Gift Exchange versus Monetary Exchange: Experimental Evidence

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Abstract

This paper reports findings from an experiment that implements the Lagos-Wright (2005) model of monetary exchange. We find that subjects generally avoid the autarkic equilibrium of that model and make trading decisions consistent with the monetary equilibrium predictions of that model. Aliprantis, Camera and Puzzello (ACP, 2007) show that providing periodic access to centralized markets as in the Lagos and Wright framework may facilitate the sustainability of social norms of gift exchange, thus rendering money inessential in decentralized exchange. We also explore this hypothesis by replacing the centralized market of the Lagos-Wright model with a version of the centralized market of ACP’s model. We find that the essentiality of money is not threatened by the presence of centralized meetings. Indeed, the efficiency of allocations is significantly higher in the environment with money than without money, suggesting that money plays a role as an efficiency enhancing coordination device.

Keywords: Money, Search, Gift Exchange, Social Norms, Experimental Economics, Repeated Games.

JEL codes: C72, C92, D83, E40.
1 Introduction

Money is considered essential when it is possible to support a larger set of allocations with money than without it. The conditions under which money is essential have been explored in micro-founded search theoretic models (see Williamson and Wright (2010) for a survey) but to date there has been little empirical evidence addressing the insights of that literature. In this paper we empirically address the essentiality of money issue by conducting laboratory experiments in an economic environment where money is not essential as there exists a more efficient, gift exchange equilibrium without money.\footnote{The reasons for the inefficiency of monetary equilibria in the search-theoretic models are numerous and include timing constraints, storage constraints and bargaining power. In our framework the inefficiency results from a timing constraint that money received in exchange cannot be immediately spent on consumption.} We find that laboratory subjects are unable to coordinate on this more efficient, non-monetary equilibrium and instead behave more in accordance with the less efficient monetary equilibrium while avoiding the autarkic, no trade equilibrium.

We also study environments without money, where the same efficient non-monetary equilibrium exists and find that subjects in that environment are also far from achieving that efficient equilibrium. In this no-money environment, subjects are even closer to the autarkic no-trade equilibria. Thus, while money is not essential in the environment we study, we find that the existence of fiat money leads to a large welfare increase relative to the environment without money and in this sense, money plays a critical, if not essential role in fostering economic exchange.

The first economic environment we study is Lagos and Wright’s (2005) model, a workhorse model in the large and growing search-money literature. By contrast with an earlier generation of search-money models, (e.g. Kiyotaki and Wright (1989)), this model has both divisible goods and money, endogenous prices (via bargaining) and it gives rise to a degenerate distribution for money holdings by appending a centralized market to a decentralized market and using quasi-linear preferences—features that allows for simple analytic results. As the newer generation of search-money models has prices, it is possible to use these models to evaluate a number of important topics such as monetary policies and the welfare cost of inflation that would be difficult to address under the earlier generation of models with their fixed prices and storage constraints.

In the Lagos and Wright environment we study, money is not essential due to the finite numbers of agents and the (induced) discount factor. There exists an efficient, non-monetary equilibrium where individuals discard their endowments of fiat money in favor of an equilibrium involving reciprocal gift exchange. However there also exists a less efficient but unique monetary equilibrium where exchange decisions involve both a certain quantity of goods to be produced and a certain monetary payment to be received in exchange for that production. There also exists a non-monetary, autarkic (no trade) equilibrium.

The second economic environment we study is due to Aliprantis, Camera and Puzzello (ACP, 2007) and consists of a modified version of the Lagos and Wright environment where there is no money. In this environment, ACP show that the Pareto efficient, non-monetary
gift-exchange equilibrium can be sustained by use of the information provided by the centralized market and a contagious strategy wherein deviations from the efficient equilibrium allocation are quickly punished. Thus in the ACP environment, money is also not essential, and indeed, no individual is endowed with any money.

In addition to studying these two environments, with and without money, we also consider whether the size of the economy is important to whether the efficient or the monetary equilibrium is adopted. We speculated that non-monetary gift exchange might be easier to sustain via the contagious strategy in smaller economies of 6 agents than in larger economies of 14 agents.

Thus our experiment consists of a $2 \times 2$ experimental design where the main treatment variables are whether there exists a fiat money object or not and whether the size of the economy consist of $N = 6$ or $N = 14$ agents.

Our experiment has resulted in several important findings. The main result is that subjects do not make trading decisions in a manner that is consistent with the efficient (i.e. first best) non-monetary gift-exchange equilibrium in either the Lagos and Wright environment with money or in the ACP environment without money. Indeed, choices are always far from the first best outcome. In the Lagos and Wright environment, choices are more consistent with the unique monetary equilibrium as subjects choose to include money in 80–100 percent of all exchange proposals and quantities and prices are close to monetary equilibrium predictions. Further, there is evidence that subjects are using the centralized market to rebalance their money holdings in the manner prescribed by the monetary equilibrium. By contrast in the ACP environment where there is no money, outcomes are closer to the autarkic, no-trade equilibrium than to the first best. Further, we find clear evidence that welfare is significantly higher in the environment with money than in the environment without it. Thus, while money is not essential in any of the environments we study, outcomes involving monetary exchange lead to the highest observed welfare.

2 Related Literature

There already exists an experimental literature examining conditions under which money is used as a medium of exchange (see Duffy (2008) for a survey).

Lian and Plott (1998) examine whether money is used in a general equilibrium experimental economy, but where money has a final redemption value. McCabe 1989, Camera et al. 2003 and Deck et al. 2006 study the use of intrinsically worthless money in economies with finite horizons. Brown (1996), Duffy and Ochs (1999 and 2002) study the Kiyotaki and Wright (1989) model with either commodity or worthless fiat money where the planning horizon is indefinite. In that model, the adoption of commodity or fiat money is essential to expanding the Pareto frontier. By contrast, in the Lagos and Wright (2005) environment we study, money is not essential to achieve the first best allocation, and in ACP’s (2007) model there is no money at all.

The closest paper to this study is by Camera and Casari (2010), who also study an indefinitely repeated game where, in one treatment, an intrinsically worthless money ("tickets")
is introduced. In their dynamic game, money is not essential to achieve the efficient (first best) outcome which, as in this paper, can be supported instead by social norms. However, their model is essentially a reduced form version of the older, Kiyotaki and Wright (1989) environment in that ticket prices are fixed (there is no bargaining), money and goods are indivisible, there are restrictions on money holdings and there is only random matching (there is no centralized market). They also consider rather small groups of just 4 subjects, which may facilitate social norm mechanisms. Indeed, they find that the introduction of money does not improve average overall cooperation rates (exchanges) relative to an environment without money.

By contrast, in the Lagos and Wright environment that we study experimentally, goods and money are divisible, quantities, money amounts and prices are endogenously determined, there are no restrictions on money holdings and the stage game consists of both a decentralized and a centralized meeting round. Further, we consider different group sizes of subjects, populations of size 6 or 14 so as to address the robustness of the social norm mechanism. Finally, we reach a different conclusion, as we find that welfare in the Lagos and Wright environment with money is significantly higher than in the ACP environment without money.

3 The Lagos-Wright Environment

We study a simplified version of the Lagos and Wright ([15]) model with finite population. Time is discrete and the horizon is infinite. Let \( A = \{1, 2, ..., 2N\} \) denote the population consisting of \( 2N \) infinitely lived agents whose discount factor is \( \beta \in (0, 1) \).

Each period is divided in two subperiods that differ in terms of the matching technology, economic activities and payoff functions. Indeed, two types of markets alternate over time: a decentralized market with a double coincidence problem and a frictionless centralized market.

In the first subperiod agents are randomly and bilaterally matched. Every agent is either a producer or a consumer in his match with equal probability. This generates a double coincidence problem. We denote by \( x \) and \( y \) consumption and production of the special good during the first subperiod. In the second subperiod, agents trade in a centralized Walrasian market and all agents produce and consume a general good. Let \( X \) and \( Y \) denote production and consumption in the second subperiod.

Preferences are given by

\[
U(x, y, X, Y) = u(x) - c(y) + X - Y,
\]

where \( u \) and \( c \) are twice continuously differentiable with \( u' > 0, c' > 0, u'' < 0, c'' \geq 0 \). Also, \( u(0) = c(0) = 0 \), and there exist \( q^* \in (0, \infty) \) such that \( u'(q^*) = c'(q^*) \).

Furthermore, the goods produced during the two subperiods are perfectly divisible and nonstorable. There is another object called fiat money that is perfectly divisible and storable in any amount \( m \geq 0 \). The total money stock is fixed at \( M \). The environment lacks commitment and formal enforcement.\(^2\)

\(^2\)The original Lagos and Wright model has a positive probability, \( (1 - \alpha) \), that agents remain unmatched,
Since our population is finite, in addition to the monetary equilibrium, there exist multiple nonmonetary equilibria. We start by providing a characterization of the monetary equilibrium.

### 3.1 Monetary Equilibrium

If a large population is a good proxy for anonymous trading, the only feasible trades involve exchanging fiat money against the special good in the first subperiod, and fiat money against general good in the second subperiod. Let \((m^1, m^2, \ldots, m^{2N})\) denote the initial distribution of money holdings, where \(m^i\) denotes the money holdings of agent \(i\). We denote by \(m^i_t\) the money holdings of agent \(i\) at the beginning of period \(t\).

Since the total money stock is fixed at \(M\), we clearly have \(\sum_{i=1}^{2N} m^i_t = M\) for all periods \(t = 1, 2, \ldots, 1\). Let \(\phi\) denote the price of money in terms of the general good in the centralized market. Under the assumption of take-it-or-leave-it offers where the consumer has all the bargaining power, it is possible to show that the steady state is unique (see the Appendix for details), and the steady state condition is given by

\[
\frac{u'(\tilde{q})}{c'(\tilde{q})} = 1 + \frac{1 - \beta}{\beta},
\]

where \(\tilde{q}\) denotes the amount of special good exchanged in each bilateral match. Each individual demand for money is \(M^D = \frac{c(\tilde{q})}{\phi}\). The aggregate demand is then \(2N \cdot c(\tilde{q})\), and since supply is equal to \(M\), the equilibrium price of money in the steady state is \(\phi = \frac{c(\tilde{q})}{2N}\). Also, note that the distribution of money at the beginning of the decentralized market is degenerate at \(M\).

It is easy to see that \(\tilde{q} < q^*\) since \(\beta < 1\), and that \(\tilde{q} \rightarrow q^*\) as \(\beta \rightarrow 1\), thus the monetary equilibrium does not achieve the first best.

### 3.2 Social Norms in the Lagos-Wright Environment

In addition to the monetary equilibrium, there may exist contagion non-monetary equilibria that sustain the first-best (see Kandori (1992) and Araujo (2004)).

Consumers propose terms of trade so that we can identify their action set with \([0, \tilde{q}] \times [0, M]\). As for producers, their actions set is \(\{0, 1\}\) where 0 stands for reject and 1 stands for accept.

Consider the following _gift-giving_ social norm:

"Do not participate to the CM. Participate only to the DM.

\[\text{a positive probability } \delta \text{ of double coincidence meetings and a probability } \sigma \text{ of being consumer or producer.}\]

We set \(\alpha = 1, \delta = 0, \text{ and } \sigma = 1/2\). This does not affect the qualitative results.

\[\text{This environment is not immune to the construction of folk type theorems and informal enforcement schemes (see Kandori [14], Ellison [13], and Aliprantis et al. [2]).}\]

\[\text{Recall that both the special good and general good are nonstorable.}\]
Propose \((q^*, 0)\) every time you are a consumer and accept \((q^*, 0)\) whenever you are a producer, so long as everyone has produced \(q^*\) for you in your past meetings. If you have observed a deviation then, whenever a producer, reject the terms of trade forever after.”

An adaptation of Araujo (2004) argument to our framework, shows that the social norm described above can be supported as a sequential equilibrium if agents are patient enough. The proof is straightforward, and thus here we just report two conditions guaranteeing that this social norm is a sequential equilibrium in our environment. These two conditions guarantee that agents do not have an incentive to deviate from the social norm on and off the equilibrium path. In particular, the first condition ensures that, if no deviation has been observed, producers are better off by accepting rather than by rejecting to produce, thus starting the autarkic contagion process. The second condition ensures that, once a deviation is observed, agents have an incentive to contribute to spread the contagion by refusing to produce rather than slowing it down by accepting the consumer’s proposal.

The first condition ensures that no deviation from the equilibrium path is profitable:

\[
-q^* + \frac{\beta}{1 - \beta} \frac{1}{2} [u(q^*) - q^*] \geq e_1 [I - \beta A]^{-1} \pi_1 \frac{1}{2} u(q^*) - \frac{1}{2} u(q^*), \tag{1}
\]

while the second condition ensures that no deviation from the off-equilibrium path is profitable (and thus agents do not have an incentive to cooperate even if they observed a deviation in the hope of slowing down the diffusion of information about a deviation):

\[
-q^* + e_2 [I - \beta A]^{-1} \pi_2 u(q^*) - \left(\frac{2N-2}{2N-1}\right) \frac{1}{2} u(q^*) \leq e_3 [I - \beta A]^{-1} \pi_3 \frac{1}{2} u(q^*) - \left(\frac{2N-3}{2N-1}\right) \frac{1}{2} u(q^*), \tag{2}
\]

\(e_i\) is the \(2N\)-dimensional \(i\)th fundamental vector

\(A = (a_{ij})\) is a \(2N \times 2N\) matrix with \(a_{ij} = \Pr (D_{t+1} = j \mid D_t = i)\),

\(D_t = \) number of defectors at time \(t\)

\[
\pi = \frac{1}{2N-1} \begin{pmatrix}
2N - 1 \\
2N - 2 \\
2N - 3 \\
\vdots \\
2 \\
1 \\
0
\end{pmatrix}
\]

where \(\pi_i = \Pr (\text{a defector meets a cooperator} \mid D_t = i)\).

\(^5\)The social norm considered by Araujo is the same as ours, except that we do not consider double coincidence meetings: “Every time an agent meets another, in a single-coincidence meeting where the latter likes his good, he gives the good as long as everyone has done so in the past for him. If in a meeting an agent fails to give a good that the other agent likes, neither agent will ever produce again in single-coincidence meetings. In double-coincidence of wants meetings, agents exchange goods simultaneously, irrespective of their previous private history. In any other situation, there is no exchange at all” (p. 244)
4 The Environment without Money

The environment with money displays a multiplicity of equilibria, and allows us to test which equilibrium is selected. However, the environment with money may fail to be a good test of the essentiality of money.\(^5\) In particular, the design could be perceived as favoring the emergence of the monetary equilibrium, as subjects are endowed with tokens and so they may be induced to use them in exchange.

We think that a cleaner test of whether money allows to achieve better allocations is to consider an environment without money. This will allow us to compare allocations in the two environments and determine whether money is behaviorally essential, even though it is not theoretically so.

To this end, we next describe an environment where there is no money. Nonetheless, the first best can be supported as a sequential equilibrium. This environment is close to the environment formalized in Aliprantis et al. \([2]\), who suggest that the presence of centralized meetings facilitates the sustainability of cooperation. In this environment agents do not need money to have access to centralized meetings, as opposed to the former environment. Also, agents would get zero payoff in the absence of cooperation. We designed this treatment to give cooperation its best shot at emerging.

This treatment is interesting in itself as it also allows to test whether the presence of centralized meetings favors the emergence and sustainability of cooperation.

The environment is similar to the one described above, except that there is no money and that agents now interact in decentralized and centralized meetings. In particular, centralized markets are now replaced by centralized meetings where agents put down production and their consumption is determined by average production.\(^7\) Without loss of generality, in the decentralized meetings, we can think of \(\{0, 1\}\) as the producers’ action set, and \([0, \bar{q}]\) as the consumers’ action set. As for the centralized meetings, agents are both producers and consumers so we can think of \([0, \bar{q}]\) as their action set (each agent gets to consume average production).

We can find a social norm that specifies a rule for cooperation and punishment for undesirable behavior. Here, cooperation is identified with production of a certain level of output in decentralized and centralized meetings, and undesirable behavior is a deviation from this level of output. We make things more precise next.

The first best can be sustained as a Nash equilibrium by the following gift-giving social norm:

“In the decentralized meeting, propose \(q^*\) whenever you are a consumer and accept to produce \(q^*\) whenever you are a producer.

Produce \(L \in [0, \bar{q}]\) in the centralized meeting. Continue to do so if you have observed cooperation (i.e., you received or produced \(q^*\) and \(L\) was the average production in the CM). If you have observed a deviation, then choose reject whenever a producer in the decentralized

\(^6\)Money is essential if better outcomes can be supported in an environment with money than without money.

\(^7\)This is similar to Aliprantis et al. (2007) except for the population’s cardinality which here is finite.
meeting and produce 0 forever after in the centralized meeting”

Clearly, this social norm attains the first best. Also, it is easy to show that this social norm can be sustained as a sequential equilibrium.

To this end, observe that on the equilibrium path, we have

\[ V_{DM}^* = \frac{1}{1-\beta} \frac{1}{2} [u(q^*) - q^*] \quad \text{and} \quad V_{CM}^* = \frac{\beta}{1-\beta} \frac{1}{2} [u(q^*) - q^*] \]

To guarantee that this strategy is a sequential equilibrium we need to check on-equilibrium and off-equilibrium incentives.

On-equilibrium, agents have incentives to follow the strategy in the decentralized meeting if

\[ -q^* + V_{CM}^* \geq 0 + \frac{2N-2}{2N} L \]

or

\[ \beta \geq \frac{2N-2}{2N} L + q^* + \frac{1}{2} \frac{u(q^*) - q^*}{u(q^*) - q^*} = \beta. \]

In the centralized meeting we have

\[ \beta V_{DM}^* \geq \frac{2N-1}{2N} L + 0 \]

\[ \beta \geq \frac{2N-1}{2N} L + \frac{1}{2} \frac{u(q^*) - q^*}{u(q^*) - q^*} = \beta. \]

It is easy to check that off-equilibrium is always better to follow the altruistic strategy, i.e., it is better not to produce, because it is myopically optimal and agents cannot slow down the information diffusion process by producing (unlike in the social norm considered in the LW environment which relies on purely decentralized interactions). Thus, if agents are patient enough, i.e., \( \beta \geq \max \left\{ \beta, \overline{\beta} \right\} \), it is possible to sustain the first best.\(^8\)

In this environment, even though agents only observe an aggregate outcome in the centralized meeting, namely, average output, it is still possible to support cooperation because the population is finite. In other words, the observation of average output reveals information about individual actions.

5 Experimental Design and Procedures

We consider a \( 2 \times 2 \) experimental design where the treatment variables are the environment (money) [Lagos-Wright (2005)] versus no money [ACP (2007)] and the population size, \( N = 6 \) versus \( N = 14 \).

\(^8\)Note that \( \beta \geq \overline{\beta} \) if and only if \( \frac{1}{2} [u(q^*) - q^*] \left[ q^* - \frac{L}{2N} \right] \geq 0 \) or \( \left[ q^* - \frac{L}{2N} \right] \geq 0. \) Also, \( L \) is arbitrary and the smallest is \( L \) the easier is to sustain cooperation (i.e., the lower is \( \beta \)), and the higher is \( 2N \), the lower is \( \overline{\beta} \).
Our experiment was computerized and implemented in z-Tree (Fishbacher (2007)).

Each session consisted of several supergames or “sequences”. Each sequence consisted of an indefinite number of repetitions (periods) of a stage game. Each sequence began with play of at least one stage game. At the end of the stage game, the sequence continued with another period of the stage game with probability $\beta$ and ended with probability $1 - \beta$. If a sequence ended, subjects were told that depending on the time available, a new indefinite sequence would begin. Specifically, our computer program drew a random number uniformly from the set $\{1, 2, 3, 4, 5, 6\}$. If the number drawn was not 6, then the sequence continued with another round, otherwise, if a 6 was drawn, the sequence ended. In this manner we induced a discount factor or continuation probability of $\beta = 5/6$. We suggested that subjects think of this random draw as the result of rolling a six-sided die.\footnote{We recruited subjects for a three hour length of time, but our sessions all ended after around 2 hours. Our stopping rule which was not announced to subjects was to obtain approximately 30 periods of data (stage games) per session.}

In both environments the stage game consists of a decentralized market round and a centralized market round. For the decentralized market we induced (via payoff tables) the utility function $u(q) = A \log(1 + q)$ and the cost function $c(q) = C q$.

Prior to the start of each decentralized round, subjects were randomly matched and within each pair, one player was chosen with probability $1/2$ to be the producer and the other was then designated as the consumer. All random pairings and assignments were equally likely.

In the stationary monetary equilibrium, these imply the following value function

$$V = \frac{1}{1 - \beta} \left\{ \frac{1}{2} \left[ A \cdot \log(1 + \tilde{q}) - C \cdot \tilde{q} \right] \right\}.$$

The per period expected payoff in the monetary steady state is given by

$$v = \left\{ \frac{1}{2} \left[ A \cdot \log(1 + \tilde{q}) - C \cdot \tilde{q} \right] \right\}.$$

The per period expected payoff in the first best is given by

$$v^* = \left\{ \frac{1}{2} \left[ A \cdot \log(1 + q^*) - C \cdot q^* \right] \right\}.$$

### 5.1 Parameterization Choices and Equilibrium Benchmarks

In this section we characterize the equilibrium predictions associated with our parametrization choices.

**Lagos-Wright Predictions**

We have chosen the following parameters: $A = 7$, $C = 1$, $\beta = \frac{5}{6}$. Under these parameters, some theoretical benchmarks from LW are provided next:
Efficient quantity: $q^* = 6$

Monetary Equilibrium quantity: $\tilde{q} = 4$

Upper bound in DM: $\tilde{q} \in [21, 22]$

Upper bound in CM: $\tilde{Y} = 22$

Equilibrium price: $\phi = \frac{c(\tilde{q})}{M/2N} = \frac{4}{M/2N}$

Centralized market price of money: $M/2N = 8 \Rightarrow \phi = 1/2$

Centralized market price of general good: $1/\phi = 2$

Decentralized market price of special good: $\frac{M/2N}{\tilde{q}} = \frac{8}{4} = 2$

Per period stationary equilibrium payoff: $v = \left\{ \frac{1}{2} \left[ 7 \cdot \log 5 - 4 \right] \right\} = 3.63$

Per period first best: $v^* = \left\{ \frac{1}{2} \left[ 7 \cdot \log 7 - 6 \right] \right\} = 3.81$

Social Norm Predictions in the Lagos-Wright Environment

Simple computations (provided in the Appendix) show that under this parameterization, the conditions ensuring that the first best can be supported as a sequential equilibrium in a purely decentralized environment are satisfied. Thus, the first best outcome can be supported as a sequential Nash equilibrium in the modified Lagos-Wright environment.

Predictions in the ACP Environment without Money

Since cooperation is difficult to emerge (e.g., Duffy and Ochs (2009)), we further simplified the design to facilitate the emergence of cooperation. Specifically, we discretized the choice of $L$ and we restricted it to just two levels $L \in \{0, 1\}$, so that $L = 1$ can unambiguously be identified with production.

It is easy to see that since $L \leq 1$, $\beta = \frac{5}{6} > \beta$ both for $2N = 6$ and $2N = 14$, so that the first best can be sustained as a sequential Nash equilibrium by means of the social norm.

6 Experimental Results

We report results from 12 experimental sessions involving 120 subjects. Characteristics of the 12 sessions are reported in Table 1

Subjects were University of Pittsburgh undergraduates with no prior exposure to the economic environments implemented here. No subject participated in more than one session.
Each session consisted of two parts. In the first part the group of 6 or 14 subjects participated in either the money or no money environment as described above. In this part of the session, they participated in an average of 6 supergames averaging about 31 total periods. In the second part of the session they were asked to participate in an individual choice paired lottery choice experiment designed to elicit their risk attitudes in which they could earn additional amounts of money. The total length of each session was about 2 hours. Total earnings from both parts of the session are averaged.

Our results are summarized as a number of findings that address the propositions of sections 3-4. The most important finding is Finding 3.

**Finding 1** Offers are accepted with a higher probability when \( N = 6 \) than when \( N = 14 \). In the money environment, 80–100% of decentralized trades involve money.

**Finding 2** Quantities exchanged in the decentralized meeting are greater when there is money than when there is no money. But quantities in both environments are well below the efficient equilibrium level.

**Finding 3** Welfare is higher in economies with money than in economies without money.

**Finding 4** For a given environment, (money, no money), there is (not) a difference in welfare between populations of size 6 and populations of size 14.

**Finding 5** In the money environment, there is evidence that subjects are using the centralized meeting to re-balance their money holdings. However, the distribution of money holdings is not degenerate.

**Finding 6** In the no money environment, contributions to the public good in the centralized meeting are close to zero.

**Finding 7** Subjects exhibiting greater risk aversion according to the Holt-Laury instrument made lower proposals of goods and money in the decentralized meeting than did subjects who exhibited less risk aversion.
7 Conclusions

This paper indicates that the essentiality of money is not threatened by the presence of centralized meetings, as shown in the work of Aliprantis, Camera and Puzzello (ACP, 2007). Indeed, our main finding that the efficiency of allocations is significantly higher in the environment with money than without money suggests that money plays a role as an efficiency enhancing coordination device. Since money can be thought as a social norm, our findings suggest that it is easier to coordinate on some social norms (such as money) than others (such as gift-giving social norms). A theory of money as a robust social norm deserves further investigation.

Our results also bring up the point that periodic access to centralized meetings is not sufficient to achieve good allocations. However, in our framework, subjects could only communicate via actions. What if they are endowed with more effective communication means? This is a natural question, especially given that field trading institutions develop over decades presumably becoming more efficient over time.

Finally, this framework can be used to explore the effects of monetary policy. In particular, we plan to conduct more sessions of the money treatment where the money supply is allowed to grow or contract at a constant rate. This will be achieved by injecting or withdrawing money via lump sum transfers in the centralized market so that \( M_{t+1} = (1 + \mu)M_t \).

In the case we study, of take-it-or-leave it offers in the decentralized market, one can show that the “Friedman rule,” which here amounts to \( \mu = \beta - 1 \), is optimal as it implies that \( q = q^* \), a hypothesis we propose to test by comparison with other money growth rates, \( \mu \).
References


Appendix

Lagos-Wright Environment

Let \((m^1, m^2, \ldots, m^{2N})\) denote the initial distribution of money holdings, where \(m^i\) denotes the money holdings of agent \(i\). We denote by \(m^i_t\) the money holdings of agent \(i\) at the beginning of period \(t\).

Since the total money stock is fixed at \(M\), we clearly have \(\sum_{i=1}^{2N} m^i_t = M\) for all periods \(t = 1, 2, \ldots\). Let \(\phi_t\) denote the price of money in terms of the general good in the centralized market. Also, let \(\varphi : A \mapsto A\) be an exhaustive bilateral matching rule, so that no agent remains unmatched.\(^{10}\)

In the first subperiod agents are randomly (uniformly) and bilaterally matched and an agent is the producer or the consumer in his match with equal probability. Each consumer proposes terms of trade and the producers’ choice variable is to accept or reject the proposed terms of trade.

In the second subperiod agents decide consumption and production of the general good and savings (or equivalently how much money to bring to the next subperiod). That is, they decide how much to sell or buy in the Walrasian market in order to rebalance their money holdings.

We denote by \(V_t(m^i_t)\) the value function for an agent with \(m^i_t\) dollars at the beginning of the decentralized market in period \(t\). In a bilateral match where the consumer has \(m\) money holdings and the producer has \(\tilde{m}\) money holdings, \(q_t(m, \tilde{m})\) and \(d_t(m, \tilde{m})\) denote the terms of trade, i.e., the amount of special good produced and the amount of money the consumer pays, respectively. We denote by \(X^b_t, Y^b_t\) and \(m^i_{t+1}\) consumption of the general good, production of the general good and savings, respectively.

Then

\[
V_t(m^i_t) = \max_{X^b_t, Y^b_t, X^s_t, Y^s_t, m^i_{t+1}} \left\{ \frac{1}{2} \sum_{j \neq i} \left[ u(q_t(m^i_t, m^j_t) + X^b_t - Y^b_t + \beta V_{t+1}(m^i_{t+1})\right] \Pr(\varphi(i) = j) \right. \\
+ \frac{1}{2} \sum_{j \neq i} \left[ -c(q_t(m^j_t, m^i_t) + X^s_t - Y^s_t + \beta V_{t+1}(m^i_{t+1})\right] \Pr(\varphi(i) = j) \right\}
\]

subject to the budget constraints associated with the centralized market

\[
X^b_t = Y^b_t + \phi_t(m^i_t - d_t(m^i_t, m^j_t) - m^i_{t+1}) \\
X^s_t = Y^s_t + \phi_t(m^j_t + d_t(m^j_t, m^i_t) - m^j_{t+1}) \\
X^b_t, X^s_t, Y^b_t, Y^s_t, m^i_{t+1} \geq 0.
\]

The terms in \(V_t(m^i_t)\) represent the expected payoff from being a consumer or a producer. After plugging in the budget constraints, it is easy to see that \(V_t(m^i_t)\) can be simplified as follows:

\(^{10}\)An exhaustive bilateral matching rule is simply a function \(\varphi : A \mapsto A\) such that \(\varphi(\varphi(a)) = a\) and \(\varphi(a) \neq a\), for all \(a \in A\). See also Aliprantis et al. [1].
We are now ready to determine the terms of trade in the decentralized market, which will allow to simplify further the expression for $V_t(m_i)$. As in Lagos and Wright [15], we use the generalized Nash bargaining solution where threat points are given by continuation values. Here, we focus on take-it-or-leave-it offers where the consumer has all the bargaining power. Thus, given the linearity, the terms of trade $(qt, dt)$ must solve the following constrained optimization problem

$$
\text{Max}_{qt, dt} \left[ u(qt) - \phi_t dt \right] \\
\text{s.t. } dt \leq m_t, qt \geq 0
$$

The solution to this optimization problem is given by

$$
qt(m_t, \bar{m}_t) = q_t(m_t) = \begin{cases} 
\phi_t^{-1}m_t & \text{if } m_t < \frac{c(q^*)}{\phi_t} \\
q^* & \text{if } m_t \geq \frac{c(q^*)}{\phi_t}
\end{cases}
$$

$$
d_t(m_t, \bar{m}_t) = d_t(m_t) = \begin{cases} 
m_t & \text{if } m_t < \frac{c(q^*)}{\phi_t} \\
c(q^*) & \text{if } m_t \geq \frac{c(q^*)}{\phi_t}
\end{cases}
$$

That is, if the consumer carries in the decentralized market at least $\frac{c(q^*)}{\phi_t}$ money holdings, he gets $q^*$ for $\frac{c(q^*)}{\phi_t}$. If his money holdings are less than $\frac{c(q^*)}{\phi_t}$, then he is cash constrained and he spends all his money holdings to buy $c(q_t, \bar{m}_t)$ of the special good.

Next, note that the terms of trade depend only on the consumer’s money holdings and $-c(q_t(m_t, \bar{m}_t)) + \phi_t d_t(m_t, \bar{m}_t) = 0$. This allows to further simplify the value function:

$$
V_t(m_i) = \frac{1}{2} \left[ u(q_t(m_i) - \phi_t d_t(m_i) \right] \\
+ \phi_t m_i + \text{Max}_{m_{i+1}} \left\{ -\phi_t m_{i+1} + \beta V_{t+1}(m_{i+1}) \right\}.
$$

By repeated substitution, we obtain that the savings’ choice of $m_{i+1}$ solves a sequence of simple static optimization problems:

$$
\text{Max}_{m_{i+1}} \left\{ -\phi_t m_{i+1} + \beta \frac{1}{2} \left[ u(q_{t+1}(m_{i+1} - \phi_{t+1} d_{t+1}(m_{i+1}) \right) \right\}.
$$

Note that the take-it-or-leave-it offer implies higher allocative efficiency among the class of Nash bargaining trading protocols.
The savings’ choice is governed by trading off the benefit (liquidity return) given by
\[ \beta \frac{1}{2} \left[ u(q_{t+1}(m_{t+1}^t) - \phi_{t+1}d_{t+1}(m_{t+1}^t)) \right] \] with the cost of holding money \(- (\phi_t - \beta \phi_{t+1})m_{t+1}^t\) associated with delayed consumption. Any equilibrium must satisfy \(\phi_t \geq \beta \phi_{t+1}\). Furthermore, the assumptions on the utility and cost functions imply the strict concavity of the objective function, the uniqueness of the solution and thus a distribution of money holdings degenerate at \(\frac{M}{2N}\).

A monetary equilibrium is any path \(\{q_t\}_{t=1}^{\infty}\) with \(q_t \in (0, q^*)\) such that
\[
\frac{u'(q_{t+1})}{c'(q_{t+1})} = 1 + \frac{c(q_t)}{c(q_{t+1})} - \frac{\beta}{2}
\]

Furthermore, the steady state (or stationary equilibrium) is unique, and the steady state condition is given by
\[
\frac{u' \bar{q}}{c' \bar{q}} = 1 + \frac{1 - \beta}{\beta}.
\]

Each individual demand for money is \(M^D = \frac{c(\bar{q})}{\phi}\). The aggregate demand is then \(2N \frac{c(\bar{q})}{\phi}\), and since supply is equal to \(M\), the equilibrium price of money in the steady state is \(\phi = \frac{c(\bar{q})}{\frac{M}{2N}}\).

Note that \(\bar{q} < q^*\) since \(\beta < 1\), and that \(\bar{q} \to q^*\) as \(\beta \to 1\). Also, the monetary steady state value function is given by
\[
V = \frac{1}{1 - \beta} \left\{ \frac{1}{2} \left[ u(\bar{q}) - c(\bar{q}) \right] \right\}.
\]
Social Norm in the Lagos-Wright Environment

It is easy to see that under our parameterization choice, conditions 1 and 2 are satisfied for $2N = 6$ and $2N = 14$, respectively:

I. $2N = 6$

Condition 1 simplifies to

$$13.053 \geq 2.12 \times 6.81 - 6.81$$

$$13.053 \geq 7.627$$

Condition 2 simplifies to

$$-6 + 1.344 \times 6.81 - \frac{4}{5} \times 6.81 \leq 0.84 \times 6.81 - \frac{3}{5} \times 6.81$$

$$-3.929 \leq 0$$

II. $2N = 14$

Condition 1 simplifies to

$$-q^* + \frac{\beta}{1 - \beta} \frac{1}{2} [u(q^*) - q^*] \geq e_1 [I - \beta A]^{-1} \pi \frac{1}{2} u(q^*) - \frac{1}{2} u(q^*),$$

$$-6 + 5 \frac{1}{2} [7 \ln 7 - 6] \geq 2.798 \frac{1}{2} 7 \ln 7 - \frac{3}{2} 7 \ln 7$$

$$-6 + 5 \frac{1}{2} 7.621 \geq 1.798 \frac{1}{2} 7 \ln 7$$

$$13.053 \geq 12.246$$

Condition 2 simplifies to

$$-q^* + e_2 [I - \beta A]^{-1} \pi \frac{1}{2} u(q^*) - \left( \frac{2N - 2}{2N - 1} \right) \frac{1}{2} u(q^*) \leq e_3 [I - \beta A]^{-1} \pi \frac{1}{2} u(q^*) - \left( \frac{2N - 3}{2N - 1} \right) \frac{1}{2} u(q^*),$$

$$-6 + 2.158 \times 6.81 - \left( \frac{12}{13} \right) 6.81 \leq 1.739 \times 6.81 - \left( \frac{11}{13} \right) 6.81$$

$$-6 + 14.69 - 6.286 \leq 11.843 - 5.762$$

$$2.403 \leq 6.081$$
\[-3.678 \leq 0\]

The largest population size under which these conditions are not satisfied is $2N = 18$. We did not pick the largest population size compatible with these conditions. The next largest population, namely $2N = 14$, is a more appropriate choice, to avoid that conditions 1 and 2 are barely satisfied by the chosen parameters.
<table>
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<th>Money (LW) or not (ACP)</th>
<th>No. of Sequences</th>
<th>No. of Periods</th>
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<td>30</td>
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Table 1: Characteristics of Experimental Sessions

<table>
<thead>
<tr>
<th>Session No., Treatment</th>
<th>Acceptance Rates</th>
<th>% Monetary Offers</th>
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<tbody>
<tr>
<td></td>
<td>$1^{st}$ half</td>
<td>$2^{nd}$ half</td>
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<tr>
<td>1, $N = 6$, Money</td>
<td>53.3</td>
<td>35.6</td>
</tr>
<tr>
<td>2, $N = 6$, Money</td>
<td>50</td>
<td>57.8</td>
</tr>
<tr>
<td>3, $N = 6$, Money</td>
<td>43.2</td>
<td>48.9</td>
</tr>
<tr>
<td>Avg. Sess. 1-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4, $N = 14$, Money</td>
<td>32.5</td>
<td>42.9</td>
</tr>
<tr>
<td>5, $N = 14$, Money</td>
<td>36.1</td>
<td>34.3</td>
</tr>
<tr>
<td>6, $N = 14$, Money</td>
<td>47.1</td>
<td>46.2</td>
</tr>
<tr>
<td>Avg. Sess. 4-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7, $N = 6$, No Money</td>
<td>52</td>
<td>68.6</td>
</tr>
<tr>
<td>8, $N = 6$, No Money</td>
<td>58.3</td>
<td>52</td>
</tr>
<tr>
<td>9, $N = 6$, No Money</td>
<td>22.2</td>
<td>25</td>
</tr>
<tr>
<td>Avg. Sess. 7-9</td>
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<td></td>
</tr>
<tr>
<td>10, $N = 14$, No Money</td>
<td>36.1</td>
<td>39.5</td>
</tr>
<tr>
<td>11, $N = 14$, No Money</td>
<td>43.9</td>
<td>46.7</td>
</tr>
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<td>12, $N = 14$, No Money</td>
<td>29.4</td>
<td>46.2</td>
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<td>Avg. Sess. 10-12</td>
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Table 2: Average Acceptance Rates and % Monetary Offers Each Session
<table>
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<tr>
<th>Session No., Treatment</th>
<th>Average $q$</th>
<th></th>
<th>Average $d$</th>
<th></th>
<th>Avg. Price</th>
<th></th>
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<td>2nd half</td>
<td>All</td>
<td>1st half</td>
<td>2nd half</td>
<td>All</td>
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<tr>
<td>1, $N = 6$, M</td>
<td>4.82</td>
<td>4.18</td>
<td>4.45</td>
<td>5.35</td>
<td>5.27</td>
<td>5.18</td>
</tr>
<tr>
<td>2, $N = 6$, M</td>
<td>4.62</td>
<td>4.25</td>
<td>4.41</td>
<td>5.1</td>
<td>5.8</td>
<td>5.48</td>
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<tr>
<td>3, $N = 6$, M</td>
<td>5.05</td>
<td>4.09</td>
<td>4.54</td>
<td>4.54</td>
<td>6.90</td>
<td>5.8</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Avg. Sess. 1-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4, $N = 14$, M</td>
<td>3.64</td>
<td>3.81</td>
<td>3.74</td>
<td>4.27</td>
<td>6.03</td>
<td>5.29</td>
</tr>
<tr>
<td>5, $N = 14$, M</td>
<td>4.49</td>
<td>2.09</td>
<td>3.34</td>
<td>4.03</td>
<td>4.54</td>
<td>4.28</td>
</tr>
<tr>
<td>6, $N = 14$, M</td>
<td>4</td>
<td>2.46</td>
<td>3.24</td>
<td>5.28</td>
<td>5.25</td>
<td>5.26</td>
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<td></td>
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<tr>
<td>Avg. Sess. 4-6</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7, $N = 6$, NM</td>
<td>1.3</td>
<td>1.22</td>
<td>1.25</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>8, $N = 6$, NM</td>
<td>1.36</td>
<td>1.04</td>
<td>1.21</td>
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<td>n/a</td>
<td>n/a</td>
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<td>9, $N = 6$, NM</td>
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<td>0.57</td>
<td>1.11</td>
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<tr>
<td>Avg. Sess. 7-9</td>
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<tr>
<td>10, $N = 14$, NM</td>
<td>1.59</td>
<td>0.99</td>
<td>1.28</td>
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<td>1.08</td>
<td>1.46</td>
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<td>n/a</td>
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<td>12, $N = 14$, NM</td>
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<td>0.66</td>
<td>0.89</td>
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<td>n/a</td>
<td>n/a</td>
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<td></td>
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<tr>
<td>Avg. Sess. 10-12</td>
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Table 3: Trade Average Offer Quantities and Prices, Each Session
<table>
<thead>
<tr>
<th>Session No., Treatment</th>
<th>Efficiency w.r.t First Best Eq.</th>
<th>Efficiency w.r.t. Monetary Eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; half</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; half</td>
</tr>
<tr>
<td>1, N = 6, Money</td>
<td>0.45</td>
<td>0.3</td>
</tr>
<tr>
<td>2, N = 6, Money</td>
<td>0.46</td>
<td>0.53</td>
</tr>
<tr>
<td>3, N = 6, Money</td>
<td>0.40</td>
<td>0.44</td>
</tr>
<tr>
<td>Avg. Sess. 1-3</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>4, N = 14, Money</td>
<td>0.30</td>
<td>0.21</td>
</tr>
<tr>
<td>5, N = 14, Money</td>
<td>0.40</td>
<td>0.31</td>
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<tr>
<td>Avg. Sess. 1-3</td>
<td>0.28</td>
<td>0.38</td>
</tr>
<tr>
<td>6, N = 14, No Money</td>
<td>0.34</td>
<td>0.26</td>
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<tr>
<td>7, N = 6, No Money</td>
<td>0.14</td>
<td>0.07</td>
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<tr>
<td>Avg. Sess. 7-9</td>
<td>0.22</td>
<td>0.20</td>
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<tr>
<td>8, N = 14, No Money</td>
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<td>0.24</td>
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<tr>
<td>9, N = 6, No Money</td>
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<td>0.17</td>
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<tr>
<td>Avg. Sess. 10-12</td>
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Table 4: Efficiency Relative to First Best or Monetary Equilibrium, Each Session

<table>
<thead>
<tr>
<th>Session No., Treatment</th>
<th>Average Centralized Market Price</th>
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<tbody>
<tr>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; half</td>
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<tr>
<td>1, N = 6, Money</td>
<td>1.16</td>
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<tr>
<td>2, N = 6, Money</td>
<td>0.96</td>
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<tr>
<td>3, N = 6, Money</td>
<td>1.26</td>
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<tr>
<td>Avg. Sess. 1-3</td>
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</tr>
<tr>
<td>4, N = 14, Money</td>
<td>1.30</td>
</tr>
<tr>
<td>5, N = 14, Money</td>
<td>2.52</td>
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<tr>
<td>6, N = 14, Money</td>
<td>1.67</td>
</tr>
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<td>Avg. Sess. 4-6</td>
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Table 5: Average Centralized Market Price, Each Money Session
<table>
<thead>
<tr>
<th>Session No., Treatment</th>
<th>Average Public Good Contribution</th>
<th>1st half</th>
<th>2nd half</th>
<th>All Periods</th>
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<tbody>
<tr>
<td>7, N = 6, No Money</td>
<td>0.06 0.03 0.05</td>
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<tr>
<td>8, N = 6, No Money</td>
<td>0.04 0.2 0.12</td>
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<tr>
<td>9, N = 6, No Money</td>
<td>0.04 0 0.02</td>
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<td>Avg. Sess. 7-9</td>
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<tr>
<td>10, N = 14, No Money</td>
<td>0.02 0.01 0.02</td>
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<td>Avg. Sess. 10-12</td>
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Table 6: Average Public Good Contribution, Each No Money Session

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<tr>
<th>Session No., Treatment</th>
<th>Holt-Laury Score</th>
<th>Mean</th>
<th>St. Dev.</th>
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<th>Maximum</th>
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<td>2, N = 6, Money</td>
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<tr>
<td>3, N = 6, Money</td>
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</tr>
<tr>
<td>Avg. Sess. 1-3</td>
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<tr>
<td>4, N = 14, Money</td>
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<tr>
<td>6, N = 14, Money</td>
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<tr>
<td>Avg. Sess. 4-6</td>
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<td>7, N = 6, No Money</td>
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<tr>
<td>8, N = 6, No Money</td>
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<tr>
<td>9, N = 6, No Money</td>
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<tr>
<td>Avg. Sess. 7-9</td>
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<td>10, N = 14, No Money</td>
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<td>Avg. Sess. 10-12</td>
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Table 7: Holt-Laury Score, Each Session