On the Limits of Cheap Talk for Public Good Provision*

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January 18, 2012

Abstract

We study a situation where, as a consequence of private information, agents do not have the incentive to invest in a public good if they are unable to have prior discussion with their partners. We show that in a voluntary contribution mechanism with cheap talk, any finite message space does not provide efficiency gain relative to a binary message space when agents truthfully report their type. Using laboratory experiments, we observe that communication is a useful mechanism to enhance efficiency, mainly by allowing players to coordinate on the zero contribution when the project is not desirable for at least one of them. However, we find that such efficiency gain seems to be very limited, since the simplest communication structure ("Yes" or "No" messages) provides the same incentives to the agents as larger message spaces.

JEL codes: C72; C91; D83; H41.

Keywords: Voluntary contribution mechanism; Incomplete information; Communication; Cheap talk; Threshold equilibria; Experiments; Coordination games

1 Introduction

A recurrent issue in Economics is understanding when the collection of individual choices is able to generate the socially desired outcome, such as the provision of a public good or the implementation of a joint project. The literature shows that under asymmetric information or coordination failure, individual actions may lead to allocations that yield suboptimal outcomes. However, it has been shown that communication, an inherent aspect to human relations, can be helpful in aligning individual incentives to social ones, i.e., one can enhance efficiency by allowing subjects to use costless and non-binding messages.

Looking at economic relations, it is unlikely that agents would commit resources to a joint relationship without prior discussion with their partners. For example, no entrepreneur would invest in a project when he does not have information about his partner's intended contributions. Similarly, two parties would not engage in building an alliance without any sign of commitment by the other party. In both these situations, a unilateral decision would be too risky for agents and communication arises as a coordination device to reduce the risk inherent in the relationship and, possibly, to increase efficiency.

This article studies a situation where, as a consequence of private information, agents do not have an incentive to invest in a public good if they are unable to have prior discussions with their partners. It has been shown (Agastya *et al.* 2007) that by adding a prior stage of communication (binary message space) there exist situations where individuals have incentives to invest and the project is undertaken. This provides some efficiency gain relative to the no communication game where, unless stated otherwise, efficiency is measured by the probability of the project being undertaken. We show, however, that gains from communication are very limited since any finite message space does not increase the probability of the project being implemented

*We appreciate the discussions with Carlos Eugenio da Costa, Paulo Braulio Coutinho, Erik Eyster, Gilat Levy, Flavio Menezes, Marcelo Moreira, Joisa Saraiva and seminar participants at LSE. We are also thankful for the assistance of Pedro Aratanha, Pedro Bretan and Amanda Pimenta during the experiments. We are grateful for the financial support of the Getulio Vargas Foundation, Graduate School of Economics and CNPq.

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relative to the binary message space when agents report their types honestly. The intuition behind this result is that, since agents use a threshold rule to contribute, in any situation with more than one contribution threshold, they have incentives to understate their types and thereby free-ride on their partners' investment. Hence, there is no truthful strategy profile that supports a Pareto dominant equilibrium in a more refined message space. Communication is then a coordination device that signals whether or not players should invest. We use laboratory experiments to test all these results.

More technically, Agastya *et al.* (2007) show that in a threshold public good contribution game where agents have concave priors, the unique equilibrium is zero contribution. The authors show that by adding a pre play communication stage in which agents can send binary messages (e.g., "Yes, I intend to contribute" or "No, I do not intend to contribute"), the public good is implemented with positive probability in some equilibria. They also argue that a game with uniform priors and full disclosure has the same equilibrium outcome as the binary communication game. We show that when agents have concave priors, there is no finite message space that supports an equilibrium in which the public good is more likely to be implemented than with a binary message space.

The model we follow belongs to both the public goods and the strategic communication literature developed from Crawford and Sobel's (1982) seminal paper. That paper showed that even self-interested agents may choose to reveal information through costless and non-binding communication, also known as *cheap talk*. In a voluntary contribution mechanism environment, we model communication as being a one-period, simultaneous-move game where both players choose their messages from a finite set of possibilities. Our framework allows agents not only to reveal private information but also to declare their intentions. In this sense, our model also is related to the literature that uses communication purely as a coordination device.

Using laboratory experiments, we observe that people do contribute to the joint project even in the no communication game, and that communication does not increase the probability of a project being implemented. However, we observe that communication provides efficiency gain through the reduction of an important variable not directly modeled: the unproductive contribution. Also, we find evidence that players strategically use the larger message space as a binary message space, as our theoretical result points out. Consequently, this evidence suggests that larger message spaces do not provide efficiency gain relative to the binary one.

The paper is organized as follows, after discussing the related literature below, we introduce the model and present the theoretical results in Section 2. Section 3 presents the experimental design and the hypotheses to be tested. In Section 4, we discuss the laboratory results and analyze subjects' behavior. Concluding remarks are made in Section 5. Proofs are presented in the Appendix.

Related literature

The incentive conflicts behind issues of public interest that are decided by a collection of individual choices intrigue social scientists not only by their practical relevance, but also because of what they reveal about human nature. Holmstrom (1982) showed that a social optimum may not be achieved by an equilibrium in a non-cooperative game, suggesting that people following their individual interests try to free-ride on their partners. Menezes *et al.* (2001) presented a similar result for discrete public goods in the presence of incomplete information. In a common agency game with private information, Martimort and Moreira (2010) also find that the social optimum is not achieved in equilibrium, not because of free riding but because of the screening effect between informed principals.

Experiments corroborate these inefficiency results and show that people behave in ways that produce results between the social optimum and the individual interest (Marwell and Ames, 1979), and that repetition reduces the cooperation between individuals in terms of contributions to a public good (Isaac *et al.*, 1985). Looking at coordination games, van Huyck *et al.* (1990, 1991) and Cooper *et al.* (1990) showed that even with perfect information, individuals fail to select the payoff-dominant equilibrium. Since these articles were published, much work has led to the identification of factors, one of which is communication, that can enhance the provision of public goods. Ledyard (1994) provides a good survey on this topic.

Next, we discuss the theoretical models of communication on public good provision and related games, and then we present some empirical findings. After the publication of Crawford and Sobel (1982), a series of extensions and applications of their model were published. Gilligan and Krehbiel (1987) used a similar model to study information theory of legislative rules and Austen-Smith (1990) found that information can be fully aggregated by communication when preferences are sufficiently close, a finding close to Crawford and Sobel's results.

In contrast to the above models, Palfrey and Rosenthal (1991) used an environment where both players have private information and decision power. In a binary setting, they showed that perfect coordination is not Bayesian-incentive compatible and that agents have weak incentives to free-ride in this kind of game. Doraszelski *et al.* (2003) used a similar model to analyze the substitutability between communication and voting. The authors found that both are perfect substitutes, or intuitively, that communication works as a pre-play version of the decision game where agents have zero payoff in the first round of the game.

Our basic model departs from a similar structure which uses two privately informed agents who can contribute continuously, as in Agastya *et al.* (2007). That paper showed that without communication, agents do not have an incentive to contribute to the public good and that binary communication gives them incentive to provide the public good with positive probability. In a n-player setting, Kawamura (2011) shows there always exists an equilibrium where binary messages are credible and that, when n goes to infinity, the most efficient equilibrium is the one with binary communication.

These cheap talk results are not limited to the voluntary contribution mechanism (VCM) literature. Farrell (1987) showed that cheap talk can achieve partial coordination in a game similar to the "battle of the sexes". Forges (1990) used a job market application to show that the set of payoffs found in an equilibrium of the cheap talk game is larger than in the original game. Baliga and Sjostrom (2004) used an arms race context to show that cheap talk helps players to coordinate their action in reaching the payoff dominant equilibrium of a "stag hunt" game.

Given the difficulty of testing these models with field data, several authors had undertaken laboratory experiments to help understand the role of cheap talk. Isaac and Walker (1988) added a communication stage to a VCM model without threshold and observed that communication reduced the free-rider behavior. Closer to our article, Menezes and Saraiva (2005) studied the effects of binary communication and a refund scheme in a threshold VCM model similar to Menezes *et al.* (2001), and found that only the refund rule increased contribution. Palfrey and Rosenthal (1991) tested their theoretical findings with an experiment where both messages and actions are binary. In this sense, the public good threshold is not on the contributed amount (as in our case) but on the number of contributing subjects. Their experiments supported the no communication equilibrium and suggested that subjects use a cutoff decision rule when it is optimal to do so. However, they observed that communication failed to provide efficiency gain and that players' behavior in the communication stage was very non systematic.

Cai and Wang (2006) tested the Crawford and Sobel (1982) model in a discrete setting (states, messages, and action). Their results supported the finding that communication leads to efficiency gain and that the closer the preferences of principal and agent, the more the agent transmits information. The authors observed that subjects over-communicate as message senders, in the sense that messages are more informative than the model predicts. Also, they found that messages are more informative to receivers, since they rely on them more than expected. This "truth bias" on communication also was observed by Kawagoe and Takizawa (2009) relative to a level-k model.[1]

Some papers went beyond the theoretical models and studied how face-to-face communication affects public good provision, such as Cason and Khan (1999), and Belianin and Novarese (2005). As is usual in experiments with this kind of treatment, both found that communication increases cooperation. Bochet *et al.* (2006) addressed this issue by designing an experiment with three types of communication in a standard VCM model: face-to-face communication, anonymous chat room, and numerical messages. They found that verbal communication (i.e., face-to-face and chat room) strongly increased cooperation, while the numerical messages affected neither efficiency nor contributions.

In the coordination literature, Cooper *et al.* (1989) did not observe coordination failure on a "battle of the sexes" game with cheap talk. In a later work, Cooper *et al.* (1992) showed that one-way communication or two-way communication can have different effects depending on whether the game has a Pareto-dominant strategy. Other experiments have studied cheap talk in various contexts such as bargaining. Crawford (1998) is a good survey of experiments on cheap talk.

[1]The level-k model is a non-equilibrium model of agents' behavior, reflecting strategic thinking. Its main point is to impose structure on the set of agents' beliefs.

2 The model

We model the investment choice of two players participating in a joint project, similarly to Agastya *et al.* (2007).[2] Player $I(=1,2)$ has an initial endowment w_I and has to decide privately how much to contribute, c_I, to a joint project. This project is undertaken when the sum of the contributions is greater than or equal to the project cost k, i.e., the joint project is undertaken if $c_1 + c_2 \geq k$.

Each player I is given his own valuation for the joint project, which is private information. The project value for each player is a random variable with a continuous distribution function F_I independently distributed in the interval $[\underline{v}_I, \overline{v}_I]$, where $0 \leq \underline{v}_I < \overline{v}_I$.

An agent's payoff is a function of his project value, the amount invested by him in the joint project, c_I, and the total amount invested in the project:

$$U(v_I, c_I, c_{-I}) = \begin{cases} v_I + w_I - c_I & , \text{if } c_1 + c_2 \geq k \\ w_I - c_I & , \text{if } c_1 + c_2 < k. \end{cases} \tag{1}$$

The benefit of not undertaking the project is normalized to zero. We assume that it may be advantageous for players to undertake the project, i.e., $\overline{v}_1 + \overline{v}_2 > k$ (otherwise the problem would not make sense). On the other hand, if $\underline{v}_1 + \underline{v}_2 \geq k$, it is always *ex post* efficient to implement the project, and we have a class of equilibria such that the public good is always provided and the private information is irrelevant. So, in order to make the private information critical, we assume that $\underline{v}_1 + \underline{v}_2 < k$. Since our interest is in studying the interaction between agents, we want each player to be pivotal for the project, i.e., neither agent should have the incentive to implement the project individually. To avoid equilibria in which a player with a sufficiently high value individually provides the public good, we assume that $\overline{v}_I < k$ for $I = 1,2$.

2.1 The contribution game

First we analyze the game without communication between players. It is a one stage game where each player observes his assigned project value and decides how much to invest in the joint project. Let $E_{-I}[v_{-I}] \equiv \int_{[\underline{v}_I, \overline{v}_I]} x \frac{dF_{-I}}{dx}(x)dx$. A pair of functions $C_I : [\underline{v}_I, \overline{v}_I] \to \mathbb{R}_+$, $I = 1,2$, where $C_I(v_I) \in \text{argmax}_{c_I} E_{-I}[U_I(c_I, v_I, C_{-I}(v_{-I})|v_I]$ is said to be an equilibrium of this game. We define the following special strategies:

Definition 1 *(Threshold Strategy) A function $C_I : [\underline{v}_I, \overline{v}_I] \to \mathbb{R}_+$, $I = 1,2$, is said to be a threshold strategy if there exists $x_I > 0$ and $\hat{v}_I \in [\underline{v}_I, \overline{v}_I]$ such that*

$$C_I(v_I) = \begin{cases} x_I & , \textit{if } v_I > \hat{v}_I \\ 0 & , \textit{otherwise.} \end{cases}$$

We say that an equilibrium is a cost sharing equilibrium if both players use a threshold strategy. Agastya *et al.* (2007) proved that a necessary and sufficient condition for the existence of a cost sharing equilibrium is that a pair of players' types exists such that the sum of expected benefits exceeds the project's costs, i.e., there exists $\widehat{v}_I \in [\underline{v}_I, \overline{v}_I)$, $I = 1,2$, such that

$$(1 - F_2(\widehat{v}_2))\,\widehat{v}_1 + (1 - F_1(\widehat{v}_1))\,\widehat{v}_2 \geq k. \tag{2}$$

We are interested in understanding how communication can increase the probability of a project being undertaken. So, we look at the extreme case where the only equilibrium of the contribution game is totally inefficient, i.e., the project is never undertaken. In order to do so, we assume that the priors are concave, i.e., $F_I(\cdot)$ is concave for $I = 1,2$. Agastya *et al.* (2007) state the following:

Proposition 1 *If $F_I(\cdot)$ is concave for $I = 1,2$, then in the unique equilibrium of the contribution game, each player makes a zero contribution. The project is never undertaken.*

[2] We will use the terms joint project or public good, and the terms investment or contribution interchangeably throughout the text since the model fits both terms in both cases.

The intuition[3] of this result is that when $F_I(\cdot)$ is concave, the left hand side of condition (2) is convex and its maximum is achieved in one of the distribution's support corners $(\underline{v}_1, \underline{v}_2)$, $(\underline{v}_1, \overline{v}_2)$, $(\overline{v}_1, \underline{v}_2)$ or $(\overline{v}_1, \overline{v}_2)$. Evaluating (2) in these four cases one can see that this condition is never satisfied.[4]

2.2 The contribution game with cheap talk

One way to address the extreme result of Proposition 1 is by allowing players to have a prior discussion about their intentions. We do this by introducing a prior communication stage to the game. This new stage makes the equilibrium set larger, which allows us to look for the existence of more efficient equilibria. The timing of the game is the following:

1. Nature plays and v_I is realized, $I = 1, 2$;
2. Players observe their type v_I and send messages m_I, $I = 1, 2$;
3. Players observe their partner's message m_{-I} and contribute c_I, $I = 1, 2$;
4. Players receive their payoffs.

The communication consists of each player sending a message m_I to his partner. Differently from Agastya *et al.* (2007) we do not restrict messages to be binary. We follow Crawford and Sobel (1982) and define the message space as a finite partition of the interval $[\underline{v}_I, \overline{v}_I]$. The idea is that each player can send a signal indicating his type or his intention, by communicating an element of the message space. Technically, $m_I \in \Lambda_I$, where $\Lambda_I \in \mathbf{\Lambda}_I$. The collection of finite partitions $\mathbf{\Lambda}_I$, $I = 1, 2$, is defined by the elements:

$$\Lambda_I \equiv \left\{[a^0, a^1), [a^1, a^2), ..., [a^{n-2}, a^{n-1}), [a^{n-1}, a^n]\right\}$$

where $n \in \mathbb{N}$ and $\underline{v}_I \equiv a^0 < a^1 < ... < a^n \equiv \overline{v}_I$.

So, we have changed the single-stage contribution game to a two-stage game with cheap talk communication in which players may send any message independent of their assigned project valuation. Since there is no commitment in the first stage, players also can choose freely in the contribution stage despite any exchanged messages. Let this two-stage game be denoted by $\mathsf{C}(\Lambda_1, \Lambda_2)$, where Λ_1 and Λ_2 are the two message sets. The equilibrium concept of this game is the Perfect Bayesian Equilibrium. We say that an equilibrium is *truthful* if the players reveal themselves truthfully in the communication stage, i.e., a player sends a message m_I only if his value belongs to this interval.

For example, if both value distributions have support $[0, 100]$, a possible message space is $\Lambda = \{[0, 50), [50, 100]\}$. This means that players can communicate $m_I = [0, 50)$ or $m_I = [50, 100]$. As communication is cheap talk, the player can send either message, independent of their actual type v_I.

As we will show, players will play a relatively simple strategy in all equilibria of interest. It will be helpful to have this strategy in mind throughout our discussion, so we define it in advance:

Definition 2 *(Communication Threshold Strategy)*[5] *Let Λ_I be a partition of n_I elements, for $I = 1, 2$. A strategy profile $\Gamma = (C_I, m_I)_{I=1,2}$ of the game $\mathsf{C}(\Lambda_1, \Lambda_2)$ is said to be a communication threshold strategy if*

1. *At the communication stage, messages are given by functions $m_I : [\underline{v}_I, \overline{v}_I] \to \Lambda_I$, for $I = 1, 2$, such that*

$$m_I(v_I) = m_I^{i_I}, if \, v_I \in m_I^{i_I};$$

[3] See Proposition 6 in Agastya *et al.* (2007) for the complete proof.

[4] In a n-player subscription game, Barbieri and Malueg (2010) show that continuous contribution, as we have here, yields to greater contributions than discrete contributions when F_I are concave. The intuition of their result applies to our case, such that this no contribution result emerges in a setting where players are using the most efficient contribution technology.

[5] The *simple strategy* of Agastya *et al.* (2007) is a special case of this definition when $n_1 = n_2 = 2$, $a^1 = x$, and $b^1 = k - x$.

2. *At the contribution stage, contributions are functions* $C_I : [\underline{v}_I, \overline{v}_I] \times \Lambda_1 \times \Lambda_2 \to \mathbb{R}_+$, *for* $I = 1, 2$, *such that there exists* $\left(\widehat{i}_1, \widehat{i}_2\right)$ *with* $a_1^{\widehat{i}_1 - 1} + a_2^{\widehat{i}_2 - 1} = k$ *and*

$$C_I(v_I, m_1^{i_1}, m_2^{i_2}) = \begin{cases} a_I^{\widehat{i}_I - 1} & , \text{ if } v_I \in m_I^{i_I},\ i_1 \geq \widehat{i}_1 \text{ and } i_2 \geq \widehat{i}_2 \\ 0 & , \text{ otherwise} \end{cases},$$

where we denote $m_I^{i_I} \equiv [a_I^{i_I - 1}, a_I^{i_I})$ *if* $i_I < n_I$, *and* $m_I^{n_I} \equiv [a_I^{n_I - 1}, a_I^{n_I}]$.

In other words, in the communication threshold strategy players truthfully reveal their types at the communication stage and, at the contribution stage, players contribute zero unless there exists $(\widehat{i}_1, \widehat{i}_2)$ such that $a_1^{\widehat{i}_1 - 1} + a_2^{\widehat{i}_2 - 1} = k$ and both announced $(m_1^{i_1}, m_2^{i_2})$ such that $i_1 \geq \widehat{i}_1$ and $i_2 \geq \widehat{i}_2$. Note that the strategy at the contribution stage is exactly the threshold strategy of Definition 1 with $\hat{v}_I = x_I = a_I^{i_I - 1}$, $I = 1, 2$. We say that an equilibrium is a *threshold equilibrium* if it is supported by communication threshold strategy profiles. The following lemma supports our main result.

Lemma 1 *Any truthful equilibrium of* $\mathsf{C}(\Lambda_1, \Lambda_2)$, $\Lambda_I \in \mathbf{\Lambda}_I$, *for* $I = 1, 2$, *where players make non-zero contributions is supported by a strategy profile* Γ *only if* Γ *is a communication threshold strategy profile.*

For the sake of presentation, hereinafter we use a simpler notation to drop players subscript. We denote $i_1 = i$, $\widehat{i}_1 = \widehat{i}$ and $i_2 = j$, $\widehat{i}_2 = \widehat{j}$, and the partition thresholds $a_1^{i_1} = a_i$ and $a_2^{i_2} = b_j$.

Figure 1 helps us understand Lemma 1. By backward induction, we first look at the contribution stage assuming that players truthfully revealed their types at the communication stage, and then we determine whether truthful strategies are optimal in the first stage. A strategy profile of the communication game must have a contribution rule that says how much to contribute after every message history. In equilibrium, the sum of contributions must equal the project cost, otherwise players would be better off reducing their contributions.

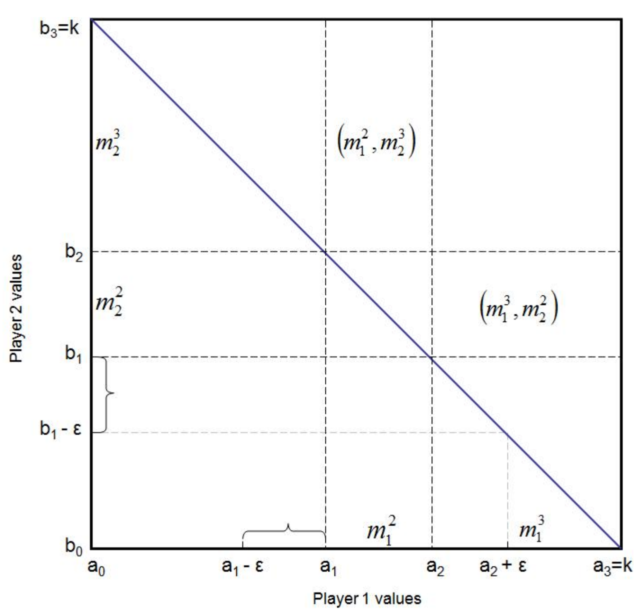

Figure 1: Sketch of the proof of Lemma 1

Looking at Figure 1, suppose this contribution rule says that player 1 after some message, for example $\left(m_1^3, m_2^2\right)$, must contribute $a_2 + \varepsilon$, where $\varepsilon > 0$. Since in equilibrium the sum of contributions must be equal k, player 2 must contribute $k - (a_2 + \varepsilon) = b_1 - \varepsilon$. Hence, all players with types in $(b_1 - \varepsilon, b_1)$ have no incentive to communicate their type truthfully.

Now, suppose the contribution rule says that player 1 must contribute $a_1 - \varepsilon$, where $\varepsilon > 0$, following some message history $\left(m_1^2, m_2^3\right)$. Hence, players with types in $(a_1 - \varepsilon, a_1)$ have no incentive to truthfully communicate their type. Consequently, for any contribution rule consistent with truthfulness and positive contribution, we must have that $\varepsilon = 0$ for some message history (m_1^i, m_2^j), i.e., the contribution must follow the partition cutoffs.

Moreover, any truthful equilibrium can have at most one positive contribution level for each player. In fact, suppose that players were to contribute (a_1, b_2) following history $\left(m_1^2, m_2^3\right)$ and (a_2, b_1) following history $\left(m_1^3, m_2^2\right)$. Then, a player with type a_2 and b_2, would have incentive to under-report their types, respectively. That is, by truthfully communicating m_1^3, contributing a_2 would give zero expected utility, while he would have strict positive expected utility by communicating m_1^2. The same argument would follow analogously for player 2.

Therefore, there exists a contribution rule consistent with truthful revelation and positive contribution if and only if the message space (Λ_1, Λ_2) is such that there exists a pair of thresholds such that $a_{i-1} + b_{j-1} = k$. In this case for each such pairs (i, j), there is only one equilibrium with positive contribution in which (a_{i-1}, b_{j-1}) are the contribution threshold. In the example above, players contribute (a_1, b_2) after histories $\left(m_1^2, m_2^3\right)$ or $\left(m_1^3, m_2^3\right)$, if cutoffs (a_1, b_2) are used as contribution thresholds; or they contribute (a_2, b_1) after histories $\left(m_1^3, m_2^2\right)$ or $\left(m_1^3, m_2^3\right)$, if cutoffs (a_2, b_1) are used as contribution thresholds. In all other equilibria, contributions are always zero and the project is never undertaken. So, Lemma 1 allows us to state the following:

Proposition 2 *Given a pair of partitions (Λ_1, Λ_2), $\Lambda_1 \in \mathbf{\Lambda}_1$ and $\Lambda_2 \in \mathbf{\Lambda}_2$:*

1. *There exists a truthful equilibrium of $\mathsf{C}(\Lambda_1, \Lambda_2)$ where the project is undertaken if and only if there exist $\widehat{i} \leq n_1$ and $\widehat{j} \leq n_2$ such that $a_{\widehat{i}-1} + b_{\widehat{j}-1} = k$.*

2. *For each such pair $\left(\widehat{i}, \widehat{j}\right)$ there exists a unique non-trivial truthful equilibrium. The positive contributions in this equilibrium is $(a_{\widehat{i}-1}, b_{\widehat{j}-1})$.*

3. *There is always a trivial equilibrium of $\mathsf{C}(\Lambda_1, \Lambda_2)$ where players ignore the communication stage and contribute zero as in the contribution game.*

Proposition 2 makes a very strong statement by saying that a truthful equilibrium of the communication game with a binary message space cannot be Pareto dominated by any truthful equilibrium with any finite message space. The intuition is that communication provides efficiency gain only if it allows players to send two clear messages: "Yes, I intend to contribute", for messages m_1^i such that i is greater than a threshold $\widehat{i}$; or "No, I do not intend to contribute", for messages m_1^i such that i is less than a threshold $\widehat{i}$. The proposition is even more restrictive, since it affirms that the "Yes" message is used only when the message sets are such that there exists a pair $(a_{\widehat{i}-1}, b_{\widehat{j}-1})$ where $a_{\widehat{i}-1} + b_{\widehat{j}-1} = k$. Therefore, cheap talk improves efficiency relative to the game without communication, however this improvement is restricted to the simplest communication form, the binary one.

As stated in the third item of Proposition 2, it is important to highlight that the trivial equilibrium, where players ignore the message stage and contribute zero afterwards, always exists. This implies that when the message sets are such that in a threshold equilibrium the project may be implemented with positive probability, the game has two Pareto ranked equilibria: the threshold and the trivial. This multiplicity of equilibria will be very important when we discuss the laboratory data.

3 Experimental design

We ran a *between-subject* design experiment with a total of six sessions, two sessions for each of the following treatments: no communication, cheap talk with a binary message space, and cheap talk with a refined message space. The experiment was programmed and conducted with the software z-Tree, Fischbacher (2007). We used the same two sets of values taken from a uniform distribution and the same group matching in all the sessions.

We had 16 subjects in each session, totaling 96 participants. Subject recruitment was made through the Experimental Economic Center's website. All participants were inexperienced undergraduate students at Getulio Vargas Foundation majoring in courses such as Economics, Business, Law, Social Science, and History. Each participant received US$4.90 to show up plus the session's earnings.[6] Sessions lasted approximately 75 minutes each, including the payment time.

Each session consisted of 25 decision rounds with no practice periods. We used the *strangers* protocol in which, in each period, new groups are formed randomly in a manner such that agents never know the identity of their partners.

During the experiment, the decision to invest in the joint project was presented as an allocation decision. Any reference to social contribution was avoided in order to not bias the agent's decisions. The subject's task was to choose the amount of his initial endowment to allocate to a Group Account and how much of his endowment to retain. A detailed payoff table was presented on the subjects' computer screens in all decision stages to help them estimate their potential earnings as a function of their private information and their possible actions.[7]

At the beginning of each period, the subjects were randomly assigned to new pairs. Each subject received a non-storable endowment of 100 tokens in each period, i.e., $w = 100$. The subject's Group Account valuation, v_I, was displayed on his computer screen. This value was private information and the subject only knew that the Group Account value of the other player was uniformly distributed between 0 and 100. A subject's payoff was defined earlier by equation (1). The Group Account threshold was $k = 100$.

At the end of each period, after all participants had made their decisions, it was presented in the results screen: (i) if the total allocation to the Group Account was greater than or equal to the threshold[8], (ii) the amount allocated by the player to the Group Account, (iii) the two messages exchanged, and (iv) his profit in that period. The history of these informations was always available on the computer screen.

3.1 The no communication treatment

This is the baseline treatment, relative to the contribution game presented in Section 2.1. In each period, subjects played a one stage game where they observed their respective Group Account value, v_I, and simultaneously decided the amount, c_I, they wanted to allocate to the Group Account.

The following hypothesis concerns Proposition 1.

Hypothesis 1 *In equilibrium, each subject allocates zero to the Group Account, i.e., the project is never undertaken.*

3.2 The binary communication treatment

The participants now played a two-stage game. In the first stage, each subject observed his Group Account value, v_I, and sent one of two possible messages to his partner: "Yes, I intend to allocate tokens to the Group Account" or "No, I do not intend to allocate tokens to the Group Account". We used the same terminology as Palfrey and Rosenthal (1991). This cheap talk stage allowed players to communicate their type imperfectly, but also it let them mainly communicate their intentions. It is important to emphasize that this message was cheap talk, i.e., it was not binding.

In the second stage, each subject observed the message his partner had sent him and then decided how much to allocate to the Group Account, c_I.

The next hypothesis concerns Proposition 2 when (Λ_1, Λ_2) partitions the type space in two intervals.

Hypothesis 2 *The probability that the total amount allocated to the Group Account exceeds the project cost is greater in the cheap talk game than in the no communication game.*

[6] The total average payment was US$10.50, both values converted by US$1 =R$ 1.62, exchange rate on August 13, 2008.

[7] The use of the detailed payoff table, explained in the instructions, follows Saijo and Nakamura (1995). The instructions are available on request.

[8] We opted not to inform subjects the exact total amount allocated to the Group Account so that they could not figure out how much their partners contributed.

3.3 The refined communication treatment

This treatment consisted of the same two stage game as the binary communication treatment, with the only difference being that players could choose to send one of four messages in the first stage: $\Lambda_I \equiv \{[0,25), [25,50), [50,75), [75,100]\}$. In order to follow the binary treatment, the players had to be able to communicate their intentions. When the subjects were asked "How much do you intend to invest?" they had to send one of the four messages:

"I intend to allocate an amount between 0 and 25 to the Group Account."
"I intend to allocate an amount between 25 and 50 to the Group Account."
"I intend to allocate an amount between 50 and 75 to the Group Account."
"I intend to allocate an amount between 75 and 100 to the Group Account."

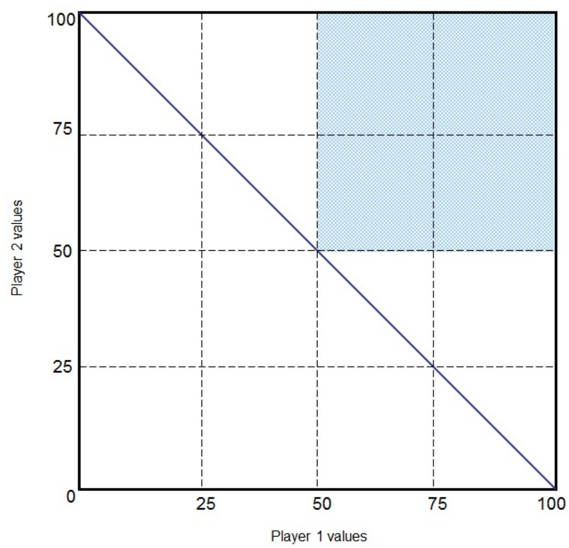

Figure 2: Partition of the refined communication treatment.

Any threshold equilibrium must have contribution partitions that create a rectangle above the negative 45-degree line in Figure 2. But there cannot be multiple such rectangles in a single equilibrium, since this would create incentives for some types to miscommunicate their type, i.e., which rectangle their value is in. Thus, there must be only one rectangle. The single rectangle that maximizes the measure of types on which the project is built is $[50, 100] \times [50, 100]$. But this is exactly the set of types that build the project in the equilibrium of the binary communication game. Thus, the refined communication game cannot improve on the probability of project implementation.

The next hypotheses concern Proposition 2 when $\Lambda_I \equiv \{[0,25), [25,50), [50,75), [75,100]\}$.

Hypothesis 3 *The probability that the total amount allocated to the Group Account exceeds the project cost is greater in the cheap talk game with a refined message space than in the no communication game.*

Hypothesis 4 *The probability that the total amount allocated to the Group Account exceeds the project cost in the cheap talk game with a refined message space is not greater than in the cheap talk game with a binary message space.*

4 Results

Figure 3 plots the average group contribution and the percentage of projects implemented along the periods for each treatment. As can be seen, we observe a more accentuated negative time trend of group contribution in the no communication treatment than in the two communication treatments. This negative time trend in the initial periods may be evidence of learning, something recurrent in laboratory experiments (note that subjects did not have trial periods). In order to make the data consistent with the one-shot game being tested, and to eliminate this learning effect, we perform all the analysis for three subsamples: all periods, the last 20 periods and the last 15 periods. The analysis does not hinge on the sample choice, so we will consider the sample dropping the five first periods in the discussion.

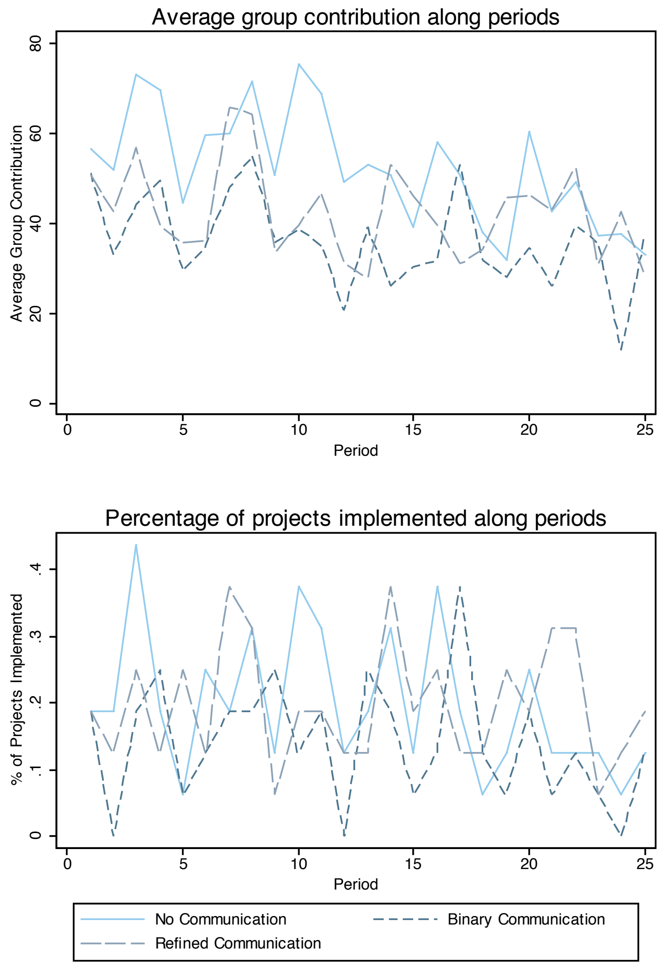

Figure 3: Group contribution and percentage of projects implemented.

Excess contribution

Interestingly, we do not observe any clear time trend of the probability of the joint project being implemented, the only dimension of efficiency discussed in our theoretical model, and in all class of VCM models. No pure-strategy equilibrium will have efficiency loss due to coordination failure, since the sum of contributions must equal the cost of the project. However, inefficiency can also be measured by the unproductive amount invested, or the excess contribution which is defined as:

$$EC = \begin{cases} c_1 + c_2 & , \text{if } c_1 + c_2 < k \\ c_1 + c_2 - k & , \text{if } c_1 + c_2 \geq k. \end{cases}$$

Hence, excess contribution can be interpreted as a measure of coordination failure of this class of models.

In the following subsections we first test the model hypotheses using only the first measure of efficiency, the probability of implementing the joint project. Then, we look at this other dimension of efficiency gain studying the effects of communication on excess contribution. Finally, we look at subject's strategic behavior.

4.1 Hypotheses test

We first look at efficiency gain as discussed in the model: the probability of the joint project being implemented. The control treatment is the no communication game, where we observed only 51% of zero contributions, the unique Nash Equilibrium strategy. The positive contribution by the other players resulted in the project being implemented in slightly less than 20% of the cases, what leads us to reject Hypothesis 1 at 5% of significance.[9] Table 1 presents the means and standard errors. This overcontribution pattern is common in public goods experiments and was also observed by Isaac and Walker (1988) and Menezes and Saraiva (2005).

	Probability of project implementation			**Excess contribution**			**Payoffs**		
	All periods	Periods [6,25]	Periods [11,25]	All periods	Periods [6,25]	Periods [11,25]	All periods	Periods [6,25]	Periods [11,25]
No Communication (NC)	.198	.194	.175	32.71	31.42	29.10	171.9	173.6	175.5
	(.003)	(.006)	(.008)	(.79)	(1.52)	(2.03)	(.15)	(.09)	(.64)
Binary Communication (BC)	.140	.141	.129	21.99	20.56	19.10	182.3	184.1	185.0
	(.030)	(.028)	(.021)	(4.83)	(5.19)	(5.40)	(4.58)	(5.88)	(6.19)
Refined Communication (RC)	.198	.200	.196	22.78	21.91	20.36	183.5	185.1	186.8
	(.008)	(.000)	(.004)	(7.33)	(6.55)	(5.53)	(7.31)	(5.57)	(4.49)
N	400	320	240	400	320	240	400	320	240

Note: Standard errors clustered by sessions presented in parenthesis.

Table 1: Sample averages.

The introduction of the communication stage should allow players to coordinate their decisions, making the project more likely to be implemented, as stated in Hypothesis 2. However, the laboratory outcome showed us that both communication schemes failed to increase the probability of the project being undertaken relative to the no communication treatment. In the binary treatment, the project was implemented in only 14% of the cases, while in the refined communication treatment it was implemented in 20% of the cases. Using Wilcoxon rank-sum tests, presented in Table 2, we see that neither the binary message space nor the refined message space increased the probability of project implementation relative to the no communication treatment. In fact, we reject the hypothesis that the project was equally likely to be implemented in the binary communication treatment and in the no communication treatment in favor of the alternative hypothesis that the project was more likely to be undertaken in the no communication treatment. Hence, we reject Hypotheses 2 and 3. As will be argued in the Subsection 4.3, this weak effect of the communication stage may be due to the multiplicity of equilibria. That is, some subjects may be using the babbling strategy and some may be using the communication threshold strategy, which thereby introduces uncertainty into the game and reduces message credibility. Palfrey and Rosenthal (1991) and Bochet *et al.* (2006) also obtained similar results.

[9] The z statistic of the Wilcoxon signed-rank test of the hypothesis that the probability of project implementation is zero for the full sample is 11.1. All results discussed are significant at 5%.

	Probability of project implementation			Excess contribution			Payoffs		
	All periods	Periods [6,25]	Periods [11,25]	All periods	Periods [6,25]	Periods [11,25]	All periods	Periods [6,25]	Periods [11,25]
H_0: NC=BC	.015	.036	.082	.000	.000	.000	.000	.000	.000
H_0: NC=RC	.500	.579	.721	.000	.000	.000	.000	.000	.000
H_0: BC=RC	.030	.046	.048	.275	.192	.330	.606	.775	.535
N	800	640	480	800	640	480	800	640	480

Note: Equality test shows the p-value of a Wilcoxon runk-sum test. The null hypotheses NC=BC and NC=RC are evaluated as a one sided test, while BC=RC is a two sided test, to match the hypotheses of Section 3.

Table 2: Equality test (p-value of a Wilcoxon rank-sum test).

Hypothesis 4 says that more refined message spaces do not support a truthful equilibrium in which the project is more likely to be undertaken than in any equilibrium supported by a binary message space. This hypothesis is not so intuitive, and the Wilcoxon rank-sum test does reject it. However, as we just argued this result does not seem to come from an efficiency gain relative to the no communication game. It seems that the larger message space reduced the noise of the binary communication and made the refined communication treatment as efficient as the no communication case.

Therefore, we can conclude that the introduction of the cheap talk stage does not increase the probability of the project being implemented.

One can be critical about the Wilcoxon rank-sum tests because multiple decision by the same individual and decisions by individuals who have interacted, are generally not independent. In order to tackle this issue, and being more conservative, we also used panel regressions with random effects that capture the interaction within the matching group. These regressions corroborate the results just discussed (see Table A1 in Appendix B). We opted to use these regression estimates as a robustness check because the small time trends of the outcomes variable over periods suggests that the strangers protocol was effective and because of the low statistical power of the panel estimates in our sample.

4.2 Efficiency

In this section we evaluate the efficiency of communication by taking into account its effect on the unproductive contribution. The model of Section 2 does not include excess contribution, however we use the four hypotheses derived in Section 3 as a benchmark for the following analysis.

As already argued, people made blind contributions in the no communication treatment. These blind contributions sustained a higher level of excess contribution, since subjects contributed with no signal about their partner's valuations or intentions. In the no communication treatment, each group wasted on average 31.4 tokens in excess contribution, while in the binary and refined communication treatments we observed an average waste of less than 22 tokens.

As presented in Table 2, by comparing each communication treatment to the no communication treatment, the Wilcoxon rank-sum test rejects the null hypothesis that communication does not affect excess contribution. Thus, an analogous version of Hypotheses 2 and 3, that communication allows efficiency gain relative to the contribution game, is supported by the data.

The same hypothesis test fails to reject the hypothesis that the two communication treatments have the same mean excess contribution. This means that, making an analogy to Hypothesis 4, the refined message space does not provide efficiency gain relative to the binary under this other efficiency measure, the excess contribution.

Combining the two efficiency measures, and looking at the group payoffs, we can see that communication indeed increased payoff relative to the contribution game and that the larger message space did not improved efficiency relative to the binary communication.

Therefore, communication seems to increase efficiency in relation to the contribution game. However, this efficiency gain is not obtained by a higher probability of the project being implemented as predicted by the model. The main effect of communication is to reduce the unproductive contribution, or the failure of coordination. With this result in mind, we believe that our findings show that communication is a useful mechanism to enhance efficiency. However, we observed that the efficiency gain due to communication is very limited, since a more refined message space failed to do better than the "Yes" or "No" messages.[10]

4.3 Behavior patterns

We now look at the subjects' behaviors, attempting to identify the strategies used by them. In the contribution game, the only equilibrium strategy is the zero contribution. However, we observed that only 51% of the decisions used this strategy, while the others contributed a positive amount. As we can see in Figure 4, the non-zero contributions do not seem to have a clear pattern, with a small spike around 50. As we will show later, we find the same pattern in contributions following a communication history that contains a "No intention to contribute" message.

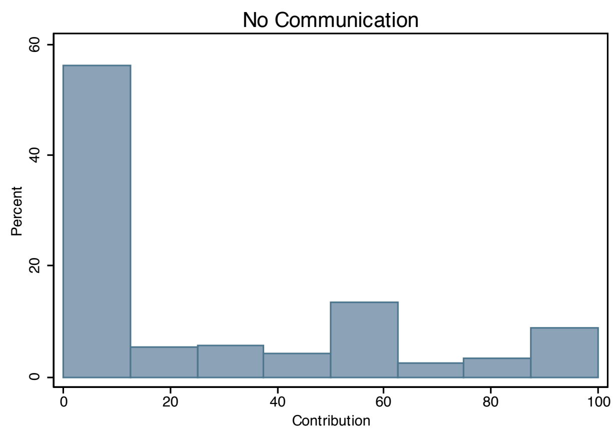

Figure 4: Positive contributions histogram.

The analysis of the communication game is not as straightforward because the two stage game has multiple equilibria. In the binary treatment we have two classes of equilibria: the babbling equilibrium, where players behave freely in the communication stage and contribute zero independently of the message history, and the threshold equilibrium. In the refined communication treatment, we have the babbling equilibrium, three threshold equilibria (one symmetric and two asymmetric) and at least a pair of non-truthful equilibria with positive contribution.[11] Note that the threshold equilibrium Pareto dominates the babbling for players with values greater than the contribution thresholds. Players with value smaller than or equal to this threshold are indifferent between playing babbling or threshold strategies, as both strategies give the same expected payoff. In what follows, we restrict our attention to only two strategies: the babbling and the symmetrical threshold.

The babbling strategy allows players to fool or truthfully reveal their types in the communication stage. However, it states that players contribute zero in the second stage independently of the message they receive. Individuals playing the communication threshold strategy truthfully reveal their types in the communication stage and their choices in the contribution stage are contingent on the messages exchanged. These players contribute 50 tokens each if the message history is such that both communicated "Yes", which in the refined treatment means that both said they intend to contribute more than 50 tokens.

We use the following three main different characteristics of these equilibria to identify them in the data: (i) we expect to observe more truthful revelation on the communication threshold strategy than on the babbling strategy; (ii) positive contribution is consistent only with the communication threshold strategy;

[10] Note that using panel regressions, Table A1 in Appendix B, we reject the equality of the two communication treatment with a p-value of 0.128. However, as already argued, this test has low statistical power.

[11] For example, a strategy where players with values greater than 50 use the message $[50, 75)$ or $[75, 100]$ as "Yes" and contribute 50 on the contribution stage when both players sent message "Yes".

and (iii) the message received should affect contribution only for players with values high enough who are playing the communication threshold strategy.

First, we look at the message sent in the communication stage. The histograms below show the communication patterns for each value interval. We can observe a similar communication pattern in both communication treatments. By looking at the values of players who sent each message, we observed a tendency of under revealing their types in the refined communication treatment. Without losing information, we bunch the messages $[50, 75)$ and $[75, 100]$ and read them hereinafter as a "Yes" message on the binary treatment, and bunch $[0, 25)$ and $[25, 50)$ hereinafter as a "No" message. Using a Kolmogorov-Smirnov test we cannot reject the hypothesis that the distribution of players' values who send a "Yes" message is equal on the two communication treatments.[12] Thus, behavior in the communication stage seems to be consistent with the equilibria strategies.

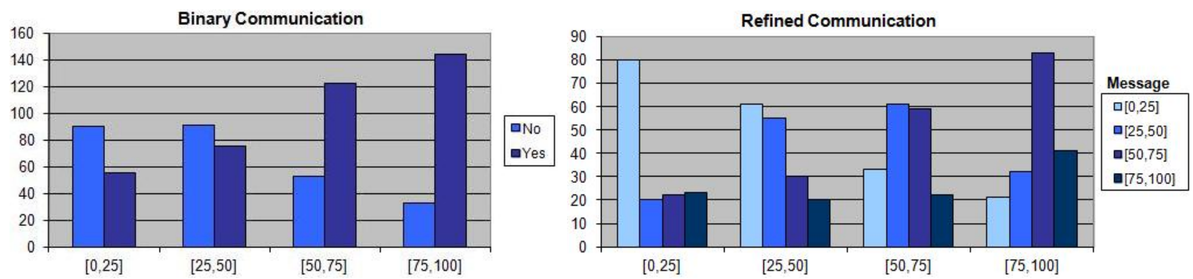

Figure 5: Message histogram by value.

Second, we now turn to the second stage of the communication treatments, i.e., the contribution stage. If a player is not playing naively, when he sends a message in the first stage he already knows whether there is a positive probability of his contribution being positive in the second stage. That is, if the subject's value is small enough or if he is playing the babbling strategy, he knows that he will contribute zero in the second stage for sure. On the other hand, someone with high value playing the communication threshold strategy knows that he will contribute a positive amount only if he receives a positive message from his partner. Note that initially, the partner does not know for sure whether he will make a positive contribution at the second stage exactly because his contribution is contingent on the message he receives.

The contribution stage is a continuation game that follows a communication history, so the analysis of the contribution must be truncated by these message histories. Figure 6 presents the contribution histograms of each continuation game. The distribution of contributions on a communication treatment following a "No" message is very similar to the distribution of contributions on the no communication treatment (see Figure 4). The difference is that we observe a higher probability of zero contribution. On the other hand, the distribution of contributions on the communication treatments following a (Yes,Yes) message history is significantly different from the distribution of contributions on the no communication treatment. We can see a smaller probability of zero contribution and a higher probability of contributing around 50. Also, we fail to reject the hypothesis that the distribution of contributions following a (Yes,Yes) message history is equal in both communication treatment. The results of these Kolmogorov-Smirnov tests are presented in Table A2 in Appendix B, and Table A3 presents the mean of non-zero contribution and the percentage of zero contributions.

Hence, these evidences suggest that the main effect of communication was to increase the share of zero contributions following a pessimistic message history, i.e., any history different from (Yes,Yes); and to reduce the share of zero contributions after an optimistic message history (Yes,Yes). Also, the evidence that some players made no contributions following optimistic histories suggests that some of them were playing the babbling strategy.

Remember that in the previous subsection, we saw that communication provides efficiency gain by reducing the excess contribution, i.e., reducing the failure of coordination. What this last discussion suggests is that this efficiency gain is mostly due to a coordination on the zero contribution when the project is not

[12] Precisely, the null hypothesis is $cdf_{Binary}(value|message\, sent = \text{"Yes"}) = cdf_{Refined}(value|message\, sent = \text{"Yes"})$. The combined K-S p-value is 0.798, and the number of observations is 669. We present the Kernel densities in Appendix B.

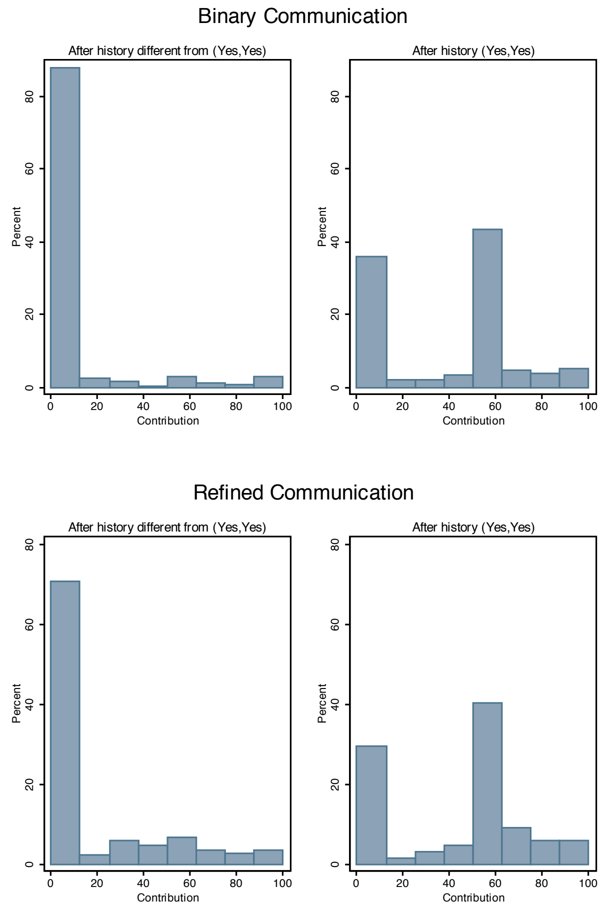

Figure 6: Contribution histograms given a communication history

desirable for at least one player. It is also interesting to note how the two communication treatments provide similar incentives in both stages, which is consistent with Proposition 2.

The last remarkable difference between the babbling and the threshold strategies is that a player's contribution is not affected by the message received whether agents are playing the babbling or the communication threshold strategy and have a value below a certain threshold. In this scenario, when an agent chooses to send a "No" message in the first stage he is also choosing to contribute zero in the second stage. So, we want to determine whether the message received by the player had different effects on his contribution by looking at players with different values who sent different messages. To do so we regress contribution on value and the received messages across different subsamples truncated by the sent messages and values, using individual random effects. The communication threshold strategy would say that the received messages are significant in explaining the contributions only for players with a value over a certain threshold who submit a truthful message. We used a dummy variable that is equal to 1 if a "Yes" message was received and zero otherwise. The coefficient of this variable captures the impact of the received message in the contribution given the player's type and his announcement in the first stage.

	Binary Communication		Refined Communication			
Values subsample	[0,50)	[50,100]	[0,25)	[25,50)	[50,75)	[75,100]
Message sent "No"	-.04	-2.59	1.80	6.42*	14.66**	-2.37
	(3.19, 178)	(2.39, 85)	(2.25, 93)	(3.17, 111)	(.75, 91)	(16.22, 53)
Message sent "Yes"	8.50	34.34**	2.90	15.01*	30.91**	15.22
	(5.44, 119)	(4.70, 258)	(1.33, 45)	(5.93, 48)	(1.80, 75)	(10.14, 124)

Note: Robust standard errors and number of observations in parentheses. Panel RE regressions with constant, value, dummy message "Yes" received and 32 matching groups. Periods [6,25]. ** p<0.01, * p<0.05, + p<0.1.

Table 3: Coefficient of dummy message "Yes" received.

As can be seen in Table 3, in both communication treatments, the message received did not affect the contribution decision of subjects with low values, independently of the message they sent in the first stage. This is consistent both with the babbling and the threshold strategies of subjects with low value. In both communication treatments, the message received is not significant to explain the contribution decision of players with value sufficiently high who sent a "No" message. This suggests that subjects used the babbling strategy even in situations where the communication threshold strategy was strictly dominant.

In both treatments, the message received significantly increases the contribution of players with higher values who sent a "Yes" message in the first stage. This is consistent with the communication threshold strategy. In fact, the message received is relevant in explaining the contribution behavior in those situations where the communication threshold strategy was dominant. In the refined treatment, the received message was significant for players with intermediary values who sent "No" message. This is consistent with players using an asymmetric communication threshold strategy (remember that the "No" message bunches $[0, 25)$ and $[25, 50)$). However, we find no spikes in the contribution histograms around these values.

Thus, we found evidence that subjects played the two possible equilibria: the babbling and the threshold equilibria. It is worth mentioning that the existence of multiple equilibria introduced uncertainty into the game, mostly for the subjects with high value who intended to contribute. When a player with high value who truthfully reported his type received a positive message in the second stage, he was not sure whether his partner was playing the communication threshold strategy as well or the babbling strategy. His contribution decision at this point is analogous to a "stag hunt" game in which there are two equilibria, one that is payoff-dominant, where both contribute 50 tokens, and another which is risk-dominant, where both contribute zero. This additional uncertainty may have precluded the project being implemented in more situations. At the other extreme, following a pessimistic message history, players did not face any additional uncertainty, and the dominant strategy was the zero contribution. So, the findings in the last two subsections are coherent with the incentives faced by the players.

5 Conclusion

This paper models the behavior of two agents in situations where non costly communication could lead to welfare gain. We argue that cheap talk can enhance efficiency relative to the no communication game. However, even when players have several (finite) messages possibilities, they cannot do better than when they can use only "Yes" or "No" messages.

Laboratory experiments were used to test these theoretical results. We find evidence that communication indeed seemed to increase efficiency relative to the contribution game. However, this efficiency gain was not obtained by a higher probability of the project being implemented, but by reducing failure of coordination, measured as the amount of unproductive contribution. Communication seemed to work by allowing players to coordinate on the zero contribution when the project was not desirable for at least one of them. We also found that larger message space does not increase efficiency.

We found evidence that subjects did play the two possible equilibria: the babbling and the threshold equilibria. The existence of multiple equilibria may have been an additional source of uncertainty in the game when players were willing to contribute to the joint project. This may have inhibited the positive effect of communication in the provision of the public good.

We believe that our findings add to the literature on the usefulness of communication to enhance efficiency. Also, the paper shad light on the mechanism that leads to this efficiency gain. However, in this setting where both players have private information and decision power, differently from Crawford and Sobel (1982), the communication gain is very limited because the simplest communication structure ("Yes" or "No" messages) provides the same incentives to agents as any finite partition of the type space.

Appendix A (Proofs)

Definition 3 *We say that a* ***continuation game*** $\left(m_1^i, m_2^j\right)$ *of* $\mathsf{C}(\Lambda_1, \Lambda_2)$ *is the contribution game after both players truthfully communicated their type in* $\left(m_1^i, m_2^j\right)$*. That is, it is the contribution game in which players have prior* $F_I(\cdot)$ *and* $v_I \in m_I^i$*,* $I = 1, 2$*.*

Lemma A *In a truthful equilibrium of* $\mathsf{C}(\Lambda_1, \Lambda_2)$*, in all continuation game* $\left(m_1^i, m_2^j\right)$ *such that* $a_{i-1} + b_{j-1} < k$ *the equilibrium contribution is zero.*

Proof. After truthful communication $\left(m_1^i, m_2^j\right)$ in the first stage, players update their priors on $m_1^i \times m_2^j$. If $a_{i-1} + b_{j-1} < k$, by the concavity of $F_1(\cdot)$ and $F_2(\cdot)$, Proposition 1 shows that the unique equilibrium contribution is zero. ■

Lemma B *Any contribution in a truthful equilibrium of* $\mathsf{C}(\Lambda_1, \Lambda_2)$ *satisfies*

$$C_1\left(v_1, m_1^i, m_2^j\right) \leq a_{i-1} \text{ and } C_2\left(v_2, m_1^i, m_2^j\right) \leq b_{j-1}.$$

Proof. Take a positive contribution $C_1\left(v_1, m_1^i, m_2^j\right) > 0$ in a continuation game $\left(m_1^i, m_2^j\right)$. By truthful revelation and Lemma A, it must be that

$$a_{i-1} + b_{j-1} \geq k. \tag{3}$$

In any equilibria of a continuation game, where contribution is positive we must have that

$$C_1\left(v_1, m_1^i, m_2^j\right) + E_2\left[C_2\left(v_2, m_1^i, m_2^j\right) | v_2 \in m_2^j\right] = k, \tag{4}$$

otherwise player 1 would have incentive to contribute less. So, every type $v_1 \in m_1^i$ and $v_2 \in m_2^j$ have identical positive contribution in the continuation game $\left(m_1^i, m_2^j\right)$. Analogous to player 2.

Clearly, no player has incentive to contribute $C_1\left(v_1, m_1^i, m_2^j\right) \geq a_i$.

Suppose that there exists i such that $C_1\left(v_1, m_1^i, m_2^j\right) \in (a_{i-1}, a_i)$. By (4) we have that $C_2\left(v_2, m_1^i, m_2^j\right) < b_{j-1}$. By (3), there exists $m_2^{j'} \in \Lambda_2$, $j' < j$, such that $C_1\left(v_1, m_1^i, m_2^j\right) + b_{j'-1} \leq k$. Hence, some players with type $v_2' \in m_2^{j'}$ will have incentive to over report their type in the communication stage, violating truthful revelation. ■

Lemma C *Any truthful equilibrium of* $\mathsf{C}(\Lambda_1, \Lambda_2)$ *can have at most one positive contribution level for each player.*

Proof. Suppose a truthful equilibrium in which players have more than one positive contribution level. Take the two smallest contribution levels

$$\begin{aligned} C_1\left(v_1, m_1^i, m_2^j\right) &= c > 0 \\ C_1\left(v_1', m_1^{i'}, m_2^{j'}\right) &= c' > 0, \end{aligned}$$

where $c < c'$. By Lemma B we know that $c \leq a_{i-1}$ and $c' \leq a_{i'-1}$. The player with type $a_{i'-1} \in m_1^{i'}$ has incentive to under report his type and communicate m_1^i. Hence, truthful revelation is violated. ■

Proof of Lemma 1. By Lemma C, we have that in any truthful equilibrium with positive contribution we may have at most one positive contribution level for each player. By Lemma B we know that this contribution must satisfy $C_1\left(v_1, m_1^i, m_2^j\right) \leq a_{i-1}$ and $C_2\left(v_2, m_1^i, m_2^j\right) \leq b_{j-1}$, for all i, j.

By Lemma A we know that we may have a positive contribution in the continuation game $\left(m_1^i, m_2^j\right)$ only if $a_{i-1} + b_{j-1} \geq k$. Also, by the equilibrium condition of the continuation game (4), then it must be that $a_{i-1} + b_{j-1} = k$ for some i, j.

Let $\widehat{i}, \widehat{j}$ be such that $a_{\widehat{i}-1} + b_{\widehat{j}-1} = k$. If $C_1\left(v_1, m_1^{\widehat{i}}, m_2^{\widehat{j}}\right) < a_{\widehat{i}-1}$, some players with type in $m_1^{\widehat{i}-1}$ would not have incentive to truthfully report their types in the communication stage. Then, the unique positive contribution of the continuation game $\left(m_1^{\widehat{i}}, m_2^{\widehat{j}}\right)$ is $C_1\left(v_1, m_1^{\widehat{i}}, m_2^{\widehat{j}}\right) = a_{\widehat{i}-1}$ and $C_2\left(v_2, m_1^{\widehat{i}}, m_2^{\widehat{j}}\right) = b_{\widehat{j}-1}$.

Suppose that contribution is zero in any continuation game except $\left(m_1^{\widehat{i}}, m_2^{\widehat{j}}\right)$. There is no optimal deviation in any continuation game $\left(m_1^i, m_2^j\right)$ such that $i < \widehat{i}$ or $j < \widehat{j}$. However, any player with type $v_1 \geq a_{\widehat{i}}$ or $v_2 \geq b_{\widehat{j}}$ would have incentive to communicate $\left(m_1^{\widehat{i}}, m_2^{\widehat{j}}\right)$. Hence, to be consistent with truthful revelation it must be that $C_1\left(v_1, m_1^i, m_2^j\right) = a_{\widehat{i}-1}$ and $C_2\left(v_2, m_1^i, m_2^j\right) = b_{\widehat{j}-1}$ for every $i \geq \widehat{i}$ and $j \geq \widehat{j}$.

If there are i, j such that $a_{i-1} + b_{j-1} = k$, the unique contribution in a truthful equilibrium of $\mathsf{C}\left(\Lambda_1, \Lambda_2\right)$ is zero.

Hence, in any truthful equilibrium with positive contribution, the contribution rule is such that there exists $\left(\widehat{i}, \widehat{j}\right)$ with $a_{\widehat{i}-1} + b_{\widehat{j}-1} = k$ and

$$C_1(v_1, m_1^i, m_2^j) = \begin{cases} a_{\widehat{i}-1} & , \textit{if } v_1 \in m_1^i,\ i \geq \widehat{i} \text{ and } j \geq \widehat{j} \\ 0 & , \text{otherwise} \end{cases} ;$$

$$C_2(v_2, m_1^i, m_2^j) = \begin{cases} b_{\widehat{j}-1} & , \textit{if } v_2 \in m_2^j,\ i \geq \widehat{i} \text{ and } j \geq \widehat{j} \\ 0 & , \text{otherwise} \end{cases} .$$

Therefore, given any finite partition (Λ_1, Λ_2), the *communication threshold strategy* is the unique strategy that supports a truthful equilibrium where players contribute non-zero values with positive probability. ■

Proof of Proposition 2. To prove necessity, let Γ be an equilibrium strategy profile where players truthfully reveal their types in the communication stage and make non-zero contributions with positive probability. Hence, by Lemma 1, (Λ_1, Λ_2) must be such that there exists a pair (i, j) with $a_{i-1} + b_{i-1} = k$.

To prove sufficiency, one just need to let players use a communication threshold strategy profile.

The uniqueness follows directly from Lemma 1 as well. ■

Appendix B (Graphs and Tables)

	Project Implementation		Excess Contribution		Payoffs	
	All periods	*Periods [6,25]*	*All periods*	*Periods [6,25]*	*All periods*	*Periods [6,25]*
	(1)	(2)	(3)	(4)	(5)	(6)
BC Treatment	-0.43*	-0.40+	-10.73**	-10.86**	10.37**	10.45*
	(0.20)	(0.23)	(3.79)	(4.20)	(3.55)	(4.56)
RC Treatment	-0.00	0.04	-9.93+	-9.51+	11.63*	11.46**
	(0.19)	(0.21)	(5.71)	(5.21)	(5.66)	(4.32)
Wald Test (p-value)						
H_0: BC = RC	.966	.947	.094	.166	.149	.128
N	1,200	960	1,200	960	1,200	960

Note: Robust standard errors in parentheses. Panel RE regressions with constant and 720 matching groups. ** p<0.01, * p<0.05, + p<0.1

Table A1: Coefficients of panel regressions.

Figure A1: Kernel density of value given sent a "Yes" message.

Null Hypothesis	p-value	No. observations
H_0:NC = {BC | not (Yes,Yes)}	0.586	259
H_0:NC = {RC | not (Yes,Yes)}	0.155	325
H_0:NC = {BC | (Yes,Yes)}	0.000	321
H_0:NC = {RC | (Yes,Yes)}	0.001	287
H_0:{BC | (Yes,Yes)} = {RC | (Yes,Yes)}	0.461	174

Table A2: Positive contribution distribution, Kolmogorov-Smirnov tests (Periods [6,25]).

	All periods			*Periods [6,25]*			*Periods [11,25]*		
Treatment and message history	**Percentage of zero contribution**	**Mean non-zero contribution**	**N**	**Percentage of zero contribution**	**Mean non-zero contribution**	**N**	**Percentage of zero contribution**	**Mean non-zero contribution**	**N**
NC	.49	51.2	800	.51	51.4	640	.55	51.5	480
	(.01)	(.72)		(.03)	(1.70)		(.02)	(1.28)	
BC | (Yes,Yes)	.37	53.9	290	.35	56.4	220	.35	54.7	160
	(.00)	(.13)		(.02)	(.40)		(.01)	(.14)	
BC | not(Yes,Yes)	.82	49.9	510	.85	49.4	420	.87	47.5	320
	(.08)	(.71)		(.09)	(1.60)		(.08)	(2.63)	
RC | (Yes,Yes)	.26	56.7	160	.27	56.9	132	.29	56.1	98
	(.04)	(3.81)		(.04)	(4.78)		(.02)	(6.89)	
RC | not(Yes,Yes)	.67	48.7	640	.69	50.6	508	.72	52.4	382
	(.11)	(1.13)		(.11)	(1.39)		(.10)	(2.66)	

Note: Standard errors clustered by sessions presented in parenthesis.

Table A3: Mean positive and zero contributions.

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