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 model’s monetary equilibrium. 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.

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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 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 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 through the assumption of quasi-linear preferences—features that allow for simple analytic results. As this newer generation of search-money models is tractable, 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 a finite population version of Aliprantis, Camera and Puzzello (ACP, 2007), which in its turn consists of a modified version of the Lagos and Wright environment where there is no money. In this environment, ACP show
that a non-monetary gift-exchange equilibrium implementing the first-best 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 matters for whether the efficient or the monetary equilibrium is selected. We speculate that non-monetary gift exchange might be easier to sustain via the contagious strategy in smaller economies of 6 agents as opposed to 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 yielded 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 re-balance 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 indef-
initely repeated game where, in one treatment, an intrinsically worthless money (“tickets”) is introduced. In their dynamic game, money is not essential to achieve the Pareto efficient (first best) outcome which, as in this paper, can be supported instead by social norms. The monetary environment they study involves both dynamic and distributional inefficiencies associated with the older, Kiyotaki and Wright (1989) money-search model in that ticket prices are exogenously fixed (there is no bargaining), money and goods are indivisible, there are restrictions on money holdings and there is only decentralized pairwise random matching (there is no centralized market involving all players). They also consider only 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 where money holdings can be re-balanced thereby eliminating distributional inefficiencies. 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.

The rest of the paper is organized as follows. Section 2 presents a simplified version of the Lagos and Wright (2005) model that is used in the experiment and characterizes the equilibrium possibilities. Similarly, section 3 presents a non-monetary version of the same model that is also used in our experiment and which is a version of the environment studied by Aliprantis et al. (2007). In the non-monetary environment we demonstrate how the Pareto efficient outcome can be sustained via a social norm of gift-giving that is a sequential equilibrium of that environment. Section 5 presents our experimental design and procedures and section 6 describes our main experimental findings. Section 7 concludes.

3 The Lagos-Wright Environment

We study a simplified version of the Lagos and Wright ([15]) model involving a 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 \( u'(q^*) = c'(q^*) \). Note that \( q^* \) maximizes surplus in a pair. Also, let \( \overline{q} > 0 \) be such that \( u(\overline{q}) = c(\overline{q}) \).

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.

Since our population is finite,\(^3\) 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.\(^4\) 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. 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

\[
\frac{u'(\bar{q})}{c'(\bar{q})} = 1 + \frac{1 - \beta}{\frac{\beta}{2}},
\]

where \( \bar{q} \) denotes the amount of special good exchanged in each bilateral match. 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 \( \phi = \frac{c(\bar{q})}{\frac{2N}{\bar{q}}} \). Also, note that the distribution of money at the beginning of the decentralized market is degenerate at \( \frac{M}{2N} \). It is easy to see that \( \bar{q} < q^* \) since \( \beta < 1 \), and that \( \bar{q} \to q^* \) as \( \beta \to 1 \), thus the monetary

\(^2\)The original Lagos and Wright model has a positive probability, \((1 - \alpha)\), that agents remain unmatched, a positive probability \( \delta \) of double coincidence meetings and a probability \( \sigma \) of being consumer or producer. We set \( \alpha = 1, \delta = 0 \), and \( \sigma = 1/2 \). This does not affect the qualitative results.

\(^3\)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]).

\(^4\)Recall that both the special good and general good are nonstorable.
equilibrium does not achieve the first best. Note also that the steady state lifetime expected payoff is given by
\[ V = \frac{1}{1 - \beta} \left\{ \frac{1}{2} [u(\bar{q}) - c(\bar{q})] \right\}. \]

### 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 \([0, \bar{q}] \times [0, M]\). As for producers, their actions set is \(\{0, 1\}\) where 0 stands for reject and 1 stands for accept.

Consider the following decentralized gift-giving social norm:

“Do not participate in the CM. Participate only in the DM.

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.\(^5\)

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

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

\(^5\)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)
$e_i$ 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 $t$

$$
\pi = \frac{1}{2^N - 1} \begin{pmatrix}
2N - 1 \\
2N - 2 \\
2N - 3 \\
\vdots \\
2 \\
1 \\
0
\end{pmatrix},
$$

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

It is easy to see that the lifetime expected payoff associated with the first-best allocation is given by

$$
V^* = \frac{1}{1 - \beta} \left\{ \frac{1}{2} [u(q^*) - c(q^*)] \right\}.
$$

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.\textsuperscript{6} 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 for the achievement of 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 us 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

\textsuperscript{6} Money is essential if better outcomes can be supported in an environment with money than without money.
markets are now replaced by centralized meetings where agents make a production decision and their consumption is determined by average production.\footnote{This is similar to Aliprantis et al. (2007) except for the population’s cardinality which here is finite.} Without loss of generality, in the decentralized meetings, we can think of \( \{0, 1\} \) as the producers’ action set, and \([0, \overline{q}]\) as the consumers’ action set. As for the centralized meetings, agents are both producers and consumers so we can think of \([0, \overline{q}]\) 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 the 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 centralized 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 \( L \in [0, \overline{q}] \) 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 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

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

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

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

In the centralized meeting we have

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

\[ \beta \geq \frac{2N-1}{2N} L + \frac{1}{2} \left[ u(q^*) - q^* \right] = \beta. \]
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., $\beta \geq \max \left\{ \frac{1}{L}, \frac{1}{2N} \right\}$, 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 and thus the contagion spread is faster under the centralized gift-giving social norm than under the decentralized gift-giving social norm.

5 Experimental Design and Procedures

We chose a $2 \times 2$ experimental design where the two treatment variables are 1) the environment, money (M) [Lagos-Wright (2005)] versus no money (NM) [ACP (2007)] and 2) the population size, $2N = 6$ versus $2N = 14$. We refer to our four treatments as M6, M14, NM6 and NM14.

Our experiment was computerized and was implemented using the z-Tree software (Fischbacher (2007)). Written instructions were passed out and read aloud in an effort to make them common knowledge.\(^9\) After the instructions were read, subjects had to correctly answer a number of quiz questions testing their comprehension of the environment in which they would be making decisions. After completion of the quiz, the experiment commenced with subjects making decisions anonymously using networked computer workstations.

Each session consisted of several “supergames” which we refer to as “sequences”. Each sequence consisted of an indefinite number of repetitions (periods) of a stage game. Each stage game involved 2 rounds, a decentralized market round and a centralized market round. Every sequence began with the play of at least one, two-round stage game. At the end of each stage game, the sequence continued with another repetition (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 a 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.\(^10\)

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\(^8\)Note that $\beta \geq \beta$ if and only if $\frac{1}{2} \left[ u(q^*) - q^* \right] \left[ q^* - \frac{L}{2N} \right] \geq 0$ 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 $\beta$.

\(^9\)Copies of these instructions are available at: http://www.pitt.edu/~jduffy/ExchangeExp/

\(^10\)We recruited subjects for a 3 hour length of time, but our sessions all ended well before that time limit, on average after 2.25 hours, so as to avoid any possible end game effects. Our stopping rule, which was not announced to subjects was to obtain approximately 30 periods of data (2-round stage games) per session.
In the money treatments, at the start of each new indefinite sequence, i.e., prior to the first decentralized meeting round, each subject was endowed with $M/2N$ “tokens”. In the non-monetary treatment, there were no tokens. Subjects in the money treatment were instructed that the total amount of tokens, $M$, was fixed and that they would not get any further endowment of tokens for the duration of that sequence. They were also instructed that if a sequence ended their token balances would be set to zero. However, if a sequence continued with a new period, they would carry over to that new period their token balance from the previous period.

Within a period (stage game), the decentralized market round began with a random pairwise matching of all $2N$ subjects to form $N$ pairs. Within each pair, one player was chosen with probability $1/2$ to be the producer and the other player was designated as the consumer for that round. We suggested that subjects think of this determination as the result of a coin flip. Subjects were instructed that all random pairings and assignments were equally likely. For the decentralized market we induced the utility function $u(q) = A \log(1+q)$ over consumption and the cost function $c(q) = Cq$ over production of the decentralized good. These functions were presented to subjects in a Table showing how a certain quantity $q$ of the decentralized good translated into a positive number, $A \log(1+q)$, of “points” in the case of consumption or a negative number, $-Cq$, of points in the case of production. Subjects were instructed in how to use that table to calculate their earnings in various scenarios. At the start of each session of all treatments, each subject was given an initial endowment of 20 points so as to minimize the possibility that any subject ended up with a negative point balance; indeed, we can report that no subject ended any of our experimental sessions with a negative point balance.

Consumers moved first and were asked to form a “proposal” as to how much of the decentralized good their randomly matched producer should produce for them. In the money treatment, consumers were informed of both their own and their matched producer’s current token balances prior to formulating their proposal. In both treatments, consumers were restricted to requesting quantities of the decentralized good, $q$, in the interval $[0, q]$. In the money treatment, consumers could offer $d$ units of their current period token balance to their matched producer as part of their proposal. Any token (money) offerings were voluntary; subjects were instructed that the amount of tokens offered, $d$, could range between 0 and their current available token balance, inclusive. Further, subjects were explicitly instructed that “tokens have no value in terms of points”. Thus, in the money treatment, each consumer formulated a proposal, $(q, d)$, while in the no money treatment each consumer formulated a proposal, $q$.

Producers moved second and were first informed of their matched consumer’s proposal. Producers were also informed of the consumer’s benefit from receiving the proposed quantity $q$, $u(q)$, and of their own cost from producing quantity $q$, $c(q)$. In the money treatment, producers were also informed of both player’s current available token balances. Producers then had to decide whether to accept or reject the consumer’s proposal. If the a producer

\footnote{While we refer to the treatment with tokens as the “money” treatment, we were careful to avoid all use of the term “money” in the experimental instructions or in the software.}
accepted the proposal, then it was implemented: producers produced quantity $q$ at a cost to themselves of $c(q)$ points. The consumer consumed quantity $q$ yielding him or her a benefit of $u(q)$ points. In the money treatment, $d$, tokens were transferred from the consumer to the producer. If the producer rejected the proposal then no exchange took place; both members of the pair earned 0 points for the round and in the money treatment, their token balances remained unchanged. At the end of the decentralized round, subjects were informed of the outcome of that round: they were informed as to whether the proposal was accepted or not and updated on any changes to their cumulative point totals, and, in the money treatment, of any changes in their token balances. After this feedback was communicated, the decentralized round was over and the centralized market round began.

Within a period (stage game), the second, centralized market round brought together all $2N$ participants to participate in the market for the homogeneous and perishable “good X”. In the money treatment, at the start of the Decentralized round, subjects were asked whether they wanted to participate in that market and if so, whether they wanted to produce-and-sell or buy-and-consume units of good X. Subjects were instructed that if they successfully sold $Y$ units of good X they would incur a cost of $Y$ points, while if they successfully bought and consumed $X$ units of good X they would receive a benefit of $X$ points. That is, subjects were instructed (again using a table) that their utility from consuming and their cost from producing units of good X were both linear. Those subjects choosing to be sellers were then asked to state a quantity $Y \in (0, Y)$ and a (single) price per unit, $p_s$, in tokens for which they were willing to produce and sell $Y$ units of good X. Those choosing to be buyers were asked to state a quantity, $X$, and a (single) price per unit, $p_b$, in tokens for which they were willing to buy and consume $X$ units of good X. Each buyer’s unit price, $p_b$, for their desired quantity, $X$, was restricted to be such that $p_bX$ did not exceed their available token balance; that is, budget constraints were enforced.

The market clearing price was determined by a call market mechanism that sorted sell prices from lowest to highest and buy prices from highest to lowest. The intersection of these two schedules (if one existed) determined the market price, $P$. All sellers with prices at or below the market price were able to sell their units (subject to available demand) while all buyers with prices at or above the market price were able to buy their units (subject to available supply). All transactions were carried out at the market price $P$. Thus, successful sellers producing $Y$ units of good X gained $PY$ additional tokens but at the production cost of $Y$ points. Successful buyers of $X$ units of good X gave up $PX$ of their available token balance but received $X$ points in exchange. Points were subtracted or added to subjects’ point totals from the decentralized market round and had the same conversion rate, i.e., 1 point = $0.20.

In the no money treatments all $2N$ subjects also participated in a centralized market round, which was termed a “centralized meeting”, where they were asked to decide how

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12 Extra marginal sellers and buyers with prices above or below, respectively, the market price were not able to sell or buy units of Good X; their point and token balances remained unchanged. In the event that the available supply (demand) at the market price exceeded demand (supply), some inframarginal sellers (buyers) whose prices were at or below (at or above) the market price were rationed as to the quantity of good X that they could sell (buy) so as to satisfy the market clearing.
many units they wanted to produce of a homogeneous and perishable good X. Production of good X was limited to 0 or 1 units for each subject. All 2N subjects were instructed that producing a unit of good X cost them 1 point and that all production decisions would be made simultaneously. After all 2N decisions were made, the average number of units of good X produced by all 2N subjects was calculated. Subjects were instructed that their net payoff from their production decision in the centralized meeting was given by the formula:

$$\text{average production of good X - your production of good X}$$

where the average production of good X was the total number of units produced divided by 2N. This net payoff in points was subtracted or added to each subjects’ point totals from the decentralized round and had the same conversion rate, 1 point = $0.20.

Following the completion of the centralized meeting round (no money treatment) or the centralized market round (money treatment), subjects were updated on their new point totals or token holdings. Then a random number was drawn from the set \{1, 2, 3, 4, 5, 6\}. If the random number drawn was not 6, the sequence continued on with another 2-round period. In the money treatment, subjects token balances as of the end of the centralized market carried over to the decentralized round of the next period in the sequence. If the random number drawn was a 6, then the sequence ended. In the money treatment if a sequence ended, token balances were set to zero.

Subjects were instructed that once a sequence ended, depending on the time available a new indefinite sequence will begin. In each new sequence of the money treatment, all subjects would begin again with 8 tokens. Point totals, however were not reinitialized between sequences; subjects cumulative point totals from all periods of all sequences played were converted into cash at the end of the session at the exchange rate of 1 token = $0.20.

5.1 Parameterization and Equilibrium Benchmarks

We have chosen the following parameters: \(A = 7\), \(C = 1\), \(\beta = \frac{5}{6}\). Given these parameters, we can further characterize the equilibrium predictions associated with our experimental designs.

In Section 3, we focused on two theoretical benchmarks in the Lagos-Wright environment with money: the monetary equilibrium and the decentralized gift-giving social norm.\(^{13}\)

We start by discussing the monetary equilibrium. The initial endowment of money per capita is \(M/2N = 8\). It is easy to see that in the decentralized market, the first best quantity implied by our parameterization is \(q^* = 6\), while the equilibrium quantity associated with the monetary equilibrium is \(\tilde{q} = 4\). A natural upper bound for the special good in the DM \(\tilde{q} = 22^{14}\). We also chose an upper bound of \(\bar{Y} = 22\) (which was never binding) for the CM. Regarding prices, the equilibrium price of the special good in the decentralized market

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\(^{13}\)In this design it was not possible to use the CM for signaling purposes, given the messages subjects received and given that in order to have prices, subjects had to use money.

\(^{14}\)Note that the quantity \(q\) satisfying \(u(\tilde{q}) = c(\tilde{q})\) is such that \(\tilde{q} \in [21, 22]\). For simplicity, we just chose \(\tilde{q} = 22\).
is given by $\frac{M/2N}{q} = \frac{8}{4} = 2$. In the CM, the equilibrium price of money in terms of the general good is $\phi = \frac{c(q)}{M/2N} = \frac{1}{2} \frac{1}{2}$ and so the equilibrium price of the general good is the reciprocal $P = 2$. Finally, for the purpose of calculating welfare, we point out that the period monetary equilibrium payoff per pair is $v = \{7 \cdot \log 5 - 4\} = 7.62$ and the period first best payoff per pair is $v^* = \{7 \cdot \log 7 - 6\} = 7.26$.

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 decentralized gift-giving social norm attaining the first-best is also an equilibrium in our lab economy with money.

Since cooperation is typically difficult to emerge (e.g., Duffy and Ochs (2009)), in the ACP environment without money 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 $L = 1$ could be identified with production and willingness to cooperate. 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 centralized gift-giving social norm.

6 Experimental Results

We report results from 16 experimental sessions involving 160 subjects. In particular we have 4 sessions of each of the 4 treatments, M6, M14, NM6, NM14. Characteristics of the 16 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, subjects participated in an average of 5.7 supergames for an average of 31.1 total periods. In the second part of the session subjects were asked to participate in an individual-choice, paired lottery decision-making task (due to Holt and Laury (2002)) to elicit their risk attitudes in which they could earn additional amounts of money. The total length of each session averaged 2.25 hours. Total earnings from both parts of the session averaged $23.54 per subject.

Our experimental results are summarized as a number of findings that address the theoretical propositions of sections 3-4.

Finding 1 There are no differences in offer acceptance rates across M and NM treatments. In the money treatment, more than 95% of accepted proposals involve positive amounts of tokens.

Support for Finding 1 can be found in Table 2 which reports the average frequency with which Producers accepted Consumer’s offers over the first half, the second half, and over all periods of each session of a treatment. Using a nonparametric, Wilcoxon Mann-Whitney
<table>
<thead>
<tr>
<th>Sess. No.</th>
<th>No. Subj.</th>
<th>Money (LW) or not (ACP)</th>
<th>No. of Sequences</th>
<th>No. of Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Money</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>Money</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Money</td>
<td>6</td>
<td>30</td>
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<tr>
<td>4</td>
<td>6</td>
<td>Money</td>
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<td>5</td>
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<td>Money</td>
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<tr>
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<td>Money</td>
<td>6</td>
<td>29</td>
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<td>7</td>
<td>14</td>
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<tr>
<td>8</td>
<td>14</td>
<td>Money</td>
<td>5</td>
<td>35</td>
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<tr>
<td>9</td>
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<td>33</td>
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<td>11</td>
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<td>31</td>
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<td>12</td>
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<td>6</td>
<td>30</td>
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<td>13</td>
<td>14</td>
<td>No Money</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>No Money</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
<td>No Money</td>
<td>4</td>
<td>34</td>
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<tr>
<td>16</td>
<td>14</td>
<td>No Money</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>Averages</td>
<td></td>
<td></td>
<td>5.7</td>
<td>31.1</td>
</tr>
</tbody>
</table>

Table 1: Characteristics of Experimental Sessions

test on the four session-level averages over all periods as reported in Table 2 for the two treatments, we cannot reject the null hypothesis of no difference in proposal acceptance rates between 1) the M6 and NM6 treatments, 2) the M14 and NM14 treatments and 3) the NM6 and NM14 treatments \( (p > .10 \) in all pairwise comparisons using a two-sided test). We do find a significantly higher acceptance frequency in the M6 treatment as compared with the M14 treatment \( (p = .08) \). As Table 2 reveals, overall acceptance rates averaged between 40 and 59% across all treatments and appeared not to increase or decrease very much from the first to the second half of each session. We note that such acceptance frequencies are inconsistent with any pure strategy equilibrium, which would require either 0 or 100 percent acceptance of Consumer proposals. On the other hand, Table 2 reveals that in the two money treatments (M6 and M14), accepted Consumer proposals involved positive token quantities more than 95% of the time on average, a finding that is very close to the monetary equilibrium prediction of 100% monetary offers.

**Finding 2** Proposals are less likely to be accepted as the quantity requested increases. In the Money treatment, proposals are more likely to be accepted the higher the number of tokens offered.

Support for Finding 2 is found in Table 3 which reports results from a random effects probit regression analysis of producer’s acceptance decisions in 1) all decentralized rounds of
### Table 2: Average Acceptance Rates and % Monetary Offers Each Session

<table>
<thead>
<tr>
<th>Session No., Treatment</th>
<th>Acceptance Rates %</th>
<th>% Monetary Offers</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, M6</td>
<td>53.3</td>
<td>35.6</td>
</tr>
<tr>
<td>2, M6</td>
<td>50.0</td>
<td>57.8</td>
</tr>
<tr>
<td>3, M6</td>
<td>42.2</td>
<td>48.9</td>
</tr>
<tr>
<td>4, M6</td>
<td>47.9</td>
<td>70.6</td>
</tr>
<tr>
<td>Avg. 1-4</td>
<td>48.3</td>
<td>53.8</td>
</tr>
<tr>
<td>5, M14</td>
<td>32.5</td>
<td>42.9</td>
</tr>
<tr>
<td>6, M14</td>
<td>35.7</td>
<td>32.4</td>
</tr>
<tr>
<td>7, M14</td>
<td>46.2</td>
<td>46.2</td>
</tr>
<tr>
<td>8, M14</td>
<td>42.9</td>
<td>42.9</td>
</tr>
<tr>
<td>Avg. 5-8</td>
<td>40.2</td>
<td>41.2</td>
</tr>
<tr>
<td>9, NM6</td>
<td>52.1</td>
<td>68.6</td>
</tr>
<tr>
<td>10, NM6</td>
<td>58.3</td>
<td>52.1</td>
</tr>
<tr>
<td>11, NM6</td>
<td>22.2</td>
<td>25.0</td>
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<tr>
<td>12, NM6</td>
<td>62.2</td>
<td>60.0</td>
</tr>
<tr>
<td>Avg. 9-12</td>
<td>48.9</td>
<td>51.6</td>
</tr>
<tr>
<td>13, NM14</td>
<td>36.1</td>
<td>39.5</td>
</tr>
<tr>
<td>14, NM14</td>
<td>44.8</td>
<td>45.9</td>
</tr>
<tr>
<td>15, NM14</td>
<td>29.4</td>
<td>46.2</td>
</tr>
<tr>
<td>16, NM14</td>
<td>46.7</td>
<td>34.8</td>
</tr>
<tr>
<td>Avg. 13-16</td>
<td>38.8</td>
<td>41.6</td>
</tr>
</tbody>
</table>

We first note that the probit regression results using all data (the first column of Table 3) confirm Finding 1 in that the coefficient on the Money treatment dummy variable is
not significantly different from zero. That is, producers’ willingness to accept offers is not significantly affected by whether tokens were available (M) or not (NM). We also note the insufficiency of the Group14 dummy indicating that acceptance decisions were unaffected by the group size across all sessions of all treatments. We next observe that in all specifications there is a significant “restart effect” wherein acceptance frequencies are higher in the first period of each new sequence (the NewSeq dummy is positive and significant) and decline over the course of the sequence as indicated by the negative and significant coefficient on the Period variable. Most importantly, as stated in Finding 2, a higher proposed quantity $q$ leads to a lower likelihood of acceptance in all samples, M+NM, NM and M separately. Perhaps the more interesting finding however, concerns the PriorCons dummy, which is positive and significant using all data and data just from the NM sessions (column 2), but becomes insignificant when the sample is restricted to just the M sessions (columns 3-4). This dummy variable captures the extent to which producer’s acceptance of current proposals are conditioned on past acceptance of proposals made by the producer when he was last a consumer. With the introduction of money, this reciprocal rationalization for exchange is no longer operative. Instead, we observe that for the M sessions, it is the amount of tokens offered ($d$) that becomes the more important concern (along with the proposed amount of $q$); a higher $d$ and a lower $q$, i.e., better terms of trade, result in a higher likelihood that a proposal is accepted. Indeed if we instead replace $q$ and $d$ M specification 1 (column 3) with $d/q$ as in M specification 2 (column 4) and we eliminate a few observations where $q = 0$, we obtain a significantly positive coefficient on the terms of trade variable, $d/q$, while the PriorCons dummy remains insignificant. We note further that in the M session, proposals are significantly less likely to be accepted the higher is the producer’s current money holdings $m_p$, and in M specification 2, proposal acceptance is also less likely the higher is the consumer’s current money holdings $m_c$. Recall that both $m_p$ and $m_c$ were reported to the producer along with the consumer’s proposal prior to the producer’s decision of whether to accept or reject that proposal. Finally, we note that we do not find evidence that subjects’ risk attitudes toward uncertain money amounts matter for proposal acceptance rates as indicated by the insignificance of the HLscore variable in all of our regression specifications.

Thus far we have found little evidence of any treatment effects. In particular, we have found that proposal acceptance rates in the decentralized market do not differ significantly between the money and no money treatments, there seems to be little effect of group size 6 or 14 on proposal acceptance rates and acceptance rates are always negatively related to the amount of the good requested in both the NM and M treatments (though acceptance rates respond positively to higher token amounts in the M treatment. We now report on the major observed difference between the NM and M treatment which concerns the quantity traded of the decentralized good.

**Finding 3** _Quantities exchanged in the decentralized meeting are significantly greater when there is money than when there is no money. However, quantities in both environments are well below the efficient equilibrium level._

[Figure 1 here]
<table>
<thead>
<tr>
<th></th>
<th>All Sessions</th>
<th>NM Sessions</th>
<th>M Sessions (1)</th>
<th>M Sessions (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.197</td>
<td>2.508*</td>
<td>0.989***</td>
<td>-0.356</td>
</tr>
<tr>
<td></td>
<td>(0.638)</td>
<td>(1.427)</td>
<td>(0.308)</td>
<td>(0.315)</td>
</tr>
<tr>
<td>Session</td>
<td>0.019</td>
<td>-0.094</td>
<td>0.060</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>(0.057)</td>
<td>(0.127)</td>
<td>(0.058)</td>
<td>(0.062)</td>
</tr>
<tr>
<td>Group14</td>
<td>-0.382</td>
<td>0.158</td>
<td>-0.687***</td>
<td>-0.614**</td>
</tr>
<tr>
<td></td>
<td>(0.268)</td>
<td>(0.601)</td>
<td>(0.272)</td>
<td>(0.288)</td>
</tr>
<tr>
<td>NewSeq</td>
<td>0.285***</td>
<td>0.460***</td>
<td>0.360***</td>
<td>0.306***</td>
</tr>
<tr>
<td></td>
<td>(0.077)</td>
<td>(0.122)</td>
<td>(0.111)</td>
<td>(0.110)</td>
</tr>
<tr>
<td>Period</td>
<td>-0.010***</td>
<td>-0.033***</td>
<td>-0.074**</td>
<td>-0.0489**</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>PriorCons</td>
<td>0.182***</td>
<td>0.317**</td>
<td>0.038</td>
<td>-0.0173</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
<td>(0.098)</td>
<td>(0.088)</td>
<td>(0.0924)</td>
</tr>
<tr>
<td>HLscore</td>
<td>-0.018</td>
<td>-0.045</td>
<td>-0.002</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.084)</td>
<td>(0.035)</td>
<td>(0.0372)</td>
</tr>
<tr>
<td>Money</td>
<td>0.556</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.472)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$q$</td>
<td>-0.151***</td>
<td>-0.658***</td>
<td>-0.344***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.582)</td>
<td>(0.031)</td>
<td></td>
</tr>
<tr>
<td>$d$</td>
<td></td>
<td></td>
<td>0.208***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.024)</td>
<td></td>
</tr>
<tr>
<td>$d/q$</td>
<td></td>
<td></td>
<td></td>
<td>1.219***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.094)</td>
</tr>
<tr>
<td>$m_p$</td>
<td>-0.015*</td>
<td>-0.014*</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_c$</td>
<td>0.002</td>
<td>-0.029***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.009)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. obs.</td>
<td>2,487</td>
<td>1,274</td>
<td>1,213</td>
<td>1,184</td>
</tr>
</tbody>
</table>

Table 3: Probit Regression Analysis of Proposal Acceptance Decisions
Table 4: Trade Average Offer Quantities and Prices, Each Session

Support for Finding 3 can be found in Figure 1 and Table 4 which report mean amounts of the decentralized good that were exchanged (proposed and accepted) across all treatments. For the money treatments we also report the mean number of tokens traded (again, proposed and accepted). Figure 1 and Table 4 reveal the striking finding that mean offers in the money treatments are around 3 times greater than in the no money treatment. In the M6 treatment, the mean accepted quantity in the decentralized market is 4.16 units and the mean accepted price is 5.50 tokens while in the NM6 treatment, the mean accepted quantity is 1.27 units. Using a Mann-Whitney test on the four session-level averages of these two treatments we reject the null hypothesis of no difference in favor of the alternative that quantities are significantly higher in the M6 treatment as compared with the NM6 treatment (p = .02). A similar difference exists between the M14 and the NM14 treatments. In the M14 treatment, the mean accepted quantity is 3.51 units and the mean accepted price is 5.16 tokens while in the NM14 treatment, the mean accepted quantity is just 1.22 units. Again using a Mann-Whitney test on the four session-level averages of these two treatments, we can again reject the null hypothesis of no difference in favor of the
alternative that quantities are significantly higher in the M14 treatment as compared with the NM14 treatment ($p = .02$).

In all 4 treatments, the mean accepted quantities lie well below the efficient equilibrium level of 6 units. However in the two money treatments, the mean accepted quantities are rather close to the monetary equilibrium prediction of $\tilde{q} = 4$ units.

Findings 1 and 3 suggest that welfare should be higher in the money treatment as compared with the no money treatment as there is 1) no significant difference in the frequency with which producers accept proposals, 2) the average quantities traded are significantly higher in the money treatment than in the comparable no money treatment. We further note that 3) aggregate earnings in the centralized market of both the money and no money treatments always net to zero due to the linear specification we chose for utility and cost of good X in our experimental design. Thus, the differences in the quantities traded in the decentralized market should be reflected in differences in overall efficiency measures. Indeed, we have:

**Finding 4** Welfare is higher in economies with money than in economies without money.

Support for Finding 6 comes from Table 5 which reports two different but related measures of efficiency. The first efficiency measure is the ratio of the payoffs earned by all subjects relative to the payoffs they could have earned by playing according to the first best equilibrium strategy in all periods of all sequences. Recall that the period first best payoff per pair is $v^* = 7.62$, which we used as our benchmark. The second measure is the ratio of the payoffs earned by all subjects relative to the payoffs they could have earned by playing according to the less efficient monetary equilibrium, which has a period equilibrium payoff per pair of $v = 7.26$.

In examining welfare differences we look at the efficiency ratios over all rounds of all periods of all sequences of each session. Using the four session-level efficiency ratios for each treatment (either “w.r.t. the first best” or “w.r.t. the monetary equilibrium” as reported in Table 5) Wilcoxon Mann-Whitney tests on session-level efficiency ratios allow us to reject the null hypothesis of no difference in efficiency ratios between 1) the M6 and NM6 treatments and 2) the M14 and NM14 treatments in favor of the alternative that efficiency ratios are higher in each of the two M treatments relative to the comparable NM treatment ($p = .02$ for the first test and $p = .04$ for the second test using either efficiency ratio). Finding 3 indicates that white money is not essential to expanding the Pareto frontier in the environments we study, money is nevertheless efficiency enhancing relative to an environment without a money object.

We note that the efficiency ratios reported in Table 5 are all rather low – averaging 50 percent or less in most sessions. These low efficiency ratios are a reflection of the low acceptance rates of decentralized market proposals by producers as reported earlier in Table 2; recall that decentralized market acceptance rates also average 50 percent or less in most sessions. The low acceptance rates are largely attributable to consumers requesting high quantities in the decentralized meetings and, in the money treatment, to consumers offering too few tokens as part of their proposals. Recall from Table 3 that decentralized meeting
<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>1st half</td>
<td>2nd half</td>
</tr>
<tr>
<td>1, M6</td>
<td>0.45</td>
<td>0.30</td>
</tr>
<tr>
<td>2, M6</td>
<td>0.46</td>
<td>0.53</td>
</tr>
<tr>
<td>3, M6</td>
<td>0.40</td>
<td>0.44</td>
</tr>
<tr>
<td>4, M6</td>
<td>0.36</td>
<td>0.60</td>
</tr>
<tr>
<td>Avg. 1-4</td>
<td>0.42</td>
<td>0.47</td>
</tr>
<tr>
<td>4, M14</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>5, M14</td>
<td>0.30</td>
<td>0.21</td>
</tr>
<tr>
<td>6, M14</td>
<td>0.40</td>
<td>0.31</td>
</tr>
<tr>
<td>7, M14</td>
<td>0.35</td>
<td>0.27</td>
</tr>
<tr>
<td>Avg. 5-8</td>
<td>0.34</td>
<td>0.28</td>
</tr>
<tr>
<td>7, NM6</td>
<td>0.28</td>
<td>0.36</td>
</tr>
<tr>
<td>8, NM6</td>
<td>0.34</td>
<td>0.26</td>
</tr>
<tr>
<td>9, NM6</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>10, NM6</td>
<td>0.39</td>
<td>0.31</td>
</tr>
<tr>
<td>Avg. 9-12</td>
<td>0.29</td>
<td>0.25</td>
</tr>
<tr>
<td>11, NM14</td>
<td>0.22</td>
<td>0.20</td>
</tr>
<tr>
<td>12, NM14</td>
<td>0.28</td>
<td>0.24</td>
</tr>
<tr>
<td>13, NM14</td>
<td>0.16</td>
<td>0.17</td>
</tr>
<tr>
<td>14, NM14</td>
<td>0.28</td>
<td>0.17</td>
</tr>
<tr>
<td>Avg. 13-16</td>
<td>0.23</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Table 5: Efficiency Relative to First Best or Monetary Equilibrium, Each Session

prices in the money treatments always average less than the monetary equilibrium price of 2. We note further that some efficiency loss in the money treatment also arises from the lack of use of tokens in exchange proposals in around 5 percent of all accepted proposals. There is no legal requirement for the use of tokens in the money environments we consider.

In the no money treatments, the efficiency ratios reported in Table 2 are typically lower than in the comparable money treatments, but efficiency in the no money treatments is still greater than under the autarkic equilibrium, a reflection of the 40-50 percent acceptance rates and non-zero mean quantities exchanged in the no money treatments. As Tables 2-3 make clear, in the no money treatments, most accepted offers involved the exchange of a single unit of the decentralized good \( q = 1 \) though subjects could and did propose quantities less than 1, even 0.

**Finding 5** Welfare is higher in treatment M6 as compared with treatment M14; there is no welfare difference between treatments NM6 and NM14.

Support for Finding 6 comes again from Table 5. Using either efficiency ratio (relative to first best or the monetary equilibrium) over all periods of each of the four sessions of
a treatment, Wilcoxon Mann-Whitney tests allow us to reject the null of no difference in efficiency between M6 and M14 in favor of the alternative that efficiency is higher in M6 ($p = .02$, two sided test). By contrast, we are unable to reject the null of no difference in efficiency between NM6 and NM14 ($p = .24$, two sided test). The latter result is largely owing to one session of NM6 (session 11) where efficiency was the lowest in any of the 16 sessions we conducted; more generally efficiency ratios are higher in the other three sessions of NM6 as compared with any of the four sessions of NM14.

An explanation for Finding 6 comes from Table 3, where we found that in the M treatment alone, Producers were significantly less likely to accept proposals in the M14 treatment as compared with the M6 treatment. This difference in acceptance rates is the main explanation for the difference in welfare between these two treatments.

Finding 6 provides some evidence that a social norm of the use of money as a medium of exchange may be easier to achieve in a smaller population of size $2N = 6$ as compared with larger populations of size $2N = 14$. We note that theory is silent on the role of population size on social norm adoption. One might conclude from this finding is that for larger populations, legal restrictions requiring the use of money to mediate some or all exchanges may be necessary to ease coordination problems and to facilitate the adoption of money as a social norm.

**Finding 6** *In the money treatments, centralized market prices and trade volume are positive but lower than predicted in the monetary equilibrium. There is evidence that subjects are using the centralized meeting to re-balance their money holdings.*

[Figures 2-3 here]

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>1st half</td>
<td>2nd half</td>
</tr>
<tr>
<td>1, M6</td>
<td>.81</td>
<td>1.16</td>
<td>1.30</td>
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<tr>
<td>2, M6</td>
<td>.77</td>
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<tr>
<td>Avg. 1-4</td>
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<td>1.48</td>
<td>1.44</td>
</tr>
<tr>
<td>5, M14</td>
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<td>1.30</td>
<td>1.58</td>
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<tr>
<td>6, M14</td>
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<td>2.52</td>
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<tr>
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<td>1.67</td>
<td>2.31</td>
</tr>
<tr>
<td>8, M14</td>
<td>.66</td>
<td>1.36</td>
<td>1.52</td>
</tr>
<tr>
<td>Avg. 5-8</td>
<td>.73</td>
<td>1.71</td>
<td>2.14</td>
</tr>
</tbody>
</table>

Table 6: Participation Rates, Market Prices and Volume in the Centralized Round of the Money Treatment Sessions
Support for Finding 6 is found in Table 6 and Figures 2-3. As the first column of Table 6 indicates, participation as a buyer or seller in the centralized market of the Money treatments was high, averaging 83 percent in the M6 sessions and 73 percent in the M14 sessions. We note that participation here refers to the submission of a bid or an ask in the centralized market and not necessarily at prices that allowed the participant to exchange tokens for good X (bid) or good X for tokens (ask). Still these participation rates for the centralized market are high. Together with the high use of money in decentralized market proposals these findings are inconsistent with the first-best social optimum, where money is not used and thus there is no need for the centralized market. Table 6 further reveals that there were positive trading volumes and market prices in the centralized market. In the M6 sessions, the market price of good X averaged 1.46 while in the M14 sessions, the market price of good X averaged 1.93. These market prices are close to, but in both treatments lie below the monetary equilibrium prediction of $P = 2$. Trading volume of good X is predicted to be $4N$ in the monetary equilibrium (and zero in the first best or autarkic equilibrium). In the M6 treatment, trading volume averaged 5.51 units of good X traded each round, or 46 percent of the monetary equilibrium prediction of 12 units. In the M14 treatment, trading volume averaged 9.23 units of good X in each round or 33 percent of the monetary equilibrium prediction of 28 units. While the total volume of units of good X traded over all sessions of the M14 treatment is larger than that of all sessions of the M6 treatment, the difference in average centralized market volume per round using session level data from all rounds of both treatments is not significantly different according to a Wilcoxon Mann-Whitney test ($p = .15$). The lower-than-monetary-equilibrium trading volume in both of the money treatments is largely a reflection of (and is highly correlated with) the low acceptance rates of offers in the decentralized market; recall from Table 2 that decentralized market acceptance rates were 51 percent in the M6 treatment and were lower, at 41 percent in the M14 treatment. If there is no money-for-good exchange in the decentralized market, then there is no reason to use the centralized market to re-balance one’s money holdings.

Evidence for the use of the centralized market to re-balance money holdings in the M6 and M16 sessions is provided in Figures 2 and 3, respectively. In these figures, we plot the change in each individual subjects’ money holdings at the end of each decentralized market $\Delta_{DMm}$ (horizontal axis) against the change in the same individual’s money holdings a the end of the subsequent centralized market round $\Delta_{CMm}$ (vertical axis). If individuals are using the centralized market to re-balance their money holdings as predicted in the monetary equilibrium, then we should see a negative relationship between $\Delta_{DMm}$ and $\Delta_{CMm}$, and indeed, that is precisely what we see. The fitted (red solid) line shown in the graph for each session has a slope coefficient that is negative and significantly different from zero ($p \leq .05$ for all sessions). While the equilibrium prediction would call for perfect re-balancing, (i.e., $\Delta_{DMm} = -\Delta_{CMm}$) as indicated by the dashed 45 degree line in each graph, the experimental data suggest that rebalancing was less than perfect in that $|\Delta_{DMm}| > |\Delta_{CMm}|$. This suggests some possible precautionary hoarding of money relative to monetary equilibrium predictions, but it may also simply reflect out-of-equilibrium behavior in both the decentralized and centralized markets, i.e., the decentralized and centralized prices are not equilibrium prices, acceptance rates of offers are not 100 percent.
Finally, we consider behavior in the centralized meeting of the NM treatments. We have the following main result:

**Finding 7** In the no money treatments, contributions to the public good in the centralized meeting are close to zero irrespective of the population size.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Session No., Treatment} & \text{Average Public Good Contribution} \\ 
& 1^{\text{st}} \text{ half} & 2^{\text{nd}} \text{ half} & \text{All Periods} \\ 
\hline
9, NM6 & 0.06 & 0.03 & 0.05 \\ 
10, NM6 & 0.20 & 0.04 & 0.12 \\ 
11, NM6 & 0.04 & 0.00 & 0.02 \\ 
12, NM6 & 0.00 & 0.00 & 0.00 \\ 
\text{Avg. 9-12} & 0.08 & 0.02 & 0.05 \\ 
\hline
13, NM14 & 0.02 & 0.01 & 0.02 \\ 
14, NM14, & 0.02 & 0.01 & 0.02 \\ 
15, NM14, & 0.01 & 0.00 & 0.01 \\ 
16, NM14, & 0.04 & 0.02 & 0.03 \\ 
\text{Avg. 13-16} & 0.02 & 0.01 & 0.02 \\ 
\hline
\end{array}
\]

Table 7: Average Public Good Contributions in the Centralized Round of the No Money Treatment Sessions

Support for Finding 6 is found in Table 7 which reports the mean contributions to the public good by all 6 or 14 subjects over the first, second and over all periods of each of the 8 No Money Sessions. We observe that, despite the possibility of using contributions to the public good in the centralized meeting of the no money treatment as a means of signaling cooperative intent, there is little evidence to suggest that this mechanism was used by most subjects in any of our NM sessions. Contributions to the public good started off quite low, averaging just .08 (.02) units in the first half of the M6 (M14) sessions respectively and only declined further with experience. A Wilcoxon Mann-Whitney test reveals that there is no difference in the centralized public good contributions between the NM6 and the NM14 treatments using the four session level averages over all periods as reported in Table 7 \((p = .55)\). We conclude from this evidence and well as the low offer amounts in the NM treatment that the first best equilibrium is not attained in our NM treatment despite the theoretical possibility of sustaining such an equilibrium as a sequential Nash equilibrium by means of the social norm.

7 Conclusions and Suggestions for Further Research

Our experimental findings indicate 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). To the contrary, our main finding is that the efficiency of allocations is significantly higher in environments with money than in environments without money suggesting that money plays an important role as an efficiency enhancing coordination device even though it does not expand the Pareto frontier in the environments that we consider. 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 is thus deserving of further investigation.

Our findings reveal that periodic access to centralized meetings does not suffice to achieve good allocations. However, in our framework, subjects could only communicate via their actions. A further possibility to explore would be to endow subjects with a more effective means of communication, for example pre-play communication. This is a natural further extension especially given that field trading institutions develop over long periods of time, presumably becoming more efficient over time.

Finally, we note that the framework we have implemented experimentally can be used to empirically assess the effects of monetary policy. In particular, in future work we hope to conduct further sessions of our money treatment where the money supply is allowed to grow or contract at a constant rate. This could 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 that can be tested by comparison with other money growth rates, $\mu$. 

23
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 \(\varphi : A \rightarrow A\) be an exhaustive bilateral matching rule, so that no agent remains unmatched.\(^\dagger\)

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 \(X_t, Y_t\) and \(m^i_{t+1}\) consumption of the general good, production of the general good and savings, respectively.

Then

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

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

subject to the budget constraints associated with the centralized market

\[
X^b_t = Y^b_t + \phi_i(m^i_t - d_t(m^j_t, m^i_t) - m^i_{t+1})
\]

\[
X^s_t = Y^s_t + \phi_i(m_t^i + d_t(m^j_t, m^i_t) - m^i_{t+1})
\]

\[
X^b_t, X^s_t, Y^b_t, Y^s_t, m^i_{t+1} \geq 0.
\]

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:

\(^\dagger\)An exhaustive bilateral matching rule is simply a function \(\varphi : A \rightarrow A\) such that \(\varphi(\varphi(a)) = a\) and \(\varphi(a) \neq a\), for all \(a \in A\). See also Aliprantis et al. [1].
\[ V_t(m^i_t) = \left\{ \frac{1}{2} \sum_{j \neq i} \left[ u(q_t(m^i_t, m^j_t) - \phi_t d_t(m^i_t, m^j_t) \right] \Pr (\varphi(i) = j) \right. \]
\[ + \frac{1}{2} \sum_{j \neq i} \left[ -c(q_t(m^j_t, m^i_t)) + \phi_t d_t(m^i_t, m^j_t) \right] \Pr (\varphi(i) = j) \left. \right\} + \phi_t m^i_t \]
\[ + \max_{m^i_{t+1}} \left\{ -\phi_t m^i_{t+1} + \beta V_{t+1}(m^i_{t+1}) \right\} . \]

We are now ready to determine the terms of trade in the decentralized market, which will allow to simplify further the expression for \( V_t(m^i_t) \). 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.\(^{16}\)

Thus, given the linearity, the terms of trade \((q_t, d_t)\) must solve the following constrained optimization problem

\[ \max_{q_t, d_t} \left[ u(q_t) - \phi_t d_t \right] \quad \text{s.t.} \quad d_t \leq m_t, \; q_t \geq 0 \]

The solution to this optimization problem is given by

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

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

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 \( c^{-1}(\phi_t m_t) \) of the special good.

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

\[ V_t(m^i_t) = \frac{1}{2} \left[ u(q_t(m^i_t) - \phi_t d_t(m^i_t)) \right] \]
\[ + \phi_t m^i_t + \max_{m^i_{t+1}} \left\{ -\phi_t m^i_{t+1} + \beta V_{t+1}(m^i_{t+1}) \right\} . \]

By repeated substitution, we obtain that the savings’ choice of \( m^i_{t+1} \) solves a sequence of simple static optimization problems:

\[ \max_{m^i_{t+1}} \left\{ -(\phi_t - \beta \phi_{t+1}) m^i_{t+1} + \beta \frac{1}{2} \left[ u(q_{t+1}(m^i_{t+1}) - \phi_{t+1} d_{t+1}(m^i_{t+1})) \right] \right\} . \]

\(^{16}\)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
\[ \beta \frac{1}{2} \left[ u(q_{t+1}(m_{t+1}^j) - \phi_{t+1}d_{t+1}(m_{t+1}^j)) \right] \] with the cost of holding money \(-(\phi_t - \beta \phi_{t+1})m_{t+1}^j \) 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
\[
\frac{u'(q_t+1)}{c'(q_t+1)} = 1 + \frac{c(q_t)}{c(q_{t+1})} - \beta \frac{\beta}{2}
\]

Furthermore, the steady state (or stationary equilibrium) is unique, and the steady state condition is given by
\[
\frac{u'(\bar{q})}{c'(\bar{q})} = 1 + \frac{1 - \beta}{\frac{\beta}{2}}.
\]

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 \( \phi = \frac{c(\bar{q})}{M} \).

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

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

\[-3.9298 \leq 0\]

II. \(2N = 14\)
Condition 1 simplifies to

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

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

\[-6 + 5 \frac{1}{2} 7.6214 \geq 1.798 \frac{1}{2} 7 \ln 7
\]

\[
13.053 \geq 12.246
\]
Condition 2 simplifies to

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

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

\[-6 + 14.69 - 6.2862 \leq 11.843 - 5.762
\]

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

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.