University of Cyprus
Department of Economics

Working Paper 07-2015

Market Games as Social Dilemmas

Iván Barreda-Tarrazona, Aurora García-Gallego, Nikolaos Georgantzís and Nicholas Ziros

Department of Economics, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus
Tel.: +357-22893700, Fax: +357-22895028, Web site: http://www.ucy.ac.cy/econ/en

Market games as social dilemmas *

Iván Barreda-Tarrazona
Aurora García-Gallego
LEE & Department of Economics, Universitat Jaume I, Castellón, Spain
Nikolaos Georgantzís†
University of Reading, UK & LEE, Universitat Jaume I, Castellón, Spain
Nicholas Ziros
Department of Economics, University of Cyprus, Cyprus

Abstract

We study 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 the market. We implement a case in which the Nash equilibrium involves minimum exchange or no trade at all. This is almost never confirmed by our laboratory data. On the contrary, after a sufficiently large number of periods, convergence close to full trade is obtained, which can be supported as an epsilon symmetric strategy evolutionary stable equilibrium. We also study cheap talk communication within pairs of traders from the same (horizontal) and opposite (vertical) sides of the market. As predicted by the theory, horizontal communication restricts trade, whereas vertical communication leads to higher bids, but always lower or equal than those achieved tacitly by learning alone. Vertical messages limit the collusive effect of horizontal communication when the former precede the latter. Results do not differ when players are allowed to choose the communication mode.

Keywords: Efficiency, strategic market games, experiments, vertical communication, horizontal communication.

JEL codes: D43, C91, C73.

*The article has been greatly improved by comments from Maria Bigoni, Joaquin Coleff, Nobuyuki Hanaki, Charles Noussair, and conference participants at the 3rd Workshop on Industrial Organization in Alberobello, London Experimental Workshop 2014, Economic Science Association Meeting 2013 in Zurich, XXVIII Jornadas de Economía Industrial 2013 in Segovia, SAET Conference 2014 in Tokyo and ASSET Meeting 2014 in Aix-en-Provence. Financial support by the Spanish Ministry of Science and Innovation (project ECO2011-23634), the Spanish Ministry of Economics and Competitiveness (project ECO2013-44409-P) and the Bank of Spain Excellence Chair in Computational Economics (project 11I229.01/1) is gratefully acknowledged.

†Corresponding author: Nikolaos Georgantzís, Agriculture Policy and Development, University of Reading, n.georgantzis@reading.ac.uk, Tel. +441183787098.

1 Introduction

There is ample evidence from laboratory studies that decision makers tend to behave in a more prosocial way than would be predicted by the Nash equilibrium. This general pattern of human behavior has been observed in strategic contexts described as social dilemmas involving some conflict between individual and collective well-being. Such contexts include public good games, prisoner's dilemma, common pool resource extraction games, etc. It has been rarely noticed that markets for the exchange of goods and services may also lead to a social dilemma. Nevertheless, it has been recently observed by Duffy et al. (2011) that in laboratory market games human actions systematically avoid the emergence of a selfish, autarky equilibrium in favor of a Pareto superior Nash equilibrium with trade. This situation can be seen as a coordination game, rather than a social dilemma. In this paper, we study a class of market games in which a unique no-trade or minimum-trade equilibrium exists while maximization of social welfare requires full trade. In this context, 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.

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 bundles of goods. In more occasions than is often thought, trade may occur in the absence of money. For example, during the ongoing crisis in Greece, the absence of cash due to the closed banks forced many people to directly exchange second hand products. Also, several exchange markets exist on line 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 the economy by independently deciding the amount of money and products to be supplied into the market, determine the relative prices of goods and money.

This paper implements an experimental exchange market based on the theory of strategic market games, defined in the prototype models of Shubik (1973) and

Shapley and Shubik (1977), which has been extensively used in providing a non-cooperative foundation to perfect competition.[1] These games are derived by means of a strategic outcome function, which determines the distribution of goods as a function of the distribution 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. Moreover, an inconvenient feature of strategic market games is the persistence of no-trade (i.e., autarky) as a Nash equilibrium even in games with a large number of players or in models where the initial allocation of resources is not Pareto efficient. The initial scope of this inquiry is to test the theory by examining whether no-trade emerges in the lab.

For this purpose, we have designed an experiment based on the '*bilateral oligopolies*' paradigm in Cordella and Gabszewicz (1998) that has the exceptional property that under some conditions the *unique* Nash equilibrium is the case where all agents abstain from trading. That paradigm considers corner endowments and constitutes the most natural framework to use when prices are affected by the actions of all market participants. Moreover, we believe that the setup adopted here has many analogies to real-world situations as many markets operate with a small number of sellers and buyers, each of whom has enough power to influence market outcomes with her supplied quantities (in terms of a good or money). One such example is an input market with a small number of upstream and downstream firms, where both sides of the market want to extract increased profits by compressing the payoffs of the other side. Under such circumstances of intense competition, we often observe very low (and inefficient) levels of output, which are of course consistent with the theory studied here.

Concerning its scope, our work complements that of Duffy et al. (2011).[2] These authors report strong evidence that human subjects systematically avoid the no-trade equilibrium in favor of the alternative *good* equilibrium which, in their case, is an

[1]Indeed, it has been shown in various cases that, as the number of market participants increases, the set of Nash equilibria (of most strategic market game models) converges to some subset of the set of Walrasian equilibria, or in other words, the volume of trade converges to competitive levels. 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]Which, together with Huber et al. (2010) are, to the best of our knowledge, the only experimental approaches to strategic market games.

interior one with trade. Furthermore, they have proposed an evolutionary-theoretic explanation for their findings.[3] Contrary to that work, in our model the sub-optimal minimum and no-trade equilibrium are the only theoretical predictions under non cooperative behavior. However, despite the absence of a *good* equilibrium and the low number of agents per market ($n = 4$), we find strong convergence of the quantity bids towards the Walrasian equilibrium of the economy. In fact, surprisingly high levels of efficiency are achieved towards the last (40th) period of the experiment, suggesting that a sufficient level of learning is necessary for such a high degree of efficiency to be achieved in this context.[4] Following this result, the (co-)existence of a *good* equilibrium does not seem to be a necessary condition for subjects to coordinate away from low levels of trade.

Duffy et al. (2011) demonstrated that an increase in the number of traders pushes outcomes towards Walrasian allocations. In this paper, instead of increasing the number of traders, we allow for 'cheap-talk' communication among subjects, which, we believe, is a way of mitigating the uncertainty about the thickness of markets and the influence of other players on the market outcome.[5] We are motivated in this by the fact that it has been conjectured by many (e.g., in Mas-Colell, 1982) that some minimal amount of cooperation among agents is needed in order to get trade started. Moreover, our approach resembles a real-world situation, as casual observation suggests that it is very often the case that groups of individuals (or firms) coordinate their actions in order to turn the resulting market prices in their favor. 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 agreements on their market strategies, although the agreements are not binding and are usually not respected by the partners.

This is one of the few occasions in which horizontal and vertical cooperation can be studied and be 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

[3]See also, Samuelson (1997).

[4]Duffy et al. (2011) had allowed for 25 rounds.

[5]An interesting discussion on the relation between communication and market uncertainty can be found in Crawford (1998).

studied,[6] 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 exhibit that horizontal cartels have the expected output-reducing effect as would be predicted from standard wisdom on quantity-setting collusion.[7] On the other hand, vertical partnerships lead to higher output than horizontal ones and they limit the collusive effect of horizontal agreements when agents are first exposed to the former and then to the latter. However, vertical communication increases output initially to similar levels to those achieved tacitly by learning alone in the absence of communication, however, in latter periods vertical communication output levels lag well behind tacit coordination ones. These patterns persist when subjects are allowed to choose the communication mode, and none of the two alternatives seems to be preferred by the players or affect behavior compared to the exogenous communication mode case.

Finally, our experimental evidence has revealed some interesting behavioral effects. By testing subjects' risk attitudes we obtain that risk aversion leads to lower levels of exchange. In other words, even more trade could have been observed in a population of risk-neutral agents. Turning to gender effects, we observe that female subjects trade less, whereas males in the non-communication treatment achieve almost perfect convergence to the Walrasian allocation. Males were also found to make full-trade proposals when communicating with players of the other type, although they are especially prone to deviate from their promises under this mode of communication. Males have also exhibited a moderate preference for horizontal cartels, whereas females have preferred forming vertical ones.

The remainder of the paper is organized as follows. The next section describes the theoretical model. Section 3 outlines the experimental design, Section 4 presents a numerical example with the parameters of our design and Section 5 presents and discusses the experimental evidence. Section 6 summarizes our conclusions.

[6] 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. (2014), and Waichman et al. (2014) for quantity competition games à la Cournot; Andersson and Wengström (2007), Fonseca and Normann (2012) for price compeition games à la Bertand; Brown-Kruse, Cronshaw and Schenk (1993), and Brown-Kruse and Schenk (2000) for spatial competition games à la Hotelling.

[7] And documented since early experimental studies, like Isaac and Plott (1981).

2 Theoretical framework

In order to help the readers with the rules of the experiment, we first describe how trade takes place in our bilateral oligopoly setup. The exchange economy consists of two goods x, y and an even number of agents, n, falling into two groups of equal size. The two agent types are distinguished by endowments and preferences. Each agent i of Type I is endowed with w units of good x and zero units of good y, whereas each agent j of Type II 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 respectively of a single good (say, y). Preferences for the two types of agents are described by the following utility functions:

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

for Type I agents and

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

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

It is easy to check that the Walrasian equilibrium 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, with the associated price ratio between the two goods being equal to one. That is, each unit of good x would be exchanged for one unit of good y. In our setup, this allocation would require that each agent exchanges the whole of her endowment, w, for equal number of units of the good that she does not initially possess.

The associated market game $\Gamma(n)$ for this economy is described as follows. There is a single market where agents send their quantity bids, that is each Type I agent may offer an amount q_i of good x in exchange for good y and each Type II agent may offer an amount q_j of good y in exchange for good x. The strategy sets are $S_i = \{q_i \in \Re_+ | 0 \leq q_i \leq w\}$ for Type I agents and $S_j = \{q_j \in \Re_+ | 0 \leq q_j \leq w\}$ for Type II agents.

We also define $Q^I = \sum q_i$, $Q^{II} = \sum q_j$ as the sum of bids by Type I and Type II agents respectively, $Q^I_{-i} = Q^I - q_i$ as the sum of bids by all Type I agents other than individual i and $Q^{II}_{-j} = Q^{II} - q_j$ as the sum of bids by all Type II agents other than individual j.

Given a profile of bids, the relative price or price-ratio of the two goods when both Q^I and Q^{II} are strictly greater than zero is:

$$p = Q^I / Q^{II}$$

while $p = 0$ otherwise, and the final allocations of the two goods are:

$$(x_i, y_i) = (w - q_i, q_i/p)$$

for Type I agents and

$$(x_j, y_j) = (pq_j, w - q_j)$$

for Type II agents, where divisions over zero in the above expressions are taken to be equal to zero.

The interpretation of this allocation mechanism is that the supplied quantities of the two goods are distributed among traders in proportion to their bids.

2.1 The equilibrium notions

The standard equilibrium notion employed in strategic market games is that of a Nash equilibrium. The definition of a Nash equilibrium for our game is as follows.

Definition 1 *A Nash equilibrium is a strategy profile* $(q_i^*; q_j^*) \in \Pi S_i \times \Pi S_j$ *such that for any Type I agent,*

$$\beta(w - q_i^*) + q_i^*(Q^{II*}/Q^{I*}) \geq \beta(w - q_i) + q_i \left(\frac{Q^{II*}}{Q^{I*}_{-i} + q_i} \right) \text{ for all } q_i \in S_i,$$

and for any Type II agent,

$$q_j^*(Q^{I*}/Q^{II*}) + \beta(w - q_j^*) \geq q_j \left(\frac{Q^{I*}}{Q^{II*}_{-j} + q_j} \right) + \beta(w - q_j) \text{ for all } q_j \in S_j.$$

Hence, agents of Type I are viewed as solving the following problem:

$$\max_{q_i \in [0,w]} \beta(w - q_i) + q_i(Q^{II}/Q^I)$$

whereas agents of Type II are viewed as solving the following problem:

$$\max_{q_j \in [0,w]} q_j(Q^I/Q^{II}) + \beta(w - q_j)$$

The derivatives of the objective functions with respect to the strategic variables are:

$$\frac{\partial u_i}{\partial q_i} = \frac{\partial u_i}{\partial x_i}\frac{\partial x_i}{\partial q_i} + \frac{\partial u_i}{\partial y_i}\frac{\partial y_i}{\partial q_i} = -\beta + \frac{Q^{II}(Q^{I}_{-i})}{(Q^I)^2}$$

for Type I agents, and

$$\frac{\partial u_j}{\partial q_j} = \frac{\partial u_j}{\partial x_j}\frac{\partial x_j}{\partial q_j} + \frac{\partial u_j}{\partial y_j}\frac{\partial y_j}{\partial q_j} = \frac{Q^{I}(Q^{II}_{-j})}{(Q^{II})^2} - \beta$$

for Type II agents.

As proved in Cordella and Gabszewicz (1998) the number and the type of Nash equilibria of the game depend on the value of β and the number of agents. Indeed, if we substitute q_i and q_j with w (i.e., the level of bids that gives rise to the competitive outcome) into the last expressions, we get:

$$-\beta + \frac{(w\frac{n}{2})(w\frac{n}{2} - w)}{(w\frac{n}{2})^2} = -\beta + \frac{n-2}{n}$$

In this case, we have that the profile of competitive bids and no-trade both serve as Nash equilibria if $\beta \leq (n-2)/n$. On the other hand, no-trade is the unique Nash equilibrium if $\beta > (n-2)/n$.

Taking into account the results in Duffy et al. (2011), we also study the evolutionary stable behavior of agents. According to this approach, deviations by coalitions of at most one agent of each type are allowed and a given strategy profile fails to serve as a strong evolutionary strategy (*SESS)* equilibrium if at least one of the deviant agents is better off relative to the other agents of her type, given that at most one agent per type deviates. In other words, a strategy profile is a *SESS* if there exists no deviating coalition (with one agent per type) such that at least one member of the coalition always becomes better off after trading relative to any non-deviant agent of her type.

Consider a specific strategy profile $(q_i; q_j) \in \Pi S_i \times \Pi S_j$, and suppose that there is a coalition consisting of one agent per type, deviating from $(q_i; q_j)$ by playing $\hat{q}_i$ and $\hat{q}_j$ respectively. Given these strategies we denote by $\hat{Q}^I = Q^I_{-i} + \hat{q}_i$ the situation where one Type I agent plays $\hat{q}_i$ while every other Type I agent plays q_i, and $\hat{Q}^{II} = Q^{II}_{-i} - \hat{q}_j$ the situation where one Type II agent plays $\hat{q}_j$, while every other Type II agent plays q_j. Then, the payoff of the Type I deviant agent is $\beta(w - \hat{q}_i) + \hat{q}_i(\hat{Q}^{II}/\hat{Q}^I)$, the payoff of a Type I non-deviant agent is $\beta(w - q_i) + q_i(\hat{Q}^{II}/\hat{Q}^I)$, the payoff of the Type II deviant player is $\hat{q}_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - \hat{q}_j)$ and the payoff of a Type II non-deviant player is $q_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - q_j)$.

In this context, a profile of strong evolutionary stable strategies is defined as follows.

Definition 2 *A SESS is a symmetric strategy profile* $(q_i; q_j) \in \Pi S_i \times \Pi S_j$ *such that for any type I agent,*

$\beta(w - q_i) + q_i(\hat{Q}^{II}/\hat{Q}^I) \geq \beta(w - \hat{q}_i) + \hat{q}_i(\hat{Q}^{II}/\hat{Q}^I)$ *for all* $\hat{q}_i \in S_i$, $\hat{q}_j \in S_j$,

and for any type II agent,

$q_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - q_j) \geq \hat{q}_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - \hat{q}_j)$ *for all* $\hat{q}_i \in S_i$, $\hat{q}_j \in S_j$.

We also study an approximate version of strong evolutionary stable strategies (approximate *SESS* or ϵ-*SESS*). The interpretation of this notion is that a profile of strategies is ϵ-*SESS* if no deviation by at most one agent of each type results in a 'substantially' preferred outcome for one of the two deviants relative to her non-deviant peers.

Definition 3 *An ϵ-SESS is a symmetric strategy profile* $(q_i; q_j) \in \Pi S_i \times \Pi S_j$ *such that for any Type I agent,*

$\beta(w - q_i) + q_i(\hat{Q}^{II}/\hat{Q}^I) \geq \beta(w - \hat{q}_i) + \hat{q}_i(\hat{Q}^{II}/\hat{Q}^I) - \epsilon$ *for all* $\hat{q}_i \in S_i$, $\hat{q}_j \in S_j$ *and* $\epsilon > 0$,

and for any Type II agent,

$q_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - q_j) \geq \hat{q}_j(\hat{Q}^I/\hat{Q}^{II}) + \beta(w - \hat{q}_j) - \epsilon$ *for all* $\hat{q}_i \in S_i$, $\hat{q}_j \in S_j$ *and* $\epsilon > 0$.

The following result, shows that in our model no deviation from the competitive outcome can provide sufficiently greater payoff for one member of the deviating coalition relative to the other non-deviant agents of the same type.

Proposition 1 *For any number $\epsilon > 0$, there exists $n > 2$ such that the competitive profile of offers is an ϵ-SESS of the strategic market game $\Gamma(n)$.*

Proof. Fix any positive number $\epsilon > 0$.

Consider now a deviation from the competitive profile of bids by a coalition consisting of only one agent of each type, where $\tilde{q}_i$ is the bid of the Type I deviant and $\tilde{q}_j$ is the bid of the Type II deviant. These bids should maximize the difference between the utility of one of the two deviants (say Type I) and the average utility of the other agents of her type who do not deviate. In that case, the utility of deviant Type I agent is $\beta(w-\tilde{q}_i)+\tilde{q}_i\left(\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)$, whereas the utility of a non-deviant Type I agent is $w\left(\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)$ and their difference is

$$\beta(w-\tilde{q}_i)+\tilde{q}_i\left(\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)-w\left(\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)$$
$$=\beta(w-\tilde{q}_i)-(w-\tilde{q}_i)\left(\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)$$
$$=(w-\tilde{q}_i)\left(\beta-\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right).$$

Because $0<\beta<1$, it follows that there exists $n>2$ such that

$$(w-\tilde{q}_i)\left(\beta-\frac{(\frac{n-2}{2})w+\tilde{q}_j}{(\frac{n-2}{2})w+\tilde{q}_i}\right)\leq\epsilon.\ \blacksquare$$

At this point, it should be noted that the objective of the coalition is not to maximize the utility of the Type I deviant, but rather to maximize the difference between her utility and the average utility of a non-deviant of her type.[8] As a result, such behavior might yield utility levels for the deviants that are much lower than the competitive outcome, so the actual formation of such a deviating coalition is in question. This fact becomes clearer in the numerical example in Section 4.

The next result exhibits that playing no-trade is not evolutionary stable as there is always a coalition (with one agent per type) that opens the market, making at least one agent better off than the others of her type who choose not to trade.[9]

Proposition 2 *No-trade is not a SESS of the strategic market game* $\Gamma(n)$.

Proof. Let the market be closed and consider a deviating coalition consisting of one agent per type. Without loss of generality we consider that the bid of the Type II deviant is maximally helpful for the deviating agent of Type I. In that case, the deviating Type I agent offers γ units of unit x (that is the lowest possible subdivision of good x) and the deviating Type II agent offers w units of good y. For this profile of offers, the Type I deviant obtains utility $\beta(w-\gamma)+w$, the utility of any non-deviant agent of her type is βw and their difference is $\beta(w-\gamma)+w-\beta w=w-\beta\gamma>0$.

[8]This kind of behavior is usually termed as spiteful. See Schaffer (1988) for details.

[9]Of course, one can always find a deviating coalition such that both deviants are better off than their non-deviant peers.

Hence, there is always a deviating coalition that results in a preferred outcome for one of its members. ■

Hence, like in Duffy et al. (2011), the evolutionary approach predicts the opening of markets with agents submitting positive (and significantly greater than zero) bids.

2.2 Pre-play communication

Although pre-play 'cheap-talk' communication has no direct effect on the outcomes of a game, it has been extensively reported that it may affect the behavior of experimental subjects. To study the changes on individual behavior and on final outcomes of the strategic market game, we suppose that agents are allowed to communicate and to reach non-binding agreements about their bids before trade takes place. In particular, we examine both the case of communication between agents of the same type, for which we use the term '*horizontal communication*' and communication between 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 agreements among agents of the same type should involve identical bids. Moreover, because we have communication between agents that are on the same side of the market, the setup resembles collusion in the classical quantity-setting Cournot oligopoly. In that sense, collusive behavior dictates that any agreements should involve reduced quantities (the smaller possible positive bids) so as to extract the maximum gains for the cartel. It is also obvious that no agent will break an agreement involving no-trade by submitting a positive bid if agents of the other type also agree on submitting zero bids. If we, however, consider the evolutionary stability approach discussed earlier, then there is always benefit from breaking an agreement of submitting zero bids. Indeed, similarly to the proof of Proposition 2, there could always be a profitable deviating coalition, with one agent of each type, where its members submit positive bids of good x and y in the market.

For the case of vertical communication, we consider that sub-groups of traders (with the same number of agents of each type) are allowed to make non-binding agreements about their quantity bids. As agents of both types face symmetric problems, smaller bids from one side of the market will result to inferior results for the other side. Hence, any agreement among agents of both types should involve identical bids. Moreover, in order to exhaust the total gains from trade we should expect that the agreements should involve large offers or to be more precise, the largest possible bids (full trade), which in our case give rise to competitive allocations. However, for markets with small number of agents, full trade does not constitute a Nash equilibrium (for values that satisfy $\beta > (n-2)/n$).

3 Experimental design

The experiment was run using the z-Tree program (Fischbacher, 2007) at the Laboratorio de Economía Experimental (LEE) at the Universitat Jaume I in Castellón (Spain). A total of 160 subjects participated in the experiment during three sessions, S1, S2 and S3, of 48, 56 and 56 experimental subjects, respectively. In each session, subjects were grouped in independent matching groups of 8 players each. In each period, players of the same matching group were randomly assigned to form markets of 4 agents (two of each type). This design implies that we get 6 totally independent observations in S1 (12 markets per period), and 7 observations (14 markets per period) in S2 and S3. Each session lasted 40 periods.

In each period, agents send quantity bids to a market for two goods, X and Y. Types, denoted as Type I and Type II, have different endowments and preferences. The relative market price of the two goods is the inverse of the total quantity ratio. Endowments, bids and subsequently relative prices determine each agent's utility.

At the beginning of each period, each subject is paired in a random and anonymous way with other three 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. 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 have the same probability of occurrence.

Initial endowments are different for each type of player. Subjects of Type I start each period with an initial endowment of 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. Decisions are made simultaneously.

Subjects choose the amount of own commodity that each one of them wants to exchange with the rest of the subjects in the same market. In order to understand how a certain combination of the four members' decisions may 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 natural numbers between 0 and 20.[10] If an 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.

Before the experimental session started, subjects received specific printed instructions individually and, after several minutes, instructions were also read aloud by the experimentalist.[11]

Four treatments, T0 to T3, were implemented in three sessions, S1-S3. The baseline treatment, T0, was run throughout session S1. Subjects submitted bids over 40 periods and no communication was allowed. The other two sessions consisted 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 was changed across sessions S2 and S3, with T1 preceding (following) T2 in S2 (S3). In T1, subjects could communicate with the other participant of the same type in her market. We will refer to this protocol as 'horizontal communication'. In T2, communication was allowed with a participant of the other type in the same market. We refer to this protocol as 'vertical communication'. Finally, in treatment T3 subjects could vote for their preferred communication mode. Then, one of the four votes was randomly selected. The way in which subjects had the possibility to communicate was a structured chat through which subjects could sequentially send specific quantities to the other subject and reach a non-binding agreement.[12]

[10]It is easily understood from the theory in Section 2 and the numerical example in Section 4 that implementing a continuous rather than a discrete version of the model has no essential effect on individual behavior or market outcomes, but surely makes calculations harder and more time-consuming for the subjects. For this reason we have chosen the latter in our experimental design.

[11]The instructions to subjects, translated from Spanish, can be found in the Appendix.

[12]One of the two communicating agents was randomly selected as the one sending the initial proposal. The proposal was a number between 0 and 20. If the other agent accepted the proposal, communication ended. But if she rejected, she had to introduce a new proposal to be sent back for the other agent to accept. This sequence could last as long as they needed to agree on a common

At the end of each period, subjects received information concerning the individual and total quantities of commodities X and Y offered for trade by all participants in a market. They also received information on final amounts of both commodities and the payoffs for each participant in their market after trade took place. Then, subject's own payoff in ExCU was calculated for that period.[13] In the instructions, subjects were presented with two tables reporting, for each type of agent, the earnings in ExCUs for specific combinations of quantities. If the subject decided not to trade, this would imply that, at the end of the period, she would enjoy the utility corresponding to the initial endowment.

Subjects were paid individually in cash at the end of the session. At the end of the last period, the system randomly chose 12 periods, three of each block of 10 periods in which the session was divided, and added up the earnings in ExCUs that each subject obtained in those selected periods. To that amount, an equivalence factor was applied of 1 ExCU=0.1 Euro and then the final payoff in Euro was calculated by the system and appeared in each subject's screen. Average payoff was approximately 18 Euros after approximately 2 hours of play.

4 Numerical example

In this section we consider the market game with the parameterization of our experimental design. The exchange economy consists of four agents, with agents $i = 1, 2$ of type I possessing twenty units of good x and zero units of good y, and agents $j = 3, 4$ of type II possessing twenty units of good y and zero units of good x.

For $\beta = 0.6$ the corresponding utility functions are

$$u_i(x, y) = 0.6x + y \qquad \text{for } i = 1, 2 \text{ and}$$

$$u_j(x, y) = x + 0.6y \qquad \text{for } j = 3, 4.$$

According to the Nash behavior, Type I agents are viewed as solving the problem:

$$\max_{\hat{q}_i \in [0,20]} 0.6(20 - \hat{q}_i) + \hat{q}_i \left(\frac{q_3 + q_4}{q_{-i} + \hat{q}_i} \right)$$

and Type II agents are viewed as solving the problem:

quantity.

[13]Experimental Currency Units.

$$\max_{\hat{q}_j \in [0,20]} \hat{q}_j \left(\frac{q_1 + q_2}{q_{-j} + \hat{q}_j} \right) + 0.6(20 - \hat{q}_j).$$

In this example, it can be easily checked that no-trade is a Nash equilibrium, because a zero bid is an agent's best response to the zero bid of the other three agents. However, it should be noted that if the participants' bids are restricted to be integers, as in our experiment, the strategy profile $(q_1, q_2, q_3, q_4) = (1, 1, 1, 1)$ that involves minimum trades also serves as a Nash equilibrium. Concerning the competitive equilibrium, a substitution of the values $q_i = q_j = 20$ into the first derivatives of the above objective functions yields negative values. Therefore, the strategy profile $q_i = q_j = 20$ is not a Nash equilibrium, as each agent can increase her payoff by decreasing her level of bids. In fact, if all other players choose $q_i = q_j = 20$ then the best response of a Type I agent is $\hat{q}_i = 16.515$. Now, if we restrict bids to be integers we see that the best responses of a Type I agent (when all other players choose full trade) are $\hat{q}_i = 16$ or $\hat{q}_i = 17$, as both of them yield equal utility levels.

Turning now to the evolutionary stable behavior, submitting zero bids cannot be an ϵ-*SESS* for any $\epsilon \in [0, 20)$, as proved in Proposition 2. Therefore, in contrast to the unique Nash prediction for autarky, the evolutionary approach predicts positive bids, a fact that is also supported by our experimental findings. For the competitive profile of bids $q_i = q_j = 20$, if a coalition (consisting of one agent of Type I and one agent of Type II) is formed and if we further assume that the deviation of the Type II deviant is maximally helpful for the deviating Type I, we have the following problem:

$$\max_{0 \le \tilde{q}_i, \tilde{q}_j \le 20} 0.6(20 - \tilde{q}_i) + \tilde{q}_i \left(\frac{20 + \tilde{q}_j}{20 + \tilde{q}_i} \right) - 20 \left(\frac{20 + \tilde{q}_j}{20 + \tilde{q}_i} \right)$$

with $\tilde{q}_i$ being the deviation of the Type I deviant and $\tilde{q}_j$ being the deviation of the Type II deviant.

Numerically solving the problem we derive that $\tilde{q}_j = 0$ and $\tilde{q}_i = 16.515$. Substitution of these deviations into the utility functions yields a level of utility equal to 11.137 for the Type I deviant and a level of utility equal to 10.954 for the Type I non-deviant. Hence, the utility of the deviant of Type I is higher by the amount of 0.183 as compared with the utility of the other Type I agent who played the agreed strategy. Therefore, for any $\epsilon \geq 0.183$, the competitive profile of bids constitutes an ϵ-*SESS*.[14] If we now restrict bids to be integers, then $\tilde{q}_j = 0$ and $\tilde{q}_i = 16$ or $\tilde{q}_i = 17$ yield that the utility of the deviant of Type I is higher by the amount of 0.18 as compared with the utility of the other Type I agent who played the competitive bid.

5 Results

In this section, we discuss the experimental results. In order to have an overview of our empirical findings, we focus first on the graphical representation of the data.

As a first approach to the aggregate behavior observed throughout the experiment, we refer first to Figure 1. Observe that the zero-trade non-cooperative prediction of the static Nash equilibrium has received almost no support at all, being the least frequently chosen bid among all the strategies available to the subjects. Unit bids are the second least frequent bid. On the contrary, full trade (20 units) has been among the most frequently chosen strategies, following 10-unit and 7-unit bids which have been the two most frequent. 15-unit bids is the fourth most frequent option, indicating some attraction to prominent numbers like 10, 15 and 20.

To see the underlying dynamics, Figure 2 presents the evolution of median bids in the absence of any pre-play agreement or communication (Session 1). The figure shows a clear increasing trend of trading which gradually converges close to the Walrasian full trade allocation. Recall that, in our framework, there is no interior Nash equilibrium with significant trade. Thus, unlike in the setup used by Duffy et al. (2011), the intense trading behavior observed here cannot be attributed to some attraction towards an interior non-cooperative equilibrium. Instead, an explanation of the attraction towards almost full trade in S1, can be supported by the evolutionary model presented in the theoretical section, according to which (Propositions 1 and 2) full trade is predicted in our experimental setting while no-trade is not. Furthermore, as will be argued based on the econometric analysis presented below, the dynamics of bids towards the observed high volumes of trade is also compatible with some degree of subjects' adaptive learning from past strategies. Given the shorter horizon of the experiments by Duffy et al. (2011) as compared to our sessions (25 rounds versus 40,

[14] As pointed out earlier, the coalition's objective is to maximize the difference between the Type I deviant and the utility of the non-deviant agent of her type. However, in our example this kind of behavior leads to utility levels for the deviants (11.137 and 12 respectively) that are significantly lower to those corresponding to the competitive allocations (20).

respectively), we conjecture that a longer learning process helps the market converge closer to the Walrasian outcome than was found in their article. Specifically, referring to Figure 3, if we focus on the individual bids in matching groups 1-6, corresponding to Session 1, we can see 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.

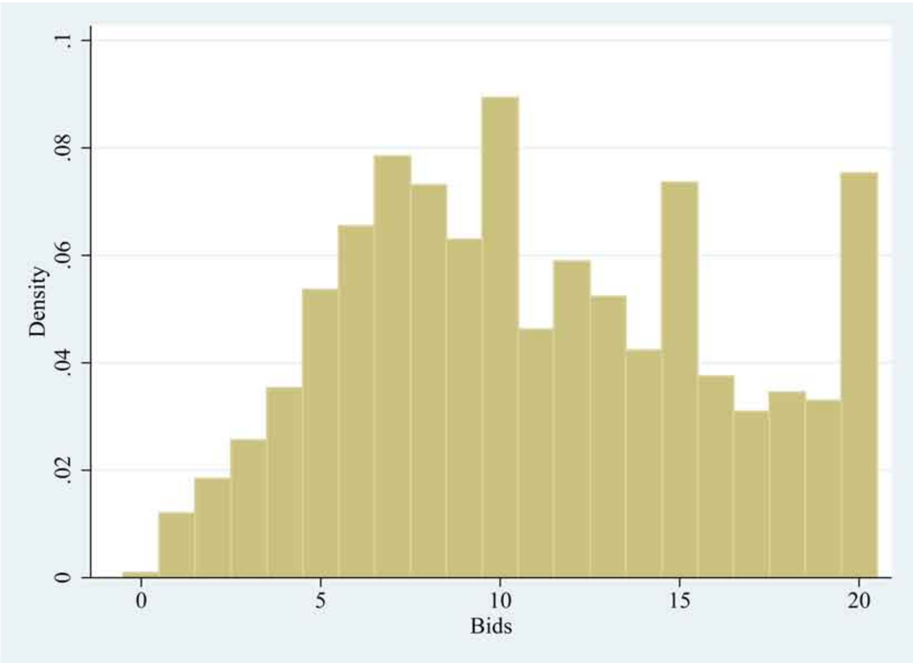

Figure 1: Frequency of bidding strategies (all sessions, all periods).

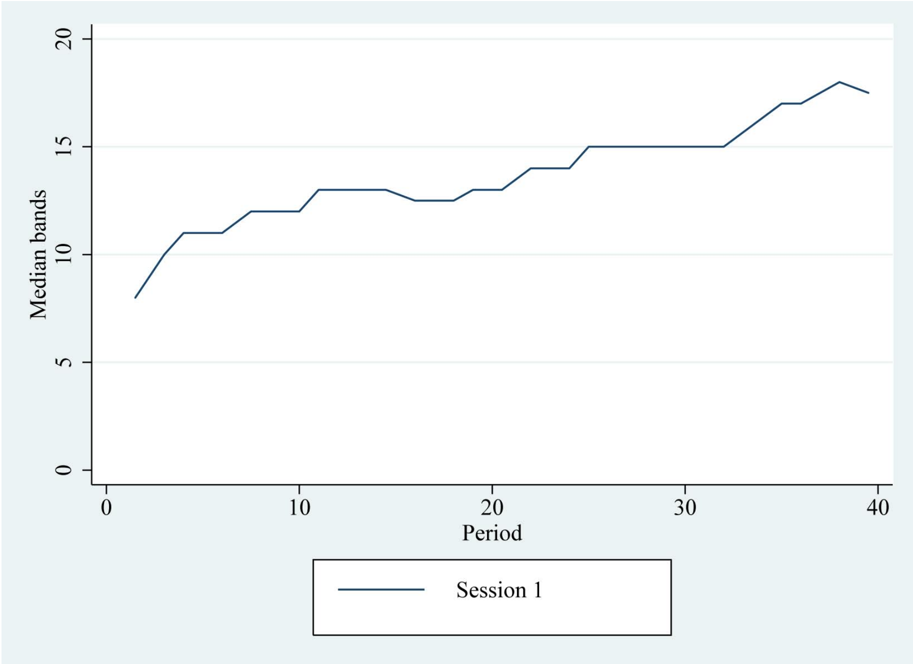

Figure 2: Session 1: Evolution of period median bids.

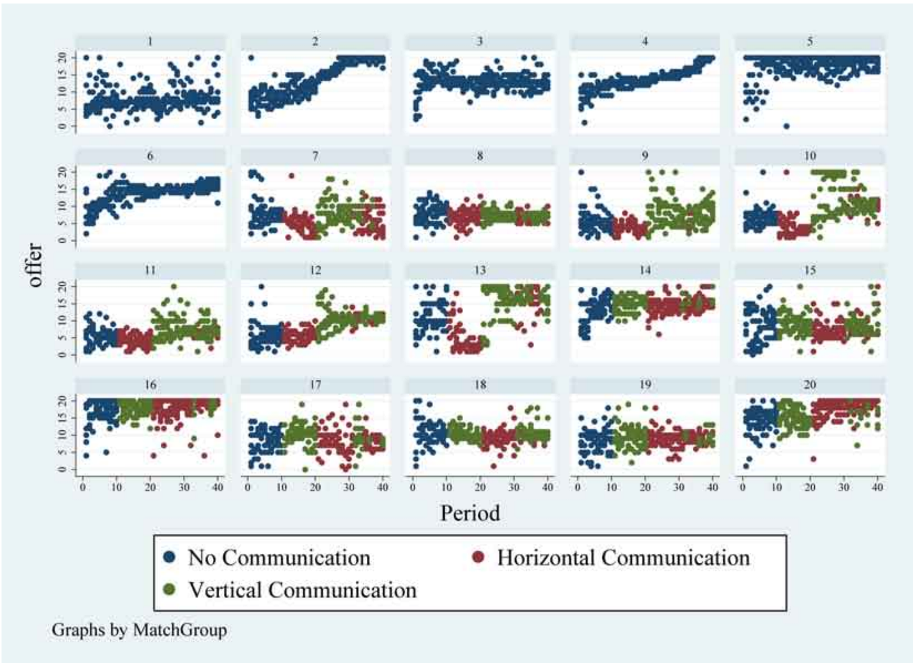

Figure 3: Evolution of individual bids by matching group (S1, groups 1-6; S2, 7-13, S3, 14-20).

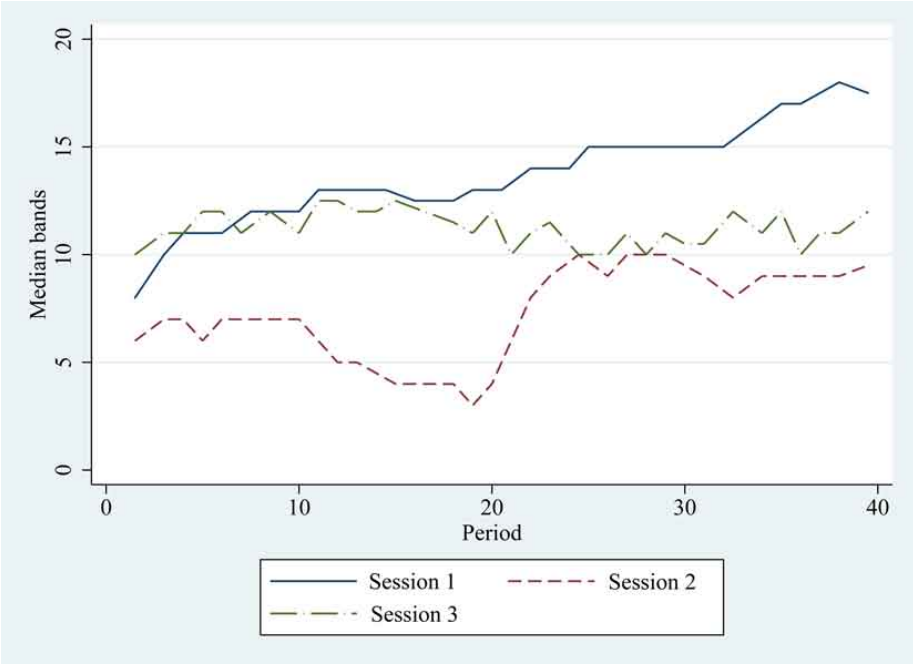

Figure 4: Sessions 2 (Horizontal-Vertical-Endogenous Communication) and 3 (Vertical-Horizontal-Endogenous Communication) against Session 1. Evolution of period median bids

We explain now Figure 4 in detail. We plot sessions S2 and S3 against the *learning-only* session, S1. The second 10-period subsessions of S1 and S3 are not different from each other, indicating that following the first 10 learning rounds, vertical communication (S3) and further learning (S1) have similar effects. Comparing the median bids in both cases (median bid S1= 13 and median bid S3= 12 for the comparable periods 10 to 20) the result of a Mann-Whitney U test is that we obtain $Z = -0.772$ and $p = 0.440$, hence, we are not being able to reject the null hypothesis that they are equal. This means that learning *and* vertical communication did not have any further effect beyond what learning alone did. On the contrary, the second 10-period horizontal communication interval of Session 2 shows a sharp decline of the bids. With a median bid of S2= 4 again 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 ($Z = -8.506$ and $p = 0.000$ compared to S1, and $Z = -8.963$ and $p = 0.000$ compared to S3). Similarly, a decline is also observed in the third 10-period horizontal communication interval of S3. Both cases, confirm the output-restricting prediction of horizontal collusion in this framework. Vertical communication in the third 10-period interval of S3 has a trade-enhancing effect, but bids do not get close to the corresponding *learning alone* bids of S1. In other words, the order in which subjects are exposed to the two communication protocols matters, with horizontal communication mitigating the effect of vertical communication when the former precedes the latter and vice versa. That is, bids have always been significantly higher in S3, where vertical communication precedes horizontal communication, both in the case of vertical (Mann-Whitney $Z = -8.512$ and $p = 0.000$) and horizontal communication (Mann-Whitney $Z = -3.661$ and $p = 0.000$). Finally, the endogenous choice of communication mode (vertical vs horizontal) causes similar effects to those observed when the mode was exogenously imposed. In this case, the exogenous order of communication mode that they have experienced before continues to play a role, given that the last 10 periods of S2 and S3 are still statistically different from each other (Median bids of S2= 9 and Median bids of S3= 11, Mann-Whitney $Z = -4.02$ and $p = 0.000$, Median bids of S1= 17 are much higher in the last 10 periods.).

Summarizing, no communication bids are above the corresponding bids of all other treatments, except for the case of the second 10-period interval of S3 in which learning and vertical communication has been as efficient as learning alone (of S1). And vertical communication induces higher bids than horizontal communication, creating a persistent effect.

To see the effect of communication on bids, Figures 5 presents the data, aggregated across sessions and periods, by communication mode.

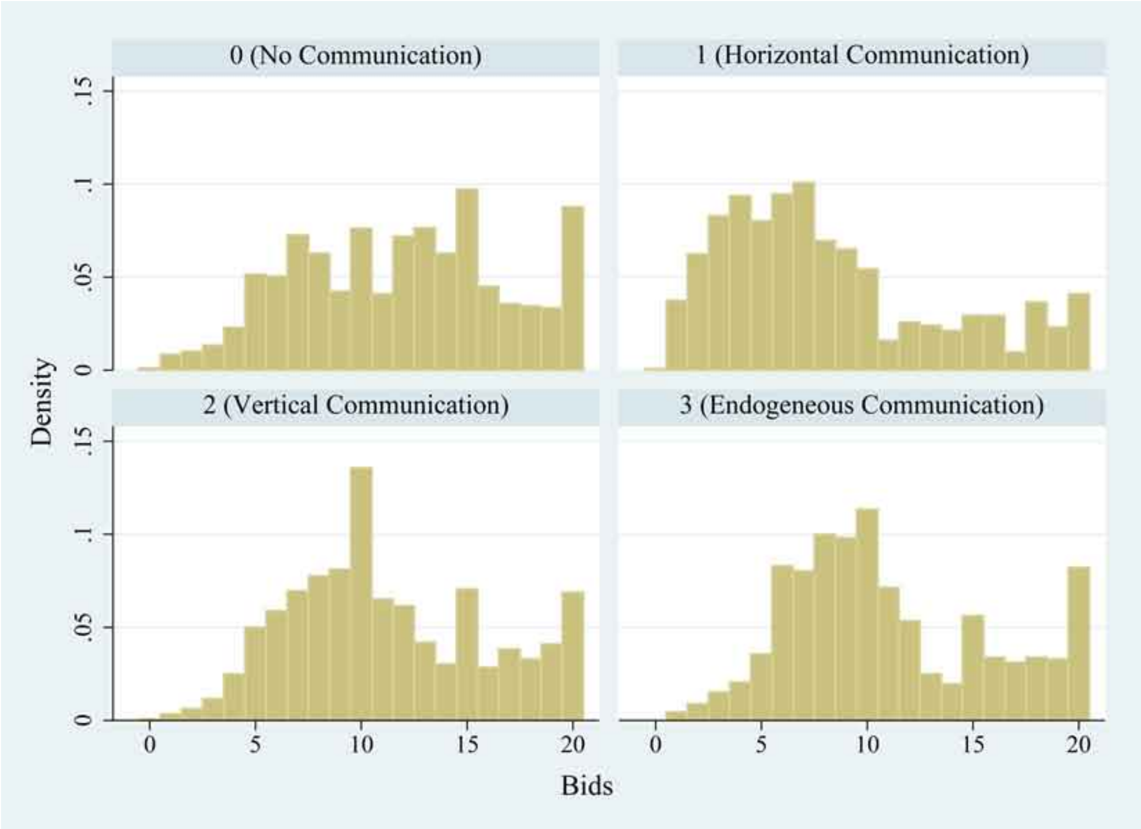

Figure 5: Distribution of bids by communication mode.

As shown on Figure 5, horizontal communication has resulted in the expected output-restricting effect, compatible with textbook wisdom on quantity-setting cartels. Vertical communication seems to have led to a moderate output-enhancing effect. Referring to the last 10 periods (corresponding to Treatment 3) of Sessions 2 and 3, where we allowed for an endogenous determination of the communication mode, we observe an intermediate pattern between those of treatments 1 and 2, but far more leptokurtic than T0.

Whether the communication mode is chosen by the subjects or is exogenously imposed by design, the results obtained are similar, with horizontal cartels reducing bids and vertical cartels enhancing them, although no more than the baseline treatment. In fact, as shown on Figure 6, subjects' choice of communication mode in the endogenous communication periods (31-40) of Sessions 2 and 3 indicates the subjects' indifference between horizontal and vertical cooperation.

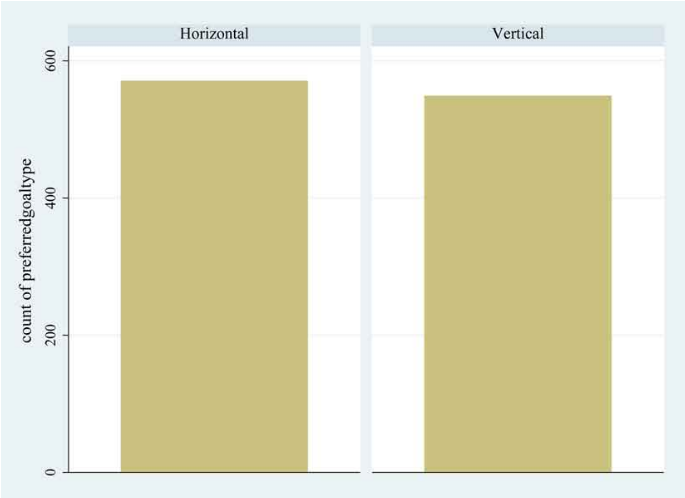

Figure 6: Preferred communication mode.

A possible explanation of this pattern can be traced on Figure 7, where we plot the evolution of agreed and actual median bids under the two communication modes. We see that although both types of agreements were made in the right direction of output expansion under vertical and output restriction under horizontal communication, actual strategies have systematically deviated from the agreed ones towards bids around 10. Thus, communication has not brought the desired and agreed results, finally motivating subjects' indifference between the two communication modes, and at the same time hindering in effect coordination in higher bids.

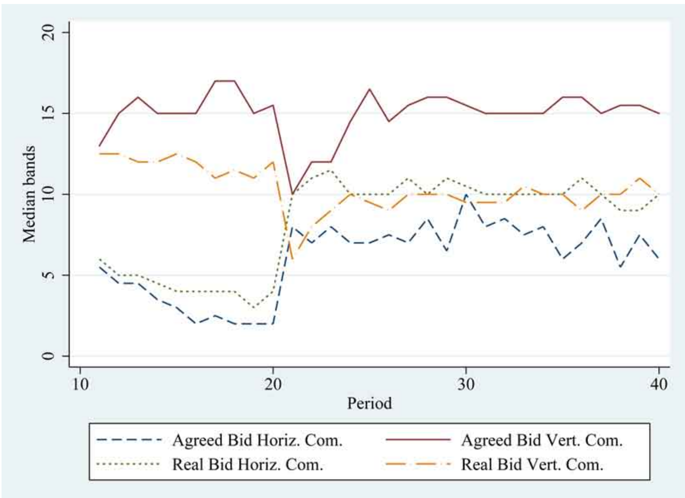

Figure 7: Evolution of median agreed and actual bids under the two communication modes.

Finally, Figures 8-10 reveal an interesting gender effect. In the absence of communication, males have achieved almost full convergence to the Walrasian allocation in

Session 1. Furthermore, they have agreed to post bids compatible with full trade in the case of vertical communication, showing a perfect understanding of the strategic aspects of this setup. At the same time, they have also deviated in the expected direction from the agreed bids. Given the failure of vertical communication to sustain the agreed level of trade, they have exhibited a moderate preference for horizontal cartels, whereas females have preferred forming vertical ones.

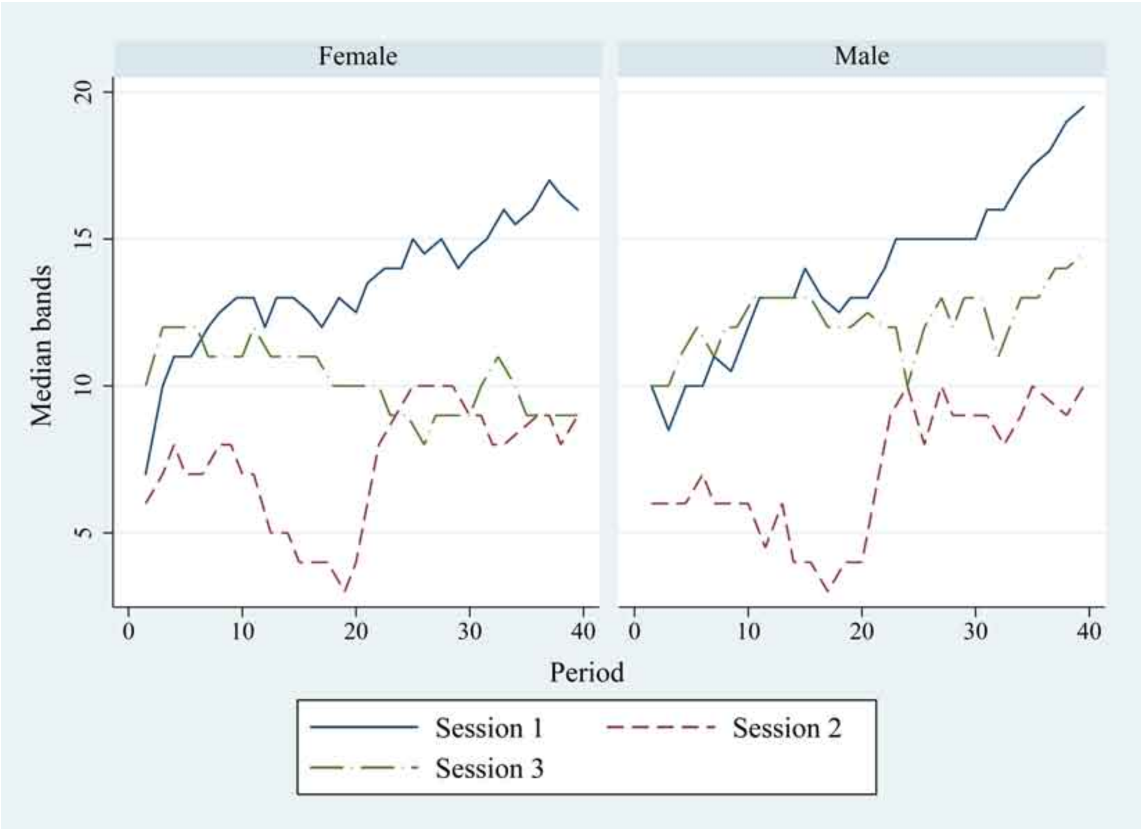

Figure 8: Evolution of median bids by session and gender.

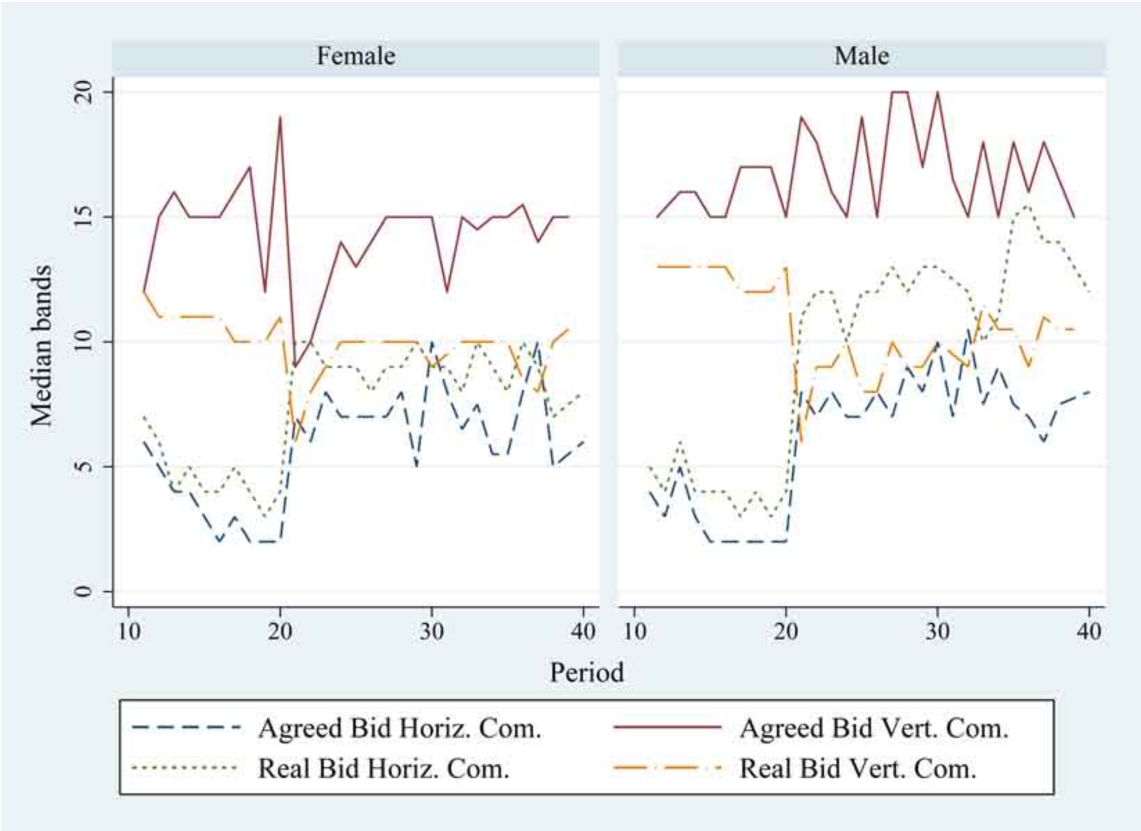

Figure 9: Agreed and actual bids by gender.

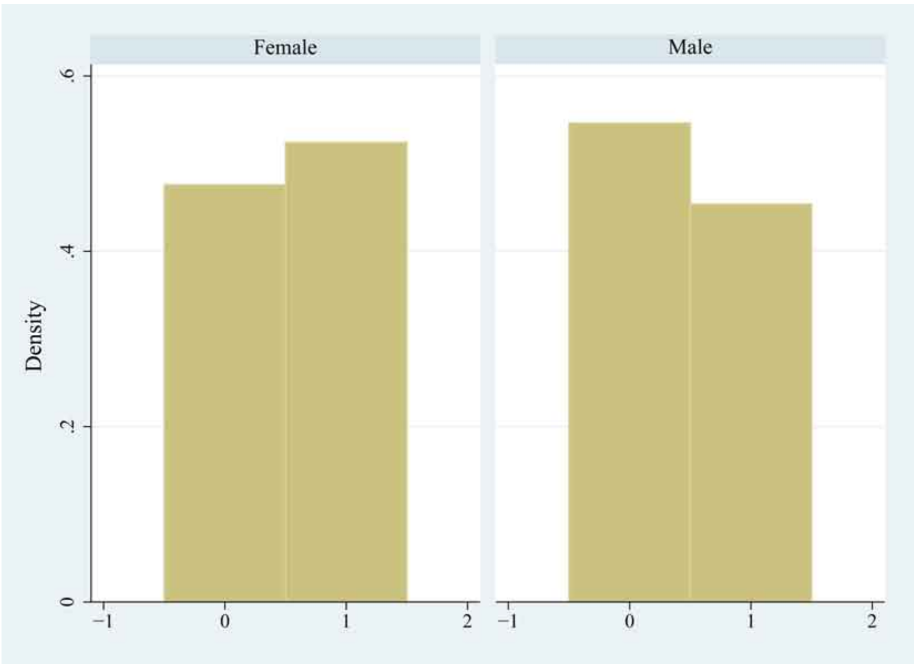

Figure 10: Preferred communication mode by gender

(0=horizontal, 1=vertical).

Not surprisingly, the relative prices observed have not been significantly different from 1, which is fully compatible with the theoretical prediction. However, convergence has been much sharper in Treatment 1, whereas in the other Treatments, communication, agreements and deviations have led to a much more unstable pattern, as shown in Figure 11.

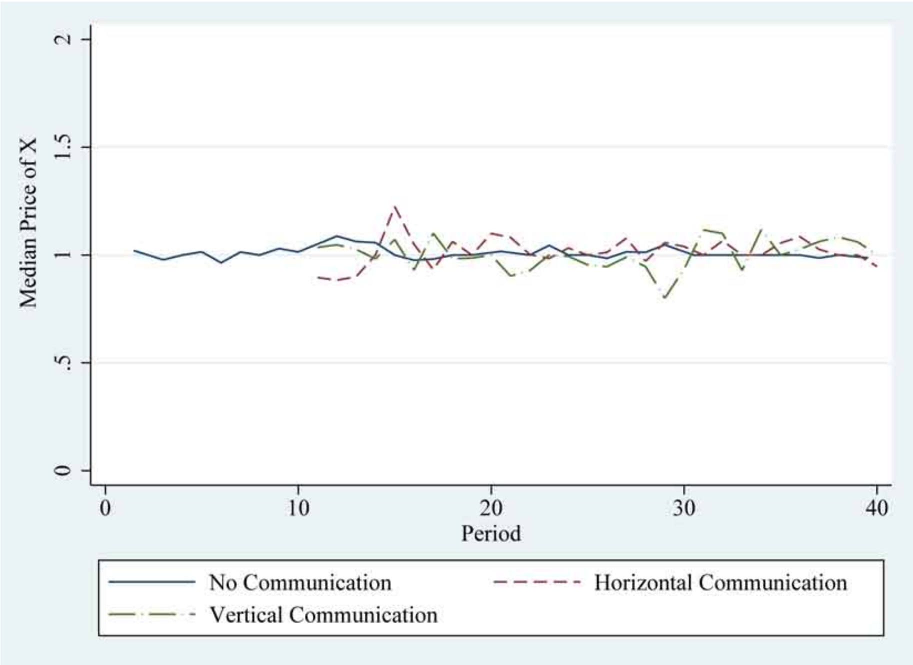

Figure 11: Evolution of the relative price of X.

The final allocations, represented in Figure 12, obtained in the absence of any communication have been closer to the socially optimal allocation in which Type I (II) players should possess good y (x) only. It is also true that final allocations in the absence of any communication have converged closer to the efficient frontier than has been achieved by communicating agents. Therefore, combined with the aforementioned price stability, we see that communication, agreements and deviations from them have resulted in less efficient allocations and more noisy relative prices than has been achieved by a sufficiently long learning horizon in the absence of any communication in Session 1.

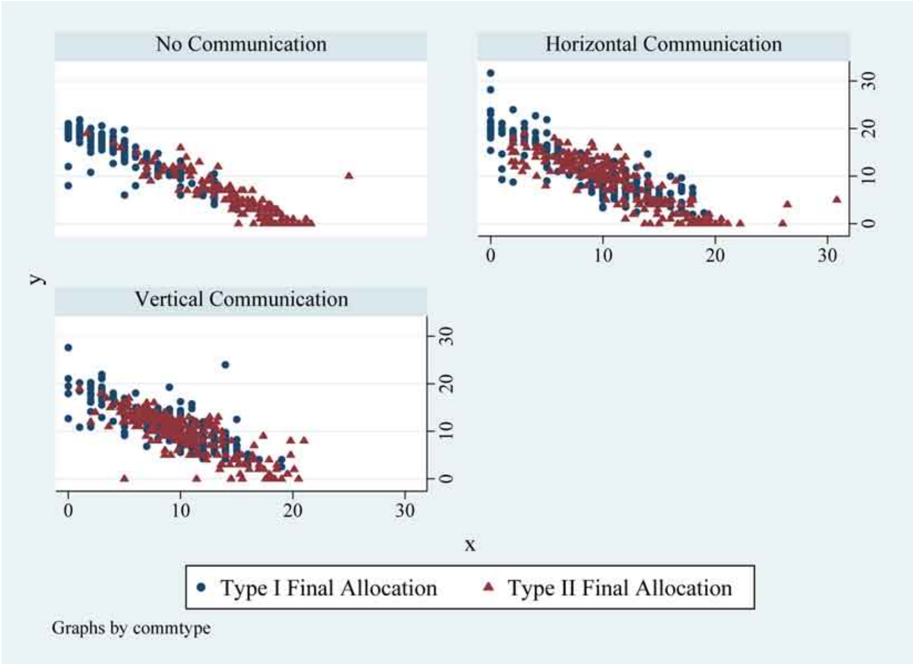

Figure 12: Final allocations of both player types, last 10 periods.

The results reported in the preceding paragraphs are further statistically supported by regression analysis whose results are reported in Table 1. First of all, we confirm that learning in the baseline treatment has had a stronger exchange-enhancing impact than any type of communication. In fact, as predicted, horizontal communication has also significantly decreased bids. Particularly, in the last 10 periods (T3) endogenous communication has hindered cooperation compared to tacit learning in Session 1. Bids increase over time and they are higher, the higher the agreed bids. Interestingly, our subjects learnt from the feedback they obtained from variations with respect to their bids in previous periods. According to the empirical model, subjects increase their present bid if they have experienced a payoff increase (decrease) in the last period following an increase (decrease) in their bid and vice versa. Apart from gender, we have also controlled for subjects' risk aversion, and we obtain that both of them exert a negative effect on a subject's bids.[15]

[15]The Sabater and Georgantzis (2002) task was used to elicit our subjects' risk attitudes.

	Coef.	Std. Err.	z	P>z	95% Conf. Interval
constant (T0)	11.11	0.34	32.55	**0.000**	[10.44, 11.78]
T1	-4.76	0.23	-20.23	**0.000**	[-5.22, -4.30]
T2	-3.74	0.26	-13.94	**0.000**	[-4.27, -3.21]
T3	-5.24	0.29	-17.62	**0.000**	[-5.83, -4.66]
Period	0.14	0.009	14.81	**0.000**	[0.12, 0.16]
Feedback	0.023	0.002	8.04	**0.000**	[0.018, 0.029]
Agreed Bid	0.17	0.01	16.77	**0.000**	[0.15, 0.19]
Female	-1.16	0.20	-5.59	**0.000**	[-1.56, -0.75]
Risk Aversion	-0.20	0.05	-3.78	**0.000**	[-0.31, -0.09]

Table 1: Prais-Winsten regression, heteroskedastic panels corrected standard errors (PCSEs) for Bids. Group variable: id; Time variable: period; Number of obs = 6,080; Number of groups = 160; Panels: heteroskedastik (balanced); Autocorrelation: common AR(1); Obs. per group: 38; Estimated covariances = 160; Estimated autocorrelations = 1; Estimated coefficients = 9; $R^2 = 0.15$; Wald $\chi^2(8) = 858.58$; Prob $> \chi^2 = 0.000$; $\rho = 0.667$.

6 Conclusions

Despite the fact that the main difference between our set up and that of Duffy et al. (2011) is the lack or the existence of a Pareto superior equilibrium with trade, a major question arises: are real world markets more similar to a coordination game or to a social dilemma? These authors have shown that if the former is true, coordination occurs on the Pareto superior equilibrium. If the latter is the case, we have shown that learning and communication across different types of players facilitate the way of human actions away from the non cooperative equilibrium state of autarky in favor of intense, social welfare-improving trade.

We report results from a market game experiment designed to address the question whether a good equilibrium attractor is necessary for subjects to avoid the inefficient equilibrium outcomes of the static game. Contrary to a previous experiment by Duffy et al. (2011), we implement an alternative version of the game in which the only Nash equilibrium involves (minimum or) no trade. Despite the lack of a *good* non-cooperative attractor, we obtain surprisingly high volumes of trade. Convergence to the Walrasian allocation, which is sustainable as an evolutionary stable equilibrium, is compatible with an adaptive learning process supported by the empirical model fitted to our data.

Moreover, two alternative treatments are run allowing for communication between agents on the same and across different sides of the market. It should be noted that this is the first work in the literature on communication among oligopolists that allows for vertical communication and for endogenous choice between horizontal and vertical communication. The two modes have the expected effects; horizontal communication restricts trade and vertical communication increases it. Nevertheless, learning alone in the absence of any communication seems to have the clearest exchange-enhancing effect. We also obtain an output-reducing effect associated to subjects' risk aversion, suggesting that even more trade would have been observed in a population of risk-neutral agents. Finally, males are found to make full-trade proposals when communicating with players of the other type, although they are especially prone to deviate from their promises under this mode of communication, which they seem to prefer less than horizontal communication.

References

[1] Andersson, O., Wengström, E., (2007). Do antitrust laws facilitate collusion? Experimental evidence on costly communication in duopolies. *Scandinavian Journal of Economics* 109, 321-339.

[2] Brown-Kruse, J., Cronshaw, M.B., Schenk, D.J., (1993). Theory and experiments on spatial competition. *Economic Inquiry* 31, 139-165.

[3] Brown-Kruse, J., Schenk, D.J., (2000). Location, cooperation and communication: An experimental explanation. *International Journal of Industrial Organization* 18, 59-80.

[4] Cordella, T., Gabszewicz, J.J., (1998). "Nice" trivial equilibria in strategic market games. *Games and Economic Behavior* 22, 162-169.

[5] Crawford, V., (1998). A survey of experiments on communication via cheap talk. *Journal of Economic Theory* 78, 286-298.

[6] Daughety, A.F., Forsythe, R., (1987). The effects of industry-wide regulation on industrial organization. *Journal of Law, Economics, and Organization* 3, 397-434.

[7] Dubey, P., Shubik, M., (1978). A theory of money and financial institutions. The non-cooperative equilibria of a closed trading economy with market supply and bidding strategies. *Journal of Economic Theory* 17, 1-20.

[8] Duffy, J., Matros, A., Temzelides, T., (2011). Competitive behavior in market games: Evidence and theory. *Journal of Economic Theory* 146, 1437-1463.

[9] Fischbacher, U., (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics* 10, 171–178.

[10] Fonseca, M.A., Normann, H.T., (2012). Explicit vs. tacit collusion - The impact of communication in oligopoly experiments. *European Economic Review* 56, 1759-1772.

[11] Huber, J., Shubik, M., Sunder, S., (2010). Three minimal market institutions with human and algorithmic agents: Theory and experimental evidence. *Games and Economic Behavior* 70, 403-424.

[12] Isaac, R.M., Plott, C.R., (1981). The opportunity for conspiracy in restraint of trade: An experimental study. *Journal of Economic Behavior and Organization* 2, 1-30.

[13] Koutsougeras, L.C., (2009). Convergence of strategic behavior to price taking. *Games and Economic Behavior* 65, 234–241.

[14] Mas-Collel, A., (1982). The Cournotian foundations of Walrasian equilibrium theory: An exposition of recent theory. In: *Advances in Economic Theory*, W. Hildenbrand, Ed., Cambridge University Press.

[15] Normann, H.T., Rösch, J., Schultz, L.M., (2015). Do buyer groups facilitate collusion? *Journal of Economic Behavior and Organization* 109, 72-84.

[16] Peck, J., Shell, K., Spear, S., (1992). The market game: Existence and structure of equilibrium. *Journal of Mathematical Economics* 21, 271-299.

[17] Postlewaite, A., Schmeidler, D., (1978). Approximate efficiency of non-Walrasian Nash equilibria. *Econometrica* 46, 127-135.

[18] Sabater, G., Georgantzis, N., (2000). Accounting for risk aversion in repeated prisoners' dilemma games: An experimental test. *Journal of Economic Behavior and Organization* 48, 37-50.

[19] Samuelson, L., (1997). *Evolutionary games and equilibrium selection.* MIT Press.

[20] Schaffer, M.E., (1988). Evolutionary stable strategies for a finite population and a variable contest size. *Journal of Theoretical Biology* 132, 469-478.

[21] Shapley, L.S., Shubik, M., (1977). Trade using one commodity as a means of payment. *Journal of Political Economy* 85, 937-968.

[22] Shubik, M., (1973). Commodity money, oligopoly, credit and bankruptcy in a general equilibrium model. *Western Economic Journal* 11, 24-38.

[23] Waichman, I., Requate, T., Siang, C.K., (2014). Communication in Cournot competition: An experimental study. *Journal of Economic Psychology* 42, 1-16.

7 Appendix: Instructions to subjects (translated from Spanish)

Welcome to the LEE. This research is supported by public funds. Read carefully the instructions, which explain how your monetary reward will be calculated at the end of the session, depending on the decisions made by you and the rest of the participants. If you have any questions, please raise your hand. Communication with any other participant is strictly forbidden.

In this session, the 56 (48 in Session 1) participants will be divided into two groups of equal sizes: Participants of type I and participants of type II. Your type will be announced to you at the beginning of the session on the computer screen and will be kept constant throughout the session.

The game in each period

The session lasts for 40 periods. Every 10 periods, new instructions will be given to you, which may change some of the rules of the game. At the beginning of each period, you will be matched by the computer in a random and anonymous way with another three participants, one of the same type as you and two of the other type, to form a market. The identity of players matched together will remain secret throughout the session and after the end of it.

Endowments at the beginning of each period and strategies

- If you are of Type I, you will start each period with an initial endowment of 20 units of commodity X and zero units of commodity Y.

- If you are of Type II, you will start each period with an initial endowment of zero units of commodity X and 20 units of commodity Y.

This endowment will be given to you at the beginning of each period independently of what happened in previous periods. Once the 4-player markets are formed, you have to use the decision screen to submit the units (an integer between 0 and 20) that you want to exchange with (a share of) the commodity submitted for exchange by the players of the other type.

Your allocation at the end of each period

After trade has taken place, your allocation will contain the units of your initial endowment which were not submitted for exchange, as well as your share of the other commodity as specified above. Your share of the other commodity is equal to your participation in the total quantity submitted by you and the other player of your type in the market. If you submit 0 units, you will not receive any of the commodity submitted for exchange by the players of the other type and your final allocation for this period will be the same as your initial endowment. If 0 units are submitted by both players of the other type, you will receive nothing in exchange to the units you submitted to the market.

This is explained in more detail below:

Your allocation at the end of each period is the quantity of X and Y that you will have after trade has taken place.

Let $\sum x$ be the total quantity of commodity X offered for exchange by all members of your market. And let $\sum y$ be the quantity of commodity Y offered for exchange by all members of your market. If you are of Type I and your choice consisted of exchanging some amount x of commodity X with commodity Y, then your allocation at the end of the period will be determined in the following way:

- Allocation of commodity X: $20 - x$

- Allocation of commodity Y: $(x/\sum x) \sum y$

If, on the contrary, you are of Type II and your choice has consisted in exchanging some amount of commodity y of commodity Y with commodity X, then your allocation at the end of the period will be determined in the following way:

- Allocation of commodity X: $(y/\sum y) \sum x$

- Allocation of commodity Y: $20 - y$

Remember:

1) If you are the only of your type in your market who is willing to exchange a commodity, you will have 100 % of the other good offered for exchange by the participants of the other type. In any case, your market share of the other good (in the case that some exchange is offered by members of the other type in the market) will be proportional to your relative contribution to the total supply of the commodity that you are offering for exchange, $x/\sum x$ or $y/\sum y$.

2) In order to increase your assignment of a commodity at the end of a period with respect to the initial endowment, there must be 'supply' and 'demand' in both parts of the market, that is, both $\sum y$ and $\sum x$ must be positive.

In order to help you in this task, a simulator-calculator available on your screen will allow you to see how different combinations of quantities submitted by you and the others to your market will affect your and the other players' earnings.

Your earnings at the end of each period

Your earnings, in points, at the end of each period depend on your type and your final allocation. Let us call xf and yf, respectively, your allocation at the end of the period.

Then:

If you are of Type I, your earnings in experimental currency units (ExCUs) are $= 0.6 \cdot xf + 1 \cdot yf$. If you are of Type II, your earnings in ExCUs are $= 1 \cdot xf + 0.6 \cdot yf$

The computer will calculate and show on the screen these earnings at the end of each period.

Please note that:

1. If you decide not to trade, your end-of-period allocation will be equal to your initial endowment. Your earnings in ExCUs for that period will be: $0.6 \cdot 20 + 1 \cdot 0 = 12$ ExCUs if you are of Type I, and $1 \cdot 0 + 0.6 \cdot 20 = 12$ ExCUs if you are of Type II. In this case, your earnings will not be affected by the rest of the members' decisions in the market.

2. If you are of Type I, your payoff increases as you get more units of commodity Y. However, any increase in your payoff compared to the one with no trade will depend on whether commodity Y was offered in your market.

3. If you are of Type II, your payoff increases as you get more units of commodity X. However, any increase in your payoff compared to the one with no trade will depend on whether commodity X was offered in your market.

Information

At the end of each period you will receive information concerning the individual and total quantities of commodities X and Y offered by all the participants in your market, yourself included. Additionally, you will be informed about the final amounts of both commodities and the payoffs for each participant in your market after trade takes place. Finally, your own payoff in ExCU will be calculated for that period. Tables I1 and I2 below include the earnings in ExCUs for each type of player.

Monetary earnings

At the end of the session, the system will randomly choose 12 periods, three of each block of 10 periods in which the session is divided, and will sum up the earnings in points that you have obtained in those selected periods. To that amount we apply an equivalence factor of 1 ExCU=0.1 Euro. The corresponding amount will be calculated by the system and will appear in your screen. You will be paid in cash individually at the end of the session.

Units of Y at the end of the period											
	X/Y	0	1	5	10	15	20	25	30	35	40
Units	0	0	1	5	10	15	20	25	30	35	40
of X	1	0.6	1.6	5.6	10.6	15.6	20.6	25.6	30.6	35.6	40.6
at the	5	3	4	8	13	18	23	28	33	38	43
end	10	6	7	11	16	21	26	31	36	41	46
of	15	9	10	14	19	24	29	34	39	44	49
the	19	11.4	12.4	16.4	21.4	26.4	31.4	36.4	41.4	46.4	51.4
period	20	12	-	-	-	-	-	-	-	-	-

Table 1: Earnings in ExCUs for player of Type I (her initial endowment is 20 units of commodity X)

Units of Y at the end of the period											
	Y/X	0	1	5	10	15	20	25	30	35	40
Units	0	0	1	5	10	15	20	25	30	35	40
of X	1	0.6	1.6	5.6	10.6	15.6	20.6	25.6	30.6	35.6	40.6
at the	5	3	4	8	13	18	23	28	33	38	43
end	10	6	7	11	16	21	26	31	36	41	46
of	15	9	10	14	19	24	29	34	39	44	49
the	19	11.4	12.4	16.4	21.4	26.4	31.4	36.4	41.4	46.4	51.4
period	20	12	-	-	-	-	-	-	-	-	-

Table 2: Earnings in ExCUs for player of Type II (her initial endowment is 20 units of commodity Y)

7.1 Specific instructions [*periods 11-20 in Session 2, and periods 21-30 in Session 3*]

In this part of the session you have the opportunity to communicate with the other participant of your type in the market. You will be able to reach an agreement regarding the amount of good you want to exchange in the market. The way in which you will be able to communicate is indicated on your screen. Any other communication beyond that will be punished with exclusion from the experiment. After the agreement, the decision making process will go on as in previous stages.

In fact, the agreement will not be automatically implemented, so in each trading period you will have to submit the quantity bid that you are willing to exchange in the market.

7.2 Specific instructions [*periods 11-20 in Session 3, and periods 21-30 in Session 2*]

In this part of the session you have the opportunity to communicate with one participant of the other type in your market. With whom you will communicate will be randomly determined by the computer. Therefore, you will have the possibility to reach an agreement concerning the amount of good that you want to exchange in the market. The way in which you will be able to communicate is indicated on your screen. Any other communication beyond that will be punished with the exclusion from the experiment.

After the agreement, the decision making process will go on as in previous periods. In fact, the agreement will not be automatically implemented, so in each trading period you will have to submit the quantity bid that you are willing to exchange in the market.

7.3 Specific instructions [*periods 31-40 in Sessions 2,3*]

In this part of the session you have the possibility to choose, in each period, whether you want to communicate with the other participant of your type or with one of the other type in order to reach an agreement on the amount of good you want to exchange in the market.

In order to determine the type of communication that will take place in your market in a specific period, your choice, together with those of the rest of the participants in your market, will be used like balls in a lottery, that is, we will take your choice and pool it with those of the other 3 members of our market, then we will randomly draw one of your four choices.

Once the type of communication in the market is determined, it will be implemented in the same way as in the corresponding block of the previous periods. Any other communication beyond that will be punished with the exclusion from the experiment.

After the agreement, the decision making process will go on as in previous periods.

In fact, the agreement will not be automatically implemented, so in each trading period you will have to submit the quantity bid that you are willing to exchange in the market.