

# **Everyone-a-banker or the Ideal Credit Acceptance Game: Theory and Evidence<sup>1</sup>**

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## **Abstract**

Is personal credit issued by participants sufficient to operate an economy efficiently, with no outside or government money? Sorin (1995) constructed a strategic market game to prove that this is possible. We conduct an experimental game in which each agent issues her own IOUs and a costless efficient clearinghouse adjusts the exchange rates among them so the markets always clear. The results suggest that if the information system and clearing are so good as to preclude moral hazard, any form of information asymmetry, or need for trust, the economy operates efficiently at any price level without government money. Conversely, perhaps explanations for prevalence of government money should be sought in either the above mentioned frictions or our unwillingness to experiment with innovation.

Keywords: government and individual money, efficiency, experimental gaming

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## 1. INTRODUCTION

For many years there has been a debate as to whether both outside and inside (i.e., government and private) money are needed to run an economy. Do we need a system where almost all of the means of payment are debt instruments—IOWs issued by individuals or banks or government? Government fiat money without offsetting government debt may be regarded as paper gold against which there is no clear offsetting asset<sup>2</sup>. In other words, can the means-of-payment system contain an instrument for each country for which there is no offsetting real asset? Such an instrument would be “paper gold” instead of the real asset, such as gold itself.

The proponents of an economy without government money have argued that if all individuals and institutions were to issue their own debt as a means of payment, the market would sort out the reputations and the levels of risk in accepting such paper from different issuers (for example, see Black 1970). Practices in markets for money, and even the language of banking, seem to be consistent with this view. In the City of London, rates of interest in dealings with “prime” and “lesser” names are different. In the free banking era in the United States, there was an active market for discounting bills issued by hundreds of banks.

The question of whether outside money is needed to run an economy based on monetary payments has been addressed formally through modeling the economy as a strategic market game—outside or government money is not needed if there is perfect clearing and no default. Like the Modigliani-Miller’s (1958) observation about the neutrality of the cost of capital with respect to leverage, this result is valid under conditions that are clearly counter-factual. Given exogenous uncertainty, dispersed and imperfect information, a smoothly functioning economy using individually created credit lines with no default appears to be institutionally difficult to obtain, even if it were logically possible. The problem lies not in the usual economic equilibrium models but in the information and evaluation network. Process dynamics, trust and evaluation are core issues in the functioning of the financial system, and these are not present in the Black or Modigliani-Miller observations.

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<sup>2</sup> If one takes a dollar bill to Federal Reserve Bank one will obtain another bill in exchange, thus the exchange can be regarded an identity operator, when applied it yields itself.

There is another fact of life in favor of government money that goes against the abovementioned formal results. No matter how well known it is, no bank—much less an individual—can match the visibility of the government which is known to essentially everyone. It is no surprise that governments have issued money at least since the Lydians around 630 BC.

The use of government money initially became accepted because of the government's reputation and ability quickly and uniformly to enforce the rules of the game. Additionally, it expedited and simplified taxation, and as an unintended consequence, handed government an instrument to choose heretofore inaccessible policy options (e.g., to finance war) and to control the economy in other ways. Private issue of money weakens the power of government arising from its control of money.

The acceptance of government as well as individual IOUs as money requires an expectation that there are plenty of others who will accept the instrument as a means of payment. Since there may be little recourse to nonperformance on IOUs issued by government or individuals who go bankrupt, accepting such money involves an element of trust. The universal acceptability of money issued by stable and trustworthy governments may exceed the acceptability of instruments issued by their nearest competition—the big banks.

Gold, in spite of its unwieldiness, has longevity and direct commodity value that makes it more trustworthy than government-issued paper money, but government money may be more trustworthy and generally acceptable than paper issued by banks. Most individuals, being virtually unknown to the public at large, would find it difficult to have their IOUs accepted as a means of exchange.

In international trade, many countries issue their own respective means of payment. In international context, each agent is a long-lived bureaucracy with a reputation and it engages in trades that are settled with considerable time lags. “Everyone-a-banker” game is an abstraction from this phenomenon, stripped of the context.

In the one period game, as noted below, there is a continuum of equilibrium points with any price level between zero and an upper bound being feasible. In international trade the decision to opt for a hard or soft currency depends on macroeconomic specifics such as unemployment and inflation. Since the possibility of a complex set of internal

policy reasons for having the exchange rate as an important economic control variable is not present in this model, we have no economic prediction about where, if at all, the absolute price level may settle, only relative prices are determined by the mechanism.

In the laboratory, we used a computer to compute the exchange rates among the units of personal money issued by individual agents, and to function as a clearinghouse as well as a perfect reputation enforcement mechanism preventing individuals from renegeing or going bankrupt. The computer helped us cleanse the lab economy of the frictional and informational issues so we could examine the everyone-a-banker model in absence of such alternative explanations for the prevalence of government money. Briefly, this mechanism yields efficiencies as high or higher than the three market games studied in Huber et al. (HSS, 2007), confirming that an economy with individual credit is logically as well as behaviorally feasible and efficient. We show that a key claim in competitive market theory that government money is not needed to achieve efficient exchange can be established experimentally as well as theoretically. This result appears to depend on ideal contract enforcement, credit evaluation and clearing arrangements in the economy. These are implicit in the model as well as the laboratory set up.

In Section 2 we discuss the model, touching on the multiplicity of equilibria and the selection of a numeraire. Section 3 gives the experimental setup and results, and Section 4 contains our concluding remarks and notes on further research.

## **2. The Model**

A strategic market is a game in strategic or extensive form, usually representing an exchange or exchange-and-production economy, and is closely related to the general equilibrium model of an exchange-or-exchange and production economy. A basic difference between a strategic market game and general equilibrium model is that the former provides an explicit mechanism for price formation, and the latter does not. The game serves as the basis for a playable experiment with full process details given.

There are two basic versions of the strategic market game: the ‘trading post’ and the ‘clearinghouse’ model. The trading post model is completely decentralized. Imagine one trading post for each of  $m$  goods. The manager of each trading post deals only in one good. She collects the consignments of that good offered for sale, and the money being

offered to buy that good, calculates the clearing price and allocations, and transfers the traded goods and money among the traders. In contrast the clearinghouse model requires a centralized agency that gathers the consignments of all goods and bids of personal money or IOU notes for all goods and calculates a set of exchange rates that clear all markets among all of the individual credit lines issued by every trader. Thus in order to balance all books the clearing house also has to calculate the appropriate exchange rates. We use Sorin's notation to sketch the general formal model. Consider a set  $A$  of  $n$  agents and set  $I$  of  $m$  goods. There are  $m$  posts, one for each good where each agent  $\alpha$  bids quantity of money  $b_i^\alpha$  for good  $i$  and offers a quantity of goods  $q_i^\alpha$  of good  $i$  for sale. The equations defining prices in terms of the unit of account are:

$$p_i \left( \sum_{\alpha} q_i^\alpha \right) = \sum_{\alpha} t^\alpha b_i^\alpha, \forall i \in I.$$

And the budget balance gives

$$t^\alpha \left( \sum_i b_i^\alpha \right) = \sum_i q_i^\alpha p_i, \forall \alpha \in A.$$

Thus each agent  $\alpha$  obtains from the trading post  $i$  the quantities  $q_i^\alpha p_i$  units of account and  $t^\alpha b_i^\alpha / p_i$  units of good  $i$ , and each unit of money of agent  $\alpha$  is equal to  $t^\alpha$  units of account.

The system is homogeneous of order zero. If a set of prices  $p$  and a profile of exchange rates  $t$  define an equilibrium, so will  $\lambda p$  and  $\lambda t$  for any  $\lambda > 0$ .

The paper establishes the existence of an active<sup>3</sup> noncooperative equilibrium set of prices and exchange rates and then goes on to show that as the number of trading agents increases this converges to a competitive equilibrium<sup>4</sup>.

The IOUs of some arbitrarily selected agent can be used as a numeraire. The clearing house balances all expenditures and revenues for each agent<sup>5</sup>.

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<sup>3</sup> There could also be an inactive equilibrium without trade.

<sup>4</sup> The noncooperative equilibrium need not be unique, but in this experiment the conditions were chosen so that the equilibrium is unique.

## 2.1. The non-cooperative equilibrium solution

Appendix A gives the solution for the non-cooperative equilibrium of the formal sell-all model that serves as the basis for the experiments reported on here.<sup>6</sup> There are two types of traders and two goods. Traders of Type 1 each own an endowment of  $(a, 0)$  and traders of Type 2 each own  $(0, a)$ .<sup>7</sup> Each trader puts up all of his/her assets for sale and is allowed to “print” and bid units of a personal currency to buy each of the two goods. The reasons for having each trader sell all endowed assets are two-fold. This market structure cuts the size of the strategic actions of each individual to two—the number of goods in the economy. Also, it reflects a modern economy in which individuals buy virtually all their consumption needs from markets, instead of consuming any significant amount of what they produce.

A strategy by an individual  $i$  is a pair of bids  $(b^i_1, b^i_2)$ ,  $b^i_1 + b^i_2 \leq m^i$ , where  $m^i$  is some upper bound on the total amount each individual is permitted to bid (personal money permitted to print, or credit permitted to extend to themselves). It can be interpreted as an upper limit on a credible bid, or merely as a rule of the game. An upper bound is needed to construct a playable game that does not lose definition by degenerating into a contest of who can name a bigger number.

With no more than ten traders in each experimental session, the influence of each trader is large enough so the non-cooperative equilibrium can be distinguished from the competitive equilibrium. Furthermore, in our closed economy the difference between the non-cooperative and the competitive equilibria is manifested in income as well as expenditures. Although the payoff function is identical across traders, and is symmetric in the two goods, endowments are asymmetric— $(a, 0)$  and  $(0, a)$ . When traders are few, purchases from the market for the endowed good influence the owner’s income and bring more revenue from its sale back to the trader (as compared to purchase from the other

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<sup>5</sup> A banker usually grants credit and makes loans, as well as accepts deposits. We use the word “banker” in the title of the paper for simplicity; our agents can issue credit, but accept no deposits. For our present purposes, the absence of the ability to accept deposits is not important. Furthermore, the agents issue credit only to themselves, each producing and spending his/her own money

<sup>6</sup> Since all endowment of goods is automatically offered for sale, each subject has only one dimensional decision (the amount of money to print and bid) in each market. This is characteristic of sell-all markets (see HSS 2007).

<sup>7</sup> In the experiment, we chose  $a = 200$ .

market). Each individual has a per-period payoff of the form:  $B\sqrt{xy}$  where  $B$  is a parameter and  $x$  and  $y$  are the amounts purchased of the first and second goods (recall that all goods endowments are sold and all purchases are “consumed”).

For purposes of comparison first consider a market that uses a commodity money with marginal utility as a consumption good is, say,  $\mu = 1$ . The per period payoff to the individual becomes  $\beta\sqrt{xy} + (M-b)$ , where the last term in parentheses is the ending money balance<sup>8</sup>. The presence of a money with marginal worth as a consumption good is sufficient to anchor the price level.

Table 1 indicates the equilibrium bids and purchases of goods by traders of Type 1 (i.e., traders with endowment of  $(a, 0)$ ) for the two goods as the number of traders is varied when each trader is endowed with 6,000 units of a commodity money with constant marginal utility  $\mu = 1$ . In competitive equilibrium, each trader bids an identical 2,000 units of money for each of the two goods, and buys 100 units of each good at a price of 20 per unit, leaving 2,000 units of money unspent. With five traders of each type, the amount bid for the owned good is 22 percent ( $= (2214-1811)/1811$ ) more than the amount bid for the other (non-owned) good.

(Insert Table 1 about here)

In the experiment we report here, there is no commodity money to anchor the prices. Instead the individuals are given an upper bound on the amount of individual credit units they can extend. If we were to impose a bound of 6,000 units on each trader then any price level consistent with these bounds would be feasible. Table 1 provides one of the many solutions consistent with individual credit.

## 2.2 A Continuum of Equilibria

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<sup>8</sup> The money could be a direct consumption good such as bags of tea, bales of tobacco, cigarettes or bars of salt (see Dubey, Geanakoplos and Shubik, 2003). The distinction between the asset and the flow of services obtained from the asset is discussed there.

A continuum of prices is consistent with the equilibrium distribution of resources.<sup>9</sup> The clearinghouse arrangement allows for equilibrium prices to be supported with all individuals having different exchange rates. For example, if each trader has a credit line of 6,000; total endowments of the two goods are (200, 200) and half the traders bid all their 6,000 units of credit (3,000 in each market) while the other half bid 3,000 (1,500 in each market) the prices at competitive equilibrium would be  $p_1 = p_2 = 30 = (3,000t^1 + 1,500t^2)/200$  with  $t^1 = 1$  and  $t^2 = 2$ . In this equilibrium each player buys 100 units of each good. Suppose now that the second traders each bid half as much, 750 instead of 1500 the distribution of goods would still be the same and the prices at competitive equilibrium would be  $p_1 = p_2 = 30 = (3,000t^1 + 750t^2)/200$  with  $t^1 = 1$  and  $t^2 = 4$ . If both traders cut their bids in half then because player 1's currency is the numeraire and by definition equal to one, prices would be  $p_1 = p_2 = 15$ .

### 2.3 Numeraire

When there is a money with a constant marginal utility  $\mu^\alpha$  to each individual  $\alpha$ , the selection of a numeraire is more or less natural; society may fix its price level at one by transforming each utility function of form  $u(x^\alpha, y^\alpha) + \mu^\alpha(m - b^\alpha)$  to be  $(1/\mu^\alpha)u(x^\alpha, y^\alpha) + (m - b^\alpha)$ .

When there is a government fiat money a price of one can be attached to it. When there is neither a commodity nor fiat money, the normalization can be made in many ways such that assigning a value of one to the overall wealth in the economy and using that to normalize prices<sup>10</sup>. Another, and possibly easier, way to anchor prices is to arbitrarily assign a weight of  $t^\alpha = 1$  to the  $\alpha^{th}$  agent. This is the method utilized in the laboratory experiment.

## 3. Experiment

### 3.1 Setup

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<sup>9</sup>More precisely we can state that the price is defined on a half open interval  $0 < p \leq P$ , where  $P$  is the upper bound to price given by all individuals spending all of their credit line on a single good. In order to have a playable game it is necessary to place an upper bound on the amount an individual can bid. The size may be arbitrary but it must be specified to prevent bids from being unbounded.

<sup>10</sup> See Qin and Shubik (2006) for a detailed discussion of problems with normalization.



In operationalizing the game as a laboratory experiment, we utilize individuals or two-person teams to play the role of each agent, and use an instantaneous clearinghouse mechanism. Each individual can issue his or her own credit and knows that prices will emerge in such a way that all accounts will balance and that the cost of their purchases will match the revenue from their sales with no opportunity for default and no threat to their reputations.

In experiments with both human as well as Gode-Sunder (1993) artificial agents we chose a simple setup with ten traders, two goods (A and B), and equal or differing upper limits on the personal money each trader could issue. In the sell-all market structure we used, traders did not directly control the goods they were endowed with. They received as income the proceeds from selling their endowments of goods at the market clearing price. Five traders were endowed with 200 units of A and zero of B, while the other five were endowed with zero units of A and 200 of B. In treatment T1 each trader was allowed to issue up to 6,000 units of personal currency each period; in treatment T2 the allowances to print money varied – two traders (one each endowed with A or B) were allowed to print 500, 1000, 2000, 4000, and 8000 units respectively.

In each period each participant decided how much money to “print” to buy each good A and B. The computer, playing the role of a clearinghouse market mechanism, constructed a matrix of all the amounts and inverted it to calculate prices and exchange rates so that (1) the number of units of each good bought and sold in the respective markets were equal, and (2) the net cash position of each trader was zero. Each period’s earnings for each trader were calculated as ten times the square root of units of A times units of B purchased (i.e.,  $B = 10$ ). These earnings are converted to real dollars at the end of the experiment at a pre-announced exchange rate. Traders learned about their personal, as well as the market average, earnings at the end of each period. All endowments were reinitialized at the start of a new period (see Instructions in Appendix B).

### **3.2 Implementation**

We report the results of five laboratory sessions of “everyone-a-banker” experiment, and compare these results with the outcomes of three other simple market structures reported earlier in Huber, Shubik and Sunder (2007; sell-all, buy-sell, and double auction in which money balance had a constant marginal payoff). From July to

November 2006 three sessions for T1 (uniform limits on money individuals could “print”) and two runs for T2 (heterogeneous limits on money) were conducted at Yale University. Four of the runs (two for T1 and two for T2) were conducted each with ten undergraduate students from Yale College. Each student acted individually and no communication was allowed.

One run (run 3 of T1) was conducted with 18 students who were primarily undergraduate majoring in economics with a few master’s degree students in management. 16 of the students were randomly assigned to eight pairs, while the remaining two students participated without a partner. This became necessary because two students did not show up as planned. Communication among participants was forbidden in the first four runs. The two students in each team had to reach a decision together and were allowed to talk in Run 3 of T1. Communication across the teams was not permitted.

### **3.3 Results**

Allocation of money to buy goods A and B is of greater interest than the overall spending. As explained above, there is a general equilibrium solution with an equal amount of money allocated to the two goods by each individual. There is also a non-cooperative equilibrium where 10 (5 + 5) participants spend 22.2 percent more on the good they are endowed with than on the other good. In both scenarios the overall spending level does not matter, as the exchange rate is always set to equalize spending and income through the clearinghouse mechanism.

Figure 1 shows that in all five sessions allocation of total spending by all traders is balanced between the two goods; investment in A ranging from 49.3 to 51.3 and the remaining 48.7 to 50.7 percent invested in good B. This overall equality was observed throughout the 10-15 periods of the five sessions, with no systematic change from early to later parts of the sessions.

(Insert Figure 1 about here)

However, the equality of total spending on the two goods is not inconsistent with those endowed with proceeds from good A spending more for A, and those endowed with good B spending more for good B, as the non-cooperative equilibrium suggests. The data are weakly consistent with the non-cooperative equilibrium in four of the five sessions (see Table 2). Across the five sessions those endowed with proceeds from good A

invested 51.7 percent of their money in A, while those endowed with proceeds from good B invested only 48.4 percent of their overall spending in A. While this imbalance points into the direction of the non-cooperative equilibrium, the spending on the owned good is only 7 percent higher than the spending on the other good on average. The traders are therefore closer to the general equilibrium which predicts no difference in spending on the two goods, than to the non-cooperative equilibrium with a prediction of 22 percent difference. Only Session 1 of Treatment 1 is close to the non-cooperative equilibrium, while the other two sessions of Treatment 1 are essentially in general equilibrium. Over the 10-15 periods of the five sessions, there is no trend in the difference between spending on the two goods—there is no indication of either narrowing or widening of the gap over time (see Figure 2).

(Insert Table 2 and Figure 2 about here)

While the experiment with commodity money sell-all markets mostly led to the non-cooperative equilibrium (see Huber, Shubik and Sunder 2007), the general equilibrium dominates in everyone-a-banker sell-all markets. We have no structural explanation for this difference. Perhaps this is attributable to the more complicated task participants face—a commodity-money sell-all market the traders have to decide how much to spend on each good. With personal money, some participants reported that they thought about the total spending first, and then usually split that amount equally between the two goods.

To measure the ‘symmetry’ of investment between the goods, we take the amounts of money invested in goods A and B and divide the smaller number by the larger. The resulting number lies in 0-1 range (0 if all money is invested in a single good and 1 if each good received equal investment). This ratio was calculated for each trader for each period, and period-wise average is charted in Figure 3 with different lines for each of the five sessions. Observed ‘symmetry’ ranges from 0.70 to 0.95 and all five sessions exhibit a slight but not significant upward trend. Compared to the HSS 2007 experiment, the current experiment yields greater average symmetry (average of 0.83 versus 0.65 in HSS 2007 markets).

(Insert Figure 3 about here)

We measure allocative efficiency of the markets by the total number of points earned by traders relative to the maximum they could have earned (which is in general equilibrium) Efficiency of these markets ranges from 96.9 to 99.3 percent, mainly because most traders invested almost equal amounts in goods A and B. Session 1, which has the lowest ‘symmetry’ of investments also has the lowest efficiency. By spending almost the same amounts for the two goods most traders ended up with almost 100 units of each good A and B, earning close to 100 points per period. Learning effects are again limited – mostly because participants made good choices right from the start (see Figure 4).

(Insert Figure 4 about here)

Another consequence of the equal split of investment between goods A and B by most traders is that the dispersion of the earnings of individual traders remains small; most participants in all sessions earned almost the same sum of points with no major outliers.

Figure 5 shows the period-wise percentage of the maximum allowed money “printed” (i.e., credit issued) by the players in the five sessions. This average varied widely between 30 to 90 percent and showed little stability within a given session. Prices (not shown) also varied accordingly. This is consistent with the existence of a continuum of non-cooperative equilibria in this strategic market game.

(Insert Figure 5 about here)

Finally, Figure 6 charts the relationship (actually lack thereof) between the percentage of maximum allowed money printed by individuals and their cash payoff. In terms of consumption payoffs, this economy confers no advantage on those who print more, nor does it penalize those who print less. The clearinghouse mechanism adjusts the exchange rate of currencies to ensure this.

(Insert Figure 6 about here)

### **3.4. Performance of the Gode-Sunder Artificial Agents**

A simple decision mechanism is employed here for Gode-Sunder (“zero-intelligence”) traders; each selects randomly from its opportunity set defined by the credit restrictions, i.e., the sum of its investments in the two goods is uniformly distributed

between zero and 6,000. In a second step it randomly splits this amount between the two goods, a fraction that is evenly distributed between 0 and 1 on good A, and the remainder on good B.

Simulations with ten Gode-Sunder traders yield average earnings of 79 points, average spending of 3,000, and ‘symmetry’ of only 0.39. This shows that the market constraints alone help achieve a relatively high degree of efficiency even with randomly chosen bids. Compared to autarkic earnings of 0, Gode-Sunder traders realize almost four-fifths of the CE maximum of 100. The human traders performed much better though, with average earnings around 99. The reason for this difference is that humans chose almost symmetric investments (symmetry of 0.80 versus 0.39) which generate higher earnings under the payoff function used.

#### **4. Conclusions**

The theoretical analysis of strategic market games indicates that an economy can closely approximate a competitive outcome with individually issued credit lines alone, without fiat or outside money or commodity money. These models also incorporate certain abstractions from what is observed in actual trade: (1) no transaction costs, (2) a perfect clearinghouse that balances accounts every period, (3) no intertemporal credit, (4) no possibility of a default, forcing each trader always to have a perfect reputation for being trustworthy. Laboratory experiments presented here are designed to replicate the conditions postulated in such model economies.

The clearinghouse balances all accounts each period, and rules out the many accounting problems associated with intertemporal trade. The combination of a powerful market mechanism plus a perfect clearinghouse puts enough structure on the game to prevent non-correlated, or at best weakly correlated behavior at mass scale to go far wrong. The sizes of the simple strategy sets are sufficiently limited that markets populated with even minimally intelligent agents do reasonably well in aggregate.

An implicit assumption in these models has been an emphasis on the role of the markets and the clearing house in promoting the efficient allocation of goods of known value. The important role of finance and markets as devices to evaluate items of uncertain worth has not been reflected in this experiment. As the tasks become more complex

involving a mixture of evaluation of the quantitative and qualitative, we suspect that the distinction in performance based on expertise may emerge.

Since the design of the present experiments corresponds almost exactly to the model (with all its abstractions from real phenomena), this experiment yields little insight into what would happen under more general conditions when one or more of these assumptions were relaxed.

To illustrate the roles of reputation and of expertise in exchange with finance would require a fresh experiment. A first step towards an exploration with endogenous formation of reputation can consist of an additional move after the clearinghouse has declared the exchange rates. While all (200) units of each individual are automatically put up for sale, individual may be allowed to make a strategic choice to deliver less. While the payout remain based on the clearinghouse prices, the deliveries are prorated if one or more traders fail to deliver in full. The penalty for the failure to deliver can vary from zero upwards, and to public disclosure of the failure. However given the simplicity of the accounting, the transparency of the violation of contract and the social context of the experimental subjects, we think that the matching of the role of reputation in the laboratory with its role in actual markets requires a separate investigation with a lot more than this simple addition.

In the meantime, our results reveal the considerable power of the market structure in promoting efficient allocation when reputation is given as perfect. The key claim that government money is not needed to achieve efficient exchange can be established experimentally as well as theoretically; but the implicit utopian assumptions concerning reputation, contract adherence and clearing efficiency stress the importance of contract enforcement, credit evaluation and clearing arrangements in the economy.

Both theory and experimentation can now verify that in an ideal financial environment individual IOU notes are sufficient for trade efficiency. The experimental and observational questions remain as to how these results are influenced by more realistic considerations of reputation and credit evaluation, contract enforcement and clearing arrangements. The free banking era shows different banknotes selling at various discounts depending on reputation and acceptability.

## 5. References

- Black, F. 1970. "Banking and Interest Rates In a World without Money: The Effects of Uncontrolled Banking." *Journal of Bank Research*, vol. 1: 9-20.
- Buiter, W. H. 2002. "The Fallacy of the Fiscal Theory of the Price Level: A Critique." *Economic Journal*, vol. 112: 459–80.
- Dubey, Pradeep, John Geanakoplos, and M. Shubik. 2003. "Is Gold an Efficient Store of Value?" *Economic Theory*, vol. 21(4): 767-782.
- Friedman, Benjamin M. 1999. "The Future of Monetary Policy: The Central Bank as an Army with Only a Signal Corps?" *International Finance*, vol. 2: 321-338.
- Friedman, Milton. 1959. *A Program for Monetary Stability*. New York: Fordham University Press.
- Gode, Dhananjay K. and Shyam Sunder. 1993. "Allocative Efficiency of Markets with Zero Intelligence Traders: Market as a Partial Substitute for Individual Rationality." *The Journal of Political Economy*, Vol. 101(1): 119-137.
- Goodhart, Charles A.E. 2000. "Can Central Banking Survive the IT Revolution?" Unpublished.
- Green, E. 1999. "We Need to Think Straight about Electronic Payments." *Journal of Money Credit and Banking*, August (2): 669–70.
- Hayek, Friedrich A. 1986. "Market Standards for Money." *Economic Affairs*, 6(4): 8-10.
- Henckel, Timo, Alain Ize, and Arto Kovanen. 1999. "Central Banking without Central Bank Money." IMF Working Paper No. 99/92.
- Huber, Juergen, Martin Shubik, and Shyam Sunder. 2007. "Three Minimal Market Games: Theory and Experimental Evidence." Cowles Foundation Discussion Paper 1623, Yale University.
- Modigliani, F., and M. H. Miller. 1958. "The Cost of Capital, Corporation Finance and the Theory of Investment." *American Economic Review*, vol. 48: 261-97.
- McCallum, B. 2003. "Monetary Policy in Economies with Little or No Money." Unpublished.
- Patinkin, D. 1965. *Money Interest and Prices*. New York: Harper & Row.

Patinkin, D. 1989. *Money Interest and Prices*. 2<sup>nd</sup> ed. abridged. Cambridge: MIT Press.

Rogers, C. 2006. "Doing without Money: A Critical Assessment of Woodford's Analysis." *Cambridge Journal of Economics*, vol. 30: 293-306.

Qin, C. Z. and M. Shubik. 2006. "A Credit Mechanism for Selecting a Unique Competitive Equilibrium." Cowles Foundation Discussion Paper No.: 1539RR, Yale University.

Quint, T. And M. Shubik "Gold, Fiat and Credit. An Elementary Discussion of Commodity Money, Fiat Money and Credit: Part II": Monopolistic and Oligopolistic Banking. Cowles Foundation Discussion Paper 1460, Yale University.

Shapley, L. S. and M. Shubik. 1977. "Trade Using One Commodity as a Means of Payment." *The Journal of Political Economy*, 85(5): 937-968.

Shapley, L. S. 1990. Class Notes, UCLA.

Shubik, M. 1973. "Commodity Money, Oligopoly, Credit and Bankruptcy in a General Equilibrium Model." *Western Economic Journal*, vol. 11(1): 24-38.

Sorin, S. 1996. "Strategic Market Games with Exchange Rates." *Journal of Economic Theory*, vol. 69(2): 431-446.

Woodford, M. 1998. "Doing without Money: Controlling Inflation in a Post-Monetary World." *Review of Economic Dynamics*, vol. 1: 173-219.

Woodford, M. 2000. "Monetary Policy in a World without Money." NBER Working Paper No.: W7853.



**Table 1: Non-cooperative Equilibria in the sell-all model**

Players on each side	Money bid for owned good	Money bid for other good	Bid owned/ bid other	Sum of bids	Money unspent	Price	Units of owned good bought	Units of other good bought	Allocative Efficiency
2	2653.51	1573.72	1.6861	4227.23	1772.77	21.14	125.54	74.46	96.68
3	2382.02	1698.17	1.4027	4080.19	1919.81	20.40	116.76	83.24	98.59
4	2273.52	1767.29	1.2864	4040.81	1959.20	20.20	112.53	87.47	99.21
<b>5*</b>	<b>2213.79</b>	<b>1810.88</b>	<b>1.2225</b>	<b>4024.67</b>	<b>1975.33</b>	<b>20.12</b>	<b>110.01</b>	<b>89.99</b>	<b>99.50</b>
6	2175.72	1840.80	1.1819	4016.52	1983.48	20.08	108.34	91.66	99.65
7	2149.25	1862.58	1.1539	4011.83	1988.17	20.06	107.15	92.85	99.74
8	2129.75	1879.13	1.1334	4008.88	1991.12	20.04	106.25	93.75	99.80
9	2114.78	1892.14	1.1177	4006.92	1993.08	20.03	105.56	94.44	99.85
10	2102.92	1902.62	1.1053	4005.54	1994.46	20.03	105.00	95.00	99.87
many	2000.00	2000.00	1.0000	4000.00	2000.00	20.00	100.00	100.00	100.00

\*Number of subject pairs in the laboratory experiment.

Money endowment ( $M$ ) = 6,000 units per trader

Goods endowment = (200,0) for one member and (0,200) for the member of each pair of traders.

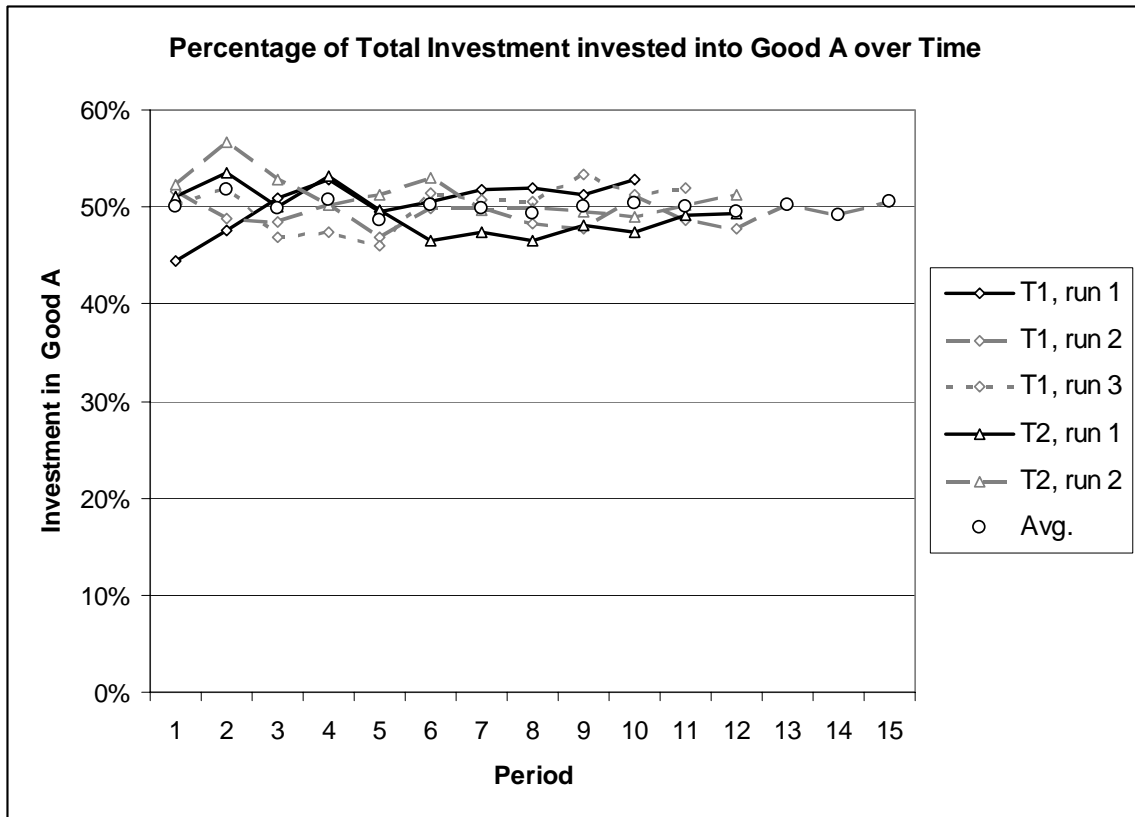
**Table 2: Percentage of total spending invested in A and B**

(Separated by those endowed with the proceeds from selling A and those endowed with the proceeds from selling B)

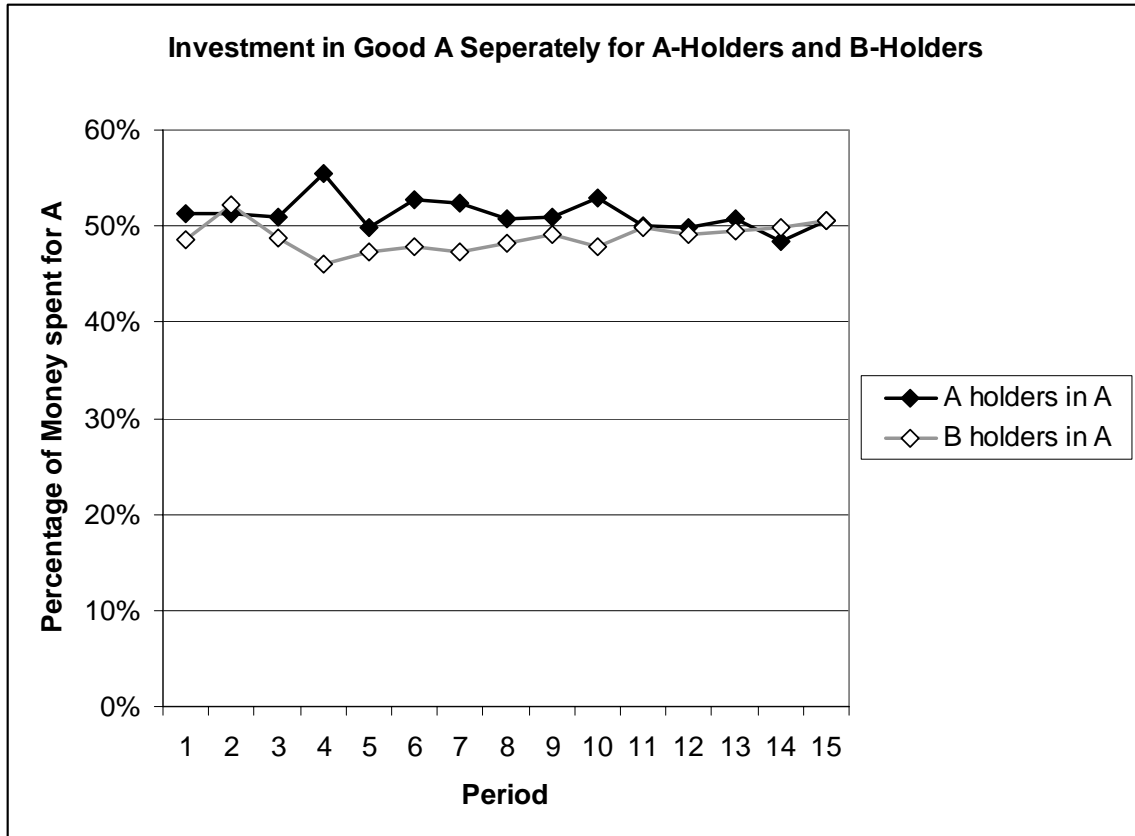
	Spending for A by A-holders	Spending for A by B-holders	Spending for B by A-holders	Spending for B by B-holders	Own-good-bias*	own-good-bias (as %age of other good)**
T1, run 1	54.6%	46.0%	45.4%	54.0%	8.6%	18.9%
T1, run 2	49.3%	49.3%	50.7%	50.7%	0.0%	0.0%
T1, run 3	50.8%	49.5%	49.2%	50.5%	1.3%	2.7%
T2, run 1	51.6%	47.0%	48.4%	53.0%	4.5%	9.9%
T2, run 2	52.3%	50.4%	47.7%	49.6%	1.9%	4.2%

\*Own-good-bias: the percentage spent for the own good minus the percentage spend for the other good.

\*\*The final column presents this bias as percentage of the spending for the other good



**Figure 1: Investment into good A as a Percentage of Total Investment**



**Figure 2: Investment in good A as a Percentage of Total Investment separately for A-holders and B-holders (Averaged Across Five Sessions)**

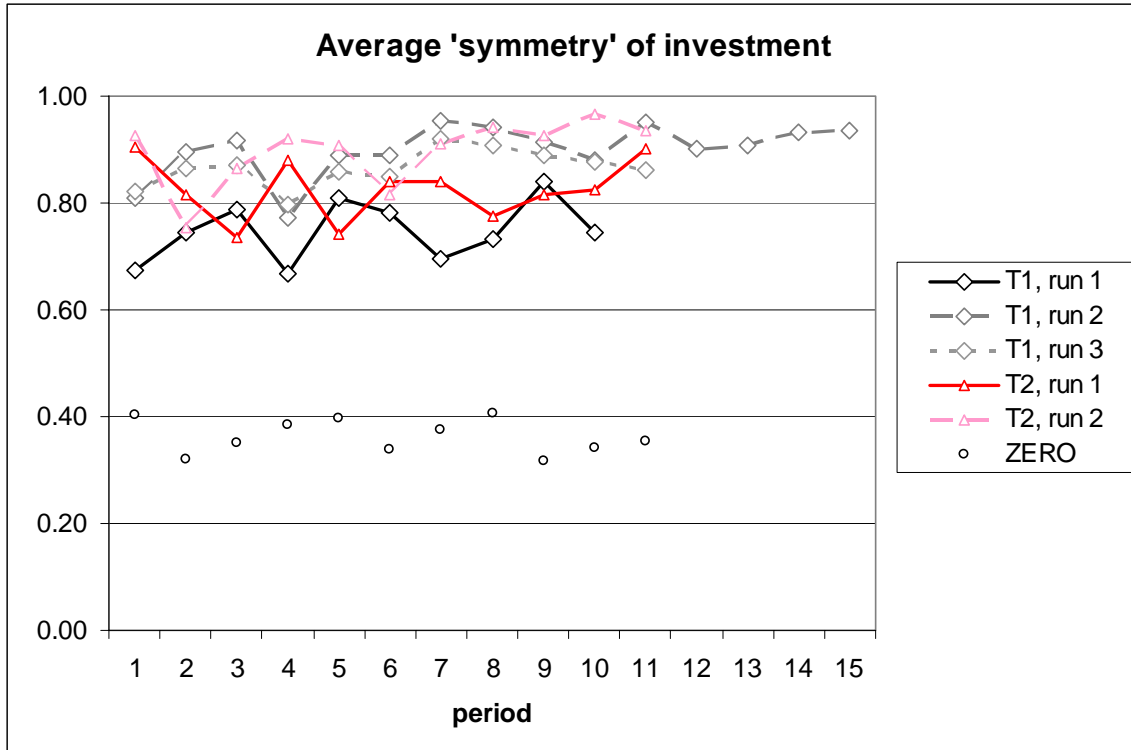
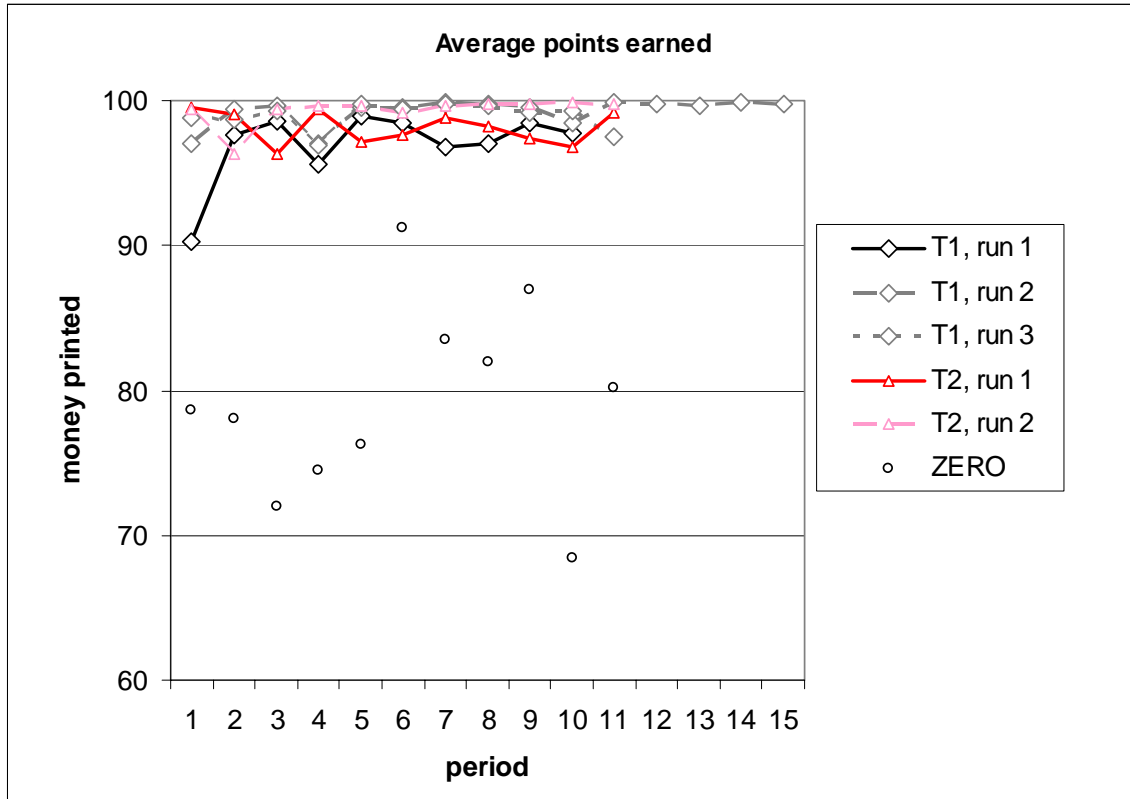
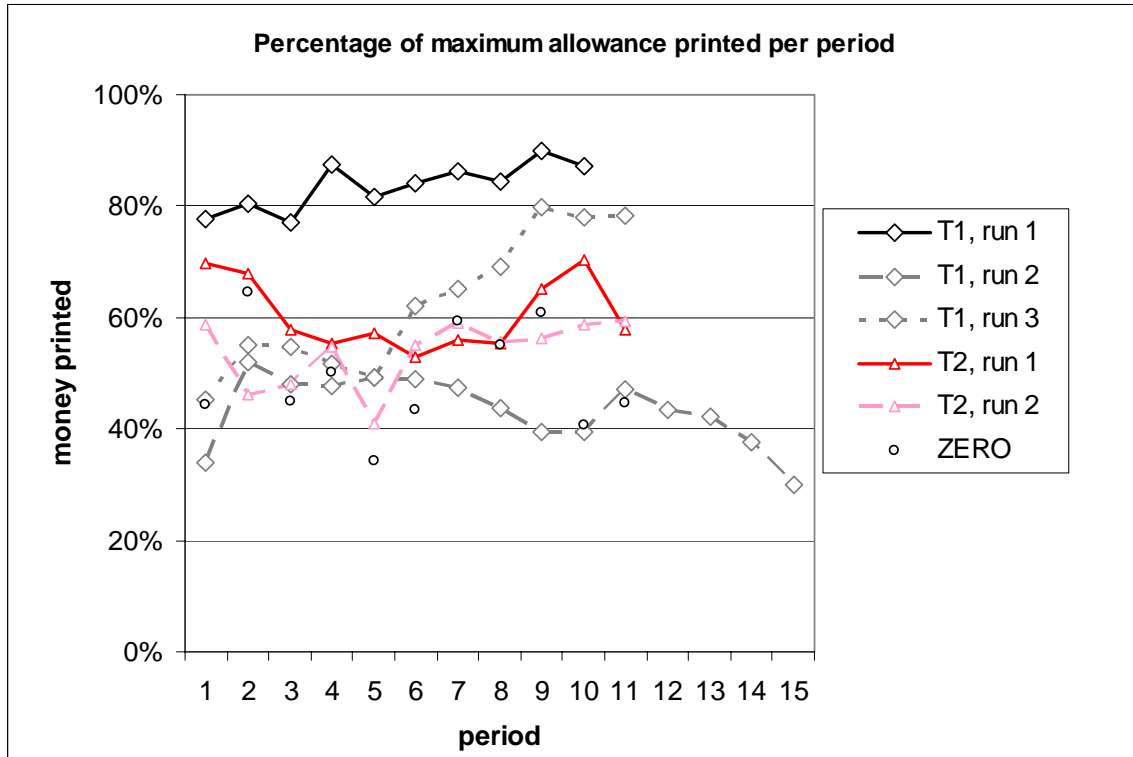


Figure 3: Average ‘symmetry’ of investment in the different experimental runs



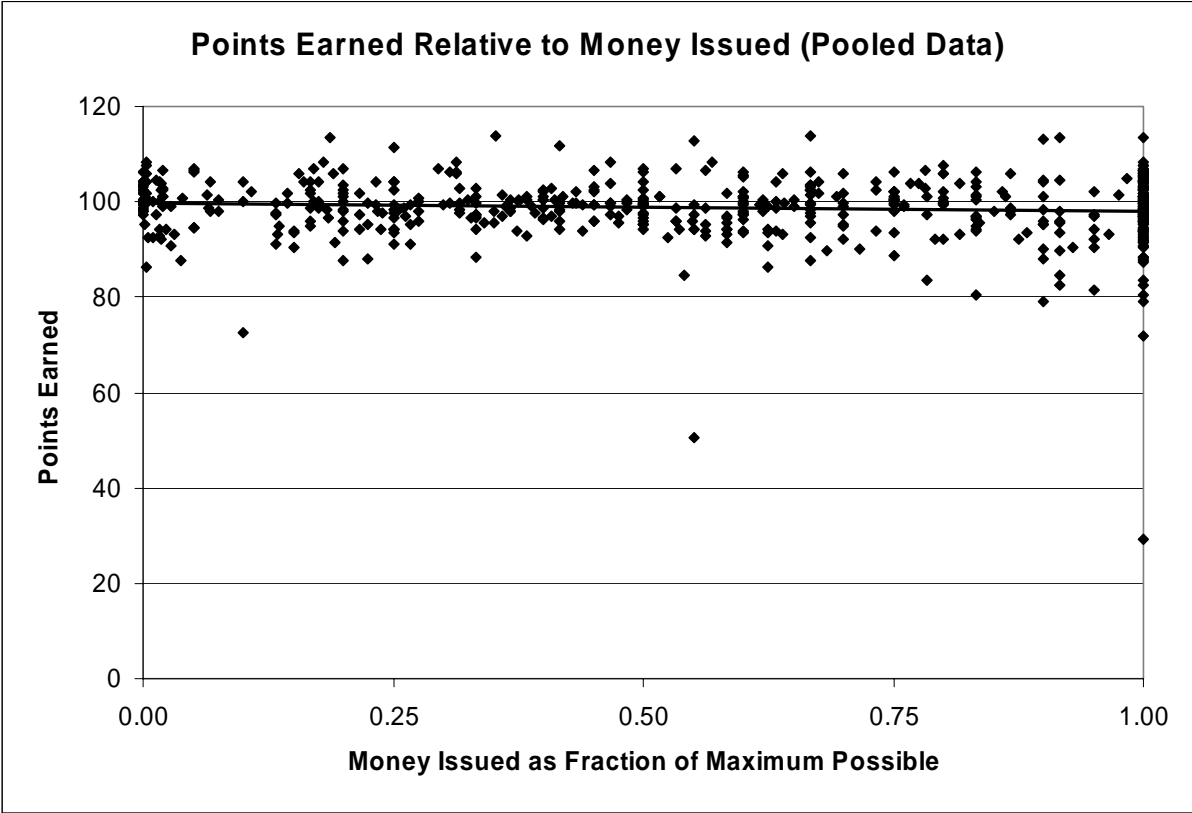
**Figure 4: Average points earned in the different experimental runs**



**Figure 5: Average amount of money printed per period as a percentage of maximum allowed**

**(Please note that this figure is not referred to in the text yet. Shyam)**

**Figure 6: Points Earned Relative to Money Issued (Pooled Data for 5 sessions)**



## Appendix A: Specific Solution to Non-Cooperative Equilibrium for Sell-All

Notation presented here is somewhat different from that in the Sorin article. In particular here only bids are strategic variables. The Sorin article considers a buy-sell strategic market game as contrasted with the sell-all model treated here, thus quantity offered for sale is also a strategic variable. The solutions to both models converge to the same limit point, but the path of convergence is somewhat different. We test sell-all convergence here.

### Notation

$b_i^{\alpha r}$  = the bid of individual  $\alpha$  ( $\alpha = 1, \dots, n$ ) of type  $r$  ( $r=1, 2$ ) in market  $i$  ( $i=1, 2$ )

$B$  = utility function scaling parameter

$p_i$  = price of commodity  $i$

$M$  = initial money holding of each trader

$(a, 0)$  = initial holding of goods in the hands of type 1 trader

$(0, a)$  = initial holdings of goods in the hands of type 2 trader.

Each individual of type 2 wishes to maximize his payoff function which is of the form:

$$\Pi = B \sqrt{\frac{b_1^{\alpha 2} b_2^{\alpha 2}}{p_1 p_2}} + (m - b_1^{\alpha 2} - b_2^{\alpha 2} + p_2 a)$$

and similarly for players of type 1.

The calculation for the sell-all model requires solution of the two equations derived for each trader from the first order conditions on the bidding in the two goods markets. By symmetry we need only be concerned with one type of trader.

We obtain the equation

$$\frac{b_2}{b_1} \left( \frac{(n-1)b_1 + nb_2}{nb_1 + (n-1)b_2} \right) = \frac{n}{n-1}$$

and can utilize this to calculate Table 1.



## Appendix B: Experimental Instructions

### General

This is an experiment in market decision making. The instructions are simple, and if you follow them carefully and make good decisions, you will earn more money, which will be paid to you at the end of the session.

This session consists of several periods and has 10 participants (some of them teams of two people). At the beginning of **each** period, five of the participants will receive as income the proceeds from selling 200 units of good A, for which they have ownership claim. The other five are entitled to the proceeds from selling 200 units of good B. In addition each participant will have the right to print and pay up to a maximum of 6,000 units of your own “personal” currency to buy goods A and B.

During each period we shall conduct a market in which the price per unit of A and B will be determined. Since different participants may print different amounts of “personal” currency, the prices of goods A and B in different currencies will generally be different. All your units of A (or B) will be sold at this price (in your personal currency), and you can buy units of A and B at this price with your “personal” currency. The following paragraph describes how the price per unit of A and B will be determined.

In each period, you are asked to enter the amount of cash (units of your “personal” currency) you are willing to print and pay to buy good A, and the amount you are willing to print and pay to buy good B (**in columns B and C of Figure 1**) during the current period. The sum of these two amounts cannot exceed the maximum amount you are allowed to print during the period (6,000 units of currency). If the currency amounts you enter in Column B or C, or the sum of these two amounts (in Column D) exceeds the maximum permissible limit of 6,000 units, the color of the cell will turn RED. You must reduce the amounts to remove the RED color before proceeding. Please note that how much currency you print is your own choice.

The computer will consider the money offered by every participant for good A. It will also calculate the total number of units of good A available for sale (1,000 if we have five participants, each with 200 units of good A). The same procedure is repeated for Good B. The computer will then calculate the prices of goods A and B, in units of the “personal” currency of each participant, so that the following conditions are satisfied:

- (1) For each trader, the proceeds from sale of goods A and B (**in Column N in Figure A-1**) equal the amount of “personal” currency printed and offered to buy goods A and B (**in Column D in Figure A-1**).
- (2) For each good A and B, the total number of units offered for sale is equal to the total amount bought at the market prices.

Note that since different traders may print different amounts of their “personal” currency, the price of goods specified in units of the “personal” currency of different traders may be different. For example if Trader 1 prints more currency than Trader 2, each unit of Trader 1’s currency may buy fewer goods than each unit of Trader 2’s currency.

The amount of currency you earn by selling the units of Good A (or B) given to you (**in Column N**) will be equal to the amount of currency you printed and offered to buy goods A and B (**in Column D**), and your net balance of currency will be zero.

If you offered to pay  $m_A$  units of your “personal” currency for good A, and  $m_B$  units of currency for good B (**in Columns B and C**), and the prices of goods A and B (in units of your personal currency) are  $p_A$  and  $p_B$  respectively (**in Columns E and F**), you get to buy (and consume)  $c_A = m_A/p_A$  units of good A and  $c_B = m_B/p_B$  units of good B (**in Columns G and H**).

The number of units of A and B you buy (and consume), will determine the amount of points you earn for the period:

Points earned (**in Column I**) = squareroot of ( $c_A \cdot c_B$ ).

*Example: If you buy 100 units of A and 25 units of B in the market you earn squareroot (100 \* 25) = 50 points.*

Figure A-1 shows the examples of these calculations for 3 periods. **Column K** shows the average number of points earned each period by the ten participants in the market.

The earnings of each period (**in Column I**) are accumulated in **Column J**. Your cumulative earnings at the end of session will determine how many “seminar points” you will get.

### How to calculate the points you earn:

The points earned are calculated according to the following formula:

Points earned = squareroot ( $c_A * c_B$ )

To give you an understanding for the formula the following table might be useful. It shows the resulting points from different combinations of goods A and B. It is obvious that, that more goods mean more points.

**Points Earned When You Consume Varying Amounts of Goods A and B**

		Units of good B you buy and consume										
		0	25	50	75	100	125	150	175	200	225	250
Units of A you buy and consume	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	25	35	43	50	56	61	66	71	75	79
	50	0	35	50	61	71	79	87	94	100	106	119
	75	0	43	61	75	87	97	106	115	123	130	137
	100	0	50	71	87	100	119	123	132	141	150	158
	125	0	56	79	97	119	125	137	148	158	168	177
	150	0	61	87	106	123	137	150	162	173	184	194
	175	0	66	94	115	132	148	162	175	187	198	209
	200	0	71	100	123	141	158	173	187	200	212	224
	225	0	75	106	130	150	168	184	198	212	225	237
250	0	79	112	137	158	177	194	209	224	237	250	

Examples:

- 1) If you buy 50 units of good A and 75 units of good B, then your points earned are = squareroot (50 \* 75) = 61.2.
- 2) If you buy 150 units of good A and 125 units of good B, then your points earned are = squareroot (150 \* 125) = 136.9.

**Figure A-1**

A	B	C	D	E	F	G	H	I	J	K	L	M	N	
Subject													1	
Maximum Amount of Personal Currency You can Print													6000 units	Note: Columns D and N should be equal
Period	Currency offer for Good A	Currency offer for Good B	Total Currency Offer (<=6000)	Market Price of A	Market Price of B	Units of A Bought ColB/ColE	Units of B Bought ColC/ColF	Earned Points sqrt(GH)	Cumulative Points	Average Pts this Period	Endowment Units of A	Endowment Units of B	Currency from sale of A and B	
1	566	1567	2134	10.67	11.07	53.10	141.56	86.70	86.70	83.64	200	0	2134	
2	2630	2617	5247	26.24	28.56	100.24	91.66	95.85	182.55	96.28	200	0	5247	
3	1929	603	2532	12.66	16.88	152.37	35.71	73.77	256.32	90.25	200	0	2532	
Dollars=Points/125=									2.05					