Escola de Pós-Graduação em Economia - EPGE

Fundação Getulio Vargas

On the Limits of Cheap Talk for Public Good Provision

Dissertação submetida à Escola de Pós-Graduação em Economia

da Fundação Getulio Vargas como requisito de obtenção do

título de Mestre em Economia

Aluno: Francisco Junqueira Moreira da Costa

Orientador: Humberto Luiz Ataide Moreira

Rio de Janeiro

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Palavra chave: Comunicação, bem público, teoria de contratos, economia experimental, *cheap talk*, *VCM*.

Contents

On the Limits of Cheap Talk for Public Good Provision

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Abstract

This article studies a model where, as a consequence of private information, agents do not have incentive to invest in a desired joint project, or a public good, when they are unable to have prior discussion with their partners. As a result, the joint project is never undertaken and inefficiency is observed. Agastya, Menezes and Sengupta (2007) prove that with a prior stage of communication, with a binary message space, it is possible to have some efficiency gain since "all ex-ante and interim efficient equilibria exhibit a simple structure". We show that any finite message space does not provide efficiency gain on the simple structure discussed in that article. We use laboratory experiments to test these results. We find that people do contribute, even without communication, and that any kind of communication increases the probability of project implementation. We also observed that communication reduces the unproductive contribution, and that a large message space cannot provide efficiency gain relative to the binary one.

1 Introduction

This article studies a model where, as a consequence of private information, agents do not have incentive to invest in a desired joint project, or a public good, when they are unable to have prior discussion with their partners. As a result, the joint project is never undertaken and inefficiency is observed. Agastya, Menezes and Sengupta (2007) prove that with a prior stage of communication, with a binary message space, it is possible to have some efficiency gain since "all ex-ante and interim efficient equilibria exhibit a simple structure". We show that any finite message space does not provide efficiency gain on the simple

[1] I am very pleased by the discussions with Humberto Moreira, Joisa Saraiva, Carlos Eugenio da Costa, Marcelo Moreira and Paulo Braulio Coutinho. I am also thankful for Amanda Pimenta, Pedro Aratanha, Pedro Bretan and Ana Gabriela Muniz assistence during the experiments. E-mail: fjmcosta@gmail.com.

structure discussed in that article when the message space is binary and players truthfully reveal themselves. The idea is that there is no strategy profile that supports a Pareto dominant truthful equilibrium in more refined message spaces, because, since agents have incentive to understate their types to free-ride in their partners investment, the gains of communication are very limited. We test all propositions in the laboratory.

In the economic relations, rarely agents do commit efforts in a joint relation without prior discussion with his partner. For example, it is difficult to imagine that two countries will engage to reduce their carbon emissions without any kind of prior argumentation or without any sign of willingness to cooperate with the other country. In the same way, no investor would spend money in a project without discussing his intentions with the entrepreneur. In all these situations, the action would be too risky, and communication can arise as a coordination device to reduce this risk. Once it is too complex to model the real world message space[2], we suppose that communication is not costly and happens in a one shot game where agents simultaneously choose their messages in a finite message space, and where there is no commitment.

The model studied here belongs to the strategic communication literature that follows Crawford and Sobel (1982) seminal paper. This work presented a model where, even self interested agents, may choose to reveal information through costless and nonbinding communication, also known by *cheap talk*. It is a principal-agent model where just the principal has decision power, only the agent has private information, and where the preferences are different, but correlated.

The model we study here is an extension of this model with two agents, privately informed, both with decision power and independent preference. We use the model of Agastya *et al* (2007) and try to make two additional contributions: answer a theoretical point, and test in laboratory the two key propositions. We also test our theoretical result.

The basic environment of the model is a game where two agents have to invest in a joint project. Each of them has private information about his utility of the project implementation. We are interested in the specific situation where anyone individually cannot finance the project. Agastya *et al* (2007) prove that, without communication, the unique equilibrium is the project be completed with zero probability. The authors claim that, with a prior stage of communication, there exist equilibria where the project is implemented with positive probability and the players truthfully reveal their types. They prove that, with binary message space, this truthful equilibrium is sustained by a simple cutoff rule. We experimentally test these two results.

The authors, then, ask in the article: "can simple equilibria (...) be dominated by other equilibria" of the two stage communication game with binary message space? In Proposition 2, we prove that it cannot be dominated by other truthful equilibrium in a two stage communication game with any finite

[2] Actually parties can discuss in different time periods, change messages, sign pre-contracts, etc.

message space.

Using laboratory experiments, we reject the two results of Agastya *et al* (2007) and we do not reject Proposition 2. We find, however, that communication may improve efficiency through a variable not predicted by the model: it reduces the unproductive contribution.

1.1 Literature

After Crawford and Sobel (1982) , a series of extensions and applications of their model came up in the literature. Our base model (i.e., Agastya *et al* (2007)) is a recent extension of the original model, but some previous works are very useful to understand the limits and extents of communication.

Close to the original results, Austen-Smith (1990) finds that the information can be fully aggregated by communication when preferences are sufficiently close. Dessein (2002) studies the delegation and communication trade-off between an employer, the decision power holder, and an employee, with private information. Dessein obtained a very interesting result showing that, when preferences do not extremely differ, delegation dominates communication because the preferences bias is lower than the cheap talk noise. Previously, Gilligan and Krehbiel (1987) used a similar communication model to study informational theory of legislative rules.

Doraszelski *et al* (2003) stand in a different strand of the literature that extended the original model using an environment where both players have decision power and private information. In their article, communication and decision are both binary, and they analyze the substitutability between communication and voting. The authors find that the both are perfect substitutes, what makes the communication game a one replay version of the game where agents have zero payoff in the first round. Their model is similar to the one by Palfrey and Rosenthal (1991), who show that perfect coordination is not Bayesian incentive compatible and that agents have weak incentives to free-ride.

Our base model departs from a similar structure, with binary message space, but with decision being made in an interval[3]. Agastya *et al* (2007) suggests that there exist equilibria in this communication game that Pareto dominate the equilibria of the game without communication.

Indeed, this cheap talk result is not limited to the voluntary contribution mechanism literature. Farrel and Gibbons (1989) introduce cheap talk in a two stage bargain game with endogenous participation. The authors show that cheap talk equilibria sustain bargain behavior that could not be sustained by a bargain equilibrium. A similar result is found by Forges (1990) in a job market application. Baliga and Sjöström (2004) study communication in a stag hunt game (more precisely, in an arms race context), and find that the introduction of a binary cheap talk raises agents expected payoffs.

Given the difficulty to test these theories with field data, several laboratory tests were made to help the understanding of the cheap talk role. Cai and

[3] Actually, the authors start using a general message space, but their principal results are for the binary message space.

Wang (2006) test the Crawford and Sobel (1982) model in a discrete setting (states, messages, and action). Their results support that communication leads to efficiency gain and that the closer the preferences of principal and agent, more information is transmitted. Dickhaut *et al* (1995) also present this result. Cai and Wang also observe that subjects overcommunicate as message senders, and that these messages are more informative to receivers than expected.

Palfrey and Rosenthal (1991) test their theoretical findings with an experiment where messages and actions are both 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 support the no communication equilibrium, and that subjects use cutoff decision rule when it is optimal to do so. However, they find that communication fails to provide efficiency gain. A very non systematic behavior in the communication stage was observed.

Much closer to our article, Menezes and Saraiva (2005) test Agastya *et al* (2007) predictions and study the relevance of refund in the model. They observe that a refund rule provide more efficiency than communication. The hypothesis that communication enhances efficiency is not rejected at 5% of significance, but it is at 1% of significance.

Other articles that study public good issues with cheap talk is Belianin and Novarese (2005), who made a cross-cultural experiment through internet, and observed a high level of cooperation in all nationalities, concluding that communication raises contributions. Cason and Khan (1999) study the role of communication and imperfect monitoring in a voluntary contribution mechanism. They find that communication provides efficiency gains, and that improved monitoring is not relevant without cheap talk. It is important to note, however, that they used face-to-face communication, which is a much bigger message space than the modeled in the other articles above. Indeed, Bochet *et al* (2006) treated this issue using three types of communication in the same VCM model: face-to-face communication, anonymous chat room, and numerical communication. They found that the verbal communication, face-to-face and chat room, strongly contribute to efficiency gain, but that the numerical messages did not affect neither efficiency or contributions.

Experiments also have studied cheap talk in other contexts, as bargain and coordination problem. A good survey of the behavior in games with communication is Crawford (1998).

2 The model

We model the investment choice of two players in a joint project, as Agastya *et al* (2007). In this model, players have an initial endowment w, and each player contributes privately c_i to the project that is undertaken if the sum of the contributions is greater than the cost of the project k, e.g. $c_1 + c_2 \geq k$. Subjects payoff is given by $U(v_i, c_i)$. Without loss of generality, we assume $w = 0$ in this section.

$$U(v_i, c_i) = \begin{cases} v_i + w_i - c_i & \text{, if } c_1 + c_2 \geq k \\ w_i - c_i & \text{, if } c_1 + c_2 < k \end{cases}$$

The project value for each player is a random variable with continuous distribution function F_i supported in the interval $[\underline{v}_i, \overline{v}_i]$. The values are private information, with independent distribution. We normalize the game so that the benefit of not undertaking the project is zero. We represent this Bayesian game by $\complement(F_1, F_2)$.

We assume that it may be advantageous for the players to undertake the project, otherwise the problem would not make sense, so that $\overline{v}_1 + \overline{v}_2 > k$. As our interest is to study the relation between the players, we want that each player to be pivotal for the project, e.g., each agent should not have the incentive to individually implement the project, so we assume that

$$\overline{v}_i < k, \text{ for } i = 1, 2. \tag{1}$$

2.1 Contribution game without communication

First we look to the case where there is no communication. Each player observes his project value and must decide how much to invest. An equilibrium of this game would be (C_1, C_2), where $C_i : [\underline{v}_i, \overline{v}_i] \to \mathbb{R}$. To analyze these equilibria where the project is implemented with positive probability, we define the *cost sharing equilibrium* as Agastya *et al* (2007).

Definition 1 *An equilibrium (C_1, C_2) is said to be a Cost Sharing Equilibrium if for $i = 1, 2$,*

$$C_i(v_i) = \begin{cases} x_i \text{ , if } v_i \geq \widehat{v}_i, \\ 0 \text{ , otherwise} \end{cases}$$

for some non-negative x_i such that $x_1 + x_2 = k$ and for some $\widehat{v}_i \in [\underline{v}_i, \overline{v}_i)$.

As present in Agastya *et al* (2007), a necessary and sufficient condition for the existence of a cost sharing equilibrium is that, given $\complement(F_1, F_2)$, there exists $\widehat{v}_i \in [\underline{v}_i, \overline{v}_i)$ such that

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

The authors give some intuition about this expression: "a pair of marginal types whose total expected benefit is at least as high as the cost of completing the project". Note that, if $\underline{v}_1 + \underline{v}_2 \geq k$, it is always ex post efficient to implement the project. In this case, a strategy where Agent 1 contributes $\underline{v}_1$ and Agent 2 contributes $k - \underline{v}_1$ support a cost sharing equilibrium where the project is completed with probability one. Hence we are interested in the cases where the support of the player's valuation satisfies

$$\underline{v}_1 + \underline{v}_2 < k. \tag{2}$$

An extreme result for the equilibrium set of this game is found:

Proposition 1 *Suppose that $F_i(\cdot)$ is concave for $i = 1, 2$ and that (2) holds. Then, in the unique equilibrium of the contribution game each player makes a zero contribution. The project is never completed.*

Proof. See Proposition 6 of Agastya *et al* (2007). ■

2.2 Contribution game with cheap talk

As Proposition 1 shows, without communication there is a large class of cases where the only equilibrium is totally inefficient. We try to solve this problem introducing a prior communication stage to the game. This new stage expands the equilibrium set, allowing us to look for efficient equilibria.

The communication stage is introduced after players have observed their types, and before they make their contribution decision. The communication follows Crawford and Sobel (1982), where the communication space is a partition of the interval $[\underline{v}_i, \overline{v}_i]$, and, consequently, an equilibrium is, as they call, a partition equilibrium. The communication consists in each player sending a message to his partner that belongs to the finite message space

$$\begin{aligned} \mathbf{\Lambda}^1 &= \{\Lambda_n = \{[a_{i-1}, a_i]\}_{i=1}^n \ ; \ n \in \mathbb{N} \text{ and } \underline{v}_1 = a_0 < a_1 < ... < a_n = \overline{v}_1\} \\ \mathbf{\Lambda}^2 &= \left\{\Lambda_m = \{[b_{j-1}, b_j]\}_{j=1}^m \ ; \ m \in \mathbb{N} \text{ and } \underline{v}_2 = b_0 < b_1 < ... < b_n = \overline{v}_2\right\} \end{aligned}$$

We assume that any interval $[a_{i-1}, a_i] \in \Lambda_n$ and $[b_{j-1}, b_j] \in \Lambda_m$ has zero measure[4]. The idea is that each player can signal his type by communicating an interval, for example Player 1 sends a message $m_1 = [a_{i-1}, a_i] \in \Lambda_n$, $i \leq n$, and Player 2 sends a message $m_2 = [b_{j-1}, b_j] \in \Lambda_m$, $j \leq m$. Observe that this communication is cheap talk, so players may communicate any interval independently of his real valuation. The timing of the game is:

1. Nature plays and v_i is realized, $i = 1, 2$;
2. Players observe their type v_i and communicate 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 payoff.

Note that at first we had a single stage game, and now we have a multistage game with observed actions, denoted by $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ (see Fundenberg and Tirole (1991)). The equilibrium concept of $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is the Perfect Bayesian Equilibrium. We say that an equilibrium $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is *truthful* if the players reveal themselves truthfully in the communication stage, i.e., Player 1 communicates $A_i = [a_{i-1}, a_i] \in \Lambda_n$ only if $v_1 \in [a_{i-1}, a_i]$, and Player 2 communicate $B_j = [b_{j-1}, b_j] \in \Lambda_m$ only if $v_2 \in [b_{j-1}, b_j]$. To help us in the analysis of these equilibria, we define a strategy profile that, despite its simplicity, is very important.

[4] This is used in Lemma 1.

Definition 2 *(n-Simple Strategy Profile of* $\complement^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$*)*[5] *A strategy profile* Γ *in* $\complement^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ *is said to be n-simple if*

1. *At the communication stage*

   - *Player 1 announces* $A_i = [a_{i-1}, a_i] \in \Lambda_n$, $i \leq n$, *only if his type* $v_1 \in A_i$;
   - *Player 2 announces* $B_j = [b_{j-1}, b_j] \in \Lambda_m$, $j \leq m$, *only if his type* $v_2 \in B_j$;

2. *At the contribution stage, neither player makes a positive contribution unless both have previously announced* A_n, B_m *such that* $a_{n-1} + b_{m-1} = k$. *In this case,*

   - *Player 1 contributes* $c_1 = a_{i-1}$ *if he communicated* A_i;
   - *Player 2 contributes* $c_2 = b_{j-1}$ *if he communicated* B_j;

We say that an equilibrium is a *n-simple equilibrium* if it is supported by a n-simple strategy profile. The next Lemma support our main result.

Lemma 1 *Suppose that* $F_i(\cdot)$ *is concave for* $i = 1, 2$. *Any truthful equilibrium of* $\complement^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ *is supported by a strategy profile* Γ *only if* Γ *is a n-simple strategy profile.*

Proof. Proposition 1 shows that the project is not completed and that neither player makes a positive contribution when the messages in the communication stage are $A_i \in \Lambda_n$, and $B_j \in \Lambda_m$ such that $a_{i-1} + b_{j-1} < k$. So, the players contribute non-zero values only if their communication is such that $a_{i-1}+b_{j-1} \geq k$. Consequently, if the communication space is such that it does not exist $i \leq n$ and $j \leq m$ such that $a_{i-1} + b_{j-1} \geq k$, the project is never completed. Though it is still a possible case, it it is less interesting, so from now on we assume that Λ_n and Λ_m are such that there exist $i \leq n$ and $j \leq m$ such that $a_{i-1}+b_{j-1} \geq k$.

By backward induction, given that $\complement^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is a truthful equilibrium, Player 1 communicates $A_i = [a_{i-1}, a_i] \in \Lambda_n$ only if $v_1 \in [a_{i-1}, a_i]$, and Player 2 communicates $B_j = [b_{j-1}, b_j] \in \Lambda_m$ only if $v_2 \in [b_{j-1}, b_j]$. Proposition 1 says that the only equilibrium of the continuation game (A_i, B_j), where $a_{i-1} + b_{j-1} < k$, is the strongly inefficient equilibrium. So, take a contribution rule given by $c_1(A_i, B_j) = a_{i-1} + \varepsilon_{1,i}$ and $c_2(A_i, B_j) = b_{j-1} + \varepsilon_{2,j}$, where $\varepsilon_{1,i}, \varepsilon_{2,j} \in \mathbb{R}$ and $c_1(A_i, B_j) + c_2(A_i, B_j) \geq k$, when $a_{i-1} + b_{j-1} \geq k$, and $c_1(A_i, B_j) = c_2(A_i, B_j) = 0$, otherwise. Without loss of generality, we analyze the strategy of Player 1.

Suppose that $\varepsilon_{1,i} > 0$. In this case, a player that values the project $v_1 \in [a_{i-1}, a_{i-1} + \varepsilon_{1,i}) \subset A_i$ would have an incentive to not truthfully reveal his type in the communication stage, or, even if he truthfully communicates his type,

[5] Note that this definition is exactly the same as the simple strategy profile of Agastya *et al* (2007) when $n = m = 2$, $a_1 = x$, and $b_1 = k - x$.

he would not have incentive to contribute $c_1(A_i, B_j) = a_{i-1} + \varepsilon_{1,i} > v_1$ in the contribution stage. So, $\mathsf{C}^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is not a truthful equilibrium.

Suppose that $\varepsilon_{1,i} < 0$. Just to highlight our point, let i, j be such that $a_{i-1} + b_{j-1} \geq k$ and $a_{i-2} + b_{j-2} < k$. A player that values the project $v_1 \in [a_{i-1} - \varepsilon_{1,i}, a_{i-1}) \subset A_1 \cup A_2 \cup ... \cup A_{i-1}$ would have an incentive to communicate $A_i = [a_{i-1}, a_i]$, because contributing $c_1(A_i, B_j)$ gives him positive utility. So, again, $\mathsf{C}^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is not a truthful equilibrium.

Consequently, the contribution rule of a strategy profile Γ that supports a truthful equilibrium $\mathsf{C}^*\left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ must have $\varepsilon_{1,i} = \varepsilon_{2,j} = 0$.

Take the continuation game (A_i, B_j), where $a_{i-1} + b_{j-1} > k$. By the contribution rule, since the communication is truthful, Player 1 believes that Player 2 will contribute $c_2(A_i, B_j) = b_{j-1}$. As Player 1 is pivotal, he has the incentive to deviate from $c_1(A_i, B_j) = a_{i-1}$ and to contribute only the necessary to implement the project $c_1^d = k - c_2(A_i, B_j)$. The same happens to Player 2 that contributes $c_2^d = k - c_1(A_i, B_j)$. So, the total contributed is

$$c_1^d + c_2^d = k - b_{j-1} + k - a_{i-1} = k + (k - a_{i-1} + b_{j-1}) < k.$$

As players are rational, $c_1(A_i, B_j) = c_2(A_i, B_j) = 0$.

Now, take the continuation game (A_i, B_j), where $a_{i-1} + b_{j-1} = k$. As Player 1 believes that Player 2 will contribute $c_2(A_i, B_j) = b_{j-1}$, his best response is to contribute $c_1(A_i, B_j) = a_{i-1} = k - b_{j-1}$. This is analogous for Player 2, and we have an equilibrium in the second stage.

Next, we look at the communication stage. The individuals with values equal the cutoffs have to be indifferent between the two possible truthful messages. So, the following conditions must be satisfied

$$\begin{aligned} u(a_{i-1}, A_i) &= u(a_{i-1}, A_{i-1}),\ \forall i \leq n \\ u(b_{j-1}, B_j) &= u(b_{j-1}, B_{j-1}),\ \forall j \leq m, \end{aligned} \tag{3}$$

where $u(v, A_i)$ is the expected utility of an agent with value v when he sends the message A_i. We can rewrite these conditions as

$$\sum_{j=1}^{m} \Pr(B_j).\iota(A_i, B_j).\left[a_{i-1} - c_1(A_i, B_j)\right] =$$

$$= \sum_{j=1}^{m} \Pr(B_j).\iota(A_{i-1}, B_j).\left[a_{i-1} - c_1(A_{i-1}, B_j)\right],\ \forall i \leq n$$

$$\sum_{i=1}^{n} \Pr(A_i).\iota(A_i, B_j).\left[b_{j-1} - c_2(A_i, B_j)\right] =$$

$$= \sum_{i=1}^{n} \Pr(A_i).\iota(A_i, B_{j-1}).\left[b_{j-1} - c_2(A_i, B_{j-1})\right],\ \forall j \leq m$$

where $\iota(A_i, B_j) = 1$ when $a_{i-1} + b_{j-1} = k$, and $\iota(A_i, B_j) = 0$ otherwise. From the contribution rule, we can simplify these conditions to:

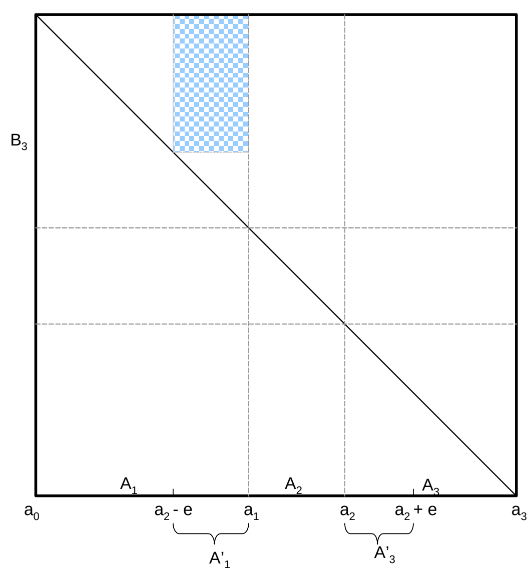
$$\begin{aligned} \Pr(B_{j-1}) . [a_{i-1} - a_{i-1}] &= \Pr(B_j)[a_{i-1} - a_{i-2}], \text{ for all } i \text{ s.t. } a_{i-1} + b_{j-1} = k \\ \Pr(A_{i-1}) . [b_{j-1} - b_{j-1}] &= \Pr(A_i)[b_{j-1} - b_{j-2}], \text{ for all } j \text{ s.t. } a_{i-1} + b_{j-1} = k. \end{aligned}$$

As the left side of the equations is zero, when $\Pr(B_j), \Pr(A_i) > 0$, the condition is not satisfied. So, when there exist $A_i \in \Lambda_n, B_j \in \Lambda_m$ such that $a_{i-1} + b_{j-1} = k$, as the message space $\Lambda_{n,m}$ is finite and the intervals do not have zero measure, the unique intervals that satisfy the condition are A_n and B_m.

In equilibrium, condition (3) is satisfied, so Λ_n and Λ_m are such that $a_{n-1} + b_{m-1} \leq k$. As $\mathfrak{C}^* (F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2)$ is being supported by a n-simple strategy profile, it is a n-simple equilibrium. ■

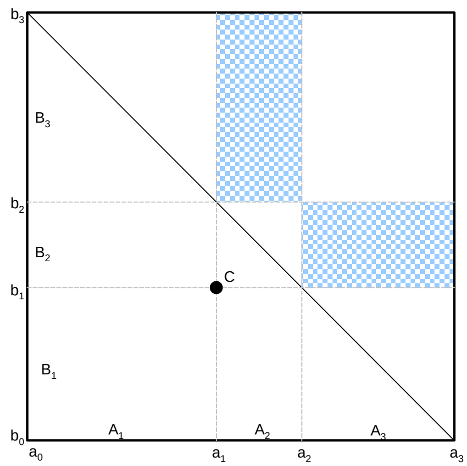
Figures 1 and 2 help us to understand the proof. Without loss of generality, take $\varepsilon > 0$. Consider a Player 1 whose value is $v \in A_3'$, shown in Figure 1. If he reveals his type, he does not have incentive to contribute $a_2 + \varepsilon$ to the project because it worths more than his value. Now, consider a Player 1 whose value is $v' \in A_1'$. He would have incentives to announce that his type is A_2 and contribute $a_1 - \varepsilon$ in case Player 2 sends the message B_3.

Figure 1



Now, suppose players have values $v_1 \in A_3$ and $v_2 \in B_3$, as in Figure 2. We know that they truthfully communicate their types, so in the contribution stage, Player 1 expects that Player 2 contributes b_2. So, his best response is not to contribute a_2, as expected, but to contribute $k - b_2 = a_1$. The same deviation is optimal to Player 2, so their contribution would be the point C. As C is under the cost line, the project would not be implemented. Since players are rational, they contribute zero and the contribution zone is the shaded area.

Figure 2



The intuition for the communication part of the proof follows the idea of Crawford and Sobel (1982). In their model, players' values are correlated and to make non-costly communication informative we have to let the bound agents indifferent between the two communication sets, giving the incentives for truthful revelation. Here, in order for agents to have the incentive to deviate from the truthful revelation, or we are in the strongly inefficient equilibrium, e.g., the message space is not informative, or the message space is such that $a_{n-1}+b_{m-1}=k$.

Proposition 2 *There exists a truthful equilibrium of* $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ *where the project is completed with positive probability if and only if* Λ_n *and* Λ_m *are such that* $a_{n-1}+b_{m-1}=k$.

Proof. For the necessity we only need that players use a n-simple strategy profile to have a truthful equilibrium of $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$. We just use Propositions 1 and Lemma 1 to prove the sufficiency. If $\mathsf{C}^* \left(F_1, F_2, \mathbf{\Lambda}^1, \mathbf{\Lambda}^2\right)$ is a truthful equilibrium, by Lemma 1, we have that $a_{n-1}+b_{m-1} \leq k$. As Proposition 1 guarantees that, if $a_{n-1}+b_{m-1} < k$, the unique equilibrium is strongly inefficient, we have that $a_{n-1}+b_{m-1}=k$. ■

Note that, despite how many communication possibilities we have, the relevant player's strategy may be summarized by two messages "Yes, I intend to contribute", A_n or B_m, and "No, I do not intend to contribute", $\Lambda_n \backslash A_n$ or $\Lambda_m \backslash B_m$. This is exactly the binary message space of Agastya *et al* (2007) who prove us that any truthful equilibrium in a finite message space is strategically equivalent to a simple equilibrium with binary message space. Therefore, cheap talk improves efficiency of the game without communication, but the improvement is very limited.

3 Experimental design

We ran two sessions for each of the three treatments: no communication, cheap talk with binary message space, and cheap talk with refined message space. To avoid randomness in the distribution value between the sessions, we used two value distribution, V1 and V2, and one group matching along the sessions. The experimental project is summarized at Table 1. The sessions were computer based[6]. Each session consisted of 25 decision rounds without practicing periods[7]. The *strangers* protocol was used to randomly form the new groups each period, in a manner that the agents never knew who was their partner. This protocol is an effort to simulate one-shot game's actions.

Table 1 - Experimental Project

Session	Communication	Value Distribution
S1	Binary	V1
S2	Refined	V1
S3	Refined	V2
S4	None	V1
S5	None	V2
S6	Binary	V2

In each session, we had 16 subjects, summing 96 subjects. The subjects recruitment was made through the Experimental Economic Center's website. All participants were unexperienced undergraduate students of Getulio Vargas Foundation. We had subjects majoring in courses like Economics, Business, Law, Social Science, and History. Each participant received R$8.00 to show up plus the experiments' gains. The total average payment is R$17.00.

All sessions were ran in a similar way. Just after all participants took their places, participants were given some time to read the instructions[8], and then the researcher read it aloud. Once individual doubts were answered, the game began. A detailed payoff table was presented on the individual computer screen in all decision stages to help players estimate their potential gains as a function of their private information and his possible actions[9].

During the experiment, the investment decision in a joint project was presented as an allocation decision. The subject's problem was to choose the amount of his initial endowment he would like to allocate to a Group Account, and how much of this endowment he would like to keep with him.

The game timing is as follow. Each period, the subjects are randomly allocated into new groups of two. Each subject receives an endowment of 100 *tokens,* and his Group Account valuation, v_i, is informed on the computer screen. This

[6] We used the Ztree program at http://www.iew.unizh.ch/ztree/ .

[7] There exists evidence of learning in the initial period, but, as we did not previously know how many periods it longs, we opted to not settle a fixed number of practice periods. We discard the initial periods later along our analysis.

[8] The instructions are available under request.

[9] This practice is standard in the literature and follows Saijo and Nakamura (1995) and Menezes and Saraiva (2005). The instructions explain the detailed payoff table.

value is a private information and the subject only knows that the Group Account value of the other player is uniformly distributed between 0 and 100. In the communication treatments, subjects first decision is to send a message to his partner. After receiving the message sent to him by his partner, each subject decides how much to allocate to a Group Account, c_i, the amount not allocated is kept with him, $100 - c_i$. Subjects payoff is given by (**??**), with threshold $k = 100$[10].

After all participants had taken their decision, a result screen was presented informing: (i) if the total allocation to the Group Account was greater or equal to k, (ii) the amount allocated by the agent to the Group Account, (iii) the two messages, and (iv) his profits. The history of these informations was also available. Once the round was over, the program randomized the groups and the next round could begin. Each session lasted around 75 minutes, including the payment time.

3.1 No communication treatment

This is the base treatment. Each round, subjects play a one stage game where they observe their Group Account value, v_i, and simultaneously type on the computer the amount to be allocated to the Group Account, c_i.

The following Hypothesis concerns about Proposition 1.

Hypothesis 1 *The only possible equilibrium is the strongly inefficient one, e.g., the total allocated to the Group Account never exceeds the threshold.*

3.2 Binary communication treatment

The participants now play a two stage game, so each round has two stages. In the first stage, each subject observes his Group Account value, v_i, and sends 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"[11]. Note that this message space does not have a common communication technology, because it does not have an explicit cutoff rule saying "If your type is $v_i \geq \overline{v}$, communicate Y , otherwise, communicate N". This cheap talk allows players to communicate their type, but mainly it let them to communicate their intentions, as it is common in the literature. It is important to enforce that this message is cheap talk, e.g., it is unrelated with the player decision in the second stage.

In the second stage, each subject observes the message their partner sent to him and, then, chooses the amount he would like to allocate to the Group Account, c_i. Again, the message sent by the subjects in the first stage does not restrain his decision in the second stage.

[10] This terminology is the voluntary contribution mechanism's standard, where any reference to social contribution is avoided, not to bias the agent's decisions.

[11] We used the same terminology of Palfrey and Rosenthal (1991).

Next Hypothesis concerns about Proposition 2 when $n = m = 2$, and Proposition 11 of Agastya *et al* (2007).

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

3.3 Refined communication treatment

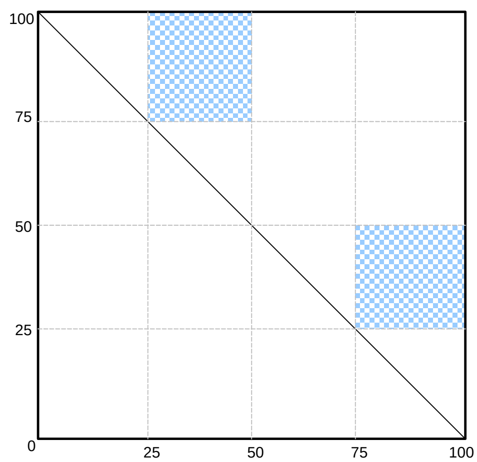
This treatment consists of a two stage game analogous to the binary communication treatment, with the only difference that the message space in the first stage is not binary. The message space here is $\Lambda = \{[0, 25], [25, 50], [50, 75], [75, 100]\}$, so players should send one of four possible messages, m_i, to their partners: $m_i = [0, 25]$, $[25, 50]$, $[50, 75]$, and $[75, 100]$. In order to follow the binary treatment, the players should communicate their intentions, not their types, so the subjects were asked "*How much do you intend to invest?*" and they would have to choose to send the following message: "I intend to allocate an amount in m_i tokes to the Group Account". Note that, now, there is a common communication technology, because, even the communication being cheap talk, there are explicit cutoffs for each of the four possible messages[12].

In order to test our hypotheses, we had to choose a message space Λ considering three points. First, the refined partition should permit efficiency gains relatively to the binary one. Indeed, a continuation game of a pair of messages $[25, 50]$ and $[75, 100]$, as shown in the shaded area of Figure 3, is a situation that is not possible in the binary treatment, and that may lead to the project completion. Second, the message space cannot support a truthful equilibrium. As $a_3 + b_3 > k$, it was demonstrated in the last section that this kind of equilibrium does not exist. Third, the message space should support a non-truthful equilibrium[13]. So, the subjects may have the possibility to play a strategy profile that is strategically equivalent to a binary one, e.g., they may be able to use the refined message space as a binary space. The following strategy profile satisfies this condition: in the communication stage, subjects communicate $[50, 75]$ if their value are greater that 50, and truthfully communicate otherwise; in the contribution stage, players allocate 50 to the Group Account if they follow the history $([50, 75], [50, 75])$, and allocate zero otherwise.

[12] We opted not to use a communication technology without explicity cutoffs, analog to the one in the binary treatment, because it could lead to erratic behavior.

[13] A message space that does not support any equilibrium could lead to too erratic behavior, and could not be very informative.

Figure 3



Next Hypothesis concerns about Proposition 2 when $n = m = 4$.

Hypothesis 3 *The probability that the total allocated to the Group Account exceeds the threshold in the cheap talk game with refined message space is not greater than in the cheap talk game with binary message space.*

4 Results

Along this section we use two efficiency measures: the probability of the joint project to be implemented when it is socially optimum, P, e.g., the probability of the project to be implemented when the aggregate project value is greater than his cost; and the contribution excess (4) that we define as the unproductive amount invested:

$$CE = \begin{cases} c_1 + c_2 & , \text{if } c_1 + c_2 < k \\ c_1 + c_2 - k & , \text{if } c_1 + c_2 \geq k. \end{cases} \quad (4)$$

Note that the theoretic model does not mention contribution excess[14], so we study this efficiency measure using an hypotheses analogous to the ones in the model.

We observed evidence of learning in the eight first periods, where investment was decreasing in time[15]. As the model tested is an one-shot game, we discarded the data from the eight first periods.

[14] Actually, the game theory approach states that in equilibrium the contribution excess is equal zero, otherwise players would have a profitable desviation by reducing their contribution.

[15] We regressed contribution on period, value, treatments dummy and value distribution dummy truncated by periods to find when the period variable was not significant at 5%.

4.1 Hypotheses test and efficiency

We begin by looking to the efficiency measure discussed in the model: the probability of the joint project to be implemented when it is socially optimum, P. The base treatment is the no communication game, where we observe that the joint project is implemented in 12.7% of the groups, meaning that a lot of people do not play the zero contribution Nash Equilibrium strategy. Indeed, through a mean equality test, we reject Hypothesis 1 at 1% significance, Table 1 presents the statistics. This result was also observed by Menezes and Saraiva (2005).

Two possible behavior patterns could explain this result. One is that people overestimate the conditional distribution function of his partner contribution given his own contribution, which makes contribution more attractive, e.g., the bias on the expected distribution function may support an equilibrium with non-zero contribution in some states. The other possibility is that people behave naïvely and contribute without estimating his expected payoff.

Even if the base treatment does not exhibit the strongly inefficient equilibrium, the introduction of a communication stage increases the equilibrium set, which contains more efficient equilibria, as it was proved. The idea of Hypothesis 2 is that the multi-stage communication game would allow players to coordinate in a more efficient equilibrium. Next result, however, shows that players were not able to do so. Using a mean equality test, Hypothesis 2, which states that the binary communication increases the probability of the project implementation, is rejected at 1% significance. Palfrey and Rosenthal (1991) and Bochet *et al* (2006) also obtained this result, which does not agree with the findings of Menezes and Saraiva (2005) and Cai and Wang (2006). As we are going to discuss next, a very non systematic behavior in the communication stage was observed, what may have introduced more noise in the cheap talk, lowering the messages credibility.

Table 1 - P Mean Equality Test

	Mean	t statistic
No Communication (NC)*	0.129	
Binary Communication (BC)*	0.103	
Refined Communication (RC)*	0.162	
H_0:NC=0**	0.129	6.33
H_0:BC-NC=0**	-0.03	0.72
H_0:RC-NC=0**	0.03	1.09
H_0:BC-RC=0**	-0.06	-2.03

Note: Number of observations: *272, **542.

Hypothesis 3 says that, although more refined message spaces have bigger equilibrium sets, these message spaces do not support truthful equilibria where the project is implemented with greater probability than the most efficient equilibria supported by a binary message space. This hypothesis is not so intuitive, and in fact, using a mean equality test, we reject the third hypothesis at 5% of significance. However, we cannot reject the hypothesis at 1% of significance.

As discussed in the previous section, there exists a non-truthful equilibrium in the refined treatment that is strategically equivalent to a truthful equilibrium in the binary message space. Next, when we discuss players' strategies, we argue that people use this non-truthful strategy profile to some extent. These strategies, however, are not easily identified because, similarly to the binary communication treatment, the refined message space increased subject's miscommunication possibility, which led to higher noise and lowered the messages credibility. Bochet et al (2006) used a communication technology that is richer than ours, but that allowed comparisons, and found that numerical communication had no effect on efficiency.

What can be said when the refined communication treatment is directly compared with the no communication one? We have seen that the binary communication does not increase the probability of project implementation relative to the base treatment, neither the refined message space relative to the binary message space. With this two results together we can test a new hypothesis: the probability of the project to be completed in the refined communication treatment is not greater than in the no communication treatment. This new hypothesis is not rejected at 1% of significance by a mean equality, see Table 1.

So, in this model, both communication technologies do not provide efficiency gain when efficiency is measured by the probability of the project implementation. This result can be better enforced by a probit regression of probability of project implementation on period, group value and treatment dummies, see Table 2. It can be seen that both treatment dummies are insignificant at 1%. This is not an intuitive result, but agrees with some literature findings, specially when communication is not verbal.

Table 2 - Regressions

	Probability of Implementation	Contribution Excess
Period	-0.01	-0.19
Group Value	0.03**	0.11**
Binary Communication Dummy	-0.18	-13.31**
Refined Communication Dummy	0.20	-12.28**
Constant	-4.40**	27.83**

Note: Significance of **1%, *5%. 863 observations.

The second relevant measure of efficiency is the contribution excess. Our theoretical model does not say much about the contribution excess as, in equilibrium, total contribution is equal to the cost of the project. So, we are going to use the three hypotheses as benchmark to the following analysis. As mentioned before, the blind contributions in the no communication treatment sustained a high level of mean contribution excess, 35.6. Using a mean equality test, we reject at 1% of significance that excess contributions are equal to zero.

The idea of Hypothesis 2 that communication allows efficiency gains in relation to the base treatment is not rejected here. Using the mean equality test, we reject two null hypotheses at 1% of significance: that the contribution excess in the no communication treatment is equal to the one in the binary treatment, and that the contribution excess in the base treatment is equal to the one in the refined treatment (see Table 3). In both cases, the null hypothesis is rejected in detriment to the alternative hypothesis that the mean contribution excess in the no communication game is greater than the communication one.

Table 3 - Contribution excess mean equality test

	Mean	t statistic
No Communication (NC)*	35.6	
Binary Communication (BC)*	22.3	
Refined Communication (RC)*	23.4	
H_0:NC=0**	35.6	17.0
H_0:BC-NC=0**	-13.3	-4.66
H_0:RC-NC=0**	-12.3	-4.38
H_0:BC-RC=0**	-1.0	-0.38

Note: Number of observations: *272, **542.

When we compare the refined and the binary communication treatments we observe that in neither efficiency measurement - probability of project completion and contribution excess - the refined message space provides efficiency gain relative to the binary one. Using a mean equality test, we cannot reject at 1% of significance that the two communication treatments have the same mean contribution excess (see Table 3). This result is strengthened by the regression of contribution excess in constant, period, total group value, treatment dummies and value distribution dummy. As can be seen in Table 2, both treatment dummies are significant and, more, using an F test we cannot reject at 1% of significance the equality of the two dummies coefficients.

So, communication indeed increases efficiency in relation to the one stage game, but this efficiency gain is not observed by higher probability of project implementation, as usual in the literature, but it is measured by a lower level of inefficient contribution. With this new reference in mind, we believe that our result adds to the literature that sees communication as an useful mechanism to enhance efficiency. Note, however, that this communication efficiency gain seems to be very limited, as a more refined communication space could not support a more efficient equilibrium.

4.2 Strategic profile

The first issue to understand subjects strategy profile is to check if strictly dominated strategies are being used. In our case, the strictly dominated strategy is to invest in the joint project an amount higher than the project value[16]. In 9.9%

[16] As we don't know players beliefs about their partners behavior, the zero contribution or any contribution pattern in any continuation history in the two-stage game are not a strictly

of the total 1632 observations, the subjects played strictly dominated strategies. This number may seem too high, but if compared with the literature findings, it is quite reasonable. Dawes *et al* (1985) and Issac *et al* (1985) observed 20% and 30% of this kind of rationality violation in their experiments. Using a mean equality test, we reject at 1% of significance that 20% of the strategies were strictly dominated in favor of the alternative hypothesis that our fraction of violation was lower.

Now, we can look with more attention to the individual behavior that can help us to understand the last subsection results. Following the sequence of the game, we first analyze the behavior in the communication stage.

As discussed in the last section, the message space on the binary treatment does not have an explicitly threshold to define which message is more appropriate. The "Yes, I intend to contribute" and "No, I do not intend to contribute" messages are somewhat loose in this sense, and it is interesting to estimate the threshold that makes the "Yes" message more likely? Using a probit regression of message on value, we observe that when subject's value is equal 67.1 the "Yes" message is sent with 50% chances. Theoretically, any two-thresholds such that their sum are equal to the project cost is optimum. So, the only symmetric threshold that sustains a 2-simple equilibrium is 50. This is not the case here, and the 2-simple strategy profile with threshold 67.1 observed is dominated by the theoretical threshold. This means that in the binary treatment, at least 13.4% of efficiency was lost in the communication stage. This high threshold accuses a reluctance of people to communicate, that may be motivated by a free-riding behavior or by their risk aversion.

We can observe a similar behavior when we look to the refined treatment. There is evidence of bunching of the lower types in the message $[0, 25]$ and of the higher types in the message $[50, 75]$, see the histogram in Graph 1. Observe that in all the cases, except the lowest one, most of the people underrevealed their value. More, the overcommunication pattern is quite similar to all value range, except the highest one, what accuses that people indeed under revealed their types. The free-riding and risk aversion motivations fit here.

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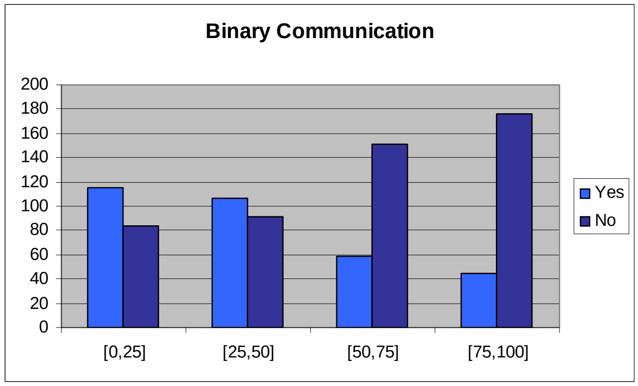
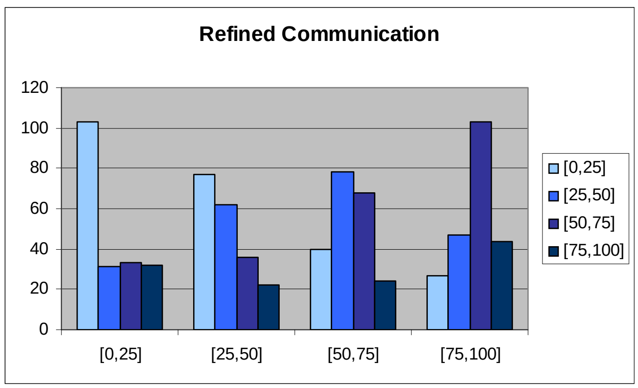
dominant strategy.

Graph 1 - Message histogram by value

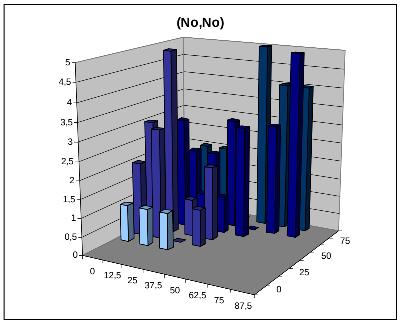


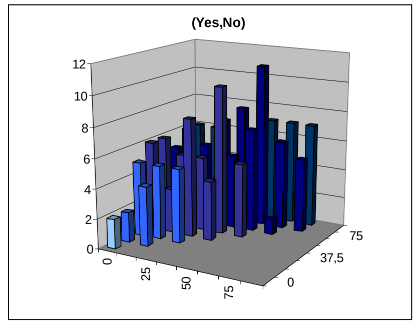


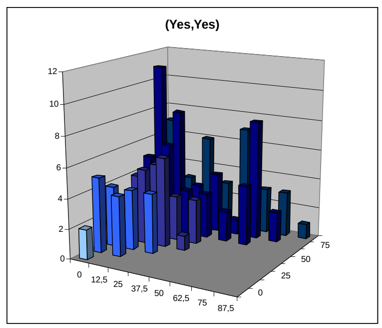
We can look to the non-truthful strategy of players when they try to mimic the binary message space in the refined treatment. Bunching the messages $[0,25]$ with $[25,50]$, and $[25,50]$ with $[75,100]$, and running a probit model analogous to the one in the binary treatment, we find that the analogous threshold of the "Yes" message, in the refined treatment, is much higher than the one in the binary treatment, equal 99. So, people reveal more their values in the binary message space than in the bigger message space, or, at least, there were more miscommunication in the refined treatment.

The non systematic behavior in the communication stage can be better seen in the three dimension message histogram, Graph 2. Palfrey and Rosenthal (1991) also observed this non systematic behavior, however, the undercommunication pattern was not observed by Cai and Wang (2006) and Blume *et al* (2002), this last in a more different setting.

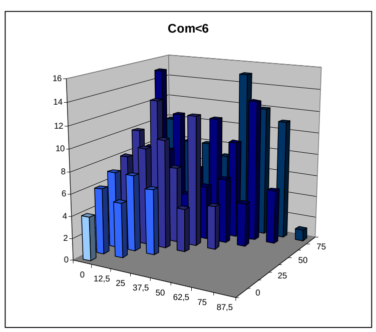
Graph 2 - Message histogram given subject's value
Binary Treatment

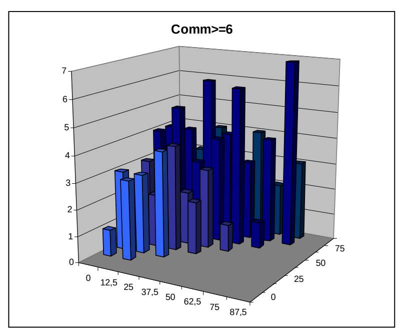






Refined Treatment





Except in the base treatment, the contribution stage is a continuation game. When there is no communication, the contribution sensitivity to value did not change along time, as can be seen in the random-effects regressions presented in Table 4. Note that this does not mean that there is no learning evidence, because the gross learning process is captured by the period variable. What we want to express here is something like a marginal learning, which is the marginal effect of the subject value in his contribution. If it changes along time, it could be a signal that people would be updating their believes about their partners.

However, the flat pattern observed can support the two conjectures made when we discussed the first hypothesis in the last subsection, e.g., that people overestimate the conditional distribution function of his partner contribution given his own contribution, and do not update their believe, or that people behave naïvely and contribute without estimating the real distribution function of the other player contribution.

Table 4 - Random Effects Regression (No communication treatment)

Dataset	constant	Period	Value	N	Wald chi2
Last 5 periods	23.7	-0.97	0.36**	160	22.49
Last 10 periods	15.0	-.073	0.43**	320	82.25
Last 15 periods	12.6	-0.60*	0.42**	480	118.8
Last 20 periods	14.5**	-0.66**	0.41**	640	143.7
All 25 periods	13.2**	-55.6**	0.39**	800	174.08

Note: Significance of **1%, *5%.

When we look to the two communication treatment, the contribution stage is a continuation game that fallows the history of the communication stage. In this case, it is useful to look the contribution truncated by the previous information set, e.g., to look to the continuation game. In the binary treatment, the mean contribution, given that the message history is (Yes, Yes), is equal to 33.8. Using a t test, we reject at 1% of significance that this mean is equal 50. Then, it can be inferred that people do free-ride in the contribution stage. The same can be observed in the refined treatment, where the mean contribution given the history $([50, 100], [50, 100])$ is equal 42.2. Again, a t test rejects at 1% of significance that the mean contribution is equal to 50. Table 5 presents the tests values.

Table 5 - Mean contribution

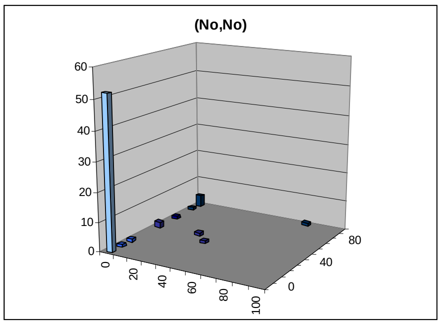
	Mean	t statistic	N
Binary Communication (BC)			
H_0:Contribution | (Yes,Yes) = 50	33.8	-9.1	290
Refined Communication (RC)			
H_0:Contribution | ([50,100],[50,100]) = 50	42.1	-3.36	160

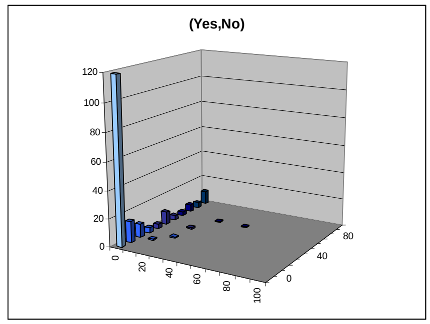
The three dimension contribution histogram helps us understand subjects behavior (see Graph 3). In both treatment, the "bad state of the world messages"[17] are informative, and people do coordinate on the double zero contribution. However, the continuation game that follows the (Yes, Yes) history, present a much bigger dispersion. Although the mode contribution is 50, very few contributions were made in the area $([50, 100], [50, 100])$. The dispersion is even higher in the refined treatment, and, again, very few observations are found

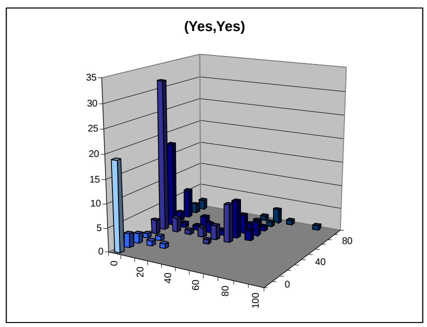
[17] We call a "bad state of the world message" the communication history containing a message "No" in the binary treatment, and communication histories where the sum of the lower bound of the two messages is lower than the project cost.

in the ([50, 100], [50, 100]) area. So, the behavior seems to be: "If the message brings good news, I contribute 50 or less, in an effort to free-ride my partner's contribution. Otherwise, if the message is not good, I contribute zero."

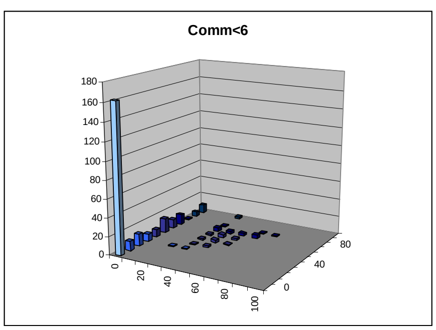
Graph 3 - Contribution histogram given communication history
Binary Treatment

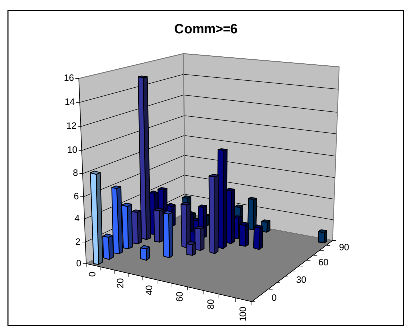






Refined Treatment





Another tool that can help us to identify the communication utility is the contribution sensitivity to value truncated by communication history. As in the base treatment, we use random effect regression (see Table 6). In the binary treatment, we find that the value is not a significant variable when the contribution follows the (No, No) history. When one of the two subjects have sent the message Yes, value is significant at 1% and, the more interesting, his sensitivity is monotonic in the number of Yes messages. This result is observed by Palfrey and Rosenthal (1991).

Table 6 - Random Effects regression truncated by communication history

Dataset	Constant	Period	Value	N	Wald chi2
Binary Communication (BC)					
Messages (No,No)	3.3	-0.09	0.11	92	1.52
Messages (Yes,No)	4.6	-0.29	0.17**	278	16.83
Messages (Yes,Yes)	10.9	-0.23	0.48**	174	45.54
Refined Communication (RC)					
Messages ([0,50],[0,50])	-1.3	0.06	0.31**	432	56.2
Messages ([50,75],[50,75])	9.5	-0.35	0.59**	40	20.6
Messages ([75,100],[75,100])	6.4	0.16	0.48**	72	18.2
Messages ([50,100],[50,100])	9.8	-0.12	0.52**	112	37.3

Note: Significance of **1%, *5%.

When we look to the refined treatment, however, not much can be said about contribution sensitivity to the value. Value is always a significant explanatory variable, but its coefficients are not monotonic and have a more difficult interpretation.

5 Conclusion

This article is an attempt to model the behavior of two persons in situations where non costly communication could lead to welfare gain. We take Agastya, Menezes and Sengupta (2007) model and prove that even when players have several messages possibilities, they cannot do better than when they only have the "Yes" and "No" messages. In other words, a bigger message space supports a bigger equilibrium set, that does not Pareto denominate the equilibrium set supported by a binary message space.

Laboratory experiments were performed to test our result and two propositions of Agastya *et al* (2007). We find that when there is no communication people make blind contributions, and the project is implemented with positive probability. The observations do not support the results that communication increases the probability of the project implementation. We found, however, that communication affects efficiency in another way, by reducing the overcontribution, e.g., the nonproductive contribution. In both aspects, the refined message space does not outperform the binary one. We found evidence of free-riding in both stages.

Theoretically, we think that this limited improvement by communication is related with the fact that private information has only one dimension. We imagine that when the agent's are privately informed in more than one dimension, more refined communication sets could provide efficiency gains.

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