

# Monetary Economics in the Laboratory

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# Three Roles of Money

- 1 As a store of value.
  - Experimental studies using overlapping generations models.
- 2 As a unit of account.
  - Experimental studies of money illusion.
- 3 As a medium of exchange.
  - Experimental studies of search-theoretic models of money.

# Overlapping Generations Models of Money as a Store of Value

- Consider a two period, pure exchange overlapping generations economy with  $n$  young ( $y$ ) and  $n$  old ( $o$ ) agents.
- All agents are endowed with  $e^y$  units of the consumption good when young and  $e_o$  units of this good when old, with  $e^y > e^o$ .
- Each member of the old generation alive at  $t$  has some units  $m_{t-1}$  of a durable but intrinsically worthless fiat object, “money,” acquired in youth that can be used to buy some of the current young generation’s consumption good at current price  $p_t$ . Total money supply at time  $t$  is given by  $M_t = \sum_{i=1}^n m_{t-1}^i$ .
- The representative young agent born at time  $t$  solves:

$$\max_{c_t^y, c_{t+1}^o} c_t^y \cdot c_{t+1}^o$$

$$\text{subject to } c_t^y = e_y - m_t/p_t, \quad c_{t+1}^o = e_o + m_t/p_{t+1}.$$

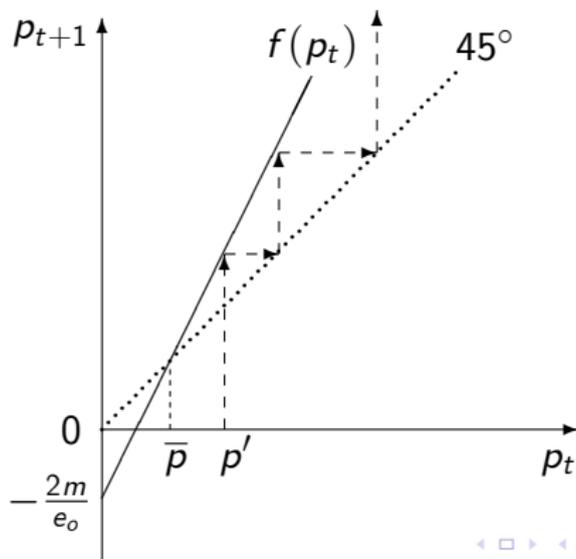
# Fixed Money Supply, $M_t = M$

- The first order conditions imply that in equilibrium,

$$p_{t+1} = f(p_t) = -\frac{2m}{e_o} + \frac{e_y}{e_o} p_t, \quad (1)$$

which has stationary solution:  $\bar{p} = \frac{2m}{e_y - e_o}$

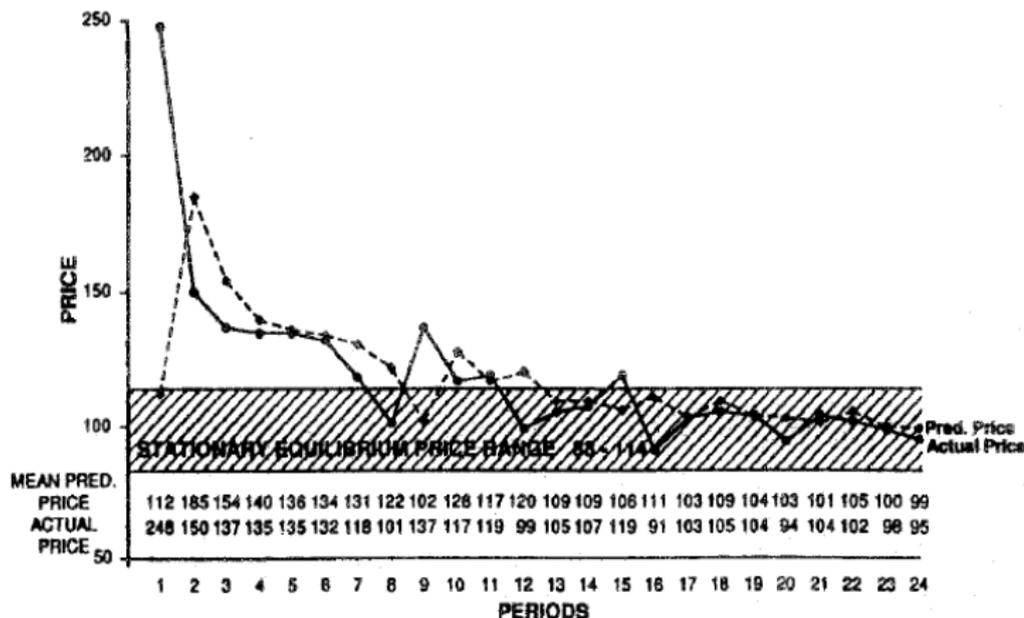
- But this solution is *unstable* unless  $p_0 = \bar{p}$ :



- Implement this model in the laboratory, following Lucas's 1986 invitation.
- Divide subjects up into cohorts of size  $n$ , young, old. Allow rebirth/learning.
- Each subject is given an endowment of  $e_y = 7$ ,  $e_o = 1$ , Initial old given 1,000 francs each (fixed  $M$ ).
- Young offer some of their endowment  $e_y$  in exchange for units of money from the old  $m = M/n$ .
- This is done using a double auction or by eliciting a supply schedule chips for francs from the young (old inelastically supply their francs).
- They consider both the perfectly competitive stationary price with the stationary Nash equilibrium price that takes account market power of the small numbers of agents.

# Findings-Price Dynamics

Prices converged towards the upper end of the range of stationary Nash solutions as opposed to the lower end defined by the competitive equilibrium. Importantly, demonetization of the economy (hyperinflation) is not observed.

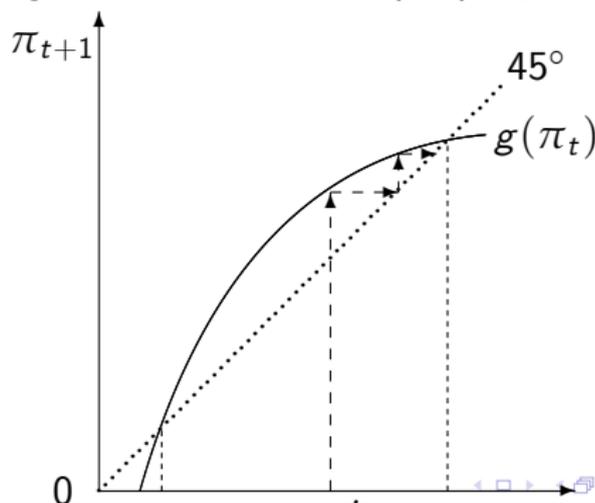


# Growing, Endogenous Money Supply to Finance Government Expenditures

- A government purchases  $d$  chips (consumption good) per capita at price  $p_t$  via printing more money, in per capita terms:

$$\Delta m = m_t - m_{t-1} = p_t d. \quad (2)$$

- Combining (1-2) and assuming rational expectations, one can derive a law of motion for gross inflation,  $\pi_t = p_t/p_{t-1}$ :  $\pi_{t+1} = g(\pi_t)$ .

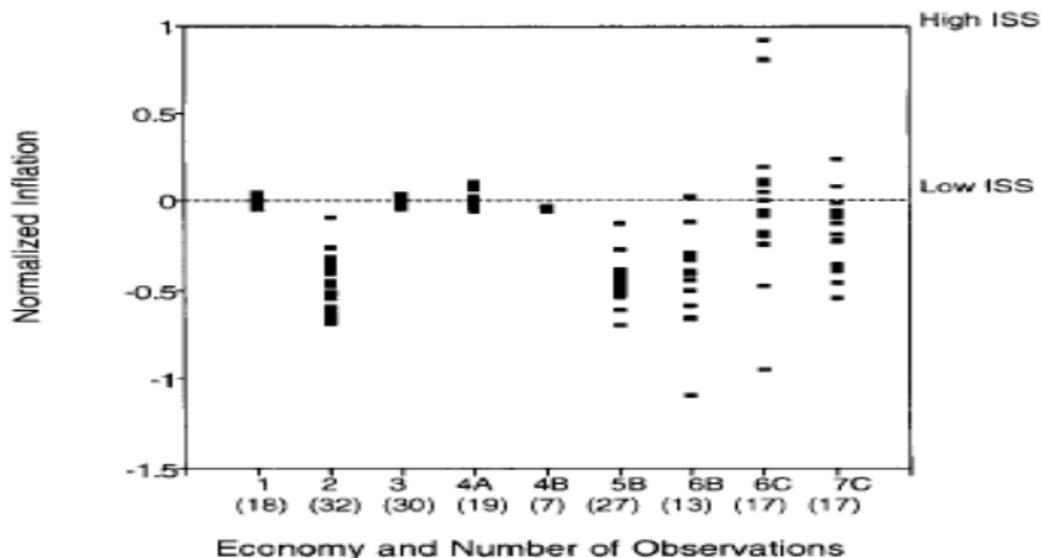


# Marimon and Sunder (*Ecmta* (1993))

- Each period,  $n$  young,  $n$  old and  $N - 2n > n$  sit on the sidelines. Agents live (are active) for two periods. Then sit on sideline, and are randomly selected to be new young agents at the start of each period.
- Sidelined agents compete to forecast  $p_{t+1}$ ; Following the final period  $T$  (not known to subjects) the average forecast is used to calculate final payoffs.
- Endowment of "chips" is higher in youth than in old age, e.g.  $e^y, e^o = \{7, 1\}$  Initial old are endowed equally with units of money.
- Young submit supply schedules of chips for money. Old agents inelastically supply money. The price at which demand equals supply is the market price of chips (consumption) in terms of money. Given savings,  $m_t$  consumption is  $e^y - m_t$  for time  $t$  young, and  $e^o + m_{t-1}/\pi_t$  for old at time  $t$ .  $u_t = \log c_t + \beta \log c_{t+1}$  is used to determine payoff.
- It is common knowledge that the government buys  $D = nd$  units of chips every period at the prevailing market price following (2).

# Marimon and Sunder's Findings

- The actual path for inflation in all of their experimental sessions is always in a neighborhood around the *low* inflation stationary equilibrium,  $\pi_{low}$ .
- Inflation rates were never observed in a neighborhood around the high inflation steady state,  $\pi_{high}$ , nor were they ever found to be explosive.



## Marimon and Sunder's Findings, Continued

- These findings can be explained by subjects' use of some kind of adaptive rather than rational expectations.

$\pi_{t+1}^e = \pi_{t-1}^e + \alpha(\pi_{t-1} - \pi_{t-1}^e)$ ,  $0 < \alpha < 1$ , fits the data from many sessions reasonably well. When estimated versions of such rules are used in place of rational expectations, the low inflation steady state,  $\pi_{low}$  is found to be locally stable, and  $\pi_{high}$  is found to be locally unstable, thereby explaining the attractiveness of  $\pi_{low}$ .

- Essentially, the mapping for equilibrium inflation is transformed so that  $\pi_{t+1} = \pi_{t+1}^e = f(\pi_{t-1}) = g(\pi_t)$ , or  $\pi_t = g^{-1}[f(\pi_{t-1})]$ .
- There also seems to be a bias for a constant consumption heuristic wherein subjects seek to equalize their consumption in both periods of life which leads to an even lower stationary inflation rate than  $\pi_{low}$ .

# Money Illusion and Money's Role as a Unit of Account

- There is no question that money serves as a unit of account, that is, as a common measure of the value of all goods and services.
- However, when it comes to thinking about the value of goods and services *over time*, taking inflation (or deflation) of prices into account, casual empiricism suggests that individuals frequently think in *nominal* or “current dollar” terms, rather than in *real* or “constant dollar” terms as is assumed in economic theories.
- Examples:
  - 1 Stock exchanges report performance in nominal terms.
  - 2 Many wage and debt contracts are not indexed to inflation though indexation is trivial.
  - 3 Movie box office: All-time non-inflation adjusted record: Avatar (2009). Inflation-adjusted, the winner is Gone with the Wind (1939).
- Of course, it remains possible that adjustments for inflation are still made, but casual empiricism suggests otherwise. Irving Fisher (1928) wrote a whole book on the subject, *The Money Illusion*.

# Survey evidence for Money Illusion

- Bewley (1999) surveyed U.S. firms and found that most had refused to cut nominal wages during the recession of 1991-92 even though unemployment was high.
- Questionnaire survey evidence by Shafir et al. (*QJE* (1997)). Look at money illusion as a framing issue. Consider this question of theirs:  
“Two competing bookstores have in stock an identical leather-bound edition of Oscar Wilde’s collected writings. Store A bought its copies for \$20 each. Tom, who works for Store A, has just sold 100 copies of the book to a local high school for \$44 a copy. Store B bought its copies a year after Store A. Because of a 10% yearly inflation, Store B paid \$22 per copy. Joe, who works for Store B, has just sold 100 copies of the book to another school for \$45 a copy. Who do you think made a better deal selling the books, Tom or Joe?”

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- 87% of a group of 130 subjects (people approached at airports, shopping malls) incorrectly chose Tom.

# Experimental Evidence of Money Illusion

- Several papers by Fehr and Tyran (*AER* 2001, *GEB* 2007, *Ecmta* 2008) -focus on GEB paper:
- A symmetric, n-player pricing game with three Pareto-ranked equilibria.
- Each player  $i$  chooses a price  $P_i \in \{1, 2, \dots, 30\}$ .
- Payoff function  $\pi_{i,t} = f(P_i, P_{-i,t})$ , presented as a  $30 \times 30$  payoff table that was common to all  $n$  subjects, either in real or nominal terms.

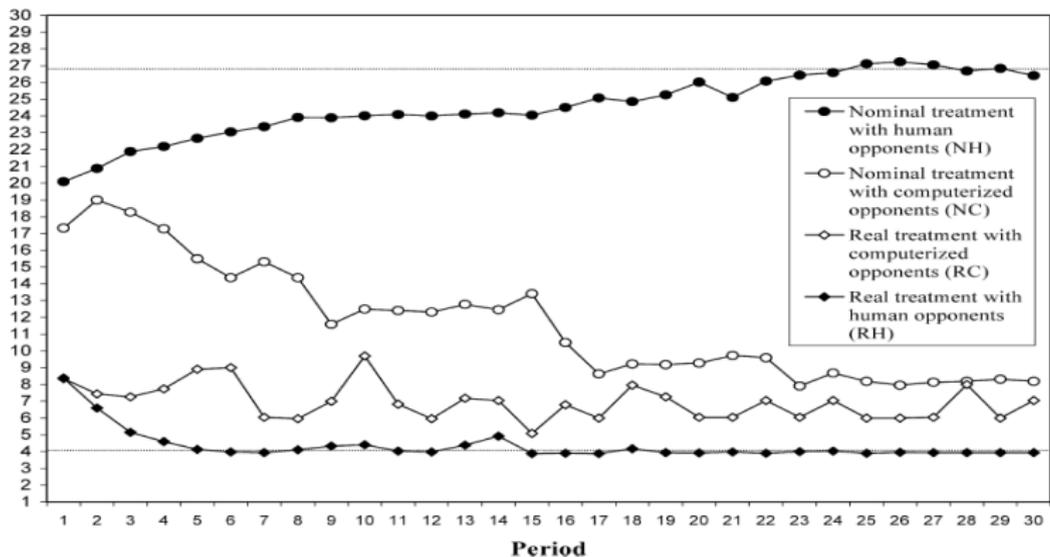
Equilibrium	Equilibrium price level	Real equilibrium payoff	Nominal equilibrium payoff
A	$P_A = 4$	$\pi_A = 28$	$P_A \pi_A = 112$
B	$P_B = 10$	$\pi_B = 5$	$P_B \pi_B = 50$
C	$P_C = 27$	$\pi_C = 21$	$P_C \pi_C = 567$

# Experimental Design

- $2 \times 2$ : Real or nominal presentation of payoffs. Subject plays against  $n - 1$  other human subjects or  $n - 1$  robot players.
- Real payoffs for all choices were identical across all treatments: subjects earned the same real payoff for any combination of  $P_i$  and  $P_{-i}$ , regardless of the treatment condition.
- Subjects in the nominal treatment were instructed that they needed to divide (deflate) payoffs by  $P_{-i}$  to get their real payoff. Subjects in the real treatment were shown real payoffs.
- Robot treatment: robot players choose a known best reply  $P_{-i}$  to the single subject's choice of  $P_i$  so in this case, subjects act as Stackelberg leaders. Solve an individual optimization problem (best choice is A,  $P_i = 4$ )
- The experiment tests the conflict between nominal and real payoff dominance. Individual optimization gets rid of noise/uncertainty about how susceptible other players are to money illusion.
- Repeated play of the same game for 30 periods in each treatment condition (with same subjects/robots).

# Experimental Results

- Human subjects only: Convergence to the inefficient equilibrium in the nominal frame, efficient equilibrium in the real frame.
- Robot/Individual optimization treatment: Slow convergence to the efficient equilibrium.



# Search Models of Money as a Medium of Exchange

- Simple game-theoretic models of monetary exchange with a focus on origins of money as a medium of exchange. Only beginning to be used for policy analysis, e.g. as in Lagos and Wright (*JPE*, 2005).
- Acceptance of a certain good(s) (money) not desired for own consumption is predicated on the belief that others will accept those same good(s) in exchange for goods that are desired for own consumption - an explicitly strategic calculation.
- The game is also explicitly dynamic - exchange occurs in real-time.
- The theory includes two frictions thought to be necessary for a coherent theory of money:
  - ① anonymity (private histories are not public information).
  - ② random matching (no fixed locations /long-term relationships).
- Explicit modeling of exchange process (unlike Walrasian CE). Experimentally a different mechanism for exchange than the double auction.

# Kiyotaki and Wright's Commodity Money Model (*JPE* 1989)

- A continuum of agents is divided up equally into three different types, labeled as types 1, 2 or 3.
- There are three different goods, labeled as goods 1, 2 or 3.
- Each player type  $i$  desires to consume the good corresponding to his type, good  $i$ , but produces some other good,  $j \neq i$ .

	"Model A" Player Type		
	1	2	3
Desires to Consume Good:	1	2	3
But Produces Good:	2	3	1

- In the absence of trade there is never a *double coincidence of wants* between any two players.
- For trade to occur requires that some individuals accept a good they do want to consume with the expectation that they will be able to use this good to obtain a good they do want to consume.
- Such a good may be called a *medium of exchange*.

## Kiyotaki and Wright Model (2)

- Agents in this model can store a single unit of any good in any period, but storage of goods is costly:

$$0 < c_1 < c_2 < c_3 < u,$$

- $u$  is the utility that all three types get from consuming the good corresponding to their type.
- In every period, agents in this model are randomly paired with one another. (Corbae et al. (*Ecmta* 2003) show that it is bilateral and not random matching that matters- results generalize if agent can choose trading partners).
- The decision they face is whether to trade the good they currently have in storage for the good the agent with whom they are paired has in storage.
- Trades must be mutually agreed upon and involve simple one-for-one swaps of goods in inventory. (Trejos and Wright (1995) allow divisible goods and bargaining over price).

## Kiyotaki and Wright Model (3)

- If a player successfully trades for his consumption good, he immediately consumes that good and produces a new unit of his production good, which becomes the good he has in storage.
  - The player earns a positive net payoff equal to  $u - c_j$ , where  $c_j$  is the storage cost of his production good.
- If trade is not mutually agreed upon or a player trades for a good that is not his consumption good.
  - The player earns a net payoff for the period of  $-c_k$  where  $c_k$  is the storage cost of the good he has in storage as of the end of the period.
- Each player's trading decision involves weighing the cost of not trading and incurring the cost of the good currently held in storage against the expected net utility benefit from trading for the good held by the other player, discounted by factor  $\beta$ .

# Optimal Trading Strategies

- It is always optimal to offer to trade for one's consumption good (only case where net payoffs are positive).
- If a player meets a good in trade which is not his consumption good and which is different from the good he currently has in storage:
  - The optimal trading strategy of types 2 and 3 is to always play a fundamental, cost-minimizing strategy (only agree to trade for goods with lower storage costs)
  - The optimal trading strategy of type 1 players depends on parameter conditions. If

$$c_3 - c_2 > (p_{31} - p_{21}) \frac{\beta u}{3}.$$

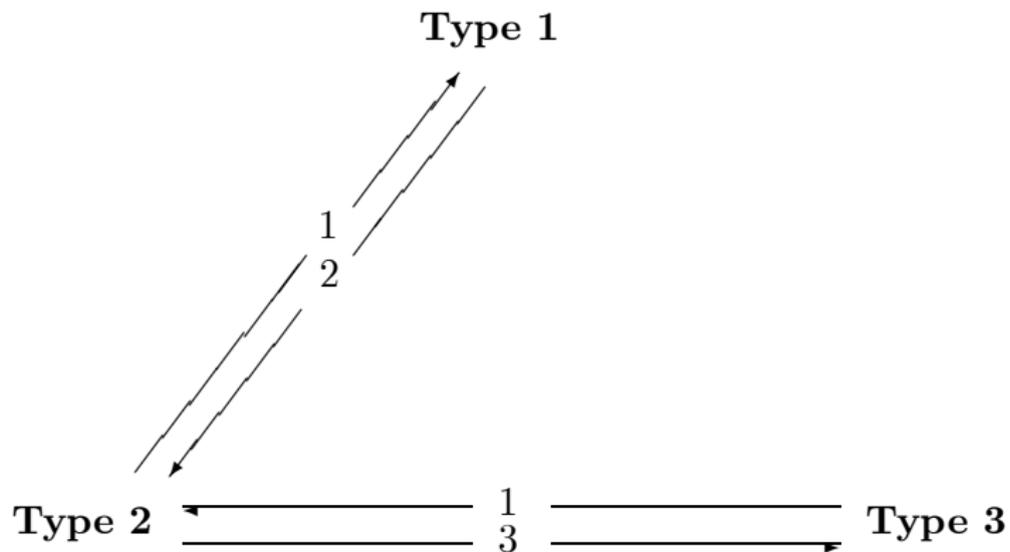
where  $p_{ij}$  is the proportion of agents of type  $i$  who have good  $j$  in storage, type 1 players should also play a fundamental, cost minimizing strategy.

- If the inequality is reversed, then type 1 players should choose a "speculative" trading strategy, offering to trade their production good 2 to type 2 players in exchange for the more costly-to-store good 3.

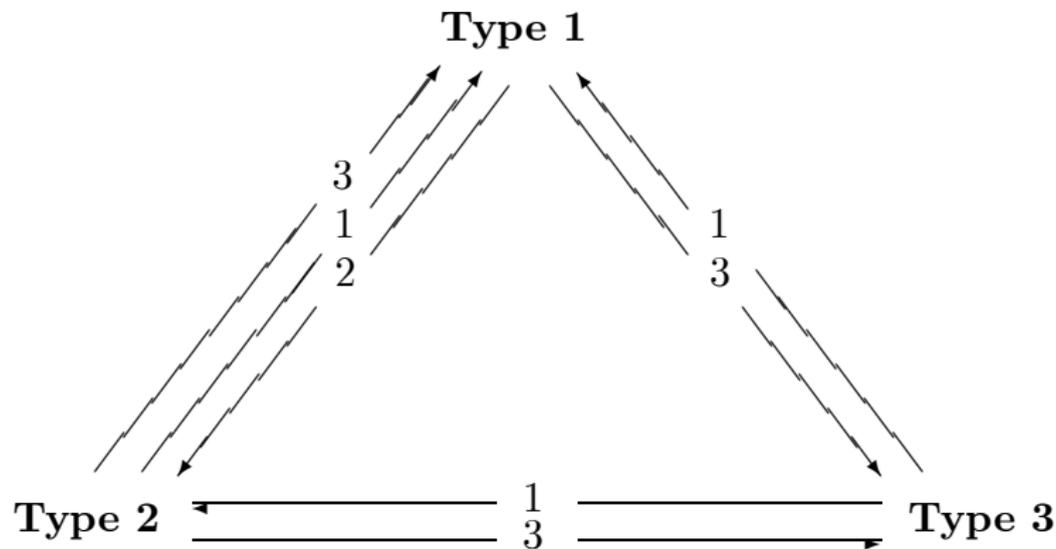
# Money as a Medium of Exchange

- One definition of money is a good not desired for consumption purposes, but which is accepted in exchange with the rational expectation that others will accept that good in exchange for a consumption good.
- In the case where all 3 types use fundamental trading strategies, good 1 fulfills this role: Type 2 trades good 3 to Type 3 in exchange for good 1. Type 2 then trades good 1 to type 1 in exchange for good 2.
- In the case where type 1 players adopt speculative trading strategies, both goods 1 and 3 serve as media of exchange: Type 2 continues with its fundamental strategy of trading good 3 for good 1. But now type 1 trades good 2 for good 3 as it anticipates that holding the more costly to store good 3 reduces the time it takes to acquire good 1 in trade (as good 3 can be directly traded with type 3 for good 1).
- The use of good 3 as a medium of exchange is interesting as this good is dominated in rate of return by the less-costly-to-store good 2.

# Exchange Patterns: Fundamental Equilibrium



# Exchange Patterns: Speculative Equilibrium



# An Experimental Test (Duffy and Ochs *AER* 1999)

- $2 \times 2$  Experimental Design: Variables were Model (A or B) and utility value of consumption.

Parameter	Model A Value	Model B Value
$u$	20 or 100	20 or 500
$\beta$	0.90	0.90
$c_1$	1	1
$c_2$	4	4
$c_3$	9	9

- Feedback on proportions of goods  $p_{i,j}$  held in storage by each player type at the end of each round
- Each session involved 24-30 subjects.
- Subjects were randomly matched each period and had to decide whether to trade the good they had in storage for the good of their match. Mutually agreed upon trades were implemented. Acquiring the consumption good immediately leads to production. Storage costs assessed each period.

# Illustration of the Decision Screen

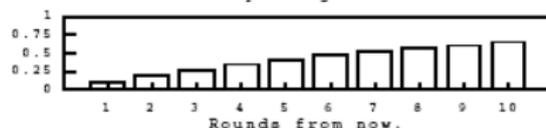
Trading Round Screen # 1

You are a type 2 player. This is Round 3. Your Point Total: 110.

You earn 20 points per unit of good 2 you obtain.  
It costs 1 point per round for storing good 1.  
It costs 4 points per round for storing good 2.  
It costs 9 points per round for storing good 3.

You currently have good 1 in storage.  
You are matched with a player of type 1.  
This player has good 2 in storage.  
Do you want to trade your good 1 for the other player's good 2? Y/N:

Probability the game will end:



Percent of Each Type of Player Storing Each Type of Good  
Historical Average as of Round 2

Type	Good 1	Good 2	Good 3
1	0.00	0.93	0.17
2	0.33	0.00	0.67
3	0.67	0.33	0.00

# Main Findings

- Players learn to play fundamental cost-reducing strategies.
- In environments where some players should play speculative strategies, they persist in playing fundamental strategies (e.g. Type 1 players in Model A).

The Frequency with Which Each Type Offers His Production Good for the Good He Neither Consumes Nor Produces Averages Over Each Half of all Model A Sessions

Model A	1 Offers 2 for 3		2 Offers 3 for 1		3 Offers 1 for 2	
	1st Half	2nd Half	1st Half	2nd Half	1s Half	2nd Half
20	.31	.30	.95	.98	.14	.07
Pred	.00	.00	1.00	1.00	.00	.00
100	.36	.36	.90	.95	.24	.25
Pred	1.00	1.00	1.00	1.00	.00	.00

- Let  $s_{jk}^i$  be the binary trading strategy of agent type  $i$  with good  $j$  in storage facing an opportunity to trade  $j$  for  $k$ :  $s_{jk}^i = 1$  if a trade is proposed, 0 otherwise.
- Two main right-hand side variables
  - Netpay $_{jk} = (\text{success}_{ji} - \text{fail}_{ji}) - (\text{success}_{ki} - \text{fail}_{ki})$ .
  - A Marketability variable. E.g, Player 1 in Model A should be concerned with whether  $c_3 - c_2 - (p_{31} - p_{21}) \frac{\beta u}{3} > 0$  or  $< 0$ .
- Probit regressions show that the netpay variable is significant in explaining strategic behavior while the marketability variable is not.

- Subjects showed a pronounced tendency to play fundamental strategies regardless of treatment conditions.
- When subjects did respond to increases in the utility value of consumption by increasing the frequency with which they played speculative strategies, this was often done by agent types who in theory, ought not to have speculated.
- The use of fundamental strategies was unaffected by our efforts to initialize inventory holdings so that they were close to the speculative equilibrium distribution of goods.
- Individual behavior reflected a response to differences in past payoffs – as assumed in reinforcement learning models, but did not reflect any response to differences in marketability conditions – as required by the theory even though subjects were given information on  $p_{ij}$ , the proportions of type  $i$  holding good  $j$ .
- Thus while subjects had all the information necessary to implement the unique speculative equilibrium, it was not observed

- A fiat object as a good that is storable but has no intrinsic value.
- *Fiat money* is a fiat object that serves as a medium of exchange.
- As Ostroy and Starr (1990, p. 4) have noted, “though a medium of exchange must necessarily be a store of value, stores of value are not necessarily media of exchange.”

# Fiat Money in the Kiyotaki-Wright Model

- Add a good 0 to the set of goods.
- No type produces nor desires to consume good 0; like fiat money, good 0 is *intrinsically worthless* in this environment.
- To introduce good 0, some a fraction,  $m$ , of each type of player is initially endowed with one unit of good 0 in storage. The remaining fraction,  $1 - m$ , of each player type is initially endowed with one unit of their production good in storage.
- If traded, good 0 swaps one-for-one with any other good.
- In Kiyotaki and Wright (1989) the storage cost of good 0 is 0. Costs of storing the other goods are as before, so  $c_0 < c_1 < c_2 < c_3$ .
- We also consider a version of the model where the fiat object is not least costly to store:  $c_1 < c_0 < c_2 < c_3$ .
- Note there always exist pure equilibria where good 0 is (is not) traded; it is common knowledge that no type desires to *consume* good 0, i.e. good 0 is known to be intrinsically worthless.

# An Experimental Test (Duffy and Ochs *IER* 2002)

- Experimental design:
  - Two main parameterizations fiat object is (is not) least costly to store.
  - Also consider variations in  $m$ ; higher  $m$ , lower

Set Number	$c_0$	$c_1$	$c_2$	$c_3$	$u$	$\beta$	$m$
1	0	1	4	9	20	0.90	0.250, 0.334, or 0.500
2	1	0	23	24	100	0.90	0.167

# Exchange Patterns: Fundamental Equilibrium (Parameter Set 1)

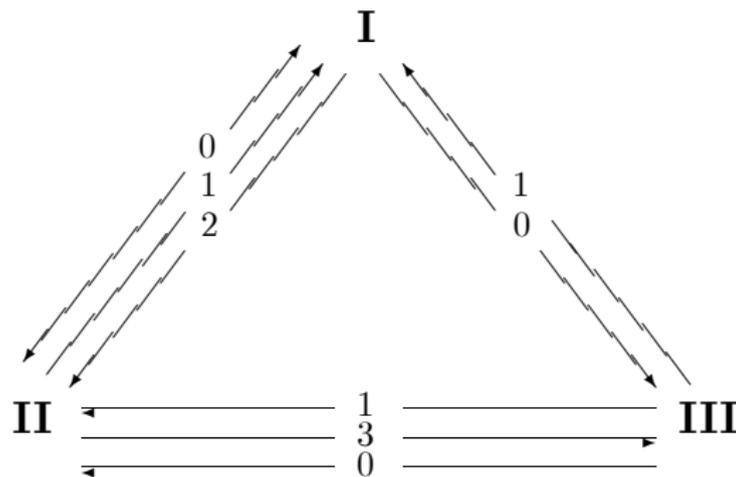


Figure 1: The pattern of exchange in the fundamental equilibrium where fiat money is the least costly-to-store good.

# Exchange Patterns: Speculative Equilibrium (Parameter Set 2)

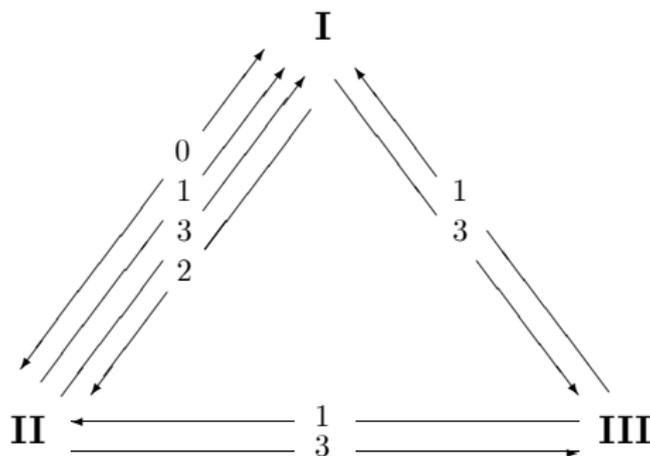


Figure 2: The pattern of exchange in the speculative equilibrium where fiat money is not the least costly-to-store good.

# Main Findings

- Subjects will indeed offer to trade for a fiat object even though this object has no intrinsic value, and may not be the least costly-to-store good.
- Again, the equilibrium predictions of the Kiyotaki–Wright model come closest to being fulfilled when all types' best response is to play fundamental strategies, as in sessions.
- Subjects have difficulty recognizing when speculative strategies are their best response in sessions where good 0 is not the lowest cost good. Many type 1s who trade for good 0 fail to recognize that they will be unable to trade good 0 directly for the good they desire, i.e. good 1, the least costly-to-store good. They frequently refuse to trade good 0 for the higher storage cost good 3 when they are matched with someone who has good 3, and to get their desired good, good 1, they need to have good 3 in storage.

# Divisible money-search models

- A problem with this earlier generation of search models of money is that agents can hold only a single unit of money,  $m \in \{0, 1\}$ . More recent search-money models allow agents to hold any  $m \in \mathbb{R}_+$ . The problem with this approach is that the distribution of money holdings,  $F(m)$ , becomes endogenous.
- Lagos and Wright (*JPE* 2005) provide a means of making  $F(m)$  degenerate. They suppose that each period is divided into two subperiods, day and night, and that agents consume and supply labor to produce goods in both periods. During the day, agents interact with one another via decentralized anonymous bilateral matches, producing special goods and consuming other special goods via barter or money exchanges. At night, agents operate in a centralized Walrasian market, producing a general good and trading it for money.
- The claim is that while the population meets repeatedly in a centralized market, the anonymous random bilateral interactions during the day suffice to ensure an essential role for money.

# Sufficient Conditions for Essentiality of Money?

- As Aliprantis, Camera and Puzzello (2006, 2007) observe, the introduction of occasional trade in a “centralized market” opens the door to an informal enforcement scheme that can sustain play of a Pareto optimal, non-monetary gift-exchange equilibrium rendering money inessential.
- This is because the centralized market allows for information on deviations from the efficient equilibrium and agents can use such information to enforce play of the efficient equilibrium via the contagious strategy of Kandori (RES 1992) and Ellison (Ecmta 1994), who originally demonstrated the use of such a strategy in an infinitely repeated prisoner’s dilemma with random matching.
- More generally, the use of such a contagious strategy will work to sustain good outcomes if there is a finite population (as in a lab setting) and agents are sufficiently patient.

# Is it Possible to Sustain a Social Norm of Efficient Allocation Under Informal, Community Enforcement?

- Note that Kandori (1992) and Ellison (1994) provide conditions (in a prisoner's dilemma game) for which community enforcement via the threat to play a contagious strategy works to ensure full cooperation even with random anonymous matching, so long as the population is finite and community members are sufficiently patient.
- Ellison (1994): "To avoid repeated game effects, it is common practice (among experimentalists) to randomly match players in an anonymous setting so that pairs of players do not meet repeatedly. The results here suggest, however, that given moderate population sizes, random matching may not solve the problem."
- Duffy and Ochs (*GEB* 2009) test the proposition that the contagious strategy can support play of the cooperative outcome in Prisoner's Dilemma games under conditions (random matching, population size, discount factor) that allow for the contagious equilibrium to exist. They find little support for the use of the contagious strategy. But see Camera and Casari (*AER* 2009) for more support.

# Essentiality of Money: Experimental Evidence

## Definition

**Essentiality:** more and/or better outcomes can be supported as equilibria with money than without money.

- Essentiality of money is related to the inability of agents to sustain a cooperative equilibrium in the absence of money.
- Various frictions, e.g. random anonymous matching, absence of formal enforcement, absence of record keeping or monitoring, absence of double coincidences of wants generally mean that cooperative gift-exchange outcomes cannot be sustained and render money essential for expansion of the Pareto frontier.
- Even these frictions may not make money essential, e.g., if there is a finite population size, agents are sufficiently patient, there is a centralized meeting opportunity as in Lagos and Wright (2005)
- Duffy and Puzzello (2014) consider the essentiality of (fiat) money under conditions for which money is theoretically inessential.

# Gift-Exchange vs. Monetary Exchange, Duffy and Puzzello (AER 2014)

- Develop modified version of Lagos-Wright (Money, M) and Aliprantis et al. (No Money, NM) with finite populations.
- Show that money is not theoretically essential in these environments; the stationary monetary equilibrium improves upon the autarkic equilibrium but it is Pareto inferior to the first-best non-monetary gift-exchange equilibrium.
- Implement modified Lagos-Wright and Aliprantis et al. models in the laboratory.
- Is behavior consistent with the theoretical predictions? Which equilibrium is selected?
- Does the population size matter for the essentiality and value of money?

- Finite population of  $2N$  infinitely-lived agents.
- Each period has two stages
  - 1 Agents are uniformly and randomly matched in pairs in the decentralized market (DM)
  - 2 All agents meet in the centralized meeting (CM)
- Preferences are additively separable across stages and periods
- All agents have the same discount factor  $\beta \in (0, 1)$  (No discounting within stages)
- Special good in Stage 1; General good in Stage 2
- Goods perishable across dates and stages
- Fiat money is storable and in a fixed supply,  $M$
- No commitment and no formal enforcement.

# Stage 1: Decentralized Meeting

- An agent is either a producer or a consumer of special good with equal probability
- Every meeting is single coincidence
- Payoff:  $u(x)$  utility of consumption of  $x$  units of the special good;  $-c(y)$  disutility of production of  $y$  units of the special good
- $u, c$  satisfy standard assumptions;  $\exists q^* > 0$  with  $u'(q^*) = c'(q^*)$
- Consumer proposes terms of trade  $(q, d)$  according to a take-it-or-leave-it bargaining protocol; if no money, just propose  $q$ .
- Producer accepts or rejects the offer
- If the offer is accepted, then trade takes place, else meeting is autarkic.

## Stage 2: Centralized Meeting

- All  $2N$  agents meet together.
- In the M treatment:
  - Centralized (Walrasian) market for a general good X that can be produced at cost in exchange for tokens (money) or bought using tokens and consumed by any agent.
  - Market price,  $P$  in terms of money is determined via a centralized (call) market mechanism.
  - The purpose of this meeting is to re-balance money holdings so as to obtain a degenerate distribution for per capita money holdings.
- In NM treatment:
  - Centralized market is an opportunity to signal cooperative behavior.
  - Subjects decide on costly production of Good X and get back the average production level as a benefit.

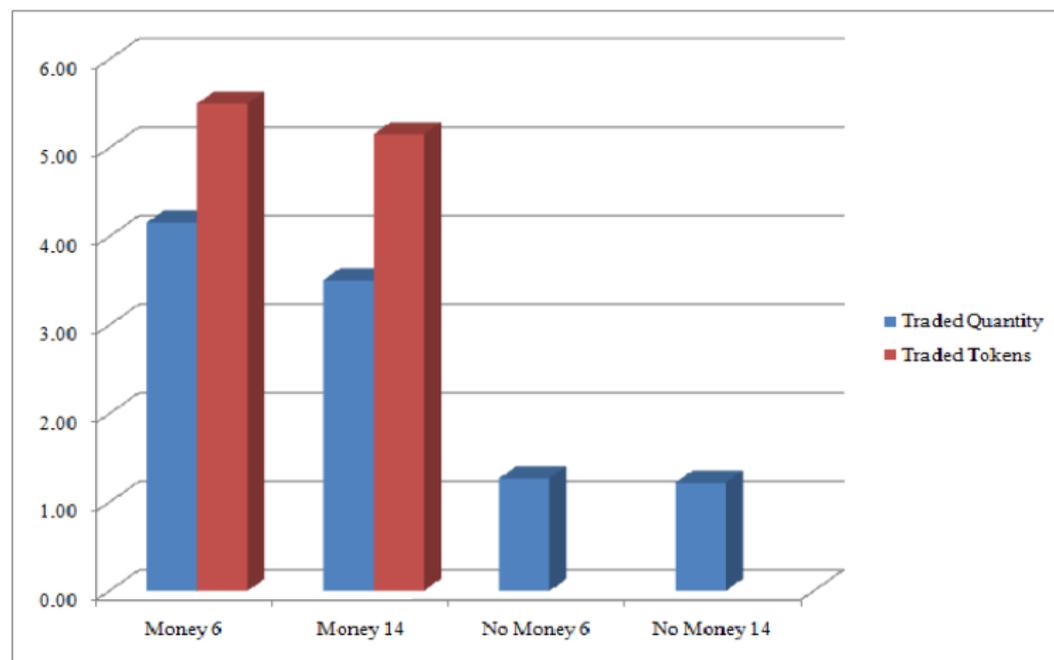
# Equilibrium predictions

- First best,  $(q^*, 0)$  is proposed and accepted if  $N$  is small enough and  $\beta$  is large enough.
- Monetary equilibrium  $(\tilde{q}, \tilde{d})$  is proposed and accepted,  
 $\tilde{q} = 1 + \frac{1-\beta}{\beta/2} < q^*$ . Note that:
  - Monetary equilibrium always exists.
  - $\tilde{q} \rightarrow q^*$  as  $\beta \rightarrow 1$ .
- Autarky: no trade.

# Main Findings

- In the environment with money, choices are consistent with monetary equilibrium predictions.
- In the environment without money, outcomes are closer to autarky than to the first-best.
- Money is empirically, if not theoretically essential: Welfare is higher in economies with money than in economies without money.

# Money is Empirically Essential for Improving Outcomes



# Summing Up

- Subjects have no trouble with fundamental, cost-minimizing strategies, but have trouble with speculative strategies.
- While money may not be theoretically essential in indefinitely repeated monetary models with finite populations of patient agents, it seems to be empirically essential in moving the economy away from autarky.
- Possible experimental extensions:
  - Varying the number of types so as to make speculative strategies more obviously appealing.
  - Allowing agents to choose/change their type - to specialize. Wright (1992).
  - Allowing partner selection-bilateral trades but non-random matching (for theory see Corbae et al. *Ecm* 2003).
  - Alternative mechanisms to money for improvements over autarky/achievement of the first-best: community-wide communication/cheap talk; gossip (i.e., communication about others), credit bureaus.

# Summary

- Money's role as a store of value: Experimental evidence against explosive hyperinflationary paths for prices in favor of stable, low inflation paths.
  - But how to explain episodes of sustained high inflation or hyperinflation?
- Money's role as a unit of account: Money unquestionably serves as a unit of account.
  - But there is evidence that individuals do not think in real terms - how to correct for this?
- Money's role as a medium of exchange: Storage costs matter for use commodity or fiat objects as media of exchange. While money may be theoretically inessential in certain macro-environments, it nevertheless appears to be empirically essential in those environments.
  - Full acceptance of money objects (especially those dominated in rate of return by other objects) may take longer-than-laboratory time allows.