be harmed by the members' concern for each others' incentives to provide implementation efforts.

In order to understand our main intuition, consider the following example of emission reduction. Suppose that as in the Montreal Protocol on Chlorofluorocarbons or the Kyoto Protocol on carbon dioxide, a group of countries aims to reduce the use of a number of gases which have a destructive effect on the earth's atmosphere. For the sake of the argument assume that countries have to decide whether to ban gas A or gas B. Since A is used more frequently than B there exists an intrinsic bias in favor of banning A. However, there also exists uncertainty about which of the two gases is the most harmful to the environment and if it was known that B is more harmful, then B should be banned.

Each country (privately) conducts research which might eventually provide evidence that A is more harmful than B or vice versa. Suppose one country, say X, has found conclusive evidence which shows that B is more harmful while the remaining countries' research has proved inconclusive. If X discloses the evidence then all countries will be certain that B is more harmful and will therefore decide to ban B. If instead X conceals the evidence then all remaining countries will remain uncertain and due to the bias mentioned above, A will be banned.

If the bias in favor of A is sufficiently strong, banning A *in the presence of uncertainty* might be expected to be more beneficial than banning B under certainty. In this case all countries other than X will be more motivated to exert enforcement efforts when X conceals the evidence than when X discloses it. Although the research of country X has shown that banning B would be the right thing to do, banning A leads to higher enforcement efforts.

This example illustrates that members of a team might manipulate their private information in order to increase each other's implementation efforts. As a consequence, decision making becomes distorted by motivational concerns.

After making this argument formal we will discuss how the above distortion depends on the institutional details of the organization under consideration. We first show that, while an increase in the number of members improves the team's aggregate information, decision making also becomes more distorted. As a consequence there exists an optimal size for which the team's decision making is optimized. The optimal size increases as decision making becomes more important. In reality, multinational organisations often find it practical to delegate decision making to a subgroup of countries, instead of drawing from a potentially larger pool of expertise. Our model provides an explanation for this phenomenon that does not depend on exogenous information aggregation costs or the increased diversity of interests. Instead, our result arises from the endogenous cost of a more distorted decision making.

We also determine the sharing rule that optimizes the organization's decision making. We find that members with larger shares in total revenue have less incentive to manipulate their information. As a consequence those members with the best information should be awarded the largest share of revenue. Conversely, when members are homogeneous revenue should be shared equally.

Finally, members might differ in their costs of providing implementation efforts. For instance, in the example above it is widely recognised that developing countries find it much more difficult to renounce to environmentally harmful technologies than more developed countries. We show that in order to optimize decision making, more able members, i.e. those with lower costs of effort, should be given access to better information. This last result provides an argument for the selection of an organization's leadership.

1.1 Related literature (Incomplete!)

Teoh (1997) considers the influence of disclosure of information in a model of public good provision. He shows that ex ante expected welfare might be higher under non–disclosure than under disclosure since the gain in incentives caused by good information might be outweighed by the loss caused by bad information. While in Teoh (1997) disclosure of information is determined by a social planner ex ante, that is before the information has been observed, in our model each member of the organization decides whether to disclose or not ex post. While our focus lies on the interaction between decision making and incentives, in Teoh (1997) decision making is absent and individuals merely decide on their level of public good provision.

Visser and Swank (2007) consider committee decision making when members have private information and aim to be perceived as able decision makers. They share our finding that members might be unable to truthfully communicate their information. However, while in our framework, this inability stems from the members concern for each others' implementation efforts, their model abstract from implementation and decision making becomes distorted due to reputational concerns.

There are two papers which share our finding that motivational concerns might interfere with decision making. In Blanes i Vidal and Möller (2007) we consider how these concerns are affected by the presence of publicly available information. Further, we show that decision making can be improved by the appointment of a self–confident leader. In a related model, Landier et al. (2008) find that heterogeneous organizations might outperform homogeneous ones since dissenting workers act as a disciplining device for the organization's management. These two papers consider hierarchic organizations in which decision making and implementation are separated. Our present focus is instead on a team, that is, a horizontal organization whose members both take decisions *and* implement them.

2 The basic model

Consider a team consisting of $N \geq 2$ members. The team's purpose is to choose one out of two mutually exclusive projects $d \in \{A, B\}$ and to implement it. There are two possible states of the world $x \in \{A, B\}$. Members share a common prior about the state of the world, i.e. each member believes that $x = A$ with probability $Q \in [\frac{1}{2}, 1)$. In addition, each member may receive (private) information about the state of the world. In particular, conditional on the state being x, with probability $q_i \in (0, 1)$ member i receives verifiable evidence that the state is x and with probability $1 - q_i$ he observes nothing.

Members exert effort in order to implement the project they selected. Member i chooses his effort from a compact interval $e_i \in [0, \bar{e}_i] \subset \Re$. Member i's cost of exerting effort $C_i(e_i)$ is assumed to be nondecreasing and continuously differentiable with $C_i(0) = 0$.

The project's "productivity", $p(d, x) \geq 0$, depends on the state of the world. It is denoted by p_d when the project fails to match the state of the world, i.e. when $d \neq x$, and by p_D otherwise. We make three assumptions. (1) Productivity is higher when the project matches the state of the world i.e. $p_A > p_a$ and $p_B > p_b$. (2) There exists a bias which makes project A more productive than project B, i.e. $p_A > p_B$ and $p_a > p_b$. (3) The members' information is decision–relevant, i.e. $p_B > p_a$. In summary:

$$p_A > p_B > p_a > p_b. \tag{1}$$

The project's revenue, $R(e, p)$, depends on the productivity parameter p and the vector of efforts $e = (e_1, e_2, \ldots, e_N)$. We assume that R is continuously differentiable and increasing in e. Marginal revenue $\frac{\partial R}{\partial e_i}$ is nondecreasing in e_{-i}, i.e. efforts are strategic complements in the sense of Bulow, Geanakoplos, and Klemperer (1985). With respect to the productivity parameter p, R is assumed to be continuous and increasing with $R(e, 0) = 0$ for all e. The assumption that drives our main results is that decision making and implementation are complements in the sense of monotone comparative statics (see Milgrom and Shannon (1994)). In particular, we assume that marginal revenue $\frac{\partial R}{\partial e_i}$ is increasing in the productivity parameter p. Below we show that due to this assumption, equilibrium efforts depend monotonically on the members' "motivation", i.e. their beliefs about the project's productivity.

Each member receives a fixed share of the project's revenue. In particular, member i receives the share $\alpha_i \in (0,1)$ and $\sum_{i=1}^{N} \alpha_i = 1$. Assuming risk–neutrality, member i's payoff is given by

$$\pi_i = \alpha_i R(e, p(d,x)) - C_i(e_i) \tag{2}$$

The timing is as follows: (1) *Information.* Nature determines the state of the world and members receive their private information. (2) *Communication.* Members exchange information. Each member i who received evidence about the state of the world may either disclose it or conceal it. (3) *Decision making.* The project is selected according to some (voting) rule. (4) *Implementation.* Members simultaneously choose their effort levels.

2.1 Efficient decision making

In order to determine the efficient project choice let us abstract from informational asymmetries. Instead consider the case where information is symmetric in the sense that whenever some member receives evidence about the state of the world then this evidence is observed by all members.

If evidence for $x = A$ has been observed then $p_A > p_b$ implies that effort is more productive in project A. Hence the organization will choose $d^* = A$. If instead evidence for $x = B$ has been received then project B is more productive than project A since $p_B > p_a$. In this case the organization will choose $d^* = B$. If the organization has received no information about the state of the world then the likelihood that $x = A$ is given by the prior Q. Given any effort vector e expected total payoff from choosing $d = A$ is

$$\sum_{i \in N} \pi_i = QR(e, p_A) + (1-Q)R(e, p_a) - \sum_i C_i(e_i) \tag{3}$$

while for $d = B$ it is

$$\sum_{i \in N} \pi_i = QR(e, p_b) + (1-Q)R(e, p_B) - \sum_i C_i(e_i). \tag{4}$$

Since $Q \geq \frac{1}{2}$, $p_A > p_B$ and $p_a > p_b$ the former is strictly greater than the latter. Hence in the absence of information about the state of the world, the organization will choose $d^* = A$.

Note that due to our assumption that $p_B > p_a$ the organization's information matters. If instead $p_B \leq p_a$ then project A would always be optimal regardless of the team's information.

In order to rule out this trivial case and to make the problem interesting, selecting a project that matches the state of the world has to be sufficiently important relative to the bias in favor of project A.

In summary, efficient decision making requires the team to select project $d^* = B$ if and only if the state of the world has been observed to be B. Otherwise project A should be chosen. The question in this paper is whether a member receiving evidence for $x = B$ will communicate this information to his fellow members. In the next section we will show that due to motivational concerns such information might be concealed. As a consequence decision making in the presence of informational asymmetries will be inefficient.

2.2 Implementation

Consider the simultaneous effort choice game. Suppose that project $d \in \{A, B\}$ has been selected and member i believes that $x = d$ with probability $\beta_i \in [0, 1]$. Member i's expected payoff is given by

$$\pi_i(e_i, e_{-i}, \beta_i) = \alpha_i[\beta_i R(e_i, e_{-i}, p_D) + (1 - \beta_i) R(e_i, e_{-i}, p_d)] - C_i(e_i). \quad (5)$$

Note that our assumptions on revenue and costs imply that π_i is continuously differentiable in e and that member i's marginal payoff $\frac{\partial \pi_i}{\partial e_i}$ is nondecreasing in e_{-i}. Hence the simultaneous effort choice game constitutes a supermodular game as introduced by Topkis (1979). Milgrom and Roberts (1990) have shown that a supermodular game has a smallest and a largest pure Nash equilibrium. Denote the latter as $e^d(\beta)$. Our assumptions on revenue and costs further imply that member i's marginal payoff $\frac{\partial \pi_i}{\partial e_i}$ is increasing in β_i. Theorem 6 of Milgrom and Roberts (1990) therefore implies that $e^d(\beta)$ is nondecreasing in β.

Note that since revenue is increasing in efforts, the equilibrium $e^d(\beta)$ is Pareto preferred to all other equilibria. To see this consider an arbitrary equilibrium $e'(\beta)$ and note that

$$\pi_i(e'_i, e'_{-i}, \beta_i) \leq \pi_i(e'_i, e^d_{-i}, \beta_i) \leq \pi_i(e^d_i, e^d_{-i}, \beta_i) \quad (6)$$

where the first inequality follows from $e^d_{-i} \geq e'_{-i}$ and the second inequality is due to the optimality of e^d_i given e^d_{-i}. Hence if the team can coordinate onto the equilibrium that is Pareto preferred by its members then e^d will be the unique outcome of the simultaneous effort choice game.

Consider member i's best response correspondence

$$E_i(e_{-i}, \beta_i) = \arg \max_{e_i \in [0, \bar{e}_i]} \pi_i(e_i, e_{-i}, \beta_i). \tag{7}$$

Since marginal profits are increasing in β_i it follows from the Monotone Selection Theorem of Milgrom and Shannon (1994) that every selection $e_i(e_{-i}, \beta_i)$ from $E_i(e_{-i}, \beta_i)$ is nondecreasing in β_i. In particular member i's largest best response $e_i^d(e_{-i}, \beta_i)$ is nondecreasing in β_i. Moreover, since π_i is continuously differentiable in e_i the Strict Monotonicity Theorem of Edlin and Shannon (1998) implies that $e_i^d(e_{-i}, \beta_i)$ is increasing in β_i on the interior of $[0, \bar{e}_i]$. Since efforts are strategic complements it follows from the Monotonicity Theorem of Milgrom and Shannon (1994) that $e_i^d(e_{-i}, \beta_i)$ is nondecreasing in e_{-i}.

Consider $\beta' \geq \beta$ and suppose that $e_k^d(\beta) \in (0, \bar{e}_k)$ for some $k \neq i$ and that $\beta_k' > \beta_k$. We already know that $e^d(\beta') \geq e^d(\beta)$. We now argue that $e_k^d(\beta') > e_k^d(\beta)$. Since a member's best response is nondecreasing in his colleagues efforts, $e_{-k}^d(\beta') \geq e_{-k}^d(\beta)$ implies that $e_k^d(\beta') = e_k^d(e_{-k}^d(\beta'), \beta_k') \geq e_k^d(e_{-k}^*(\beta), \beta_k')$. Moreover, since a member's best response is increasing in his belief on the interior of his choice interval, $\beta_k' > \beta_k$ and $e_k^d(\beta) \in (0, \bar{e}_k)$ imply that $e_k^d(e_{-k}^d(\beta), \beta_k') > e_k^d(e_{-k}^d(\beta), \beta_k) = e_k^d(\beta)$. Hence $e_k^d(\beta') > e_k^d(\beta)$. We have therefore shown that when beliefs are increased for some members without being decreased for other members then the equilibrium efforts of the former will increase as long as they are interior. We summarize our findings as follows.

Lemma 1 *Let β and β' be two vectors of beliefs such that $\beta_i' \geq \beta_i$ for all $i \in N$ with strict inequality for all $i \in M$ where $M \subset N$ and $M \neq \emptyset$. Then $e_i^d(\beta') \geq e_i^d(\beta)$ with strict inequality for all $i \in M$ such that $0 < e_i^d(\beta) < \bar{e}_i$.*

The positive relationship between efforts and beliefs is the main force driving our results. Because a member's payoff is strictly increasing in other members' efforts, he has an incentive to "motivate" his colleagues. As a consequence decision making and implementation become interdependent. Team members might conceal their private information in order to improve the motivation of their colleagues thereby distorting the organization's decision making.

2.3 Disclosure of private information

In this section we discuss whether the efficient decision making rule d^* is implementable via truthful revelation of private information. For this purpose suppose that in the decision making stage (3) project B is selected if and only if in the communication stage (2) some player i has disclosed evidence for $x = B$. Will members disclose their information truthfully or do they have an incentive to conceal it?

Consider first some member i who has received evidence for $x = A$. If member i discloses his information then all other members will learn that the state is A and project A will be selected. The belief of member i is $\beta_i = 1$ and the beliefs of his colleagues are $\beta_{-i} = (1, \dots, 1)$. In order to abbreviate notation we denote beliefs as $\beta = (\beta_i, \beta_{-i}) = (1, \mathbf{1})$. Member i's expected payoff is

$$\pi_i = \alpha_i R(e^A(1, \mathbf{1}), p_A) - C_i(e_i^A(1, \mathbf{1})). \tag{8}$$

Note that this is the highest payoff team member i can ever expect since $e_{-i}^A(1, \mathbf{1})$ is the maximum effort his colleagues will exert and the project's productivity takes its highest possible value. After receiving evidence for $x = A$, disclosure therefore constitutes a dominant strategy for player i. We therefore have the following result:

Lemma 2 *In any equilibrium a team member who receives evidence for $x = A$ will disclose this information.*

Consider now the incentive to reveal information about $x = B$. Suppose that member i has received such evidence. If i discloses his information then project B is selected and all members know that $x = B$, i.e. beliefs are $\beta = (1, \mathbf{1})$. The expected payoff of member i is

$$\pi_i^D = \alpha_i R(e^B(1, \mathbf{1}), p_B) - C_i(e_i^B(1, \mathbf{1})). \tag{9}$$

Note that member i's expected payoff from disclosing his evidence is independent of the information and behavior of his colleagues. In contrast, when member i conceals his information his expected payoff depends on whether his colleagues have also received evidence and whether they choose to disclose it. If member $j \neq i$ has received evidence for $x = B$ and discloses it then beliefs and project choice will be as above, i.e. member i's payoff will be π_i^D. Let γ_i denote the likelihood that no other member $j \in N - i$ discloses evidence. Note that γ_i depends on the likelihoods q_j with which i's colleagues observe evidence as well as on their strategies. If no evidence is disclosed, project A will be selected (inefficiently). Member i's expected payoff depends on his colleagues beliefs. Optimally none of them has received evidence and all believe that $x = A$ with probability Q, i.e. beliefs are $\beta = (\beta_i, \beta_{-i}) = (0, \mathbf{Q})$. In this case member i's payoff is given by

$$\bar{\pi}_i^Q = \alpha_i R(e^A(0, \mathbf{Q}), p_a) - C_i(e_i^A(0, \mathbf{Q})). \tag{10}$$

In the worst case, all $j \neq i$ have also received evidence (and concealed it) so that $\beta = (\beta_i, \beta_{-i}) = (0, \mathbf{0})$. In this case member i's payoff is given by

$$\underline{\pi}_i^Q = \alpha_i R(e^A(0, \mathbf{0}), p_a) - C_i(e_i^A(0, \mathbf{0})). \tag{11}$$

Note that

$$\bar{\pi}_i^Q \geq \alpha_i R(e_i^A(0, \mathbf{0}), e_{-i}^A(0, \mathbf{Q}), p_a) - C_i(e_i^A(0, \mathbf{0})) \geq \underline{\pi}_i^Q. \tag{12}$$

The first inequality follows from the optimality of $e_i^A(0, \mathbf{Q})$ while the second inequality is due to $e_{-i}^A(0, \mathbf{Q}) \geq e_{-i}^A(0, \mathbf{0})$ and is strict when $0 < e_j^A(0, \mathbf{0}) < \bar{e}_j$ for some $j \in N$, $j \neq i$. $\bar{\pi}_i^Q$ and $\underline{\pi}_i^Q$ are member i's maximal and minimal payoffs in the case that no evidence for $x = B$ is disclosed. Member i's expected payoff from concealing evidence for $x = B$ can therefore be written as

$$\pi_i^C = (1 - \gamma_i)\pi_i^D + \gamma_i[\rho_i \bar{\pi}_i^Q + (1 - \rho_i)\underline{\pi}_i^Q] \tag{13}$$

where $\rho_i \in [0, 1]$.

Let us start by considering the possibility of an equilibrium in which all team members disclose their evidence for $x = B$. If member i conceals his evidence for $x = B$ then no evidence will be disclosed if and only if no member $j \neq i$ has received evidence, i.e. $\gamma_i = \prod_{j \in N - i}(1 - q_j)$. Moreover, when project A is selected all members $j \neq i$ believe that $\beta_j = Q$ so that $\rho_i = 1$. Member i's expected payoff from concealing his information is

$$\pi_i^C \quad = \quad (1 - \gamma_i)\pi_i^D + \gamma_i \bar{\pi}_i^Q \tag{14}$$

Define

$$\Delta_i^D = \pi_i^D - \bar{\pi}_i^Q. \tag{15}$$

Disclosing evidence on $x = B$ is optimal for member i if and only if $\Delta_i^D \geq 0$. We find the following result:

Lemma 3 *An equilibrium in which all team members disclose evidence for $x = B$ exists if and only if $p_a \leq p^D$. $p^D \leq p_B$ with strict inequality if $0 < e_i^A(0, \mathbf{0}) < \bar{e}_i$ for some $i \in N$. p^D is independent of the probabilities q_i with which team members receive evidence.*

Proof: Since $\bar{\pi}_i^Q \geq \underline{\pi}_i^Q$ and $\lim_{p_a \to p_B} \underline{\pi}_i^Q = \pi_i^D$ it holds that

$$\lim_{p_a \to p_B} \Delta_i^D \leq 0. \tag{16}$$

with strict inequality when $0 < e_j^A(0, \mathbf{0}) < \bar{e}_j$ for some $j \in N$, $j \neq i$. On the other hand, since $R(e, 0) = C_i(0) = 0$ we have

$$\lim_{p_a, p_b \to 0} \Delta_i^D = \pi_i^D > 0. \tag{17}$$

Finally, we show that Δ_i^D is continuous and nonincreasing in p_a. To see this let $\tilde{p}_a > p_a$ and denote the corresponding equilibrium effort vectors given beliefs $\beta = (0, \mathbf{Q})$ as $\tilde{e}^A$ and e^A. We have

$$\alpha_i R(\tilde{e}^A, p_a') - C_i(\tilde{e}_i^A) \geq \alpha_i R(e_i^A, \tilde{e}_{-i}^A, p_a') - C_i(e_i^A) \geq \alpha_i R(e^A, p_a) - C_i(e_i^A). \tag{18}$$

The first inequality follows from the optimality of $\tilde{e}_i^A$ and the second inequality holds since $\tilde{e}_{-i}^A \geq e_{-i}^A$ and R is increasing in p. Hence there exists a unique $p_i^D \in (0, p_B]$ such that $\Delta_i^D \geq 0$ if and only if $p_a \leq p_i^D$. Define

$$p^D \equiv \min_{i \in N} p_i^D \tag{19}$$

and note that $p^D < p_B$ if $0 < e_j^A(0, \mathbf{0}) < \bar{e}_j$ for some $j \in N$, $j \neq i$. Given this definition, it is optimal for all members to disclose evidence for $x = B$ if and only if $p_a \leq p^D$. ■

The intuition for this result is as follows. From the viewpoint of a member who has learned that $x = B$, concealing this evidence has two effects. On the one hand it decreases the project's expected productivity since project A might become selected even though he knows the state of the world to be B. On the other hand it increases motivation since the other members are more inclined to work on project A than on project B whenever $e^A_{-i}(0, \mathbf{Q}) \geq e^B_{-i}(1, \mathbf{1})$.

Note that when p_a is close to p_B the loss in expected productivity becomes negligible but motivation is increased. Hence disclosure cannot be optimal. When $p_a, p_b \to 0$ it becomes crucial to avoid choosing the wrong project, since the wrong project delivers zero productivity. Hence concealing evidence cannot be optimal. An increase in p_a decreases the loss in expected productivity and at the same time increases the gain in motivation. Hence disclosure of information is an equilibrium if and only if $p_a \leq p^D$.

Note that a member who has concealed evidence never has an incentive to disclose it ex post, i.e. after the project has been selected. This is because the only evidence that is ever concealed is evidence on B and project B is only selected if some other member has already disclosed evidence on B.

Next consider the possibility of an equilibrium in which all team members conceal evidence on $x = B$. In this case $\gamma_i = 1$, i.e. if member i decides to conceal his evidence then no evidence will be disclosed and project $d = A$ will be selected. Moreover, when A is selected, member $j \neq i$ will have the belief $\beta_j = 0$ if he has received evidence for $x = B$ and $\beta_i = Q$ otherwise. Hence member i's expected payoff from concealing his evidence is

$$\pi_i^C = \rho_i \bar{\pi}_i^Q + (1 - \rho_i) \underline{\pi}_i^Q. \tag{20}$$

where $\rho_i \in (0, 1)$ and ρ_i is decreasing in q_j for all $j \in N - i$. Define

$$\Delta_i^C = \pi_i^D - \rho_i \bar{\pi}_i^Q - (1 - \rho_i) \underline{\pi}_i^Q. \tag{21}$$

Concealing evidence for $x = B$ is optimal for member i if and only if $\Delta_i^C \leq 0$. We have the following result:

Lemma 4 *An equilibrium in which all team members conceal evidence for $x = B$ exists if and only if $p_a \geq p^C$. $p^D \leq p^C \leq p_B$ with strict inequalities if $0 < e_i^A(0, \mathbf{0}) < \bar{e}_i$ for some $i \in N$. p^C is increasing in the probabilities q_i with which team members receive evidence.*

Proof: Since $\lim_{p_a \to p_B} \underline{\pi}_i^Q = \pi_i^D$ it holds that $\lim_{p_a \to p_B} \Delta_i^C \leq 0$ with inequalities being strict when $0 < e_j^A(0, \ldots, 0) < \bar{e}_j$ for some $j \in N$, $j \neq i$. Also note that $\lim_{p_a, p_b \to 0} \Delta_i^C = \pi_i^D > 0$.

Analog to the case above one can show that Δ_i^C is nonincreasing in p_a. Hence there exists a unique $p_i^C \in (0, p_B]$ such that $\Delta_i^C \leq 0$ if and only if $p_a \geq p_i^C$. Define

$$p^C \equiv \max_{i \in N} p_i^C \tag{22}$$

and note that $p^C < p_B$ if $0 < e_i^A(0, \ldots, 0) < \bar{e}_i$ for some $i \in N$. Concealing evidence for $x = B$ is optimal for all team members if and only if $p_a \geq p^C$. Finally, since $\Delta_i^C \geq \Delta_i^D$ it holds that $p_i^D \leq p_i^C$ with all inequalities being strict when $0 < e_j^A(0, \ldots, 0) < \bar{e}_j$ for some $j \in N$, $j \neq i$. Hence $p^D \leq p^C$ with strict inequality if $0 < e_i^A(0, \ldots, 0) < \bar{e}_i$ for some $i \in N$. Since ρ_i decreases in q_j for all $j \neq i$, Δ_i^C increases in q_j for all $j \neq i$. This implies that p^{Ci} is increasing in q_j for all $j \neq i$. Hence p^C is increasing in q_i for all $i \in N$. ■

In the equilibria described in Lemma 3 and 4, evidence for $x = B$ is disclosed or concealed *completely*, i.e. by all team members and with certainty. Let us consider the possibility of an equilibrium in which evidence for $x = B$ is disclosed *partially*. For example there might exist an equilibrium in which some members disclose evidence while others conceal it. There might also exist an equilibrium in which team members mix between disclosing and concealing evidence for $x = B$. Hence consider member i and suppose that members $j \neq i$ neither all disclose their evidence with certainty nor all conceal their evidence with certainty. Since some member $j \neq i$ discloses his evidence with positive probability, the likelihood that no colleague of i discloses evidence is $\gamma_i < 1$. However, conditional on no evidence for $x = B$ being disclosed, the likelihood that $\beta_j = Q$ rather than $\beta_j = 0$ is higher than when all colleagues of i conceal their information with certainty. This implies that ρ_i and thus π_i^C are larger than in the case when all colleagues of i conceal their evidence for $x = B$. Hence a team member's incentive to conceal his evidence is increasing in the likelihood with which his colleagues disclose their evidence. This implies that for $p_a \leq p^D$ the equilibrium in which all team members disclose their evidence is the unique equilibrium. It also implies that for $p_a \geq p^C$ the equilibrium in which all team members conceal their evidence is the unique equilibrium. We can therefore summarize our results in this section as follows:

Proposition 1 *There exist p^D and p^C such that $0 < p^D \leq p^C \leq p_B$ with strict inequalities if $0 < e_i^A(0, \mathbf{0}) < \bar{e}_i$ for some $i \in N$ and the following holds. All team members disclose evidence* *for $x = A$. Evidence for $x = B$ is disclosed completely if and only if $p_a \leq p^D$, disclosed partially if and only if $p^D < p_a < p^C$, and concealed if and only if $p_a \geq p^C$.*

In this section we have identified an important link between decision making and implementation in organizations. Since implementation efforts are non–contractible, members have to be concerned about each other's motivation to implement the common decision. In the presence of asymmetric information these motivational concerns can influence the organization's ability to make efficient decisions. When members have private information they may favor decisions which their fellow members consider appropriate in the absence of such information. As a consequence aggregation of information and hence decision making will be inefficient. Proposition 1 shows that decision making is inefficient when $p_a > p^D$. When in state of the world $x = B$ project A's productivity is not much smaller than project B's productivity then evidence for $x = B$ will be concealed with positive probability and project A might be implemented although efficiency requires the implementation of project B. In the following section we will consider how the range of inefficiency (p^D, p_B) depends on the parameters of the model. This will allow us to derive results about the optimal organizational setup, i.e. the setup that minimizes this inefficiency.

3 Comparative statics

Are larger teams more or less prone to distort their decision making in response to motivational concerns than small teams? How should revenues be shared in order to maximize the quality of a team's decision making? And who should have access to decision relevant information? In this section we study how the inefficiency identified in the previous section varies with the parameters of the model. In order to do so we make the following additional assumptions about the functional form of costs and revenues. We first assume that member i's cost of exerting implementation effort $e_i \in [0, 1]$ is given by

$$C_i(e_i) = \frac{1}{2a_i} e_i^2 \tag{23}$$

where $a_i \in (0, 1)$ denotes member i's ability. Secondly, we assume that revenue is given by

$$R(e, p) = p \sum_{i \in N} e_i \tag{24}$$

Finally, we normalize by setting $p_A = 1$ and since the parameter p_b does not appear in any of the equilibrium conditions we can set $p_b = 0$ without loss of generality.

Under the above assumptions a member's optimal effort choice is independent of other members' efforts. More specifically, if $d = A$ and member i believes that $x = A$ with probability β_i then in equilibrium he will choose his effort to solve

$$e_i^A(\beta_i) \in \arg\max_{e_i} \alpha_i(\beta_i + (1-\beta_i)p_a) \sum_{j\in N} e_j - \frac{1}{2a_i} e_i^2. \tag{25}$$

Hence his equilibrium effort is given by

$$e_i^A(\beta_i) = \alpha_i a_i(\beta_i + (1-\beta_i)p_a) \in (0,1). \tag{26}$$

Note that this effort is strictly increasing in the member's belief β_i about the likelihood of success of the team's decision. Similarly for project B we get

$$e_i^B(\beta_i) = \alpha_i a_i \beta_i p_B \in [0,1). \tag{27}$$

Suppose that all team members disclose evidence for $x = B$ and that member i has received such evidence. If i discloses the evidence his payoff is

$$\pi_i^D = \alpha_i p_B \sum_{j\in N} e_j^B(1) - \frac{1}{2a_i}[e_i^B(1)]^2. \tag{28}$$

If he conceals the evidence his payoff is

$$\pi_i^C = (1-\gamma_i)\pi_i^D + \bar{\pi}_i^Q \tag{29}$$

where $\gamma_i = \prod_{j\in N-i}(1-q_j)$ is the probability that no other team member has received evidence and

$$\bar{\pi}_i^Q = \alpha_i p_a[e_i^A(0) + \sum_{j\neq i} e_j^A(Q)] - \frac{1}{2a_i}[e_i^A(0)]^2. \tag{30}$$

Disclosing the evidence is optimal for member i if and only if $\Delta_i^D \geq 0$ where

$$\begin{aligned} \Delta_i^D &= \pi_i^D - \bar{\pi}_i^Q \\ &= p_B^2[\frac{1}{2}\alpha_i^2 a_i + \alpha_i \sum_{j\neq i}\alpha_j a_j] - p_a^2 \frac{1}{2}\alpha_i^2 a_i - (Q + (1-Q)p_a)p_a\alpha_i \sum_{j\neq i}\alpha_j a_j. \end{aligned} \tag{31}$$

The threshold p_i^D is the unique solution to $\Delta_i^D(p_a) = 0$.

3.1 Optimal team size

Consider a team that consists of N homogeneous members each having an equal share in total revenue, i.e. suppose that $\alpha_i = \frac{1}{N}$ and $a_i = a$ for all $i = 1, \dots, N$. In this case we have

$$\Delta_i^D = \frac{a}{N^2}\left((N - \frac{1}{2})p_B^2 - Q(N-1)p_a - (\frac{1}{2} + (1-Q)(N-1))p_a^2\right) \tag{32}$$

for all $i \in N$ and hence

$$p_i^D = p^D(N) = \frac{-Q(N-1) + \sqrt{Q^2(N-1)^2 + (1 + 2(1-Q)(N-1))(2N-1)p_B^2}}{1 + 2(1-Q)(N-1)}. \tag{33}$$

Since p^D is strictly decreasing in N the range of parameters $(p^D(N), p_{BB})$ for which decision-making is inefficient becomes larger as N increases. We can therefore state the following result:

Proposition 2 *As the size of the team increases, the team makes less use of its available information.*

Note that this result is driven by the fact that concealing evidence for $x = B$ increases the motivation of $N - 1$ players while the loss in decision–quality is independent of N due to the fact that the deviating player, after receiving evidence, has perfect information about the state of the world.

Although this result has been obtained for the specific functional forms defined above, it is of particular importance. It shows that even in the general model outlined in Section 2 the inefficiency does not necessarily disappear as the size of the organization grows large. For $N \to \infty$ the likelihood that some member has received evidence about the state of the world converges to 1. Hence the organization's "aggregate information" is approximately perfect. Nevertheless the organization is unable to make use of its nearly perfect information when $p_a > p^D$.

How many members should a team have in order to optimize its decision making. Obviously, for $N = 1$ the organization makes efficient use of its available information, i.e. $p^D(1) = p_B$. Adding an additional member improves the organization's available (private) information. However it also decreases p_D. As long as $p^D(N) > p_a$ the organization's decision making will improve. Eventually however $p^D(N)$ might drop below p_a and information on $x = B$ will cease to be communicated. Since the addition of a new member improves the available information only marginally but communication becomes less informative for all members, the size that optimizes decision making N^* is given by the maximum N for which $p^D(N) > p_a$ remains to hold. Hence N^* solves $\Delta^D = 0$ and we find

$$N^* = \frac{1}{2}\frac{p_B^2 + (2Q-1)p_a^2 - 2Qp_a}{p_B^2 + (Q-1)p_a^2 - Qp_a}. \tag{34}$$

Note that when p_a decreases, N^* increases. These results are summarized in the following:

Proposition 3 *There exists a unique size N^* for which the organization's decision making is optimized. $N^* < \infty$ if and only if $p_a > \lim_{N\to\infty} p^D(N)$. As it becomes more important to make the appropriate decision, i.e. as p_a decreases, the organization should become larger.*

3.2 Optimal sharing rule

Do members with high shares of total revenue have a stronger or a weaker incentive to disclose their private information than members with low shares? And is there a sharing rule that optimizes information transmission within the organization? In order to answer these questions, suppose that members have different shares α_i but identical abilities, i.e. $a_i = a$ for all $i = 1, \dots, N$. In this case we have

$$\Delta_i^D = a\alpha_i \left((1 - \frac{\alpha_i}{2})p_B^2 - Q(1-\alpha_i)p_a - (\frac{\alpha_i}{2} + (1-Q)(1-\alpha_i))p_a^2 \right) \tag{35}$$

and

$$p_i^D = \frac{-Q(1-\alpha_i) + \sqrt{Q^2(1-\alpha_i)^2 + (\alpha_i + 2(1-Q)(1-\alpha_i))(2-\alpha_i)p_B^2}}{\alpha_i + 2(1-Q)(1-\alpha_i)}. \tag{36}$$

Note that p_i^D strictly increases in α_i with $\lim_{\alpha_i \to 1} p_i^D = p_B$. Hence the larger a member's share of revenue the smaller is his incentive to conceal evidence. Since members might differ in the likelihood with which they receive information and since $p^D = \min_{i\in N} p_i^D$ we therefore have the following result:

Proposition 4 *In order to optimize the team's decision making, those members who are more likely to receive information should be awarded higher shares of revenue. If all members are equally likely to receive information then revenue should be shared equally.*

3.3 Optimal access to information

In many teams information is not distributed uniformly. Typically the team's leadership is more informed than the remaining members. In many occasions a designer might be able to award or restrict access to the available sources of evidence thereby influencing the distribution of information within the organization. Suppose for example that there are N sources of information. Source i provides evidence about the state of the world with probability q_i. Optimally each source of evidence should be observed by every member of the team. However, if such an arrangement is not feasible and the observation of each source of evidence has to be assigned to exactly one member then what is the assignment that optimizes the team's decision making? In order to answer this question suppose that $q_1 > q_2 > \cdots > q_N$, that is source i is more informative than source $i+1$. Let $a_1 > a_2 > \cdots > a_N$ so that member i is more able than member $i+1$. Finally assume that revenue is shared equally, i.e. $\alpha_i = \frac{1}{N}$. We then have

$$\Delta_i^D = p_B^2[\sum_{j\in N} a_j + \sum_{j\in N-i} a_j] - p_a \sum_{j\in N-i} a_j - p_a^2 \sum_{j\in N} a_j \tag{37}$$

and

$$p_i^D = -\frac{\sum_{j\in N-i} a_j}{2\sum_{j\in N} a_j} + \sqrt{\frac{\sum_{j\in N-i} a_j}{2\sum_{j\in N} a_j} + p_{BB}^2 \frac{\sum_{j\in N} a_j + \sum_{j\in N-i} a_j}{\sum_{j\in N} a_j}}. \tag{38}$$

Note that p^{Di} strictly increases in a_i. Hence more able members have less incentive to conceal information. In order to minimize the likelihood that decision making is distorted member i should therefore be assigned to observe source i. Hence we can state the following:

Proposition 5 *In order to optimize the team's decision making access to better information should be assigned to more able members.*

4 Conclusion

When several individuals exert (non–contractible) effort in order to achieve a common goal, free riding is likely to arise. Each individual prefers others to contribute a lot while contributing little himself. As a consequence efforts fall short of the efficient level and the common goal might fail to be achieved. In this paper we have shown that when individuals first have to set their goal jointly, then their choice will be influence by their concern for each other's free riding.

In teams whose members make decisions and exert effort in order to implement them, decision making can therefore be expected to be distorted by motivational concerns. Since these distortions depend on the characteristics of the team, our results have implications for an organization's optimal design. In particular we have shown that there exists a unique size for which the organizations decision making is optimized. The optimal size increases as decision making becomes more important. Moreover, we have derived the sharing rule that minimizes the distortions to the team's decision making. We have shown that decision making is optimized when better informed member receive larger shares of the organization's total revenue than less informed members. When members are homogeneous, revenues should be shared equally. Finally we have considered the optimal distribution of information within an organization. We have shown that in order to optimize decision making access to better information should be assigned to more able members.

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