Market games as social dilemmas*

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Abstract

In an experimental exchange market based on Shapley and Shubik (1977), two types of players with different preferences and endowments independently submit quantities of the goods they wish to exchange. In this context, although the Nash equilibria of the game involve zero or minimum trade, we obtain intense trade close to levels that maximize social welfare. Going a step forward, we implement communication within pairs of traders from the same (horizontal) and opposite (vertical) sides of the market. Overall, we find that

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horizontal communication tends to reduce bids whereas vertical communication has no effect.

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1 Introduction

Even before the introduction of money, trade has been used by humans to improve life in society by the exchange and reallocation of goods. In modern economies, in which complex transactions occur, the use of money has facilitated interaction among sellers and buyers of different goods. In more occasions than is often thought, trade may occur even in the absence of money. Several exchange markets exist online in which traders directly exchange second hand books or electric appliances. In such markets, the relative price of two items is determined by their relative scarcity. Both in pure exchange and monetary economies, the relative price of goods is determined as the result of decentralized decisions by the suppliers of each good. For example, the monetary and the productive sectors of an economy determine the relative prices of goods and money by independently deciding the amount of money and products to be supplied into the market. Also, the decision of countries to increase the supply of money determines to a large extent the relative price of their currencies, that is, the exchange rate.

In a laboratory experiment replicating an exchange market, Duffy et al. (2011) find that human actions systematically differ from the selfish, autarky equilibrium prediction in favor of an alternative Pareto superior Nash equilibrium with trade. Essentially, the existence of two equilibria in that study results in a coordination game, in which agents tacitly reach the Pareto superior equilibrium. In the present study, we consider a class of market games in which only no-trade or minimum-trade equilibria exist, while maximization of social welfare requires full trade, that is, agents exchanging their whole endowments. In that case, exchange markets lead to a genuine social dilemma in which different types of decision makers may exchange high volumes of goods or remain in autarky.

We consider an experimental exchange market based on strategic market games, defined in the prototype models of Shubik (1973) and Shapley and Shubik (1977), which have been extensively used to provide a non-cooperative foundation to perfect competition.[1] The key feature of these games is a strategic outcome function, which determines the allocation of goods in an economy as a function of individual activities. Generally, the framework leads to a multiplicity of Nash equilibria, many of which are Pareto inferior due to agents' market power, that is, the ability to manipulate prices and generally the terms of trade. In particular, we study an exchange market, based on the paradigm adopted by Cordella and Gabszewicz (1998), which has the exceptional property that the *unique* Nash equilibrium involves all agents abstaining from trading. We test the theory by examining whether no trade emerges in the lab, or alternatively whether traders manage to avoid the selfish no-trade equilibrium as observed in other social dilemmas (tragedy of the commons, public good games, prisoner dilemma games, common pool resource extraction games, etc.).[2]

Our work complements that of Duffy et al. (2011) (which together with Huber et al., 2010 are, to the best of our knowledge, the only experimental approaches to strategic market games). They report strong evidence that human subjects can systematically avoid the no-trade equilibrium in favor of the alternative more efficient equilibrium which, in their case, is an interior one with trade. Contrary to that work, in our model the sub-optimal minimum and no-trade equilibria are the only theoretical predictions under non-cooperative behavior. However, despite the absence of a Nash equilibrium with intense trade and the low number of agents per

[1]The interested reader on the issue is referred to Dubey and Shubik (1978), Postlewaite and Schmeidler (1978), Mas-Colell (1982), Peck et al. (1992), and Koutsougeras (2009) to name a few.

[2]From the famous pamphlet by Lloyd (1833) and the seminal papers by Hardin (1968), Ostrom (1990) and Ostrom et al. (1999) on the Tragedy of the Commons, a plethora of papers have experimentally studied situations of divergence between individual and collective interests. Despite the predominance of the Tragedy of the Commons paradigm in early studies, it was mostly Voluntary Contribution to Public Goods (see, for instance, Fischbacher and Gachter, 2010) and the Prisoner's Dilemma (Sabater-Grande and Georgantzis, 2002) games which have provided the framework for the study on human behavior in the presence of a conflict between private and public well-being. Recently, García-Gallego et al. (2016) studied an extraction game from a public good. In all of these studies, there is a systematic deviation by either the majority or a substantial portion of subjects who behave against the prediction of a selfish behavior leading to the socially suboptimal Nash equilibrium.

market ($n = 4$), we obtain systematic evidence against the minimal or zero trade predictions.

To further explore the role of coordination mechanisms, we allow for 'cheap-talk' communication among subjects. We are motivated in this by the popular conjecture (e.g., in Mas-Colell, 1982) that some minimal amount of cooperation among agents would be necessary in order to get trade started. With this in mind, we have tested two communication protocols, labeled *horizontal* and *vertical* communication, within pairs of players on the same and opposite sides of the market, respectively. Communication is used by pairs of agents to reach non-binding agreements on their market strategies. This is one of the few occasions in which horizontal and vertical cooperation can be studied and compared to each other in the same framework, and we believe that this is one of the merits of the current study. In fact, although the effects of communication between agents from the same side of the market have been extensively studied[3], we are not aware of any work that also examines communication between agents from different sides of the market, e.g. sellers and buyers. Concerning the impact of communication on outcomes, our results show that horizontal communication has the expected output-reducing effect as would be predicted from standard wisdom on quantity-setting collusion (and documented since early experimental studies, like Isaac and Plott, 1981). On the other hand, communication within pairs of agents from opposite sides of the market (vertical partnerships) leads to higher output than horizontal ones. These patterns persist when subjects are allowed to choose the communication mode, and none of the two alternatives seems to be strongly preferred by the players or affect behavior compared to the exogenous communication mode case.

The remainder of the paper is organized as follows. The next section describes the theoretical model. Section 3 outlines the experimental design and Section 4 presents and discusses the experimental evidence. Section 5 summarizes our conclusions.

[3] There is a long list of papers with experimental studies featuring communication among oligopolists. A partial list includes Daughety and Forsythe (1987), Normann et al. (2015), and Waichman et al. (2014) for quantity competition games à la Cournot; Andersson and Wengström (2007), Fonseca and Normann (2012) for price competition games à la Bertrand; Brown-Kruse et al. (1993), and Brown-Kruse and Schenk (2000) for spatial competition games à la Hotelling.

2 Theoretical framework

We begin by describing the bilateral oligopoly paradigm on which our experimental design is based. The exchange economy consists of two goods x, y and an even number of agents $n > 2$, falling into two groups of equal size. The two agent types are distinguished by endowments and preferences. Each agent $i = 1, ..., n/2$ is of Type I and is endowed with w units of good x and zero units of good y, whereas each agent $i = n/2 + 1, ..., n$ is of Type II and possesses w units of good y and zero units of good x. If we suppose that good x serves as commodity money, then the two types can be thought of as buyers and sellers of good y. Preferences of the two types of agents are described by the following utility functions

$$u_i(x, y) = \beta x + y$$

for Type I agents and

$$u_i(x, y) = x + \beta y$$

for Type II agents, with $0 < \beta < 1$ being the marginal rate of substitution between the more and the less preferred good for each agent.

It is easy to check that the maximization of social welfare for this exchange economy requires that each Type I agent consumes w units of good y and zero units of x, whereas each Type II agent consumes w units of commodity x and zero units of good y. This profile of efficient allocations, together with the associated price ratio between the two goods being equal to one, is the unique Walrasian equilibrium for this economy.

The associated market game for this economy is as follows: there is a single market where agents send their quantity bids, that is each Type I agent may bid an amount q_i of good x in exchange for good y and each Type II agent may bid an amount q_i of good y in exchange for good x. Hence, the strategy sets are $S_i = \{q_i \in \Re_+ | 0 \leq q_i \leq w\}$ for all agents.

Given a profile of bids, the relative price of good y is

$$p = \frac{\Sigma_{i=1}^{n/2} q_i}{\Sigma_{i=n/2+1}^{n} q_i}$$

and the final allocations of the two goods are

$$(x_i, y_i) = (w - q_i, \frac{q_i}{p})$$

for Type I agents and

$$(x_i, y_i) = (pq_i, w - q_i)$$

for Type II agents, where divisions over zero in all the above expressions are taken to be equal to zero. The interpretation of this allocation mechanism is that the total supplied quantities by one type of agents are distributed among agents of the other type in proportion to their bids.

The solution concept that is employed in the market game literature is the standard pure strategy Nash equilibrium. As proved in Cordella and Gabszewicz (1998) the number and the type of equilibria of this particular game depend on the value of β and the number of agents, with no-trade (all agents choosing $q_i = 0$) being the unique Nash equilibrium if $\beta > (n-2)/n$.[4]

For our experimental parameterization, the values of β and n are chosen so as to satisfy the above inequality. We assume $n = 4$ agents, two of each type, and we set $w = 20$ and $\beta = 0.6$, with the corresponding utility functions being $u_i(x, y) = 0.6x + y$ for $i = 1, 2$ and $u_i(x, y) = x + 0.6y$ for $i = 3, 4$.

For each agent i let us denote by q_{-i} the bid of the other agent of the same type. Hence agents are viewed as solving the following problems:

$$\max_{q_i^* \in [0,20]} 0.6(20 - q_i^*) + q_i^* \left(\frac{q_3 + q_4}{q_{-i} + q_i^*} \right)$$

for $i = 1, 2$ and

$$\max_{q_i^* \in [0,20]} q_i^* \left(\frac{q_1 + q_2}{q_{-i} + q_i^*} \right) + 0.6(20 - q_i^*)$$

for agents $i = 3, 4$.

[4]Indeed, due to the symmetry of the problem, any Nash equilibrium of the game must involve equal bids for all agents of both types. However, when $\beta > (n-2)/n$ no symmetric profile of positive bids can serve as a Nash equilibrium, as an agent's best response to such bids involves lowering her bid. Hence, no-trade is the unique Nash equilibrium of the game.

As stated above, no-trade (all agents choosing $q_i = 0$) is the unique Nash equilibrium when we have a continuous strategy space. However, if participants' bids are restricted to be integers, as in our experimental design, the game allows for some more equilibria with low volumes of trade. In such a case, the symmetric strategy profiles $(q_1, q_2, q_3, q_4) = \{(0,0,0,0), (1,1,1,1), (2,2,2,2), (3,3,3,3)\}$ and the asymmetric strategy profiles $(q_1, q_2, q_3, q_4) = \{(1,0,1,0), (1,0,0,1), (0,1,1,0), (0,1,0,1)\}$ all serve as Nash equilibria.

2.1 Pre-play communication

Although pre-play 'cheap-talk' communication has in theory no direct effect on the outcomes of a game, it has been extensively reported that it may affect the behavior of experimental subjects.[5] We examine both the case of communication between agents of the same type, for which we use the term *horizontal communication*, and the case of communication between two agents of different types, for which we use the term *vertical communication*.

For the case of horizontal communication, it is obvious that (due to the symmetry of the problem) any agreement between two agents from the same side of the market should involve identical bids. Moreover, given that the integer setting of our game allows for equilibria with positive trade, there is some room for collusive reduction of offers as in the classical quantity-setting Cournot oligopoly. Hence, any agreements should probably involve the lowest possible positive bids (one unit in our setup) so as to extract the maximum gains for the 'cartel'. However, such an agreement is vulnerable to deviations if there are higher bids from the other side of the market. Indeed, and agent can profitably deviate (her actual bid being higher than the agreed minimal bid) if agents from the other side of the market choose strategies other than those involving zero or the lowest possible positive bids and the other agent of her type sticks to the agreement. Such a deviation results in her acquiring a larger portion of the most preferred good and, hence, in an increase in her payoff.[6]

[5]See, among many others, Crawford and Sobel (1982), Rabin (1994), Farrell and Rabin (1996), Farrell (1998), and Whinston (2008), for studies on the impact of pre-play communication.

[6]For example, in an economy with our experimental parameterization, if agents from the other side of the market choose individual bids equal to 2 units, an agent could deceive the other agent of her type who chooses to stick to the agreed one unit bid. Indeed, she can profitably deviate by

For the case of vertical communication, it is clear that lower bids from one side of the market will result in inferior outcomes for the other side. Hence, any fair agreement that promotes the mutual interests of the two traders should involve identical positive bids. Moreover, in order to exhaust the total gains from trade we should expect that agents agree on submitting the highest possible bids (full trade). Therefore, this communication protocol should have an exchange-enhancing effect on agreed bids. However, such bids do not constitute a Nash equilibrium and hence there are strong incentives for deviations by submitting bids which are lower than the agreed ones.

3 Experimental design

The experiment was run using z-Tree (Fischbacher, 2007) at the Laboratorio de Economía Experimental (LEE) of the Universitat Jaume I in Castellón (Spain). A total of 160 subjects participated in the experiment.

At the beginning of each period, each subject is paired in a random and anonymous way with three other participants, one of the same type and two of the other type. Although each subject's type is permanent, all members of a market can vary from period to period within a fixed matching group. Each matching group is randomly formed by 8 people at the beginning of the experiment and participants from one matching group never interact with participants from other matching groups throughout the session.

The identity of the members of a market is never revealed to the subjects. Within a matching group, any combination of two members of Type I and two members of Type II has the same probability of occurrence.

Four treatments, T0 to T3 are implemented. In T0 no communication is allowed. In T1, subjects could communicate with the other participant of the same type in her market. We refer to T1 protocol as 'horizontal communication'. In T2, communication is allowed with a participant of the other type in the same market. We refer to T2 protocol as 'vertical communication'. In T3 subjects privately vote

offering 2 units. Such a deviation costs one more unit of the good that she values at 0.6, and results in her consuming two thirds, instead of one half, of the offered quantity (4 units) of the good that she values at one.

their preferred communication mode between horizontal and vertical, and then, one of the four votes in each market is randomly selected by the computer program to decide which communication mode will be implemented for that period in that particular market.

Subjects of Type I start each period with an initial endowment of $w = 20$ units of commodity x and zero units of commodity y. Subjects of Type II start each period with an initial endowment of zero units of commodity x and 20 units of commodity y. An agent values her units in 0.6 each, while she values at 1 each unit of the good that she does not possess in the beginning. Initial endowments are the same at the beginning of each period independently of what happened in previous periods. Within a market, decisions in each period are made simultaneously.

Subjects choose the amount of own commodity that each one of them wants to exchange in the market. In order to understand how a certain combination of the four members' decisions will affect the results for each member of the market, subjects are allowed to use a simulator-calculator for pre-play trials without monetary consequences. Decisions have to be integer numbers between 0 and 20. If the agent decides not to submit a quantity bid, she will not participate in any exchange between the two commodities and, as a consequence, at the end of the period she will have the initial endowment

Treatments are implemented in three sessions: S1, S2 and S3, of 48, 56 and 56 experimental subjects, respectively. In each period, players of the same matching group are randomly assigned to form markets of 4 agents (two of each type), generating thus 12 markets per period in S1 and 14 in S2 and S3. Given our matching groups of 8, this implies that we get 6 independent observations in S1, and 7 in S2 and S3. Each session lasts 40 periods.

The baseline treatment T0 is run throughout session S1 during the 40 periods. Sessions S2 and S3 consist of four 10-period subsessions each, corresponding to treatments T0 (first 10 periods) to T3 (last 10 periods). The order of treatments T1 and T2 in the central 20 periods is changed across sessions S2 and S3, with T1 preceding (following) T2 in S2 (S3). The way in which subjects have the possibility to communicate is a structured chat through which subjects might sequentially send specific quantities to the other subject until a non-binding agreement is reached.[7]

[7]One of the two communicating agents is randomly selected as the one sending the initial pro-

Before the experimental session starts, subjects individually receive printed instructions and, after several minutes, instructions are also read aloud by the experimenter.[8]

At the end of each period, subjects receive information concerning the individual and total quantities of commodities x and y offered for trade by all participants in a market. They also receive information on final amounts of both commodities and the payoffs for each participant in their market after trade has taken place. Then, subject's own potential payoff in ExCU (Experimental Currency Unit) is calculated for that period. In the instructions, subjects are presented with two tables reporting, for each type of agent, the earnings in ExCUs for specific combinations of quantities.

Finally, parallel to the main experiment, subjects completed the Sabater-Grande and Georgantzis (2002) risk elicitation task. We believe that risk attitudes might contribute to explanations of possible behavior differences.[9]

Subjects are paid individually in cash at the end of the session. To calculate each subjects' reward, the system randomly selects three periods from each 10-period block.[10] An exchange rate of 1 ExCU = 0.1 Euro is applied. Average payoff was approximately 18 Euros. The average duration of a session was 2 hours.

4 Results

We first look at some general patterns observed in our experimental data. Pooling bid data across all treatments and sessions, we note that zero trade is the least frequently chosen bid among all available strategies. The most frequent bids were

posal. The proposal is a number between 0 and 20, both extremes included. If the other agent accepts the proposal, communication ends. But if she rejects, she has to insert a new proposal to be sent back for the other agent to accept. This sequence can last as long as they need to agree on a common quantity.

[8]The instructions to subjects for the main experiment, in Spanish and in English, can be found in the Online Appendix.

[9]The lottery panels of this task are included in the Online Appendix. Details regarding the mapping of risk choices in the task on utility parameters in an expected utility framework can be found in Attanasi et al. (2018).

[10]We adopt this reward system to avoid wealth accumulation effects which may undermine the salience of latest period profits. This also helps mitigating the randomness entailed in paying out too few periods.

10, 7 and 20 units. A histogram of bid frequencies over the whole strategy space is presented on Figure A1 in the Online Appendix.

When we disaggregate this picture by treatment, we obtain Figure 1 on which the effects of communication on the bids distribution can be visualized. As we will establish in a more formal way below, overall, communication has a negative impact on bids.

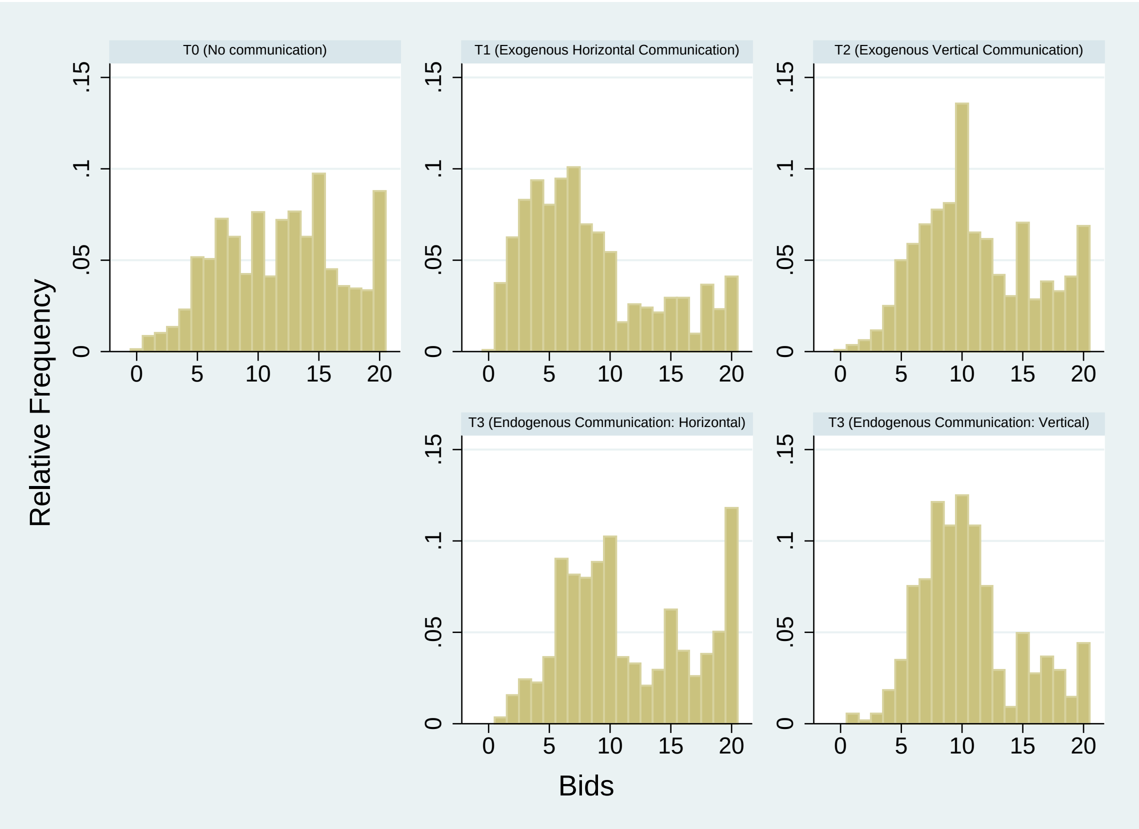

Figure 1: Distribution of bids with no communication (*left-hand side*). Distribution of bids with exogenous (up) and endogenous (down) horizontal and vertical communication (*right-hand side*)

To see the underlying dynamics, Figure 2 shows the evolution of median bids in the three sessions. In the absence of any pre-play agreement or communication (S1), the figure shows a clear increasing trend of trading which gradually converges near full-trade levels. Recall that, in our framework, there is no Nash equilibrium with significant trade. Thus, the intense trading behavior observed here cannot be attributed to coordination on a Nash equilibrium.

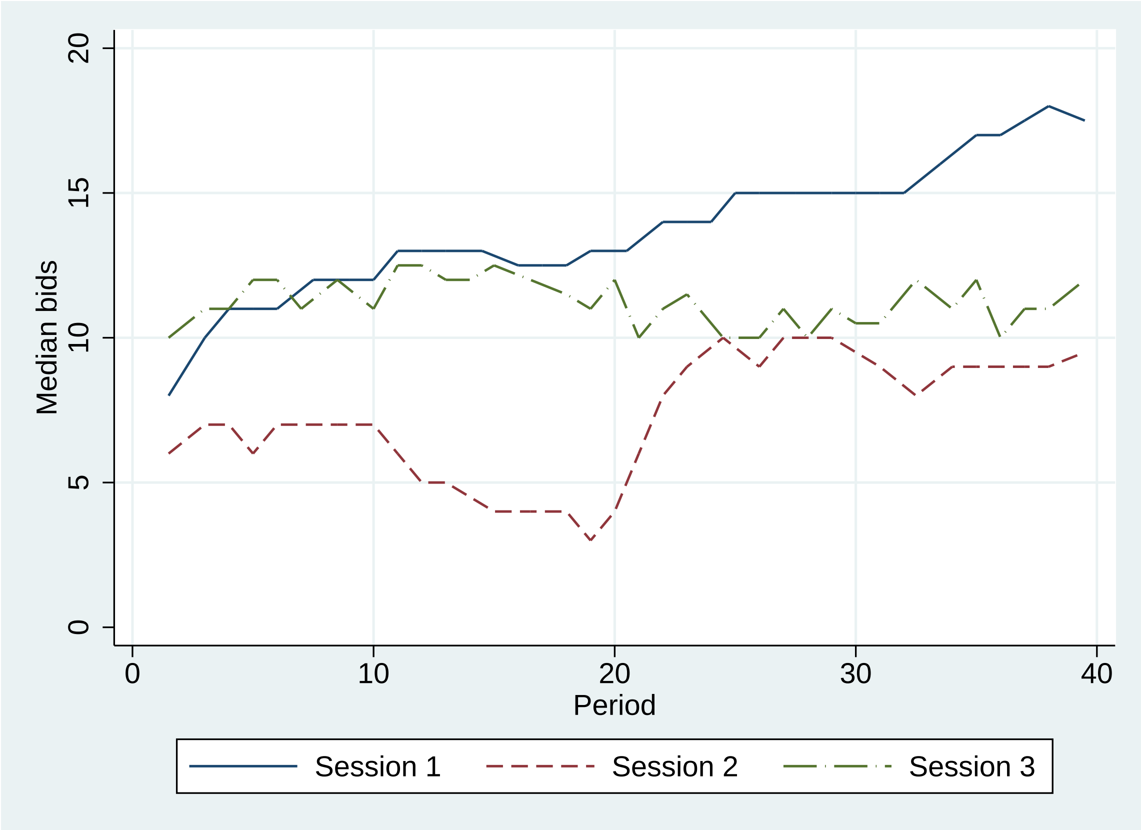

Figure 2: Evolution of period median bids through all four 10-period subsessions. S1 (throughout no communication), S2 (No communication-Horizontal-Vertical-Endogenous Communication) and S3 (No communication-Vertical-Horizontal-Endogenous Communication).

Given the shorter horizon of the experiments by Duffy et al. (2011) as compared to ours (25 rounds versus 40, respectively), we conjecture that a longer learning process may have led our S1 markets closer to the outcome that maximizes social welfare. Specifically, referring to Figure 3, let us focus on the individual bids in matching groups 1-6, corresponding to S1. Observe that in all 4 groups in which convergence close to full trade was achieved (matching groups 2, 4, 5 and 6), some learning seems to have been necessary before bids stabilized at the high levels observed towards the end of the session. Particularly for groups 2 and 4, full trade was achieved towards the very last rounds, whereas group 6 would have needed an even longer horizon for full trade to be achieved. On the contrary, group 5 needed a very low number of rounds before converging almost perfectly to full trade bids. Groups 1 and 3 have remained persistently below full trade, although well above the no-trade equilibrium prediction of the static game. Therefore, while the existence of a Nash equilibrium with trade is not a necessary condition for intense trade to occur, a sufficiently long learning process is.

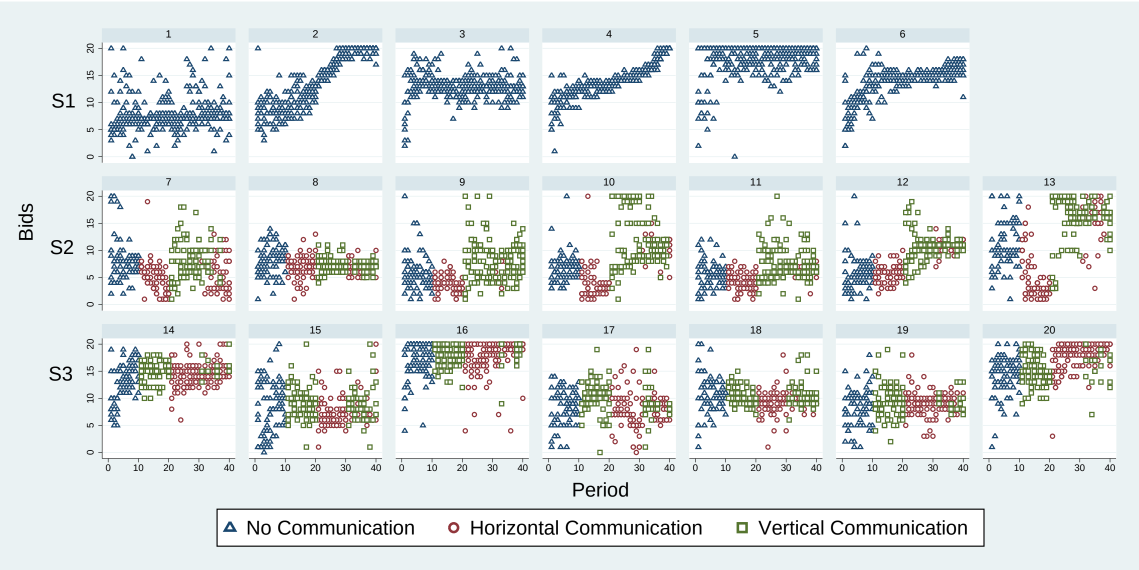

Figure 3: Evolution of individual bids by matching group (S1 (No communication): groups 1-6; S2 (No communication- Horizontal-Vertical-Endogenous Communication): groups 7-13, S3 (No communication-Vertical-Horizontal-Endogenous Communication): groups 14-20).

4.1 Comparison across sessions: Between-subject Analysis

For the inferential analysis presented hereafter the units of observation used are the independent matching groups: 6 for S1, 7 for S2 and 7 for S3.

The first 10 periods of sessions S1, S2 and S3 are immediately comparable, as they are run in the absence of any communication (T1). We compare the distribution of bids using a Mann-Whitney U test. While there is no difference between S1 and S3 ($Z = -0.286$ and $p = 0.775$), bids are significantly lower in S2 than in the other two sessions ($Z = 2.143$ and $p = 0.032$ compared to S1, and $Z = -2.558$ and $p = 0.010$ compared to S3). This difference must be taken into account when assessing the effect of communication. Although we cannot offer a conclusive explanation for this in principle unexpected session effect, a possible cause could be sought in the gender composition of S2, in which the number of females was twice the number of males.[11]

[11] Of the total sample, the percentage of females in each session was 54.17% in S1, 66.07% in S2 and 37.5% in S3. Our design does not control for any specific gender distribution.

As will be shown in the econometric analysis, where the effect of demographic factors on behavior is systematically explored, females post lower bids on average.[12]

The second 10-period subsessions of S1 and S3 are not different from each other, indicating that vertical communication had no significant impact.[13] By contrast, bids in the second 10-period interval of S2 are lower than the corresponding ones in the other two sessions.[14] Dif-in-dif analysis shows that there is a similar increase ($Z = 0.857$ and $p = 0.391$) in the bids from the first to the second 10-period block in S1 and S3, while there is a significant decrease in S2, when we switch from no communication to horizontal communication ($Z = -2.875$ and $p = 0.004$ comparing S2 to S1, and $Z = -3.003$ and $p = 0.002$ comparing S2 to S3).[15]

4.2 Treatment effects: Within-subject Analysis

As observed based on the aggregate data, communication has had a negative effect, if any, on bids. Therefore, while horizontal communication has the expected output-restricting impact on bids, vertical communication does not lead to an enhancement of output. This is so, despite the fact that the agreed cheap talk outputs clearly reflect the intention of vertical agreements to enhance output and horizontal ones to restrict it. In fact, as can be seen in Figure 2, actual output (after period 20) has been similar irrespective of the mode of communication and significantly below the levels achieved in the later rounds of S1, in which learning alone is presumably the

[12]Results from a parallel risk-elicitation task suggest that the gender effect on bids may be due to gender differences in risk attitudes. The Sabater-Grande and Georgantzis (2002) lottery panel task (see Table A.2 in the Online Appendix) was implemented in a hypothetical format and individual choices confirmed both that females are more risk averse than males and that risk aversion leads to lower bids. Results from regression analysis confirming these findings are also provided in Table A.3 in the Online Appendix.

[13]Comparing the bids between S1 and S3 (mean bid S1= 12.7 and mean bid S3= 12.4 for periods 10 to 20) through a Mann-Whitney U test ($Z = 0.280$ and $p = 0.775$) the null hypothesis that the distributions are equal cannot be rejected.

[14]With a mean bid of S2= 4.7 for the periods 10 to 20, the comparison with the other two sessions using a Mann-Whitney U test results in the bids being significantly lower in S2 than in the other two sessions ($Z = -3.000$ and $p = 0.0027$ compared to S1, and $Z = -3.130$ and $p = 0.0017$ compared to S3).

[15]The mean for each ten-period block and the difference between means across blocks, for each session, can be found in Table A.1 in the Online Appendix.

only output enhancing factor.

Apart from the differences across sessions observed in the first ten periods, a difference seems to emerge from the ordering of vertical and horizontal subsessions. Namely, whereas horizontal communication has a strong negative effect on bids in S2, where it appears before vertical communication, the difference vanishes when the order is reversed in S3. In fact, a Wilcoxon matched-pairs signed-ranks test shows that vertical communication is characterized by higher bids than horizontal communication in S2 ($Z = -2.366$ and $p = 0.018$), but not in S3 ($Z = 1.352$ and $p = 0.176$). The mean increase in the bids from horizontal to vertical communication is 5.33 in S2 and 0.75 in S3, and this difference is statistically significant (Wilcoxom rank-sum test $Z = 2.492$ and $p = 0.012$).

Subjects' choice of communication mode in the endogenous communication periods (31-40) of S2 and S3 indicates that, on aggregate, there is no strong preference for any of the two modes. The vertical mode was preferred 57% of the time in S2 and 40% of the time in S3, this difference being only marginally significant ($Z = 1.729$ and $p = 0.083$). A possible explanation of this pattern can be traced to Figure 4, where we plot the evolution of agreed and actual median bids under the two communication modes.

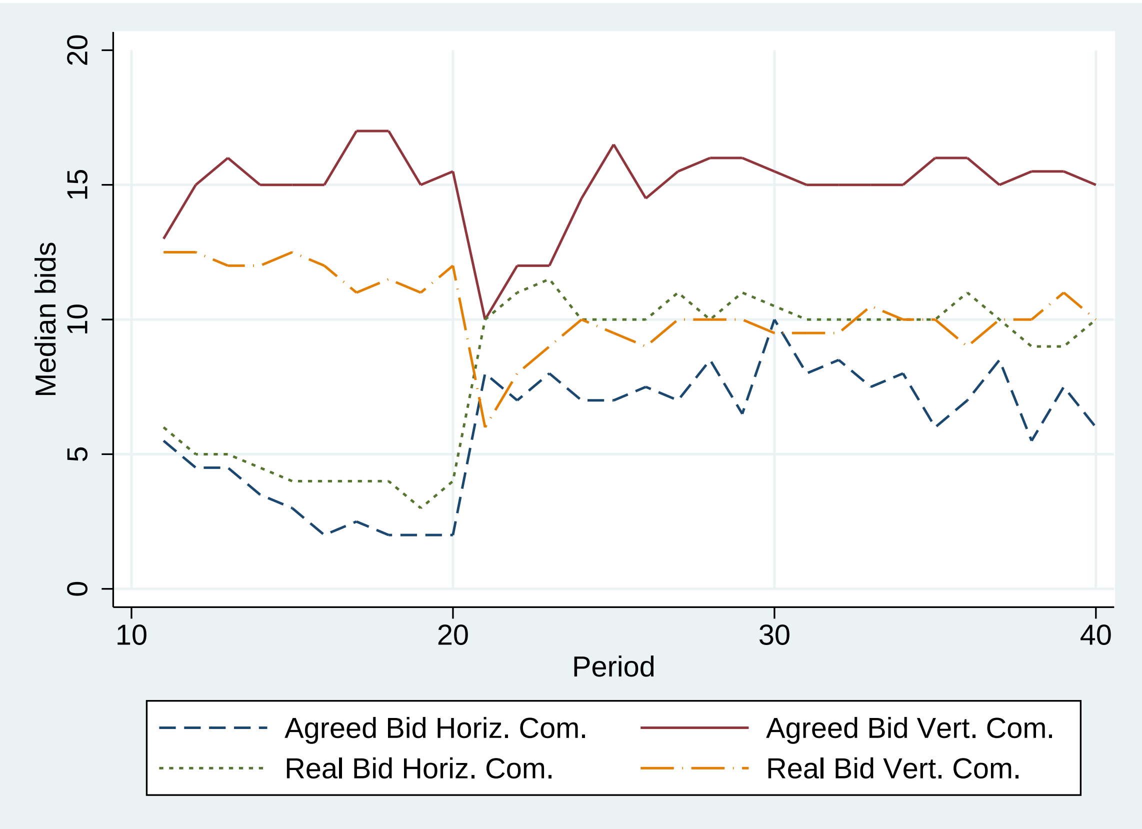

Figure 4: Evolution of median agreed and actual bids under the two communication modes. Both communication sessions S2 and S3 pooled together.

We observe that although both types of agreements were made in the predicted direction of output expansion under vertical and output restriction under horizontal communication, actual strategies have systematically deviated from the agreed ones in the expected direction: upwards from horizontal and downwards from vertical agreements towards bids of 10. Average agreed bids were 2.5 units lower than actual bids under horizontal communication and 3.1 units higher than actual bids under vertical communication. Deception, measured as the absolute value of the difference between agreed and actual bids, was larger under vertical than under horizontal communication, but this difference is significant only in S2 (Wilcoxon signed rank test $Z = -2.197$ and $p = 0.028$). Consequently, communication has not brought the desired and agreed results, eventually motivating subjects' lack of strong preference between the two communication modes.

The findings reported in the preceding paragraphs are further statistically supported by regression analysis. Table 1 presents the estimation of linear regression with robust standard errors adjusted for the 20 clusters formed by the independent matching groups. This correction allows us to take into account the contemporaneous correlation within the clusters.

The variables used in the regression are the following:

- *Current bid:* Individual bid of the current period. This is the dependent variable of the regression.
- *constant (T0):* The baseline chosen for the regression is the treatment without communication. The treatment dummies will reflect the difference in the average bid between the corresponding treatment and this baseline.
- *T1- Exog. Horizontal:* Dummy variable taking value 1 when the communication mode exogenously imposed is horizontal.
- *T2- Exog. Vertical:* Dummy variable taking value 1 when the communication mode exogenously imposed is vertical.
- *T3a- Endog. Horizontal:* Dummy variable taking value 1 when the communication mode endogenously chosen is horizontal.

- *T3b- Endog. Vertical:* Dummy variable taking value 1 when the communication mode endogenously chosen is vertical.
- *Session 2:* Dummy variable taking value 1 for Session 2 observations.
- *Session 3:* Dummy variable taking value 1 for Session 3 observations.
- *Period:* Period or round of the game.
- *Lagged bid:* Individual bid in the preceding period.
- *Feedback:* The interaction between individual previous period bid increase (or decrease) and previous period individual gains increase (decrease). It takes positive values for a successful bid increase or a failed bid decrease, while it takes negative values for a successful bid decrease or a failed bid increase in the previous period. This is a way of accounting for directional adaptive learning according to which a profitable raise (or fall) in the previous period is repeated whereas an unprofitable one is reversed.
- *Female:* Dummy variable which takes value 1 for female and 0 for male.

	Coef.	**Robust S.E.**	**t**	**P>|t|**	**95% Conf. Interval**
Constant (T0)	3.10	0.61	5.02	**0.000**	[1.80, 4.40]
T1- Exog. Horizontal	-1.09	0.31	-3.52	**0.002**	[-1.74, -0.44]
T2- Exog. Vertical	0.03	0.24	0.14	0.887	[-0.47, 0.54]
T3a- Endog. Horizontal	-0.90	0.41	-2.19	**0.041**	[-1.75, -0.04]
T3b- Endog. Vertical	-0.63	0.41	-1.52	0.144	[-1.49, 0.23]
Session 2	-1.00	0.50	-1.98	**0.063**	[-2.07, 0.05]
Session 3	0.00	0.54	0.01	0.993	[-1.13, 1.14]
Period	0.03	0.01	2.42	**0.026**	[0.00, 0.06]
Lagged Bid	0.73	0.03	21.20	**0.000**	[0.66, 0.81]
Feedback	0.024	0.003	7.84	**0.000**	[0.01, 0.03]
Female	-0.21	0.09	-2.35	**0.030**	[-0.40, -0.02]

Table 1: Least Squares Linear regression for Bids. The standard errors have been adjusted for 20 clusters according to the independent matching groups. Number of obs = 6,080; F(10, 19) = 324.12; Prob>F = 0.0000; R^2 = 0.69; Root MSE = 2.7947.

First of all, we confirm that learning had a strong exchange-enhancing impact. The positive coefficient of Period captures this increasing trend of the bids over time across sessions. Communication had a negative impact, if any, on bids. In fact, only horizontal communication had a negative effect on bids compared to the baseline, while vertical communication left them unchanged. According to the empirical model, a subject's own bidding history and feedback matter. Specifically, higher bids in the previous period predicted higher bids in the current period. Also, higher bids were posted if a subject had experienced a payoff increase (decrease) in the last period following a bid increase (decrease), and vice versa.

Female subjects have posted lower bids than males. This gender effect is compatible with gender differences observed in our subjects' risk-taking behavior (see Table A.3 in the Online Appendix). In fact, bids in S2 were lower than those in the other two sessions even after controlling for gender.

5 Conclusions

We have studied market games whose set of non-cooperative equilibria involve either minimum or no trade at all. In such markets, the conflict between individual and social optimality leads to a social dilemma. Duffy et al. (2011) show that if a market game has multiple equilibria, coordination occurs on the Pareto superior equilibrium. We have shown that, even in the absence of an equilibrium with intense trading, learning facilitates the way of human actions away from the non-cooperative equilibrium state of autarky in favor of intense, social welfare-improving trade. Moreover, two alternative treatments are run allowing for communication between agents on the same and across different sides of the market. Horizontal communication significantly restricts trade while vertical communication does not significantly promote it. Learning alone for sufficient periods in the absence of any communication seems to have the strongest exchange-enhancing effect.

Cooperative behavior in social dilemmas is usually attributed to the subjects' pro-social preferences. This explanation is certainly valid also in the type of market games studied here. However, the experimental literature has provided imperfect confirmation (Blanco et al., 2011) or even strong rejection (Burton-Chellew and West, 2013) of the hypothesis that cooperation in social dilemmas is due to some constant across-context pro-social preferences.[16]

Our results confirm the usual finding reported in other experimental studies on social dilemma games, regarding the existence of more pro-social behavior than would correspond to the Nash equilibrium. However, the typical finding of declining pro-social behavior in repeated social dilemmas and especially public good games (see for example, Neugebauer et al., 2009) is contradicted by our data. Rather than the declining trend usually obtained there, we observe an increasing trend of trade intensity. This might also indicate that the intensity of trade does not necessarily depend on intrinsic pro-social homegrown values of the subjects but from the learning process taking place during the experimental session.

Theory and experiments on the role of a grand coalition among all players in the market would constitute the natural extension of this study. It would then be interesting to check whether global cooperation could bring trade even closer to the social optimum than all bilateral communication protocols studied here and learning alone. Regarding extensions considering experimental markets with larger numbers of sellers and buyers, we conjecture that our results would hold a fortiori, as the increase in the number of agents could only shift behavior even closer to the outcome that exhausts the gains from trade.[17]

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[16]Despite that, the mainstream view is that cooperation in social dilemmas is the result of subjects' altruism or reciprocity (Camerer and Fehr, 2006; Fehr and Schmidt, 1999; Fehr and Gächter, 2002; Fehr and Fischbacher, 2003; Fischbacher and Gächter, 2010, etc.).

[17]This is due to the fact that our game with more agents of both types admits full trade as a Nash equilibrium. The interested reader is referred to Cordella and Gabszewicz (1998) for a detailed discussion of the issue.

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