An Economy with Personal Currency: Theory and Evidence

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An Overview

- Background paper (Three Minimal Market Institutions)
- Is personal credit issued by individuals sufficient to operate an economy efficiently with no outside or government money?
- Sorin (1995)'s construction of a strategic market game proves that it is possible
- We report on a laboratory experiment in which each agent issues IOUs, and a costless efficient clearinghouse adjusts the exchange rates so markets always clear
- Results: when information system and clearinghouse preclude moral hazard, information asymmetry or need for trust, such economy operates efficiently without government money
- Conversely, it may be better to look for explanations for the prevalence of government money either in the abovementioned frictions, or in our unwillingness to experiment with innovation
Three Minimal Market Institutions: Theory and Experimental Evidence (August 2007)

Jürgen Huber, University of Innsbruck
Martin Shubik, Yale University
Shyam Sunder, Yale University
Outline

• Three minimal market designs
• Experimental implementation
• Results compared to three benchmarks:
  – General equilibrium
  – Non-cooperative equilibrium with 10 traders
  – Zero-intelligence traders (simulation)
• Concluding remarks and research plans
Market setup (in all three settings)

- Two goods (A and B) traded for money
- Each trader endowed with either A or B and money
- Multiplicative earnings function:
  \[ \text{Earnings} = \sqrt{A \times B} + \text{net money} \]
- Money carried over from period to period (except in double auction)
Three Minimal Market Institutions

1. The sell-all model (strategy set dimension 1: all commodity endowment sold; each trader bids an amount of money to buy each commodity)

2. The buy-sell model (strategy set dimension 2: each trader offers the quantity of endowed good and bids money for the other good)

3. The simultaneous double auction model (strategy set dimension 4: each trader offers to sell each good and bids to buy each good)
### Sell All Market

<table>
<thead>
<tr>
<th>Periods</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

You have:

- Ownership claims for units of good A: 0
- Ownership claims for units of good B: 200
- Units of money: 6000

Amount you offer to pay to buy A: [ ]

Amount you offer to pay to buy B: [ ]
<table>
<thead>
<tr>
<th>Period</th>
<th>Total amount offered for A</th>
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<tr>
<td></td>
<td>Price of A</td>
<td>18.0</td>
</tr>
<tr>
<td></td>
<td>Units of A sold for you</td>
<td>200</td>
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<tr>
<td></td>
<td>Proceeds from sales of A</td>
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<tr>
<td></td>
<td>Units of A you bought and consumed</td>
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<tr>
<td></td>
<td>Payment for buying A</td>
<td>2200</td>
</tr>
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</table>

|        | Total amount offered for B | 21476 |
|        | Price of B                | 21.5  |
|        | Units of B sold for you   | 0     |
|        | Proceeds from sales of B  | 0     |
|        | Units of B you bought and consumed | 88 |
|        | Payment for buying B      | 1300  |

Points earned:
- Money at start of period: 6219
- Proceeds from selling A and B: 3775
- Payment for buying A and B: 4100
- New money holdings: 5894

Your earnings this period: 1015

\[\text{Your earnings this period} = 10 \times \text{square root}(A \times B)\]

<table>
<thead>
<tr>
<th>period</th>
<th>price A</th>
<th>consumption of A</th>
<th>price B</th>
<th>consumption of B</th>
<th>money</th>
<th>earnings</th>
<th>cumulative earnings</th>
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<td>104</td>
<td>19.6</td>
<td>92</td>
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<td>21.5</td>
<td>96</td>
<td>5894</td>
<td>1015</td>
<td>2964</td>
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</table>
Buy-Sell Market

Period

4

Remaining time [sec]: 20

You have:
Units of good A you own: 0
Units of good B you own: 200
Units of money: 5500

Units of B you sell

Amount you offer to pay to buy A
<table>
<thead>
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<th>Period</th>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>10600</th>
<th></th>
<th>9300</th>
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<tbody>
<tr>
<td>Market amount bid for A</td>
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<td></td>
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<td>Total units of A offered for sale</td>
<td>470</td>
<td></td>
<td>450</td>
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<td>Price of A</td>
<td>22.6</td>
<td></td>
<td>20.7</td>
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<td>Units of A you sold</td>
<td>100</td>
<td></td>
<td>2000</td>
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<tr>
<td>Proceeds from sales of A</td>
<td>2255</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units of A you own at end of period</td>
<td>100</td>
<td></td>
<td>97</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Market amount bid for B</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total units of B offered for sale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price of B</td>
<td>20.7</td>
<td></td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Amount you offered for B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units of B you buy</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units of B you own at end of period</td>
<td></td>
<td></td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

Money balance at start of period 2333
Proceeds from selling A or B 2255
Payment for buying A or B 2000
Money balance at end of period 2588

Points earned
Your earnings this period: 984

\[ \text{Points earned} = 10 \times \text{square root}(A \times B) \]

<table>
<thead>
<tr>
<th>period</th>
<th>price A</th>
<th>consumption of A</th>
<th>price B</th>
<th>consumption of B</th>
<th>Money</th>
<th>earnings</th>
<th>cumulative earnings</th>
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<td>2333</td>
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<td>22.6</td>
<td>100</td>
<td>20.7</td>
<td>97</td>
<td>2589</td>
<td>984</td>
<td>1800</td>
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</table>
Double Auction

Market for good A
Units of A you hold: 0

Money: 1140

Market for good B
Units of B you hold: 20

[Diagram showing bidding and asking for goods A and B]
Endowments
(Good A/Good B/Money)

- 200/0/6000 or 0/200/6000 in sell-all
- 200/0/4000 or 0/200/4000 in buy-sell
- 20/0/4000 or 0/20/4000 in double-auction

- 10 traders in each market (5+5)
- One buy-sell market with 20 traders (10+10)
<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
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<th>CGE Quantity/Price</th>
<th>NCE (5+5) Quantity/Price</th>
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<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Sell All</td>
<td>200</td>
<td>0</td>
<td>100/20</td>
<td>100/20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>110/20.1</td>
<td>90/20.1</td>
</tr>
<tr>
<td>Buy Sell</td>
<td>200</td>
<td>0</td>
<td>100/20</td>
<td>100/20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>122/20</td>
<td>78/20</td>
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<tr>
<td>Double Auction</td>
<td>20</td>
<td>0</td>
<td>10/100</td>
<td>10/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11/100</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
Figure 1: Efficiency of Allocations (Average Earnings) for $n = 5+5$

![Graphs showing efficiency of allocations for different trading mechanisms with average earnings for each run and mean values.](image-url)
Figure 2: Performance of Buy-Sell Market with \( n = 10 + 10 \)

- **Earnings (Mean=98.1)**
- **Prices (Mean=16.4 for A, 16.5 for B)**
- **Symmetry (Mean=0.81)**
- **Unspent money (Mean=62.45 percent)**
- **Standard dev. Of Earnings (Mean=118)**
- **Trade as % of trade needed to achieve GE**
Figure 3: Price Levels and Developments for $n = 5+5$

Sell-All (Run 1, Avg. A=18.92; B=20.90)

Sell-All (Run 2, Avg. A=21.52; B=20.49)

Buy-Sell (Run 3, Avg. A=11.32; B=9.24)

Buy-Sell (Run 4, Avg. A=19.89; B=16.34)

Double Auction (Run 5, Avg. A=261; B=246)

Double Auction (Run 6, Avg. A=225; B=170)
Figure 4: Double Auction Transaction Price Paths within individual Trading Periods with G-S traders

Run 5: Transaction Sequence No.

Run 6: Transaction Sequence No.
Figure 5: Symmetry of Allocations for $n = 5+5$

Sell-All (Session 1, Mean=0.76)

Sell-All (Session 2, Mean=0.71)

Buy-Sell (Session 3, Mean=0.60)

Buy-Sell (Session 4, Mean=0.71)

Double Auction (Session 5, Mean=0.53)

Double Auction (Session 6, Mean=0.60)
Figure 6: Unspent money as a percentage of initial endowment for \( n = 5+5 \) traders.

- **Sell-All (Session 1, Mean=33.63)**
  - Period: 0 to 20

- **Sell-All (Session 2, Mean=29.99)**
  - Period: 0 to 20

- **Buy-Sell (Session 3, Mean=73.72)**
  - Period: 0 to 20

- **Buy-Sell (Session 4, Mean=60.47)**
  - Period: 0 to 20
Figure 7: Standard Deviation of Earnings per Period

Sell-All (Session 1, Mean=150)

Sell-All (Session 2, Mean=165)

Buy-Sell (Session 3, Mean=463)

Buy-Sell (Session 4, Mean=243)

Double Auction (Session 5, Mean=261)

Double Auction (Session 6, Mean=362)
Figure 8: Goods traded as Percentage of Trade needed to achieve GE

Sell-All (Session 1, Mean=86.63)

Sell-All (Session 2, Mean=82.97)

Buy-Sell (Session 3, Mean=105.16)

Buy-Sell (Session 4, Mean=88.75)

Double Auction (Session 5, Mean=68.40)

Double Auction (Session 6, Mean=80.91)
Figure 9: Autocorrelation functions of returns and absolute returns (Runs 5, 6)

Run 5

Run 6
Comparison of markets I

Avg. Earnings as percentage of maximum

- Sell all: 98%
- Buy sell: 92%
- Double auction: 86%
Comparison of markets II

Standard deviation of final wealth

- Sell all
- Buy sell
- Double auction
<table>
<thead>
<tr>
<th>Period</th>
<th>Symmetry</th>
<th>Buy-sell</th>
<th>Sell-all</th>
<th>Double auction</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.25</td>
<td>0.50</td>
<td>0.75</td>
</tr>
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<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
<td>0.75</td>
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<td>4</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
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<tr>
<td>5</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
<td>0.75</td>
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<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
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<tr>
<td>7</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
<td>0.75</td>
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<tr>
<td>8</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
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<tr>
<td>9</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
<td>0.75</td>
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<tr>
<td>10</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Comparison of markets III

'Symmetry' of Investment in different Treatments

- Sell All
- Buy-Sell
- Double Auction
Avg. Prices

Buy-sell

Sell-all

Double auction
Trading vol.

Buy-sell

Sell-all

Double auction
Conclusions from the Background Paper

• The non-cooperative and general competitive equilibrium models provide a reasonable anchor to locate the observed outcomes of the three market mechanisms.

• Unlike well known results from many partial equilibrium double auctions, prices and allocations in our double auctions reveal significant and persistent deviations from CGE predictions.

• The market form has a significant influence on allocative efficiency and the return distribution: the outcome paths from the three market mechanisms exhibit significant differences among them.
The Current Paper: Need for Government Money?

- Is outside or government money necessary to operate an economy efficiently?
- Proponents of alternatives to government money suggest that if all individuals and institutions could issue debt as means of payment, market will sort out the risk and reputations of accepting such paper;
- For example, Black (1970); rates of interest in the City of London for “prime” and “lesser” names, discounting of bills issued by hundreds of banks in the free banking era of the U.S.
Strategic Market Game

• Outside or government money is not needed if there is perfect clearing and no default.
• Result is valid under conditions which are clearly counterfactual (like M&M on neutrality of cost of capital with respect to leverage).
• Logical possibility of such an economy does not mean that an economy will actually function smoothly with private money under exogenous uncertainty, and dispersed and imperfect information.
• Process dynamics, trust and evaluation are core issues in functioning of a financial system and are absence in Black or M&M equilibrium models.
Acceptability of Government Money

- No bank (much less individual) can match the visibility of government,
- Government’s reputation is known to all
- Government is better able to enforce the rules of the game
- Government money expedited and simplified taxation as an unintended (?) consequence
- Handed to government additional policy options (e.g., financing of wars and control of economy)
- Acceptability of IOUs involves trust and trust in government may be higher in most instances than in even big banks (individuals have little chance)
- Everyone-a-banker game could be seen as a simplified version of governments issuing their own money in the international exchanges to settle their payments
- In the experiment presented here, we cleanse the lab economy of such frictional and informational issues to ask if the logical possibility of private money economy is also a behavioral possibility
Laboratory Modeling

- Computer implements the sell-all model
- Uses the quantities endowed and money bid for each good to calculate a market clearing price for each good and exchange rates for each trader’s money
- Computer acts as a clearing house as well as a perfect reputation enforcement mechanism (no reneging, no bankruptcy)
- Examines every-one-a-banker model in absence of uncertainty-related explanations for government money
- Yields high efficiencies
- Key theoretical claim that government money is not needed for efficiency exchanges is supported experimentally under these circumstances
  - Ideal contract enforcement, credit evaluation, and clearing arrangements
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 with tare:

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

And the budget balance gives

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

- Sorin establishes the existence of an active non-cooperative equilibrium set of prices and exchange rates which converges to a competitive equilibrium as the number of traders increases.
- The clearinghouse balances expenditures and revenues for all.
Experiment

- Two goods
- Two types of traders with endowment (200,0) and (0, 200)
- Upper limit on IOU (6,000)
- Each agent submits bids for each good each period subject to total < 6,000
- Computer calculates the prices of two goods in each personal currency and allocates goods
- Points earned = squareroot (CA* CB)
- CE: 2000 units to get 100 units of each good
- With 5+5 agents, bid 2214+1811 for the two goods
Table 1: Non-cooperative Equilibria in the sell-all model

<table>
<thead>
<tr>
<th>Players on each side</th>
<th>Money bid for owned good</th>
<th>Money bid for other good</th>
<th>Bid owned/bid other</th>
<th>Sum of bids</th>
<th>Money unspent</th>
<th>Price</th>
<th>Units of owned good bought</th>
<th>Units of other good bought</th>
<th>Allocative Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2653.51</td>
<td>1573.72</td>
<td>1.6861</td>
<td>4227.23</td>
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<td>1810.88</td>
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<td>91.66</td>
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<td>many</td>
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<td>1.0000</td>
<td>4000.00</td>
<td>2000.00</td>
<td>20.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*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.
Allocation of Money

- Fig. 1: Money spending balanced between goods A and B
- CGE predicts equal amount spent on two goods
- With 5+5 subjects, non-cooperative equilibrium predicts 22 percent more money being spent to the owned good
- Table 2 and Figure 2 data are weakly consistent with this prediction
- The results appear to be closer to CE than to non-cooperative equilibrium
Figure 1: Investment into good A as a Percentage of Total Investment
### 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)

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

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

- Smaller investment / larger investment in the two goods
- 0-1
- Period-wise averages charted in Figure 3
- Symmetry ranges from .7 to .95, slightly higher than the average of .65 in HSS 2007
Figure 3: Average ‘symmetry’ of investment in the different experimental runs
Allocative Efficiency

- Actual number of points earned/Maximum possible points (i.e. CGE)
- Observations in range 96.9 to 99.3 (Figure 4)
- Most traders invested equal amounts in the two goods
- Session 1 has lowest symmetry and efficiency
- With efficient decisions from the beginning, little opportunity to “learn” over time
- Low cross sectional dispersion of earnings
Figure 4: Average points earned in the different experimental runs

![Graph showing average points earned over different runs and periods.](image-url)
Credit Limit Actually Used

• Varied widely over range 30-90 percent (Figure 5)
• Little stability
• Suggest continuum of non-cooperative equilibria
Figure 5: Average amount of money printed per period as a percentage of maximum allowed

![Graph showing the average amount of money printed per period as a percentage of maximum allowance. The graph includes data for T1, run 1, T1, run 2, T1, run 3, T2, run 1, T2, run 2, and ZERO. The x-axis represents the period, and the y-axis represents the percentage of maximum allowance printed.](image)
Link Between Money Printed (Percent of Credit Limit Used) and Earnings of Individuals

• No detectable link
• The economy offers no advantage to those who print more
• Also, no disadvantage to those who print less
• The clearinghouse mechanism adjusts the exchange rates among money issued by various players appropriately
Figure 6: Points Earned Relative to Money Issued (Pooled Data for 5 sessions)
Minimally Intelligent Agents

- Total spending $\sim U(0, 6,000)$; split randomly between Goods A and B
- Efficiency 79% ($4/5^{th}$ of the gain from autarky to CGE from random behavior)
- Average spending 3000
- Average symmetry 0.39
  - Humans with symmetric behavior (0.80) almost 100% efficient
Introducing Moral Hazard
With Moral Hazard (T2)
With Moral Hazard (T2)
Minimally Intelligent Agents
Average earnings per period as percentage of maximum
Conclusions

- Theoretical analyses of strategic market games indicate that economy can approximate competitive outcomes with individually issued credit lines alone (without fiat or commodity money).
- This model abstracts away from transactions costs, intertemporal credit, possibility of default (forcing all traders to have perfect reputation for trustworthiness) through a perfect clearinghouse mechanism for enforcement (no accounting problems of intertemporal trade).
- The lab economy mimics these conditions postulated in the model economy (and tells us little about what would happen when these conditions are violated).
Conclusions

• This powerful market mechanism and clearinghouse puts enough structure to prevent non-correlated or at best weakly correlated behavior at a mass scale to go far wrong

• With small size of strategy sets, even economies populated with minimally intelligent agents perform reasonably well

• With more complex evaluative tasks, expertise may exhibit more value

• Design of future experiments with roles for reputation and expertise (e.g., non-delivery)
  – Social context problem in laboratory
Conclusions

• In the meantime, results reveal considerable power of market structure in producing efficient outcomes when reputation is not an issue.
• Under such circumstances, the claim that government money is not needed for efficient exchange is supported analytically as well as experientially.
• Future experiments under weaker conditions.
• In the free banking era in the U.S., different bank notes sold at different discount rates depending on their individual reputation and acceptability.
# Points Earned When You Consume Varying Amounts of Goods A and B

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<th>125</th>
<th>150</th>
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