Gift Exchange versus Monetary Exchange: Theory and Evidence

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Abstract

We study the Lagos and Wright (2005) model of monetary exchange in the laboratory. With a finite population of sufficiently patient agents, this model has a unique monetary equilibrium and a continuum of non-monetary gift exchange equilibria, some of which Pareto dominate the monetary equilibrium. We find that subjects avoid the gift-exchange equilibria in favor of the monetary equilibrium. We also study versions of the model without money where all equilibria involve non-monetary gift-exchange. We find that welfare is higher in the model with money than without money, suggesting that money plays a role as an efficiency enhancing coordination device.

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Many pre-modern societies, lacking the use of money as a medium exchange, developed sophisticated systems of "gift-exchange".[1] In these gift-exchange systems, goods were given to others without any explicit promise of re-payment. However, all involved understood the social norm that gift receivers would eventually re-pay gift givers in some (possibly indirect) manner. By contrast, modern societies engage in a form of "monetary exchange," that makes use of an intrinsically worthless fiat money as the unique medium of exchange. The transition that has occurred from a regime of gift-exchange to one of monetary exchange presents us with an interesting puzzle: theoretically, a gift exchange regime can be Pareto superior to a monetary exchange regime for a variety of different reasons including storage constraints, storage costs (e.g., inflation), and, in the framework we study, time delays between accepting money for the production of goods and services and using that money for consumption purposes.[2] The puzzle then, is why modern societies have coordinated on less efficient monetary exchange regimes. In this paper we offer a potential resolution to this puzzle using both theory and laboratory experiments.

The micro-founded search theoretic environment we study has a multiplicity of pure gift-exchange equilibrium outcomes including one that is first best. If intrinsically worthless fiat money is introduced into this same environment, there exists a unique monetary equilibrium involving use of the fiat money object that coexists with the set of pure gift-exchange equilibria. However, due to a time delay friction, the monetary equilibrium is always less efficient than a subset of the pure gift–exchange equilibria including the first best equilibrium. We first characterize the set of such gift exchange equilibria. As there is a multiplicity of such equilibria, we then put human subjects into two versions of this environment –one with and one without fiat money. We incentivize subjects to maximize their payoffs from exchange decisions and we observe the choices they make. We find that while the monetary equilibrium may be theoretically less efficient than some pure gift exchange equilibria including the first best equilibrium allocation, the introduction of the fiat money object nevertheless helps subjects to coordinate on an equilibrium – the monetary equilibrium – that involves a higher level of welfare than the less efficient (non-first-best) gift-exchange equilibrium that subjects coordinate on in the environment where there is no fiat money object. That is, we find that while money is not theoretically essential in any of the environments we study in the sense that it does not expand the Pareto frontier, *behaviorally speaking*, money is essential to improving welfare relative to a non-monetary, pure gift–exchange regime. This observation may help us to understand the puzzle of why monetary exchange systems have largely replaced gift–exchange systems even though the latter may be Pareto superior.

The first economic environment we study is Lagos and Wright's (2005) model, a standard, workhorse model in the large and growing money-search literature.[3] By contrast with an earlier generation of search-money models, (e.g. Kiyotaki and Wright (1989)), the Lagos and Wright 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 meeting to a decentralized meeting and through the assumption of quasi-linear preferences–

[1] See, for example, Malinowski (1926), Maus (1967) or Greif (2006).

[2] Milton Friedman (1969) for example, recognized the inefficiencies associated with monetary exchange in proposing that central banks target a rate of deflation equal to real rate of return on safe (government) assets so as to compensate money holders for losses due to inflation.

[3] See, Williamson and Wright (2011) for a survey.

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 version of this model that we study there exists a 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. As there is a time delay between production and consumption (discounting) and there are a finite number of agents, the Lagos-Wright environment we study has many other non-monetary "gift–exchange" equilibria that are sustained by use of information on allocations in the decentralized meeting alone together with a contagious strategy wherein any deviations from the gift exchange equilibrium allocation are punished. Some of these equilibria are more efficient than the monetary equilibrium, including the first best. There further exists a non-monetary, autarkic (or no trade) equilibrium.

The second economic environment we study is a finite population version of Aliprantis, Camera and Puzzello, "ACP," (2007ab), which consists of a modified version of the Lagos and Wright environment where there is no money. This environment again admits a multiplicity of non-monetary gift-exchange equilibria that are sustained by use of information on allocations in the decentralized meeting alone or conditional on information provided by the centralized meeting together with a contagious, punishment strategy. Among the gift exchange equilibria, many are again Pareto superior to the monetary equilibrium (of the economy with money) and among these is again the first best. Indeed the addition of money to the ACP environment would not result in any change to the set of equilibria since there exists a gift-exchange equilibrium (not involving the use of money) that implements the same equilibrium allocation as in the monetary equilibrium resulting in the same welfare. Thus in the ACP environment, money can be regarded as inessential and indeed, no individual is endowed with any money.

Our experiment is divided up into three parts. In the first, baseline experiment we implement the Lagos-Wright model of monetary exchange in the laboratory exploring whether agents who are endowed with worthless token objects learn to coordinate on the monetary equilibrium of that model or whether a non-monetary gift exchange equilibrium where tokens are not used is selected instead. We further consider whether the size of the economy–the number of agents–matters. We speculate that non-monetary gift exchange might be easier to coordinate on and sustain via the contagious strategy in smaller economies involving just 6 agents as opposed to larger economies of 14 agents. In the second part of our experiment we completely remove money (tokens) from the economy but retain the two stage sequential move structure of the Lagos and Wright environment as in ACP (2007ab), with the aim of understanding whether there is any difference in exchange behavior and welfare in this starker, purely non-monetary environment. We again consider populations of size 6 or 14 to understand whether the size of the economy matters for coordination on gift-exchange equilibria. Finally, the third part of our experiment fixes the population size at 14 and investigates the robustness of our findings for the money and no money environments when multiple rounds of bargaining are possible and there is a different centralized meeting mechanism than the one used in the first and second parts of our study; importantly, the centralized meeting mechanism in this third part of our study is common between the money and no money treatments. In addition, in this third part of our experiment we explore whether behavior in the no money treatment is affected by eliminating the centralized meeting mechanism altogether, as there exist decentralized social norm gift exchange equilibria that do not condition on the information provided by the centralized meeting.

There are good reasons to conduct an experimental analysis of the search-money and gift-exchange theories. First, it is useful to discipline theory with data so as to assess the reasonableness of the theory. Second, the control of the laboratory allows us to implement the highly structured dynamic environment of these theories and to measure and identify behavior in ways that would not be possible using non-experimental (field) data. In particular, we have precise measures of the actions chosen and of the state variables relevant to decision making and our control over the environment allows us to formulate crisp theoretical predictions that can be tested using our experimental data. Third, it is useful to know whether the theoretical predictions are robust to possible heterogeneity among the human subjects, for example in risk attitudes toward uncertain monetary payoffs. Finally, and perhaps most importantly, as noted earlier, the theoretical environments we study possess multiple equilibria. These include a number of gift-exchange equilibria including the first best equilibrium, as well as a monetary equilibrium where agents use a fiat money object in exchange, and a no-trade autarkic equilibrium. Equilibrium selection is ultimately an empirical question that experimental evidence can be used to address. Indeed, the question of equilibrium selection is the main focus of our experimental study.

Our experiment has yielded several important findings. A main finding is that subjects in the baseline Lagos-Wright model of monetary exchange do learn to adopt a worthless fiat object as a medium of exchange. Subjects are not able to achieve 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 and irrespective of the centralized meeting mechanism. 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 meeting 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, subjects coordinate on inefficient gift-exchange equilibria involving the exchange of small quantities which is closer to the autarkic equilibrium than to the first best. These results are largely unaffected by the number of rounds of bargaining allowed in the decentralized meeting, by the type of the centralized meeting mechanism, or in the ACP environment whether there even exists a centralized meeting opportunity. Most importantly, we find clear evidence that welfare is significantly greater in the Lagos Wright environment with money than in environments without money. Thus our main conclusion is that while money is not theoretically essential in any of the environments we study, outcomes involving monetary exchange nevertheless lead to the highest observed welfare.

The rest of the paper is organized as follows. The next section discusses related literature. Section II presents a simplified version of the Lagos and Wright (2005) model that is used in the experiment. In that environment we characterize both monetary equilibrium as well as non-monetary, pure gift exchange equilibrium outcomes including the first best that are possible in the Lagos-Wright environment with a finite number of agents. Section III reports on our parameterization of the Lagos-Wright model, our experimental design and predictions and our main experimental findings for that environment. Section IV considers the robustness of our experimental findings for the Lagos-Wright model with money to a version of the Lagos-Wright model without money as studied by ACP (2007ab). In that non-monetary environment we again demonstrate how the first best and other gift-exchange outcomes can be supported as sequential non-monetary equilibria via a society-wide social norm construction. We then present our experimental design and findings for this non-monetary treatment of our experiment. Section IV also reports on a third set of experimental sessions where we modify the bargaining protocol of the decentralized stage of our baseline Lagos-Wright environment and we also make the centralized meeting stage of the environment similar across the money and no money treatments. Finally, section V concludes with some possibilities for future research.

I. Related Literature

There already exists an experimental literature examining conditions under which money is used as a medium of exchange (see Duffy (2012) 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, Noussair and Tucker (2003) and Deck, McCabe, and Porter (2006) study the use of fiat 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 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 (2007ab) model there is no money at all.

The non-monetary gift-exchange equilibrium we study relies on the theory of community enforcement under random anonymous matching as first developed by Kandori (1992) and extended by Ellison (1994). Araujo (2004) and ACP (2007ab) adapted this theory to the environments that we study in this paper. Prior experimental tests of the Kandori community enforcement conjecture have involved a different environment (i.e., the Prisoner's Dilemma game as originally studied by Kandori) which does not involve any centralized meetings (see, e.g., Duffy and Ochs (2009)).

The closest paper to this study is by Camera and Casari (2013), 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 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 meeting 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. All these features are desirable since they allow us to assess the effect of money on *both* the extensive and intensive margin (i.e., on the number of trades as well as on the quantity exchanged within a trade). 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.

II. The Lagos-Wright Environment

We study a simplified version of the Lagos and Wright (2005) model involving a finite population of agents. 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 into two subperiods that differ in terms of the matching technology, economic activities and payoff functions. Indeed, two types of meetings alternate over time: a decentralized meeting and a frictionless centralized meeting.

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 formalizes a double coincidence problem in that only one agent in a pair desires the good of the other agent. 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 meeting (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

$$\mathcal{U}(x, y, X, Y) = u(x) - c(y) + X - Y,$$

where u, and c are twice continuously differentiable with $u' > 0, c' > 0$, $u'' < 0, c'' \geq 0$. There exists a $q^* \in (0, \infty)$ such that $u'(q^*) = c'(q^*)$, i.e., q^* is efficient as it 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, economy-wide money stock is fixed at M. The environment lacks commitment and formal enforcement.[4]

Since our population is finite, in addition to the monetary equilibrium, there exist multiple non-monetary equilibria.[5] We start by providing a characterization of the monetary equilibrium.

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

[5]This environment is not immune to the construction of folk type theorems and informal enforcement

A. Monetary Equilibrium

In the Lagos and Wright model there is an equilibrium where money has no value. In this section we solve for the monetary equilibrium, where money has value using dynamic programming tools. That is, "reputation" effects (repeated game dynamics) are irrelevant for this analysis: the only feasible trades involve exchanging fiat money against the special good in the first subperiod, and fiat money against the general good in the second subperiod.[6] Let $\left(m^1, m^2, ..., m^{2N}\right)$ denote the initial distribution of money holdings, where m^i denotes the money holdings of agent i. We denote by m_t^i the money holdings of agent i at the beginning of period t.

Since the total money stock is fixed at M, we clearly have $\sum_{i=1}^{2N} m_t^i = M$ for all periods $t = 1, 2, ...$. Let ϕ_t denote the price of money in terms of the general good in the centralized meeting. As in Lagos and Wright (2005), the terms of trade in decentralized meetings are determined by generalized Nash bargaining. Under the assumption of a take-it-or-leave-it bargaining protocol in the decentralized meeting (which we use in the experiment and where the consumer has all the bargaining power),[7] it is possible to show that the steady state is unique (see Appendix A for details), and the steady state condition is given by

$$\frac{u'(\widetilde{q})}{c'(\widetilde{q})} = 1 + \frac{1-\beta}{\frac{\beta}{2}},$$

where $\widetilde{q}$ denotes the amount of the special good exchanged in each bilateral match. Each individual demand for money is $M^D = \frac{c(\widetilde{q})}{\phi}$. The aggregate demand is then $2N\frac{c(\widetilde{q})}{\phi}$, and since supply is equal to M, the equilibrium price of money in the steady state is $\phi = \frac{c(\widetilde{q})}{\frac{M}{2N}}$. Also, note that the distribution of money at the beginning of the decentralized meeting is degenerate at $\frac{M}{2N}$. That is, agents can use the centralized meeting to perfectly rebalance their money holdings because of the quasilinearity of preferences. It is easy to see that $\widetilde{q} < q^*$ since $\beta < 1$, and that $\widetilde{q} \to q^*$ as $\beta \to 1$; thus the monetary equilibrium does not achieve the first best. This inefficiency is due to the discount factor $\beta < 1$. The intuition is straightforward: when a producer gets money for production of the special good he cannot turn it into immediate consumption. Money may be turned into *future* consumption, but since $\beta < 1$, producers are only willing to produce $\widetilde{q} < q^*$ units of the special good. The steady state lifetime expected payoff associated with the monetary equilibrium is given by $V = \frac{1}{1-\beta}\left\{\frac{1}{2}\left[u(\widetilde{q}) - c(\widetilde{q})\right]\right\}$.

B. Social Norms in the Lagos-Wright Environment

In addition to the monetary equilibrium and the autarkic equilibrium (producing zero regardless of the history of play is always an equilibrium), there may exist non-monetary,

schemes (see Kandori (1992), Ellison (1994), Aliprantis, Camera, and Puzzello (2007ab) and Araujo et al. (2012)).

[6] Recall that both the special good and general good are nonstorable.

[7] The quantity traded in bilateral meetings is increasing in the bargaining power of the consumer. Thus, the take-it-or-leave-it bargaining protocol achieves the highest efficiency in the class of bargaining protocols considered in Lagos and Wright (2005).

pure "gift-exchange" equilibria that sustain positive amounts of production and consumption (including the first-best) as sequential Nash equilibria through the use of a contagious strategy (see Kandori (1992), Ellison (1993) and Araujo (2004)). In such equilibria, consumers propose terms of trade so that we can identify their action set with $[0,\overline{q}] \times [0,M]$. As for producers, their action 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 centralized meeting (CM). Participate only in the decentralized meeting (DM). Let $0 < q \leq q^*$*. 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."*

Clearly, this social norm does not involve the use of money.[8] An adaptation of Araujo's (2004) argument to our framework shows that the social norm described above can be supported as a sequential equilibrium if agents are sufficiently patient.[9] The proof is straightforward, and thus here we just report two conditions guaranteeing that this social norm is a sequential equilibrium in our environment if agents are sufficiently patient. 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, condition (1) ensures that, if no deviation from the social norm has been observed, then producers are better off following the social norm and accepting rather than rejecting a consumer's proposal, as rejection would initiate a contagion process leading to the autarkic outcome:

$$-q + \frac{\beta}{1-\beta}\frac{1}{2}\left[u(q) - c(q)\right] \geq \mathbf{e}_1 \left[\mathbf{I} - \beta \mathbf{A}\right]^{-1} \boldsymbol{\pi}\frac{1}{2}u(q) - \frac{1}{2}u(q). \tag{1}$$

Condition (2) ensures that once a deviation has been initiated, agents have an incentive to continue to spread the contagion by refusing to produce rather than attempting to slow the contagion down by accepting a consumer's proposal:

$$\begin{array}{l} -q + \mathbf{e}_2 \left[I - \beta \mathbf{A}\right]^{-1} \boldsymbol{\pi}\frac{1}{2}u(q) - \left(\frac{2N-2}{2N-1}\right)\frac{1}{2}u(q) \leq \\ \mathbf{e}_3 \left[\mathbf{I} - \beta \mathbf{A}\right]^{-1} \boldsymbol{\pi}\frac{1}{2}u(q) - \left(\frac{2N-3}{2N-1}\right)\frac{1}{2}u(q), \end{array} \tag{2}$$

where

$\mathbf{e}_i$ is the $2N$-dimensional *ith* fundamental vector,

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

D_t = number of defectors at time t,

[8] Note that we do not discuss centralized social norms in the Lagos and Wright environment because in the first set of experiments it was not possible to use the CM for signaling purposes, given the information available to subjects and given that in order to have prices, subjects had to use money.

[9] The social norm considered by Araujo (2004) is the same as ours, except that we do not allow double coincidence meetings.

$$\boldsymbol{\pi} = \frac{1}{2N-1}\begin{pmatrix} 2N-1 \\ 2N-2 \\ 2N-3 \\ \vdots \\ 2 \\ 1 \\ 0 \end{pmatrix} \text{ where } \pi_i = \Pr\left(\text{a defector meets a cooperator} \mid D_t = i\right).$$

Note that if agents are sufficiently patient, even the first best can be supported as a sequential equilibrium. The steady state lifetime expected payoff associated with the first-best allocation is given by $V^* = \frac{1}{1-\beta}\left\{\frac{1}{2}\left[u(q^*) - c(q^*)\right]\right\}$. We will use this expression as the benchmark for welfare comparisons in our experiment.

III. An Experimental Test of the Lagos-Wright Model

We now describe our parameterization of the Lagos-Wright environment, our equilibrium benchmarks for that parameterization and how we implemented the Lagos-Wright environment in the laboratory. We then report on our experimental findings for this environment.

A. Parameterization and Equilibrium Benchmarks

We considered two populations of size $2N = 6$ or $2N = 14$ as we were interested in the role that group size might play on the emergence and sustainability of non-monetary social norm equilibria. As for the other parameters of the model, we set $A = 7$, $C = 1$, and $\beta = \frac{5}{6}$. The initial endowment of money per capita is given by $M/2N = 8$. Given these parameter choices we can characterize the monetary and non-monetary equilibrium outcomes for the Lagos-Wright environment as described in the previous section.

We start by discussing the *monetary equilibrium*. From the discussion in section II, it follows that in the decentralized meeting, the first best quantity implied by our parameterization of the model is $q^* = 6$, while the equilibrium quantity associated with the monetary equilibrium is $\widetilde{q} = 4$. A natural upper bound for the special good in the DM is $\overline{q} = 22$[10]. We also chose an upper bound of $\overline{Y} = 22$ (which was never binding) for the CM. Regarding prices, the equilibrium price of the special good in the decentralized meeting is given by $\frac{M/2N}{\widetilde{q}} = \frac{8}{4} = 2$. In the CM, the equilibrium price of money in terms of the general good is $\phi = \frac{c(\widetilde{q})}{M/2N} = \frac{1}{2}$ and so the equilibrium price of the general good is the reciprocal $P = 2$. Finally, for the purpose of calculating welfare, we note that the period monetary equilibrium payoff per pair is $v = \{7 \cdot \log 5 - 4\} = 7.26$ and the period first best payoff per pair is $v^* = \{7 \cdot \log 7 - 6\} = 7.62$. Thus the monetary equilibrium is predicted to achieve 95.3 percent of the welfare under the first best equilibrium.

[10] Note that the quantity q satisfying $u(\overline{q}) = c(\overline{q})$ is such that $\overline{q} \in [21, 22]$. For simplicity, we just chose $\overline{q} = 22$.

Next we consider *decentralized social norm equilibria*. In particular we consider the lowest value of the discount factor, β, for which the first best can be supported under conditions (1) and (2) of section II.B.

Doing so yields the minimal values $\underline{\beta}_6^{DM} = 0.7702$ and $\underline{\beta}_{14}^{DM} = 0.8256$, where the subscript denotes the population size and the superscript DM refers to our focus on the decentralized, non-monetary social norm. Notice that it is easier to sustain the first best under the smaller population of size 6 than under the larger population of size 14, and indeed, this was the reason we chose to consider variations in the group size. Note further that our choice for $\beta = \frac{5}{6}$ exceeds both of these minimal threshold discount factors, so that the first best can be supported as a sequential Nash equilibrium under the *decentralized gift-giving social norm*.[11]

In addition to the first best, lower but positive production and consumption levels in the decentralized meeting can also be supported as sequential, non-monetary social norm equilibria under our parameterization of the model. Specifically, equations (1)-(2), can be used to find the range of quantities that can be supported as sequential equilibria under the decentralized social norms given our choice of $\beta = 5/6$ and our other model parameters. Table 1 summarizes our equilibrium predictions for q under various types of equilibria in the Lagos-Wright environment that we implemented in the laboratory.

Group Size	Decentralized Social Norm	Monetary Equilibrium	Autarkic Equilibrium
$N = 6$	$0.2 \leq q \leq 6$	$q = 4$	$q = 0$
$N = 14$	$0.5 \leq q \leq 6$	$q = 4$	$q = 0$

Table 1: Equilibrium predictions regarding q

B. Experimental Design

The experiment was computerized using the z-Tree software (Fischbacher (2007)). Each session began with the 6 or 14 subjects being given written instructions on the game they were about to play. The subjects were all undergraduate students at the University of Pittsburgh with no prior experience with the game described here. The written instructions were read aloud in an effort to make them common knowledge.[12] 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 all subjects had correctly answered all quiz questions, 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 meeting round and a centralized meeting 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

[11] More detailed computations on the decentralized social norm conditions are provided in Appendix A.

[12] Copies of these instructions are available at: http://www.pitt.edu/~jduffy/ExchangeExp/

stage game with probability β 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 $\beta = 5/6$.[13]

At the start of each and every new indefinite sequence, i.e., prior to the first decentralized meeting round, each subject in our Lagos-Wright economy was endowed with $M/2N$ "tokens".[14] (Later in the paper we will describe another experimental design in which there were no tokens, and we will refer to those sessions as the non-monetary treatment sessions). In these sessions with tokens, subjects were informed about the total number of tokens, M. They were also informed that this total was fixed and that they would not get any further endowment of tokens for the duration of that sequence. Subjects were further instructed that if a sequence ended their token balances would be set to zero. However, if a sequence continued with a new period, their token balance as of the end of the last period would carry over to the new period of the sequence.

Within a period (stage game), the decentralized meeting 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 meeting 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 payoff 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 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. Importantly, subjects were specifically instructed that "Tokens have no value in terms of points," that is, tokens had *no redemption value*. Like fiat money, tokens were intrinsically worthless with regard to the points that subjects accrued over the course of a session (from consumption and less production) and it was these point totals that were used to determine subjects' earnings from the experiment.

Consumers moved first and were asked to form a "proposal" as to how much of the decentralized good they wanted their randomly matched producer to produce for them and how many tokens, if any, the consumer was willing to offer the producer for the quantity requested. Consumers were informed of both their own and their matched producer's current token balances prior to formulating their proposal. Consumers were restricted to requesting quantities of the decentralized good, q, in the interval $[0, \overline{q}]$ and could offer their matched

[13] 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.

[14] While we will refer to experimental sessions involving tokens as the "money" treatment sessions, we were careful to avoid all use of the term "money" in the experimental instructions or on computer screens.

producer d units of their current period token balance 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. Thus, each consumer formulated a proposal, (q, d) which was then anonymously transmitted to their matched producer.

Producers moved second and were first informed of their matched consumer's proposal. Producers were further informed about the consumer's benefit from receiving the proposed quantity q, $u(q)$, and of their own cost from producing quantity q, $c(q)$. Producers were also informed of both the consumer's and their own current available token balances. Producers then had to decide whether to accept or reject the consumer's proposal. If the producer 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. The proposed quantity of tokens, d, if positive, was 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 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 were updated on any changes to their cumulative point totals, and of any changes to their token balances. After this feedback was communicated, the decentralized round was over and the centralized meeting round began.

Within a period (stage game), the second, centralized meeting round brought together all $2N$ participants to participate in the meeting for the homogeneous and perishable "good X". At the start of the centralized round, subjects were asked whether they wanted to participate in that meeting 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 $Y \in [0, \overline{Y}]$ 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 $p_b X$ did not exceed their available token balance; that is, budget constraints were enforced.

The meeting clearing price was determined by a call meeting 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 meeting price, P. All sellers with prices at or below the meeting price were able to sell their units (subject to available demand) while all buyers with prices at or above the meeting price were able to buy their units (subject to available supply).[15] All transactions were carried out at the meeting price P.

[15] Extramarginal 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

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 meeting round and had the same conversion rate, i.e., 1 point = $0.20.

Following the completion of the centralized meeting round, 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 meeting 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 re-initialized 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.

C. Experimental Results

For this first part of our experiment, we report on results from 8 experimental sessions involving the Lagos-Wright model. The two main treatments are Lagos-Wright money model with 6 or with 14 subjects, treatments M6 and M14, respectively. Further details of our 8 sessions are given in Table 2.

Session No., Treatment	No. of Subjects	No. of Sequences	No. of Periods	Mean HL Score	St. Dev. HL Score
1, M6	6	5	30	4.8	2.8
2, M6	6	6	29	7.2	0.8
3, M6	6	6	30	5.0	0.9
4, M6	6	4	33	5.3	2.3
5, M14	14	6	23	5.4	2.2
6, M14	14	6	32	6.2	1.6
7, M14	14	6	34	6.4	1.5
8, M14	14	5	35	5.9	1.8
Averages		5.5	30.8	5.8	1.7

Table 2: Characteristics of Experimental Sessions in the Lagos-Wright Money (M) Environment

Each session consisted of two parts. In the first part a group of 6 or 14 subjects participated in several sequences (supergames) of the Lagos-Wright environment. As Table 2 indicates, subjects participated on average in 5.5 supergames over which they played on

good X that they could sell (buy) so as to satisfy the market clearing.

average a total of 30.8 periods, with each period consisting of a decentralized meeting (DM) and a centralized meeting (CM).

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), designed to elicit their risk attitudes in which they could earn additional amounts of money. The result of this second part of the experiment which lasted about 15 minutes is a Holt–Laury score for each subject ranging from 0 to 10 which provides a crude measure of their risk attitude toward uncertain monetary payments. In particular, a score of 4 is consistent with risk neutral expected utility maximizing behavior whereas a score of 0 indicates extreme risk loving behavior while a score of 10 indicates extreme risk aversion (see Holt and Laury (2002) for details). As Table 2 reveals, the average Holt-Laury score in this second part of our experiment was 5.8 with a standard deviation of 1.7 indicating relatively moderate levels of homegrown risk aversion among the participants in our experiment.

The total length of each session averaged 2.25 hours. Total earnings from both parts of the session in this first part of our experiment averaged $23.96 per subject.

Our experimental results are summarized as a number of findings that address the theoretical predictions for the model as given in sections II and III.A.

Finding 1 *Offer acceptance rates are positive, but less than 100%. More than 95% of accepted proposals involved positive amounts of tokens.*

Support for Finding 1 can be found in Table 3 which reports the 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. Table 3 also reports the frequency of monetary offers as well as the acceptance rates of monetary offers also over the first half, the second half, and over all periods of each M treatment session.

Session No., Treatment	Offer Accept Rate		% Monetary Offers		Money Offer Accept Rate	
	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All
1, M6	53.3, 35.6	44.4	93.3, 86.7	90.0	52.4, 38.5	45.7
2, M6	50.0, 57.8	54.0	92.9, 95.6	94.3	53.9, 60.5	57.3
3, M6	42.2, 48.9	45.6	97.8, 100	98.9	43.2, 48.9	46.1
4, M6	47.9, 70.6	59.6	93.8, 100	97.0	46.7, 70.6	59.4
Avg. 1-4	48.3, 53.8	51.1	94.4, 95.7	95.1	48.9, 55.1	52.3
5, M14	32.5, 42.9	37.9	100.0, 94.0	96.9	32.5, 44.3	38.5
6, M14	35.7, 32.4	34.0	99.0, 94.3	96.6	36.1, 32.3	34.2
7, M14	46.2, 46.2	46.2	98.3, 93.3	95.8	46.2, 46.0	46.1
8, M14	42.9, 42.9	42.9	99.2, 91.3	95.1	42.4, 41.7	42.1
Avg. 5-8	40.2, 41.2	40.7	99.0, 93.1	96.0	40.2, 41.1	40.6

Table 3: Offer Acceptance Rates, % Monetary Offers, and Acceptance Rates of Monetary Offers by Producers in the Decentralized Meetings of Each Session

As Table 3 reveals, overall acceptance rates averaged between 41 and 51% across our two treatments and appeared not to increase or decrease very much from the first to the second half of each session. Using a two-sided, non-parametric, Wilcoxon Mann-Whitney test on the four session-level offer acceptance frequencies over all periods as reported in the first three columns of Table 3, we can reject the null hypothesis of no difference in acceptance frequencies between the M6 and M14 treatments in favor of the alternative that offer acceptance frequencies were higher over all rounds in the M6 treatment as compared with the M14 treatment ($p = .083$). We note that the observed 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 3 reveals that accepted consumer offers were almost exclusively "monetary", that is, the offer included 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. Given the very high percentage of monetary offers, the acceptance rates of monetary offers differed very little from the acceptance rates of all consumer offers as revealed in the final columns of Table 3 for the two money treatments. The consumers' widespread use of tokens as part of their proposals provides strong evidence of coordination on the monetary as opposed to the decentralized social norm equilibria of the Lagos-Wright model.

Finding 2 *Proposals are less likely to be accepted as the quantity requested increases. Proposals are more likely to be accepted the higher the number of tokens or the better the terms of trade offered.*

Support for Finding 2 is found in Table 4 which reports results from a random effects probit regression analysis of producer's acceptance decisions in all decentralized rounds of all sessions.[16] The independent variables reported in the specifications of Table 4 consist of: M14, a dummy variables for the M14 treatment (M6 is the baseline); NewSeq, a dummy variable equal to 1 if it is the first period of a new indefinite sequence; Period, the period number; Grim is a dummy variable that is equal to 1 if, in the current sequence the producer has previously rejected a proposal or has experienced rejection of his/her proposal as a consumer, and is 0 otherwise; HLscore, the subject's Holt-Laury risk aversion score with a higher score indicating greater risk aversion toward uncertain monetary payments; q the proposed quantity; d, the number of tokens offered; d/q the ratio of d to q; m_p, the money balance the producer had at the time the proposal was made and m_c, the money balance the paired consumer had at the time the proposal was made. In support of Finding 2, the Probit regression results reveal that the amount of tokens offered (d) matters significantly for proposal acceptance decisions 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 in M specification 1 (column 2) with the terms of trade, d/q as in specification 2 (column 3) and we eliminate a few observations where $q = 0$, we obtain a significantly positive coefficient on the terms of trade variable, d/q.

Table 4 further reveals that offer acceptance probabilities are lower in the larger population size of 14 as indicated by the negative and significant coefficient on the M14 dummy variable; the latter finding was also observed in the offer acceptance frequencies reported in Table 3. We further observe that there is no "restart effect" in acceptance frequencies in the

[16] This random effects probit regression was estimated using the gllamm package for Stata 12 with robust standard errors clustered at both the individual and session level.

	Dependent Variable, Accept=1, Reject=0	
	M Sessions (1)	M Sessions (2)
Constant	1.678***	-0.215
	(0.386)	(0.298)
M14	-0.540***	-0.623***
	(0.133)	(0.153)
NewSeq	0.309	0.252
	(0.231)	(0.221)
Period	-0.043***	-0.059***
	(0.009)	(0.018)
Grim	-0.128	-0.052
	(0.148)	(0.175)
HLscore	-0.008	-0.003
	(0.028)	(0.021)
q	-0.509***	
	(0.055)	
d	0.289***	
	(0.046)	
d/q		1.462***
		(0.240)
m_p	-0.026**	-0.029*
	(0.012)	(0.017)
m_c	0.009	-0.037***
	(0.012)	(0.014)
No. obs.	1,213	1,184
Log Likl.	-730.4	-727.5

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 4: Probit Regression Analysis of Proposal Acceptance Decisions

first period of each new sequence as the NewSeq dummy variable not significantly different from zero. However, there is a decline in acceptance frequencies over time as indicated by the negative and significant coefficient on the Period variable. Finally, we note that the coefficient on the 'Grim' dummy variable is insignificantly different from zero which suggests that the grim trigger mechanism used to support non-monetary exchange under the social norm equilibrium does not seem to be operative in the Lagos-Wright environment. This last observation, along with Finding 2 provide further support for the conclusion that subjects coordinated on the monetary equilibrium of the Lagos-Wright model and not on the non-monetary, gift-exchange social norm equilibria that are also possible in this environment.

We note further that the Probit regressions in Table 4 indicate that proposals are significantly less likely to be accepted the higher is the producer's current money holdings m_p, and in 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 subjects' risk attitudes toward uncertain money amounts as measured by the HLscore variable do not seem to matter much for explaining proposal acceptance decisions.

We next consider the amount of the decentralized good and tokens that were offered and accepted in trade and how these relate to equilibrium predictions.

Finding 3 *Quantities exchanged in the decentralized meeting are below the first best equilibrium. Quantities (and prices) are closer to the monetary equilibrium.*

Session No.,	Average q		Average d		Average Price	
Treatment	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All
1, M6	5.05, 4.19	4.68	5.59, 5.63	5.61	1.18, 1.31	1.23
2, M6	4.62, 4.25	4.41	5.10, 5.80	5.48	1.12, 1.37	1.25
3, M6	5.05, 4.09	4.54	4.54, 6.90	5.81	0.92, 1.73	1.35
4, M6	3.32, 3.00	3.12	4.33, 5.61	5.14	1.52, 1.88	1.75
Avg. 1-4	4.49, 3.85	4.16	4.88, 5.97	5.50	1.19, 1.58	1.41
5, M14	3.64, 3.81	3.74	4.27, 6.03	5.29	1.15, 1.61	1.42
6, M14	4.49, 2.09	3.34	4.03, 4.54	4.28	0.96, 2.31	1.60
7, M14	4.00, 2.46	3.24	5.28, 5.46	5.36	1.40, 2.37	1.87
8, M14	4.48, 3.00	3.75	5.30, 5.87	5.58	1.33, 1.96	1.64
Avg. 5-8	4.19, 2.79	3.51	4.80, 5.47	5.16	1.23, 2.09	1.65

Table 5: Trade Average Offer Quantities and Prices, Each Session

Support for Finding 3 can be found in Table 5 which report mean amounts of the decentralized good and tokens that were exchanged (proposed *and* accepted) in both treatments. Table 5 clearly reveal that the mean exchanged quantities lie well below the efficient equilibrium prediction of $q^* = 6$ units. For the M6 treatment, the mean exchanged quantity in the decentralized meeting is 4.16 units in exchange for a mean of 5.50 tokens while in the M14 treatment the mean exchanged quantity is 3.51 units in exchange for 5.16 tokens. The evidence presented in Table 5 indicates that the mean exchanged quantity of the decentralized good traded is approximately equal to the monetary equilibrium prediction of $\widetilde{q} = 4$ units. On the other hand, the mean exchanged token quantities average only slightly more than 5, which is less than the monetary equilibrium prediction of $d = 8$. Consequently, decentralized meeting prices are less than, but not too far away from the monetary equilibrium prediction of $d/\widetilde{q} = 2$. We can further report using a Mann-Whitney test that there is no significant difference in mean traded quantities or tokens exchanged between the M6 and M14 treatments ($p = .31$ both tests). Indeed, the monetary equilibrium, (as distinct from the social norm equilibria) is not dependent on the number of agents in the economy. Further support for Finding 3 comes from Table 6 which reports a random effects generalized least squares regression analysis of accepted consumer proposals using data from all 8 sessions and explanatory variables described earlier in the regression analysis of producer acceptance

Dependent Variable:	Consumer Proposals d/q
Constant	0.388***
	(0.139)
M14	0.248***
	(0.088)
NewSeq	-0.108**
	(0.097)
Period	0.046***
	(0.006)
Grim	0.027
	(0.069)
HLscore	0.009
	(0.015)
m_c	0.009**
	(0.005)
m_p	0.019**
	(0.008)
No. obs.	512
R^2	.482

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 6: Random Effects, GLS Regression Analysis of Accepted Consumer Proposals

decisions reported in Table 4.[17] In Table 6 however, the dependent variable is the terms of trade that were offered and accepted, d/q.

The regression results reported in Table 6 reveals that the terms of trade on accepted offers are found to be significantly higher in the M14 treatment relative to the baseline M6 treatment, which mainly reflects the relatively lower amount of q offered in the M14 treatment. We further observe that terms of trade are significantly more favorable the greater are the money holdings of the consumer who is making the proposal, i.e., the greater is m_c and the greater are the money holdings of the producer who is facing the proposal, i.e., the greater is m_p.[18] Two other explanatory variables, the Grim trigger dummy variable (Grim) and the Holt Laury score (HLscore) are again found to be insignificant just as we found earlier in the probit regression analysis of producer acceptance decisions.

We next consider efficiency in our Lagos-Wright experimental economy using as bench-

[17] We again use a random effects, generalized least squares (GLS) estimator with clustering on both individuals and sessions.

[18] The intuition for the latter finding is that the higher are the money holdings of the producer, the better terms of trade the consumer needs to propose for acceptance. This finding is consistent with the finding of Chiu and Molico (2011).

marks the equilibrium payoffs per pair for our parameterization of the model as given in section III.A.

Finding 4 *Efficiency is below that of the first best equilibrium and is greater in the M6 treatment than in the M14 treatment.*

Support for Finding 4 comes from Table 7 which reports on 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 under our parameterization is $v^* = 7.62$. We used this as our benchmark in calculating the efficiency ratios reported in Table 7. Recall also that the monetary equilibrium does not achieve the first best, but is in fact less efficient in the version of the Lagos-Wright model that we study. Specifically, the period monetary equilibrium payoff per pair under our parameterization is $v = 7.26$.[19] Thus, if subjects are playing according to the monetary equilibrium of the environment, achieved efficiency should be less than the first best, specifically efficiency under the monetary equilibrium should be 95.2 percent of the first best.

Session No.,	Efficiency w.r.t. First Best Eq.	
Treatment	1^{st}, 2^{nd} half	All Periods
1, M6	0.45, 0.30	0.37
2, M6	0.46, 0.53	0.49
3, M6	0.40, 0.44	0.42
4, M6	0.36, 0.60	0.43
Avg. 1-4	0.42, 0.47	0.43
5, M14	0.29, 0.36	0.32
6, M14	0.30, 0.21	0.25
7, M14	0.40, 0.31	0.36
8, M14	0.35, 0.27	0.30
Avg. 5-8	0.34, 0.28	0.31

Table 7: Efficiency Relative to First Best or Monetary Equilibrium, Each Session

Consistent with Finding 4 the efficiency ratios reported in Table 7 are below the first best, averaging less than 50 percent in most sessions. However, the efficiency ratios are lower than in the monetary equilibrium which, as noted above, achieves 95.2 percent of the first best efficiency under our parameterization. The low efficiency ratios in our experiment are primarily a reflection of the low acceptance rates of decentralized meeting proposals by producers as reported earlier in Table 3; recall that decentralized meeting 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

[19] Of course, as shown in Table 1, there are many other equilibrium outcomes involving higher or lower payoffs than these two benchmarks, including, e.g., the autarkic equilibrium which has a payoff per pair of 0.

money treatment, to consumers offering too few tokens as part of their proposals. Recall from Table 5 that decentralized meeting prices always average less than the monetary equilibrium price of 2. We note further that some efficiency loss 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.

Using the efficiency ratios over all periods for each of the four sessions of our two treatments, a Wilcoxon Mann-Whitney test indicates that we can reject the null hypothesis of no difference in efficiency between the M6 and M14 treatments in favor of the alternative that efficiency is higher in M6 ($p = .02$, two-sided test). An explanation for this finding comes from Table 4 where we found that 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. This finding suggests that the social norm of the use of money as a medium of exchange may be easier to achieve in a smaller population of size 6 as compared with larger populations of size 14. We note that theory is silent on the role of the population size on social norm adoption. One might conclude from this finding that for larger populations, institutional (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 5 *Centralized meeting prices and trade volume are positive but lower than predicted by the monetary equilibrium.*

Session No., Treatment	Particp. Rate	Avg. Centralized Mtg. Price		Avg. Centralized Mtg. Volume	
		1^{st}, 2^{nd} half	All Periods	1^{st}, 2^{nd} half	All Periods
1, M6	.81	1.16, 1.30	1.23	8.08, 5.46	6.77
2, M6	.77	0.96, 1.03	0.99	8.29, 5.27	6.72
3, M6	.87	1.26, 1.55	1.41	4.29, 3.80	4.03
4, M6	.87	2.43, 1.84	2.11	3.85, 5.31	4.65
Avg. 1-4	.83	1.48, 1.44	1.46	6.05, 4.97	5.51
5, M14	.79	1.30, 1.58	1.45	9.82, 6.67	8.17
6, M14	.67	2.52, 3.16	2.85	4.54, 4.15	4.35
7, M14	.80	1.67, 2.31	1.99	12.18, 9.00	10.59
8, M14	.66	1.36, 1.52	1.44	14.35, 10.73	12.66
Avg. 5-8	.73	1.71, 2.14	1.93	10.55, 7.88	9.23

Table 8: Participation Rates, Prices and Volume in the Centralized Round of the Money Treatment Sessions

Support for Finding 5 is found in Table 8. As the first column of Table 8 indicates, participation as a buyer or seller in the centralized meeting 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 meeting 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 meeting are high. Together with the high use of money in decentralized meeting proposals, these findings are inconsistent with decentralized social norm pure gift exchange equilibria where money is *not* used and thus there is no need for the centralized meeting. Table 8 further reveals that there were positive trading volumes and meeting prices in the centralized meeting. In the M6 sessions, the meeting price of good X averaged 1.46 while in the M14 sessions, the meeting price of good X averaged 1.93. These meeting 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 meeting volume per round using session level averages 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 meeting; recall from Table 3 that decentralized meeting 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 meeting, then there is no reason to use the centralized meeting to re-balance one's money holdings.

[Figures 1-3 here]

Finding 6 *The distribution of money holdings at the end of the centralized meeting round is not degenerate. However, there is evidence that subjects are using the centralized meeting to re-balance their money holdings.*

Support for finding 6 is found in Figures 1-3 and in Table 9. Figure 1 illustrates the distribution of token (money) holdings following the completion of the centralized meeting. To construct Figure 1, we first averaged each subjects' token holdings as of the end of each centralized meeting round over the first and over the second halves of each session. These averages were then rounded up to the nearest token. Figure 1a presents a histogram of these average token holdings while Figure 1b shows the cumulative distribution function (CDF) of these token holdings. Figure 1 yields two important findings. First, while the distribution of money holdings following the centralized meeting is centered around 8 tokens it is not degenerate at 8 tokens. Using the data illustrated in Figure 1, a two-sided Kolmogorov–Smirnov test indicates that the CDF of money holdings for either the first or second halves of the sessions are both significantly different from the CDF associated with a degenerate distribution of money holdings at 8 tokens ($p < .01$ for both one-sample tests). Second, a two-sided Kolmogorov–Smirnov test indicates that the CDF of money holdings over the first half of all sessions is not significantly different from the CDF of money holdings over the second half of all sessions ($p > .10$ in a two-sample test).

While the distribution of money holdings is both non-degenerate and stationary over time, there is strong evidence that, consistent with the theory, subjects were using the meeting

	Dependent variable: $\Delta_{CM}m$							
Treatment,	M6	M6	M6	M6	M14	M14	M14	M14
Sess. No.	1	2	3	4	1	2	3	4
Cons	0.000	0.000	0.000	0.033	0.000	0.000	0.011	0.013
	(0.348)	(0.269)	(0.220)	(0.295)	(0.161)	(0.212)	(0.202)	(0.227)
$\Delta_{DM}m$	-0.385***	-0.370***	-0.352***	-0.635***	-0.305***	-0.604***	-0.473***	-0.478***
	(0.080)	(0.060)	(0.046)	(0.069)	(0.046)	(0.045)	(0.050)	(0.040)
R^2	0.130	0.186	0.253	0.331	0.122	0.336	0.137	0.247

*** indicates significance at the 1% significance level.

Table 9: Regression Evidence of Re-balancing in the Centralized Meeting: Coefficient Estimates and (Standard Errors) from a Regression of $\Delta_{CM}m$ on a Constant and $\Delta_{DM}m$ for Each Session

in the centralized meeting to rebalance their money holdings (token positions). Evidence for the use of the centralized meeting to re-balance money holdings in the M6 and M14 sessions is provided in Figures 2-3 and in Table 9. Specifically, in Figures 2-3, we plot the change in each individual subjects' money holdings at the end of each decentralized meeting round, denoted by $\Delta_{DM}m$ and measured on the horizontal axis, against the change in the same individual's money holdings at the end of the subsequent centralized meeting round, denoted by $\Delta_{CM}m$ and measured on the vertical axis.

If individuals are using the centralized meeting to rebalance their money holdings as predicted in the monetary equilibrium, then we should see a strong negative relationship between $\Delta_{DM}m$ and $\Delta_{CM}m$. 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 ($p < .01$ for all 8 sessions): the coefficient estimates and standard errors from a regression of $\Delta_{CM}m$ on a constant and $\Delta_{DM}m$ for each session are reported in Table 9.[20] While the equilibrium prediction would call for perfect re-balancing, (i.e., $\Delta_{DM}m = -\Delta_{CM}m$) as indicated by the dashed 45 degree line in each graph, the experimental data suggest that rebalancing was less than perfect in that $|\Delta_{DM}m| > |\Delta_{CM}m|$. More precisely, the regression coefficients on $\Delta_{DM}m$ as reported in Table 9 are always significantly less than 1 according to Wald tests ($p < .01$ for all 8 sessions). This suggests that there might have been some possible precautionary hoarding of money balances relative to monetary equilibrium predictions, but it may also simply reflect out-of-equilibrium behavior in both the decentralized and centralized meetings, i.e., the decentralized and centralized prices are not equilibrium prices and acceptance rates of offers are not 100 percent.

IV. Robustness

In this section we consider the robustness of our experimental findings for the Lagos and Wright model by addressing three main issues with our experimental design and reporting on the results of additional experimental sessions. The first and most important issue is whether endowing subjects with a money object may have promoted adoption of the monetary equi-

[20] The results reported are from a random effects, GLS regression on data for each session.

librium over other, non-monetary pure gift-exchange equilibria, especially those that Pareto dominate the monetary equilibrium such as the first best. Toward addressing this issue we study an environment similar to the Lagos and Wright model but with no money. Our main experiment finding for this environment is that subjects coordinate on very inefficient gift-exchange equilibria that are much closer to autarky than to the first best, and that welfare in this no-money environment is significantly lower than in the Lagos-Wright environment with money. The second issue we address is whether the type of centralized meeting mechanism matters for the behavior observed in our money and no-money environments. Specifically, we consider both money and no-money environments where the centralized meeting mechanism in both involves a Shapley and Shubik (1977) trading post mechanism, or in the case of the no-money environment, involves no centralized meeting mechanism. We find that our results for the money and no-money environments remain robust to these changes. The third and final issue we address is whether allowing for more than one round of bargaining in the decentralized meeting stage of both the money and no-money environment affects behavior. We find that multiple rounds of bargaining increases offer acceptance frequencies and thus welfare in the money environment but has no effect on these measures in the no money environment. Importantly, our main finding that welfare is higher in economies with money than in similar economies without money is robust to all of the robustness checks that we consider in this section.

A. The no-money environment

The first issue we address concerns the endowment of tokens that subjects were given at the start of each new supergame of our Lagos-Wright environment. Providing subjects with such token objects may have encouraged subjects to use those objects as media of exchange as opposed to coordinating on one of the non-monetary gift-exchange social norm equilibria that are also possible in the Lagos-Wright environment that we study. To address this potential confound, we also study a version of the Lagos-Wright model without money. Studying such an environment allows us to compare allocations between the money (M) and no money (NM) environments and determine whether money is behaviorally essential, even though it is not theoretically essential.

Toward that objective, we now describe an environment which is close to the environment formalized in Aliprantis, Camera, and Puzzello (2007ab), who suggest that the presence of centralized meetings (as in the Lagos and Wright model) facilitates the sustainability of cooperation. In our no money environment, there continues to be alternating decentralized and centralized meetings but the purpose of the centralized meeting is no longer to rebalance money holdings. Further, in our no money environment agents earn a zero payoff in the absence of any exchange or "cooperation". Thus our no money environment is one that gives cooperative non-monetary gift exchange a good shot at emerging yet it remains similar enough in structure to the money environment so that comparisons can be made.

Our no money environment is interesting in and of itself as it also allows us to test whether the presence of centralized meetings favors the emergence and sustainability of cooperation among randomly and anonymously matched agents. Previous experimental tests of the Kandori (1992) social norm hypothesis (e.g. Duffy and Ochs (2009)) have been conducted only under decentralized meetings without the centralized meeting possibility of our no money environment.

In the no money environment, centralized meetings in the Lagos-Wright are now replaced by centralized meetings where agents make a production decision and their consumption is determined by average production. Without loss of generality, in the decentralized meetings, we can continue to 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 $\left[0,\overline{Y}\right]$ as their action set (each agent gets to consume average production).

In addition to decentralized social norm equilibria,[21] there also exist social norm equilibria exploiting the presence of centralized meetings. More precisely, positive levels of production and consumption can be sustained as Nash equilibria by the following *centralized meeting* (CM) *gift-giving* social norm:

"Let $0 < q \leq q^*$. In the decentralized meeting, propose $0 < q \leq q^*$ whenever you are a consumer and accept proposals to produce $0 < q \leq q^*$ whenever you are a producer. Produce $L \in \left(0,\overline{Y}\right]$ 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 centralized meeting). If you have observed a deviation, then reject proposals to produce in the decentralized meeting and produce 0 forever after in the centralized meeting."

Clearly, this social norm attains the first best for $q = q^*$. To show that this social norm can be sustained as a sequential equilibrium, observe that on the equilibrium path we have:

$$V_{DM}^* = \tfrac{1}{1-\beta}\tfrac{1}{2}\left[u(q)-c(q)\right] \text{ and } V_{CM}^* = \tfrac{\beta}{1-\beta}\tfrac{1}{2}\left[u(q)-c(q)\right],$$

where V_{DM}^* and V_{CM}^* denote the equilibrium value functions at the beginning of the decentralized and centralized meetings, respectively.

To guarantee that this strategy is a sequential equilibrium we must again check on-equilibrium and off-equilibrium incentives. On-equilibrium, agents have the incentive to follow the strategy in the decentralized meeting if

$$-c(q) + V_{CM}^* \geq 0 + \frac{2N-2}{2N}L$$

or

$$\beta \geq \frac{\frac{2N-2}{2N}L + c(q)}{\frac{2N-2}{2N}L + c(q) + \frac{1}{2}\left[u(q)-c(q)\right]} = \underline{\beta}. \tag{3}$$

In the centralized meeting we have

$$\left(\frac{2N}{2N}L - L\right) + \beta V_{DM}^* \geq \frac{2N-1}{2N}L + 0$$

or

$$\beta \geq \frac{\frac{2N-1}{2N}L}{\frac{2N-1}{2N}L + \frac{1}{2}\left[u(q)-c(q)\right]} = \underline{\underline{\beta}}. \tag{4}$$

[21] The decentralized social norm equilibria in the no money environment are similar to the description of such equilibria provided in section III: *"Let $0 < q \leq q^*$. Do not produce in the CM. Produce only in the DM. Propose q every time you are a consumer and accept q 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."*

It is easy to check that off-equilibrium it is always better to follow the contagious 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" (Lagos-Wright) environment which relies on purely decentralized interactions). Thus, if agents are patient enough, i.e., if $\beta \geq \underline{\beta}^{CM} \equiv \max\left\{\underline{\beta}, \underline{\underline{\beta}}\right\}$, it is possible to sustain pure gift-exchange equilibria involving some $q > 0$.[22] In particular, when $q = q^*$, this centralized social norm supports the first best as a sequential equilibrium without the use of money.[23]

Our parameterization and experimental design for the no-money, ACP environment is very similar to the Lagos-Wright money environment described in sections III.A-III.B. Indeed, the parameterization of the model is exactly the same and we again consider populations of size $2N = 6$ or $2N = 14$. The main difference is that subjects are no longer endowed with any token objects (as there are no token objects in the no money environment) and the centralized meeting involves a public good game rather than a Walrasian call market.

Cooperation in a decentralized, anonymous random matching environment is difficult to achieve (see, e.g., Duffy and Ochs (2009)), thus in the ACP environment without money we 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.

In terms of the threshold discount factors (i.e., the lowest value of β under which the first best can be supported), it is easier to sustain the first best under the centralized social norm of the no money environment and for smaller populations. Indeed, recall that for our parameterization of the model, the lowest discount factors for which equation (1) in section III.A was binding under the decentralized social norm were $\underline{\beta}_6^{DM} = 0.7702$ and $\underline{\beta}_{14}^{DM} = 0.8256$, where the subscript denotes the population size and the superscript the type of social norm equilibrium. Given that we adopt the same parameterization for the no money environment and our choice of $L = 1$, we can find the lowest discount factors for which the first best is sustained by the centralized social norm in the no-money environment. This turns out to be determined by (3) which binds before (4). We obtain $\underline{\beta}_6^{CM} = 0.6363$ and $\underline{\beta}_{14}^{CM} = 0.6427$. Thus, we can now rank the β thresholds as $\underline{\beta}_6^{CM} < \underline{\beta}_{14}^{CM} < \underline{\beta}_6^{DM} < \underline{\beta}_{14}^{DM}$. Since $\beta = \frac{5}{6}$ exceeds all four threshold discount factors, the first best can be supported as a sequential Nash equilibrium both under the *decentralized* and *centralized gift-giving social norms* in the no-money environment.[24]

In addition to the first best, given $\beta = \frac{5}{6}$, lower but positive production and consumption levels in the decentralized meeting can be supported as sequential equilibria. Equations (1)-(4), can be used to find the range of quantities that can be supported as sequential equilibria under the decentralized and centralized social norms.[25] Table 10 summarizes our equilibrium

[22] Note that $\underline{\beta} \geq \underline{\underline{\beta}}$ if and only if $\frac{1}{2}\left[u(q) - c(q)\right]\left[c(q) - \frac{L}{2N}\right] \geq 0$ or $\left[c(q) - \frac{L}{2N}\right] \geq 0$ for $0 \leq q \leq \overline{q}$. Also, $L \in \left(0, \overline{Y}\right]$ is arbitrary and the smaller is L or the population, the easier is to sustain cooperation (i.e., the lower is $\underline{\beta}$).

[23] In this no money environment, since the population is finite, the observation of average output reveals information about individual actions and thus the spread of the contagion is *faster* under the centralized gift-giving social norm than under the decentralized gift-giving social norm.

[24] More detailed computations on the decentralized and centralized social norm conditions are provided in Appendix A.

[25] The reason why it is not possible to support quantities arbitrarily close to zero under the centralized

predictions for q under various types of equilibria in our no money environment.

Group Size	Decentralized Social Norm	Centralized Social Norm	Autarkic Equilibrium
$N = 6$	$0.2 \leq q \leq 6$	$0.058 \leq q \leq 6$	$q = 0$
$N = 14$	$0.5 \leq q \leq 6$	$0.072 \leq q \leq 6$	$q = 0$

Table 10: Equilibrium predictions regarding q in the no money environment

In the no money treatment the main design change is that in place of the centralized meeting round for rebalancing money holdings, all $2N$ subjects participated in what was termed a "centralized meeting" round where they were asked to decide how many units they wanted to produce of a homogeneous and perishable good X. As noted above we set $L = 1$ and restricted production of the homogeneous good X to either 0 or 1 units for each subject so as to facilitate coordination. 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:

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 as in the original design, with 1 point = \$0.20.

We conducted 9 sessions of this no money treatment– five no money sessions with $2N = 6$, (NM6) and four no money sessions with $2N = 14$ (NM14).[26] Characteristics of these no money sessions are given in Table 11. A comparison of Table 11 with Table 2 reveals that we had a similar number of sequences and periods in our money and no money treatment sessions, and that subjects in the no money sessions had risk attitudes that were similar to those of subjects in our money treatment sessions. On the other hand, average subject earnings in the no money treatment sessions was \$22.52, which is lower than in the money treatment sessions.

Our analysis of the experimental results from our no money treatment follows that of our money treatment sessions. Table 12 reports on offer acceptance rates and mean quantities traded in the decentralized meeting as well as on overall efficiency relative to the first best equilibrium in all 9 sessions of our no money treatment sessions. Session-level averages are reported over the first and second half of each session as well as over all rounds of each session. A comparison of the session level averages reported in Table 12 for the no money

social norm is that $L > 0$ is restricted to be 1 in the centralized market. In the new set of experiments, we do not restrict production in the centralized market and therefore also quantities arbitrarily close to zero can be supported as sequential equilibria (see Section 5 and Appendix A).

[26] As in the money treatment sessions, subjects were given written instructions that were read aloud and included a comprehension quiz. Copies of the instructions used in our no money treatment sessions are available at: http://www.pitt.edu/~jduffy/ExchangeExp/

Session No., Treatment	No. of Subjects	No. of Sequences	No. of Periods	Mean HL Score	St. Dev. HL Score
9, NM6	6	6	33	6.0	1.3
10, NM6	6	5	32	3.8	3.0
11, NM6	6	9	31	5.8	2.7
12, NM6	6	6	30	5.7	1.4
13, NM6	6	5	31	6.5	0.5
14, NM14	14	7	35	6.2	1.6
15, NM14	14	5	29	6.5	1.6
16, NM14	14	4	34	6.4	1.0
17, NM14	14	5	31	6.4	1.3
Averages		5.8	31.8	5.9	1.6

Table 11: Characteristics of Experimental Sessions in the No Money (NM) Environment

treatment sessions with the session level averages for the money treatment sessions reported in Tables 3, 5 and 7 yields the following finding:

Finding 7 *There is no difference in offer acceptance rates between M and NM sessions. However, quantities exchanged in the decentralized meeting are significantly greater in the money treatment than in the no money treatment. Consequently, welfare is higher in economies with money than in economies without money.*

Finding 7 indicates that money does not have a significant effect on the extensive margin, i.e., on the number of trades, but it does have a significant effect on the intensive margin, i.e., on the quantity that gets traded.

Support for the first part of Finding 7 can be found in the offer frequencies for the M and NM treatment sessions as reported in the first three columns of Table 3 and Table 12. Using a nonparametric, Wilcoxon Mann-Whitney test on the four or five session-level offer acceptance frequencies over all periods we cannot reject the null hypothesis of no difference in offer 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). Support for the second part of Finding 7 comes from comparing the mean quantities traded in the M treatment as reported in Table 3 with the mean quantities trades in the NM treatment as reported in the middle three columns of Table 12. Comparing the two yields the striking finding that mean traded offers are about 3 times greater in the money treatments as compared with the no money treatments. In the M6 treatment, the mean accepted quantity in the decentralized meeting is 4.16 units while in the NM6 treatment it is just 1.24 units. Using a Mann-Whitney test on the 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 ($p = .014$). A similar difference exists between the M14 and the NM14 treatments. In the M14 treatment, the mean accepted quantity is 3.51 units while in the NM14 treatment it is just 1.22 units. Again using a Mann-Whitney test on the four session-level averages of these

Session No., Treatment	Offer Accept Rate		Average q		Efficiency w.r.t. First Best Eq.	
	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All
9, NM6	52.1, 68.6	60.6	1.55, 1.26	1.37	0.28, 0.36	0.33
10, NM6	58.3, 52.1	55.2	1.36, 1.13	1.25	0.34, 0.26	0.30
11, NM6	22.2, 25.0	23.7	1.70, 0.57	1.11	0.14, 0.07	0.10
12, NM6	62.2, 60.0	61.1	1.63, 1.07	1.35	0.39, 0.31	0.35
13, NM6	44.4, 58.3	51.6	1.15, 1.05	1.09	0.24, 0.30	0.27
Avg. 9-13	48.0, 52.9	50.5	1.48, 1.02	1.24	0.29, 0.26	0.27
14, NM14	36.1, 39.5	37.8	1.67, 0.99	1.31	0.22, 0.20	0.21
15, NM14	44.8, 45.9	45.3	1.89, 1.08	1.46	0.28, 0.24	0.26
16, NM14	29.4, 46.2	37.8	1.24, 0.69	0.91	0.16, 0.17	0.17
17, NM14	46.7, 34.8	40.6	1.49, 0.94	1.24	0.28, 0.17	0.23
Avg. 14-17	38.8, 41.6	40.2	1.56, 0.92	1.22	0.23, 0.19	0.21

Table 12: Offer Acceptance Rates, Trade Average Offer Quantities, and Efficiency w.r.t. the First Best Equilibrium, Each No Money Session

two treatments, we can 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 ($p = .021$). We can further report using the Mann-Whitney test that there is no significant difference in mean traded quantities between the NM6 and NM14 treatments ($p = 1.00$); that is, the observed quantity differences arise from the presence or absence of the token money object and *not* from differences in the group size.

Given that offer acceptance rates are the same in the money and no money treatment but quantities exchanged are about 3 times greater in the money treatment sessions as compared with the no money treatment session, it logically follows that the last statement of Finding 7 must hold, namely, that welfare is higher in economies with money than in economies without money. Nevertheless, using the session-level efficiency ratios over all rounds as reported in Table 7 for the money treatment sessions and in the last three columns of Table 12 for the no money treatment sessions, a Wilcoxon Mann-Whitney test indicates that we can 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 ($p = .01$ for the first test and $p = .04$ for the second test). This is strong evidence that the presence of a money object enables agents to coordinate on a more efficient sequential equilibrium of the repeated game.

As in the money treatment sessions, we also examine producers' responses to consumers' proposals in the no money (NM) treatment sessions and the factors that may explain accepted consumer proposals. Table 13 reports on a probit regression analysis of producers' acceptance or rejection of consumers' proposals in the decentralized meetings of all money and no money sessions and in the no money treatment sessions alone. These regressions are of the same type as reported earlier in Table 4 for the money treatment sessions and use the same dependent variables as described in those regressions. Table 13 reveals that for all sessions (all

	Dep. Variable, Accept=1, Reject=0	
	All Sessions	NM Sessions
Constant	0.548*	3.725***
	(0.286)	(0.432)
NM14	-0.029	0.522***
	(0.218)	(0.197)
M6	0.836***	
	(0.314)	
M14	0.250	
	(0.256)	
NewSeq	0.193	0.0467
	(0.120)	(0.240)
Period	-0.009*	-0.043***
	(0.006)	(0.010)
Grim	-0.161*	-0.370**
	(0.089)	(0.172)
HLscore	-0.024	-0.172***
	(0.042)	(0.047)
q	-0.230***	-1.389***
	(0.087)	(0.148)
No. obs.	2,580	1,367
Log Likl.	-1564.8	-634.4

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 13: Probit Regression Analysis of Proposal Acceptance Decisions in All Sessions and in the No Money Sessions

decentralized rounds of all M and NM sessions – the first column of Table 4), two of the three treatment dummy variables are insignificantly different from zero, which is consistent with our earlier findings regarding the absence of large differences in offer acceptance frequencies. We further observe that there is no "restart effect"in acceptance frequencies in the first period of each new sequence as the coefficient on the NewSeq dummy is positive but not significantly different from zero. Further, there is a decline in acceptance frequencies over the course of the sequence as indicated by the negative and significant coefficient on the Period variable as was also found for the money treatment sessions (see Table 4). Most of these same findings carry over to the NM treatment sessions alone (column 2 of Table 4): in particular, a higher proposed quantity q leads to a significantly lower probability that an offer is accepted which is consistent with Finding 2 for the money treatment sessions.

An interesting finding from Table 13 is that the coefficient on the 'Grim' dummy variable is significantly negative in regression specifications involving the full sample (M+NM) and in the NM only sample. However, as we saw earlier in Table 4, the coefficient on Grim dummy becomes insignificantly different from zero when the sample is restricted to just the M sessions. This suggests that in the absence of money a grim trigger-type mechanism is used to support exchange among anonymous randomly matched agents but that when money is introduced the use of the grim trigger mechanism no longer plays an important role in proposal acceptance decisions. Intuitively, these findings suggest that money serves as a decentralized record-keeping device that obviates the need for grim-trigger type punishment schemes.

	All Sessions	NM Sessions Only
Dependent Variable:	q	q
Constant	3.231***	1.741***
	(0.646)	(0.097)
NM14	-0.228	-0.016
	(0.356)	(0.115)
M6	2.968***	
	(0.368)	
M14	2.011***	
	(0.373)	
NewSeq	-0.063	0.210**
	(0.233)	(0.106)
Period	-0.048***	-0.034***
	(0.009)	(0.007)
Grim	-0.407*	-0.082
	(0.216)	(0.079)
HLscore	-0.101	0.013
	(0.056)	(0.030)
No. obs.	1,101	586
R^2	0.390	0.214

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 14: Random Effects, GLS Regression Analysis of Accepted Consumer Proposals in All Sessions and in the No Money Sessions

Table 14 reports on a GLS regression of accepted consumer proposal quantities on the same explanatory variables used previously for both the entire sample (M+NM sessions) and just the NM sessions. The regression results are consistent with Finding 7: using the full sample, the coefficients on M6 and M14 are significantly greater than zero indicating that mean traded quantities are higher in those treatments than in the baseline NM6 treatment. By contrast the NM14 dummy is not significant indicating that quantities are no different between the NM6 and NM14 sessions. Restricting the subsample to just the NM sessions, we observe the presence of a restart effect in the NM sessions as evidenced by the positive and significant coefficient on the NewSeq dummy.

Finally, we consider behavior in the centralized meeting of the no money treatments. We have the following main result:

Finding 8 *In the no money treatments, contributions to the general good in the centralized* *meeting are close to zero irrespective of the population size.*

Session No., Treatment	Average General Good Contribution	
	1^{st}, 2^{nd} half	All Periods
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
13, NM6	0.00, 0.00	0.00
Avg. 9-13	0.06, 0.01	0.04
14, NM14	0.02, 0.01	0.02
15, NM14,	0.02, 0.01	0.02
16, NM14,	0.01, 0.00	0.01
17, NM14,	0.04, 0.02	0.03
Avg. 14-17	0.02, 0.01	0.02

Table 15: Average General Good Contributions in the Centralized Round of the No Money Treatment Sessions

Support for Finding 8 is found in Table 15 which reports the mean contributions to the general good by all 6 or 14 subjects over the first, second and over all periods of each of the 9 No Money Sessions. We observe that, despite the possibility of using contributions to the general 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 treatment sessions. Contributions to the general good started off quite low, averaging just .06 (.02) units in the first half of the NM6 (NM14) sessions respectively and only declined further with experience. A Wilcoxon Mann-Whitney test reveals that there is no difference in centralized general good contributions between the NM6 and the NM14 treatments using the session level averages over all periods as reported in Table 15 ($p = 1.0$). We conclude from this evidence as well as the from 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. Indeed, behavior in our NM6 and NM14 treatments more closely resembles a low trade sequential equilibrium of the "decentralized social norm" variety where the centralized meeting stage is avoided altogether and the quantity exchanged in the decentralized meeting is low but nonzero (and different from the autarkic equilibrium). Recall from Table 1 that such equilibria do exist in the environment we study and involve trade amounts as little as $q = 0.2$ or $q = 0.5$ per period depending on whether the population size is 6 or 14.

B. Trading post design

The experiments reported on in sections III and IV.A have different mechanisms in place for the centralized meeting of the money and no money treatments. In particular, we used a

Walrasian call market as the centralized meeting mechanism for the money treatments and a binary choice public good game in the centralized meeting of the no money treatments. Behaviorally, these differences may have contributed to the different outcomes we observed between the money and no money treatments, that is, the different centralized meeting mechanisms serve as a confounding factor in understanding whether the different outcomes we observed in our money and no money treatments were due to the presence or absence of tokens. In addition, we have observed that acceptance rates in the decentralized meeting of both the money and no money treatments were rather low, averaging 50 percent or less. In an effort to correct for the potentially confounding effect of having different centralized meeting mechanisms and at the same time to address the low acceptance rates of proposals in decentralized meetings, we developed a modified experimental design that deals with these issues and comprises the third and final part of our experimental study.[27]

In our modified experimental design, we allow for more than a single round of bargaining in the decentralized meeting stage of each period. Each decentralized meeting again involves random, anonymous pairwise matching of all $2N$ players to form N pairs. As before, the consumer in each pair moves first, proposing that the producer with whom he is matched produce a quantity q of the specialized good. In the money treatment only, the consumer's proposal may also include an amount of money, d, that the consumer is willing to give to the producer in exchange for producing the proposed quantity q. However, differently from before, the matched producer's choices are now to accept, reject or to make a counter-proposal q' in the no money treatment or a counter-proposal of $\{q', d'\}$ in the money treatment. If the producer makes a counter-proposal, the consumer has the opportunity to accept, reject or make a final counter-proposal to the producer, q'' or $\{q'', d''\}$. Finally, if the third round of bargaining is reached, the producer must accept or reject the consumer's final proposal; no further rounds of bargaining are possible.[28] Thus, in our modified design we now allow for up to three rounds of bargaining in each decentralized meeting stage of a period. As the consumer makes the final offer and there is no discounting between bargaining rounds, this set-up is strategically equivalent to the take-it-or-leave-it bargaining protocol (where the consumer has all the bargaining power) that we used previously and thus results in no change in the theoretical predictions for the decentralized meeting round. However, the fact that multiple rounds of bargaining are held might help subjects to correct some initially unreasonable offers, thereby increasing acceptance rates and moving behavior closer to equilibrium predictions within the compressed time frame allowed by laboratory experimentation.

The more substantive change in our modified experimental design is that the centralized meeting mechanism in *both* the money and no money treatments now involves a common, centralized trading post mechanism along the lines suggested by Shapley and Shubik (1977). In the next section we describe how this trading post mechanism works and argue that this common centralized meeting exchange mechanism can support all of the equilibria that obtained in our original experimental design.

[27]We are grateful for the comments of our anonymous referees who stimulated us to develop this modified experimental design.

[28]All proposals must be feasible, that is, $0 \leq q \leq \bar{q}$ and $d \geq 0$ cannot exceed the fixed amount of money that the consumer currently has available.

C. Theoretical Predictions in Environments with Trading Posts

We again consider two environments, with money and without money, where a common trading post mechanism is used in the centralized meeting of both environments. All other aspects of the environment including preferences, matching technology and the two subperiods within each period are the same as before.

We first consider a no money environment which is a version of Araujo et al. (2012) with one trading post. Terms of trade in the decentralized meetings are determined as in the previous environment with the exception (as discussed above) that we now allow for up to three rounds of bargaining, with the consumer having the final proposal opportunity. Following the decentralized meeting, all $2N$ agents can choose whether to participate in the centralized trading post for the general good. They first choose whether to produce $0 \leq y \leq \overline{Y}$ units of the general good, where $\overline{Y}$ denotes the upper bound on production. Second, they decide how much to bid for the general good with the constraint that their bid cannot exceed their production, i.e., $0 \leq b \leq y$.[29] The meeting price of the centralized meeting general good is determined under the trading post mechanism as the ratio of the sum of bids to the sum of individual production amounts i.e., $p = \frac{\sum b_i}{\sum y_i}$. If $\sum b_i = 0$ or $\sum y_i = 0$, then $p = 0$ and no trade takes place. Consumption for an agent whose bid is b is given by $\frac{b}{p}$. Given the linearity of preferences in the centralized meeting stage, payoffs are given by $U(b, y, p) = \frac{b}{p} - y$. As in our original experimental design, there exist decentralized social norms (where agents choose to avoid the centralized meeting altogether by choosing to produce 0) that allow agents to support positive production and consumption (including the first best) as a sequential equilibrium. In addition to decentralized social norms, there are also centralized social norms that require using the trading post price in the centralized meeting as a signaling device. It is possible to show that if agents are sufficiently patient, positive amounts of production and consumption (including the first best) can be supported as sequential equilibria (see Appendix A for details).

We next consider the same environment with money which can be viewed as a modified version of Lagos and Wright (2005) where trade in the centralized meeting is organized via a trading post or market game.[30] The trading post set up we describe here follows Green and Zhou (2005). Terms of trade in the decentralized meetings are determined as in the previous environment, with the exception that we now allow for up to three rounds of bargaining, with the consumer having the final proposal opportunity.

In the centralized meeting subjects decide whether to participate or not in the trading post. If they participate they decide how much to produce for the trading post, say $y \geq 0$. Next, they decide how much to bid in terms of money and their bid cannot exceed their money holdings, i.e., $0 \leqslant b \leqslant m$. After every subject has submitted his decisions, the price of the general good in terms of money is realized: $p = \frac{\sum b_i}{\sum y_i}$. Note that $p = 0$ if $\sum b_i = 0$ or $\sum y_i = 0$ and no trade takes place. The realized payoff in the centralized meeting is $U(b, y, p) = \frac{b}{p} - y$ since consumption is determined by $\frac{b}{p}$ and preferences are linear in the

[29] Since this is not an endowment economy, in order to bid for the general good, agents must have first agreed to produce their "endowment" and can then decide how much of that endowment they want to bid toward units of the general good.

[30] Market games have been extensively studied and provide game theoretic foundations for price-taking behavior, i.e., they have been used to provide foundations to Walrasian markets.

centralized meeting. Money holdings at the beginning of the next decentralized meeting m' are given by money holdings at the beginning of the previous centralized meeting, plus proceeds from sales, minus the amount bid: $m' = m + py - b$. In Appendix A we show that as the population N grows large, the theoretical predictions remain the same as for the Lagos and Wright (2005) model.

D. Experiment Using the Modified Design

We have conducted a number of sessions of our modified experimental design involving 3 rounds of bargaining in the decentralized meeting and a common trading post mechanism for the centralized meeting.[31] All sessions of our modified ("M") design involved 14 subjects with no experience in any prior session of our experiment. We chose to focus only on the case where $2N = 14$ (and not $2N = 6$) as the larger group size minimizes any possible strategic interactions among players in the trading post mechanism of the centralized meeting stage.[32] Among the 10 sessions conducted using our modified experimental design, 4 of these sessions were "money treatment" sessions, (labeled "MM14" for modified money treatment with 14 subjects) where each subject was initially endowed with tokens. A further 4 sessions were "no money" treatment sessions (MNM14) where there were no tokens. In addition, we conducted an additional 2 sessions of our *no*-money, 3-round bargaining model *without* the second stage, centralized meeting. In this modified "no money, no centralized meeting" treatment (MNMNC14) each period of each indefinitely repeated sequence consists only of the decentralized meeting round. The latter treatment helps us to understand whether the presence or absence of the centralized meeting in the no-money treatment matters for the equilibrium selected; recall that, in theory the centralized meeting stage is not necessary to sustain non-monetary social norm allocations including the first best as sequential equilibria.

Aside from the modifications discussed above, all other aspects and parameter choices for the model were held constant relative to the first set of experiments. In particular, the utility function in the decentralized meeting remained the same as did the continuation probability (discount factor β) of 5/6 and the endowment of tokens (8) received in the first period of each new sequence of the money treatment only. Tokens continued to have no redemption value in terms of points and token balances were set to zero at the end of each sequence. As in the money treatment of the first experiment, quantities were constrained to lie between 0 and 22 units in both the decentralized and centralized meetings of the modified experimental design (both money and no money treatments).

One consequence of allowing for more rounds of bargaining within each period is that we are not able to obtain as many periods of play of our two stage game as before within the same time frame of 2.5-3 hours. Accordingly, we had to cut the average number of periods

[31] As in the other experimental treatments, subjects were given written instructions that were read aloud and included a comprehension quiz. Copies of the instructions used in our modified experimental design are available at: http://www.pitt.edu/~jduffy/ExchangeExp/

[32] Duffy, Matros, and Temzelides (2011) is the only other experiment we are aware of that uses a Shapley-Shubik-type trading post mechanism. They report that groups of size 20 act like price takers and play according to the unique competitive equilibrium of the associated pure exchange economy they study, while smaller groups of size 4 take advantage of their strategic power and coordinate on a Nash equilibrium that differs from the competitive equilibrium.

played by 2/3 (from 31.1 to 20.7 periods) while increasing the redemption value of points earned from 1 point = 20 cents to 1 point = 30 cents so as to hold total compensation approximately constant.

As in the earlier money and no money treatments a session of our modified experimental design consisted of two parts. In the first part, each group of 14 subjects participated in either the MM14, MNM14 or MNMNC14 treatment. In the second part, each subject completed the individual-choice Holt-Laury (2002) paired lottery choice task resulting in an "HL score" for each subject. The total length of a session using our modified experimental design averaged 2.5 hours. Total earnings from both parts of our modified experimental design sessions 18–27 averaged $24.38 per subject.

For the experiment involving the modified experimental design we report results from 10 experimental sessions involving 140 subjects. Some characteristics of these 10 sessions including the mean number of supergames, periods and the mean and standard deviation of subjects' Holt-Laury scores are reported in Table 16.

Sess. No., Treatment	No. Subj.	Money (LW) or not (ACP)	Centralized Meetings?	No. of Sequences	No. of Periods	Mean HL Score	St. Dev. HL Score
18, MM14	14	Money	Yes	2	19	5.7	2.2
19, MM14	14	Money	Yes	3	21	5.4	2.5
20, MM14	14	Money	Yes	3	20	6.0	1.2
21, MM14	14	Money	Yes	3	20	6.4	1.4
22, MNM14	14	No Money	Yes	4	23	6.2	1.6
23, MNM14	14	No Money	Yes	3	22	5.5	2.8
24, MNM14	14	No Money	Yes	4	22	6.1	1.1
25, MNM14	14	No Money	Yes	3	20	6.0	1.4
26, MNMNC14	14	No Money	No	4	21	6.0	1.4
27, MNMNC14	14	No Money	No	3	19	6.0	2.4
Averages				3.2	20.7	5.9	1.9

MM=modified money, MNM = modified no money and MNMNC =modified no money no centralized meeting treatments.

Table 16: Characteristics of Sessions Using the Modified Experimental Design

A summary of the theoretical predictions for the decentralized quantity, q in the modified experimental design for our model parameterization is provided in Table 17.[33]

Group Size	Decentralized Social Norm	Centralized Social Norm	Monetary Equilibrium	Autarkic Equilibrium
$N = 14$	$0.5 \leq q \leq 6$	$0 < q \leq 6$	4	0

Table 17: Equilibrium predictions regarding q for the modified experimental design

[33] See Appendix A for details about the construction of these predictions.

E. Experimental Findings Using the Modified Design

The mean number of bargaining rounds, offer acceptance rates, the percentage of offers involving money and monetary offer acceptance rates are all reported in Table 18. This table reveals that the mean number of rounds of bargaining before a decision was made to accept or reject an offer in our modified money treatment (MM14 sessions) was 2 rounds while in the modified no-money treatment (MNM14 and MNMNC14) sessions (22-27) it was about 1.5 rounds. Thus, subjects took advantage of the additional rounds of bargaining provided by our modified design.[34] Table 18 further reveals that in the money treatment an average of roughly 90 percent of all offers (over the maximum three rounds of bargaining) involved some amount of tokens (money) and that offer acceptance rates (money offer acceptance rates) in the money treatment of the modified design involving 14 subjects are on average 63.6 percent (64.5 percent). These acceptance rates are considerably higher than for offers (monetary offers) in the M14 sessions of the original design, which averaged 40.7 (40.6 percent, respectively). Indeed, using a Wilcoxon Mann-Whitney test on the session-level overall acceptance (monetary acceptance) rates, we can reject the null hypothesis of no difference in these offer acceptance rates ($p = .02$, two-sided test) in favor of the alternative that acceptance rates are higher in the MM14 sessions as compared with the M14 sessions. These higher offer acceptance frequencies for the modified money treatment sessions are likely owing to the additional opportunities to bargain that are provided in the modified design, which probably facilitated coordination on agreeable terms of trade. However, Table 18 also reveals that offer acceptance rates in the modified no money treatment design involving 14 subjects (MNM14 sessions) averaged just 44.8 percent. While these acceptance rates are significantly lower than in the comparable modified money treatment MM14 sessions ($p = .02$, two-sided test) they are not significantly different from offer acceptance frequencies in the NM14 sessions of the original design where offers were accepted an average of 40.2 percent of the time ($p = .38$, two-sided test). We further note that in the two sessions of the modified no money, no centralized (NC) meeting design (MNMNC sessions 26-27) offer acceptance rates appear to be consistent with those observed for both the MNM14 and NM14 sessions, averaging 41.1 percent.

Mean traded quantities, and in the money treatment, money amounts and implicit prices in the decentralized meeting of the modified design are reported in Table 19. The overall mean traded quantity in the modified money sessions (MM14 sessions 18-21) is 3.91 units which is again close to the monetary equilibrium prediction of 4. The mean traded quantity amounts for the MM14 sessions are indistinguishable from those found for the original M14 sessions, which averaged 3.51 ($p = .39$, two-sided test using session-level data).

By contrast, the mean traded quantity in the modified no money treatment sessions (MNM14 sessions 22-25) is just 1.12 units, and much lower than in the modified money treatment sessions. The higher mean traded quantity of in the money treatment sessions

[34] Of course, via backward induction, all bargaining should theoretically end after a single round. For the four MM14 sessions we do find that the mean number of bargaining rounds in the second half of each session is significantly (but marginally) lower than in the first half of those sessions (Wilcoxon signed ranks test $p = .07$) while there is no difference in the number of bargaining rounds between the first and second halves of the modified no money sessions 22-27, $p = .24$. We would further add that bargaining lengths of 1, 2 and 3 rounds comprise, respectively, 51%, 27% and 22% of all observations over all sessions using our modified design.

Session No., Treatment	Rounds Bargaining		Offer Accept Rate		% Monetary Offers		Money Offer Accept Rate	
	1^{st}, 2^{nd} Half	All	1^{st}, 2^{nd} Half	All	1^{st}, 2^{nd} Half	All	1^{st}, 2^{nd} Half	All
18, MM14	1.98, 1.84	1.91	57.1, 57.1	57.1	96.8, 84.3	90.2	59.0, 66.1	62.5
19, MM14	1.96, 1.78	1.86	65.7, 58.4	61.9	88.6, 83.1	85.7	67.7, 62.5	65.1
20, MM14	2.33, 1.79	2.06	72.9, 54.3	63.6	98.6, 87.1	92.9	73.9, 55.7	65.4
21, MM14	2.17, 2.14	2.16	70.0, 72.9	71.4	98.6, 100.0	99.3	69.6, 72.9	71.2
Avg. 18-21	2.12, 1.89	2.00	66.7, 60.6	63.6	93.3, 86.5	89.8	66.0, 62.7	64.5
22, MNM14	1.69, 1.75	1.72	53.2, 48.8	50.9	n/a	n/a	n/a	n/a
23, MNM14	1.56, 1.44	1.50	50.6, 62.3	56.5	n/a	n/a	n/a	n/a
24, MNM14	1.40, 1.40	1.40	41.6, 41.6	41.6	n/a	n/a	n/a	n/a
25, MNM14	1.29, 1.27	1.28	25.7, 31.4	28.6	n/a	n/a	n/a	n/a
Avg. 22-25	1.49, 1.48	1.48	43.2, 46.4	44.8	n/a	n/a	n/a	n/a
26, MNMNC14	1.80, 1.74	1.77	44.3, 45.5	44.9	n/a	n/a	n/a	n/a
27, MNMNC14	1.41, 1.40	1.41	39.7, 34.3	36.8	n/a	n/a	n/a	n/a
Avg. 26-27	1.62, 1.58	1.60	42.1, 40.1	41.1	n/a	n/a	n/a	n/a

Table 18: Mean Number of Bargaining Rounds and Offer Acceptance Rates in the Decentralized Meetings of Each Session of the Modified Experimental Design

18–21 relative to the no money treatment sessions 22–25 (or all modified no money sessions 22-27), is statistically significant ($p \leq .02$ for the null of no difference using a two-sided test on session-level data). The mean traded quantity amounts for the MNM14 sessions are indistinguishable from those found for the original no money (NM14) treatment sessions, which averaged 1.22 ($p = .38$, two-sided test using session-level data). Thus using our modified design we find no difference in traded quantities in the decentralized meeting stage of a given treatment relative to the original design for that same treatment and we continue to find that traded quantities are significantly greater *with* money than without money. We further observe that the presence or absence of the centralized meeting stage does not have much of an impact on the amount traded in the decentralized meeting when there is no money; in the two sessions 26-27 without a centralized meeting stage, the mean traded quantity in the decentralized meeting is just 1.02 units which is similar to the mean of 1.12 units traded in the no money sessions with a centralized meeting stage.

In the modified money treatment sessions, the mean traded amount of money, d is 4.08. This amount is lower than in the comparable M14 sessions of the original design where d averaged 5.16 and this difference is marginally significant, ($p = .08$ using the four session-level averages for each treatment, two-sided test). However a consistent finding is that d quantities in both designs lie below the monetary equilibrium prediction of 8. A consequence of the lower amount of d is that the decentralized meeting price in our modified design, d/q, averages just 1.14, which is lower than the mean decentralized price of 1.41 reported for the original design; again, there is some consistency in that both decentralized meeting prices lie below the monetary equilibrium prediction of 2. The lower than monetary equilibrium quantities for d (and hence d/q) arise from the hoarding of money holdings by a few subjects, which makes money more scarce and thus more valuable than it would otherwise be in equilibrium.

Efficiency ratios with respect to the first best equilibrium predictions for the modified experimental design sessions are reported in Table 20. Given that acceptance frequencies and quantities traded in our modified experimental design are higher with money than without

Session No., Treatment	Average q		Average d		Average Price	
	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All	1^{st}, 2^{nd} half	All
18, MM14	3.81, 2.87	3.31	3.48, 3.34	3.41	1.05, 1.18	1.11
19, MM14	3.92, 2.97	3.45	4.25, 4.90	4.57	1.14, 1.68	1.41
20, MM14	5.15, 3.83	4.59	4.65, 4.53	4.60	0.93, 1.04	0.98
21, MM14	4.98, 3.60	4.28	3.59, 3.79	3.69	0.94, 1.15	1.05
Avg. 18-21	4.48, 3.31	3.91	4.00, 4.16	4.08	1.01, 1.27	1.14
22, MNM14	1.40, 0.42	0.91	n/a	n/a	n/a	n/a
23, MNM14	1.50, 0.71	1.07	n/a	n/a	n/a	n/a
24, MNM14	1.96, 0.61	1.29	n/a	n/a	n/a	n/a
25, MNM14	2.17, 0.49	1.24	n/a	n/a	n/a	n/a
Avg. 22-25	1.75, 0.56	1.12	n/a	n/a	n/a	n/a
26, MNMNC14	1.92, 0.54	1.19	n/a	n/a	n/a	n/a
27, MNMNC14	1.37, 0.29	0.84	n/a	n/a	n/a	n/a
Avg. 26-27	1.66, 0.42	1.02	n/a	n/a	n/a	n/a

Table 19: Trade Average Offer Quantities and Prices, Each Session of the Modified Experimental Design

money, it should again come as no surprise that efficiency relative to the first best is higher in our modified design sessions with money (18-21) than in our modified design sessions without money (22-25) or (22-27) ($p \leq .02$ for the null of no difference using session-level observations on the welfare measure, two-sided tests). We summarize this main result from our modified experimental design as follows:

Finding 9 *Finding 7, that welfare is higher in economies with money than in economies without money continues to hold in the modified environment involving up to three rounds of bargaining and the same centralized trading post mechanism in the money and no money treatments.*

Further experimental findings involving our modified design and paralleling findings reported using the original designs can be found in Appendix B.

V. Conclusions and Suggestions for Further Research

Our main finding is that the efficiency of allocations is significantly higher in the Lagos-Wright environment with money than 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 environment we study. Since money can be thought as a particular type of social norm, our findings suggest that it is easier to coordinate on some social norms (such as money) than others (such as more efficient gift-giving social norms). A theory of money as a robust social norm is thus deserving of further investigation.

Session No., Treatment	Efficiency w.r.t. First Best Eq.	
	1^{st}, 2^{nd} half	All Periods
18, MM14	0.47, 0.40	0.44
19, MM14	0.53, 0.40	0.46
20, MM14	0.68, 0.43	0.55
21, MM14	0.61, 0.61	0.61
Avg. 18-21	0.58, 0.46	0.52
22, MNM14	0.29, 0.12	0.20
23, MNM14	0.30, 0.26	0.28
24, MNM14	0.25, 0.13	0.19
25, MNM14	0.17, 0.09	0.13
Avg. 22-25	0.25, 0.15	0.20
26, MNMNC14	0.29, 0.12	0.20
27, MNMNC14	0.22, 0.06	0.14
Avg. 26-27	0.25, 0.09	0.17

Table 20: Efficiency With Respect to the First Best, Each Session of the Modified Experimental Design

Our findings reveal that periodic access to centralized meetings does not suffice to achieve good allocations. Furthermore, the nature of the centralized meeting mechanism (call meeting, trading post or public good) or even its presence or absence in the no money treatment does not appear to matter for the behavior observed. 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 meeting so that $M_{t+1} = (1 + \mu)M_t$. In the case we study, of take-it-or-leave it offers in the decentralized meeting, 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, μ.

We leave these extensions to future research.

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Appendix A: Theoretical Predictions

Lagos-Wright Environment

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

Since the total money stock is fixed at M, we clearly have $\sum_{i=1}^{2N} m_t^i = M$ for all periods $t = 1, 2, ...$. Let ϕ_t denote the price of money in terms of the general good in the centralized meeting. Also, let $\varphi : A \twoheadrightarrow A$ be an exhaustive bilateral matching rule, so that no agent remains unmatched.[35]

In the first subperiod (decentralized meeting), agents are randomly (uniformly) and bilaterally matched and an agent is randomly chosen to be 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 (centralized meeting) agents decide on consumption and production of the general good and on their savings (or equivalently how much money to carry over to the next decentralized meeting 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 $V_t(m_t^i)$ the value function for an agent with m_t^i money holdings at the beginning of the decentralized meeting in period t. In a bilateral match where the consumer has m money holdings and the producer has $\widetilde{m}$ money holdings, $q_t(m, \widetilde{m})$ and $d_t(m, \widetilde{m})$ 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_{t+1}^i consumption of the general good, production of the general good and savings, respectively.
Then

$$V_t(m_t^i) = \underset{X_t, Y_t, m_{t+1}^i}{Max} \left\{ \tfrac{1}{2} \sum_{j \neq i} \left[u(q_t(m_t^i, m_t^j) + X_t^c - Y_t^c + \beta V_{t+1}\left(m_{t+1}^i\right) \right] \Pr\left(\varphi(i) = j\right) \right.$$
$$\left. + \tfrac{1}{2} \sum_{j \neq i} \left[-c(q_t(m_t^j, m_t^i) + X_t^p - Y_t^p + \beta V_{t+1}\left(m_{t+1}^i\right) \right] \Pr\left(\varphi(i) = j\right) \right\},$$

subject to the budget constraints associated with the centralized meeting:

$$X_t^c = Y_t^c + \phi_t(m_t^i - d_t(m_t^i, m_t^j) - m_{t+1}^i),$$
$$X_t^p = Y_t^p + \phi_t(m_t^i + d_t(m_t^j, m_t^i) - m_{t+1}^i),$$
$$X_t^c, X_t^p, Y_t^c, Y_t^p, m_{t+1}^i \geq 0.$$

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

[35] An exhaustive bilateral matching rule is simply a function $\varphi : A \twoheadrightarrow A$ such that $\varphi(\varphi(a)) = a$ and $\varphi(a) \neq a$, for all $a \in A$. See also Aliprantis, Camera, and Puzzello, "ACP" (2007ab).

$$V_t(m_t^i) = \left\{ \frac{1}{2}\sum_{j\neq i} \left[u(q_t(m_t^i, m_t^j) - \phi_t d_t(m_t^i, m_t^j)\right] \Pr\left(\varphi(i) = j\right) \right.$$
$$\left. +\frac{1}{2}\sum_{j\neq i} \left[-c(q_t(m_t^j, m_t^i)) + \phi_t d_t(m_t^j, m_t^i)\right] \Pr\left(\varphi(i) = j\right) \right\} + \phi_t m_t^i$$
$$+\underset{m_{t+1}^i}{Max}\left\{-\phi_t m_{t+1}^i + \beta V_{t+1}\left(m_{t+1}^i\right)\right\}.$$

We can now determine the terms of trade in the decentralized meeting, which will allow us to further simplify the expression for $V_t(m_t^i)$. As in Lagos and Wright (2005), 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 of the bargaining power.[36] Thus, given the linearity, the terms of trade (q_t, d_t) must solve the following constrained optimization problem:

$$\begin{array}{l} \underset{q_t, d_t}{Max}\left[u(q_t) - \phi_t d_t\right] \\ \text{s.t. } d_t \leq m_t,\ q_t \geq 0 \end{array}.$$

The solution to this optimization problem is given by:

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

That is, if the consumer carries over to the decentralized meeting at least $\frac{c(q^*)}{\phi_t}$ money holdings, then he gets q^* in exchange 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 $-c(q_t(m_t, \widetilde{m}_t)) + \phi_t d_t(m_t, \widetilde{m}_t) = 0$. This allows us to further simplify the value function:

$$V_t(m_t^i) = \tfrac{1}{2}\left[u(q_t(m_t^i) - \phi_t d_t(m_t^i)\right]$$
$$+\phi_t m_t^i + \underset{m_{t+1}^i}{Max}\left\{-\phi_t m_{t+1}^i + \beta V_{t+1}\left(m_{t+1}^i\right)\right\}.$$

By repeated substitution, we obtain that the amount of money carried over from the centralized to the decentralized meeting (or savings), m_{t+1}^i, solves a sequence of simple static optimization problems:

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

[36]Note that the take-it-or-leave-it offer implies higher allocative efficiency among the class of Nash bargaining trading protocols.

This savings choice is governed by trading off the benefit (the liquidity return to money) given by $\beta\frac{1}{2}\left[u(q_{t+1}(m^i_{t+1}) - \phi_{t+1}d_{t+1}(m^i_{t+1})\right]$ with the cost of holding money $-(\phi_t - \beta\phi_{t+1})m^i_{t+1}$ 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 that the solution is unique and thus the distribution of money holdings is degenerate at $\frac{M}{2N}$.

A monetary equilibrium is any path $\{q_t\}_{t=1}^{\infty}$ with $q_t \in (0, q^*)$ such that

$$\frac{u'(q_{t+1})}{c'(q_{t+1})} = 1 + \frac{\frac{c(q_t)}{c(q_{t+1})} - \beta}{\frac{\beta}{2}}.$$

Furthermore, the steady state (or stationary equilibrium) is unique, and the steady state condition is given by

$$\frac{u'(\widetilde{q})}{c'(\widetilde{q})} = 1 + \frac{1-\beta}{\frac{\beta}{2}}.$$

Each individual's demand for money is $M^D = \frac{c(\widetilde{q})}{\phi}$. The aggregate demand for money is therefore $2N\frac{c(\widetilde{q})}{\phi}$, and since the money supply is equal to M, the equilibrium price of money in the steady state is $\phi = \frac{c(\widetilde{q})}{\frac{M}{2N}}$. Note that $\widetilde{q} < q^*$ since $\beta < 1$, and that $\widetilde{q} \to q^*$ as $\beta \to 1$. Also, the monetary steady state value function is given by

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

Social Norms in the Lagos-Wright Environment

Under our parameterization choice, the first best can be supported as a sequential equilibrium under the decentralized social norm. In particular, conditions (1) and (2) in the paper are satisfied for $q^* = 6$ when $2N = 6$ and $2N = 14$, respectively:

I. $2N = 6$

Condition (1) simplifies to:

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

$$-6 + 5\frac{1}{2}\left[7\ln 7 - 6\right] \geq 2.12 * \frac{1}{2}7\ln 7 - \frac{1}{2}7\ln 7, \text{ or}$$

$$13.053 \geq 2.12 * 6.81 - 6.81, \text{ or}$$

$$13.053 \geq 7.627.$$

Condition (2) simplifies to:

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

$$-6 + 1.344 * 6.81 - \frac{4}{5} * 6.81 \leq 0.84 * 6.81 - \frac{3}{5} 6.81, \text{ or}$$

$$-3.929\,8 \leq 0.$$

II. $2N = 14$

Condition (1) simplifies to:

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

$$-6 + 5\frac{1}{2}\left[7 \ln 7 - 6\right] \geq 2.798 * \frac{1}{2} 7 \ln 7 - \frac{1}{2} 7 \ln 7, \text{ or}$$

$$-6 + 5\frac{1}{2} 7.\,621\,4 \geq 1.798 \frac{1}{2} 7 \ln 7, \text{ or}$$

$$13.053 \geq 12.246.$$

Condition (2) simplifies to:

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

$$-6 + 2.158 * 6.81 - \left(\frac{12}{13}\right) 6.81 \leq 1.739 * 6.81 - \left(\frac{11}{13}\right) 6.81, \text{ or}$$

$$-6 + 14.69 - 6.\,286\,2 \leq 11.843 - 5.762, \text{ or}$$

$$2.403 \leq 6.081, \text{ or}$$

$$-3.678 \leq 0.$$

The largest population size under which both conditions (1) and (2) are satisfied is $2N = 16$. We did not pick the largest population size compatible with these conditions. Instead, we chose as our upper bound the next largest population size, namely $2N = 14$, which we consider a more appropriate choice, as it is avoids the case where conditions (1) and (2) are barely satisfied by the chosen parameters.

Similar computations were conducted to find the lowest quantity q, that satisfies these inequalities and these are reported in Tables 1 and 17 of the paper.

Centralized Social Norms in the No Money Environment

Here we report the computations used to find the equilibrium range of values for q, as reported in Table 1 of the paper. We used equations (3) and (4) of the paper. Observe that if $c(q) \geq L/2N$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\beta} = \frac{\frac{2N-2}{2N}L+c(q)}{\frac{2N-2}{2N}L+c(q)+\frac{1}{2}[u(q)-c(q)]}$, while if $c(q) < L/2N$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\underline{\beta}} = \frac{\frac{2N-1}{2N}L}{\frac{2N-1}{2N}L+\frac{1}{2}[u(q)-c(q)]}$.

Given our parameterization with $L = 1$, we then have the following:

I. $2N = 6$

If $q \geq 1/6$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\beta} = \frac{\frac{4}{6}+q}{\frac{4}{6}+q+\frac{1}{2}[7\ln(1+q)-q]}$. It is easy to check that $\underline{\beta} \leq \frac{5}{6}$ is always satisfied for $q \geq 1/6$.

If $q < 1/6$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\underline{\beta}} = \frac{\frac{5}{6}}{\frac{5}{6}+\frac{1}{2}[7\ln(1+q)-q]}$. It is easy to check that $\underline{\underline{\beta}} \leq \frac{5}{6}$ is satisfied for $q \geq 0.058$.

Thus, given $\beta = \frac{5}{6}$, any $q \in [0.058, 6]$ can be supported as a sequential equilibrium for $2N = 6$.

II. $2N = 14$

If $q \geq 1/14 \approx 0.072$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\beta} = \frac{\frac{12}{14}+q}{\frac{12}{14}+q+\frac{1}{2}[7\ln(1+q)-q]}$. It is easy to check that $\underline{\beta} \leq \frac{5}{6}$ is always satisfied for $q \geq 1/14$.

If $q < 1/14$, $Max\{\underline{\beta}, \underline{\underline{\beta}}\} = \underline{\underline{\beta}} = \frac{\frac{13}{14}}{\frac{13}{14}+\frac{1}{2}[7\ln(1+q)-q]}$. It is easy to check that $\underline{\underline{\beta}} \leq \frac{5}{6}$ is never satisfied for $q < 1/14$.

Thus, given $\beta = \frac{5}{6}$ any $q \in [0.072, 6]$ can be supported as a sequential equilibrium for $2N = 14$.

Theoretical Predictions in Environments with a Trading Post

This section provides details for the theoretical predictions associated with the environments where trade in the centralized meeting is arranged via a trading post as in our modified experimental design.

Sequential Equilibrium Outcomes in the Environment with a Trading Post and No Money

We represent strategy profiles by means of automata, as they allow to us to group histories into equivalence classes associated with the states of the automata therefore allowing us to discuss strategies in a more compact way. Furthermore, it is possible to show that automata induce strategies and, conversely, any strategy profile can be represented by an automaton (see Mailath and Samuelson (2006) for a discussion of automaton representations of strategy profiles).

Next we show that there exists an equilibrium that sustains positive production and consumption (including the first–best) if agents are sufficiently patient. Let $0 < q \leq q^*$. We can define as {yes, no} the action sets of agents in the decentralized meeting, where yes is identified with accepting a proposal of amount q. If both agents in a meeting say yes, q is produced and consumed. If at least one agent says no, then no production or consumption takes place in that meeting. The action set in the centralized meeting consists of the set $\left\{(y,b) \in \left[0,\overline{Y}\right]^2 : b \leq y\right\}$. Define σ^* to be the strategy profile in which an agent behaves according to the following automaton. The set of states is $W = \{C, D, A\}$ and the initial state is C. Intuitively, C stands for cooperation, D for defection, and A for autarky. The decision rules for decentralized and centralized meetings are given by

$$f_1(w) = \begin{cases} \text{yes} & \text{if} \quad w \in \{C, D\} \\ \text{no} & \text{if} \quad w = A \end{cases} \quad \text{and} \quad f_2(w) = \begin{cases} (x,x) & \text{if} \quad w = C \\ (x,0) & \text{if} \quad w = D \\ (0,0) & \text{if} \quad w = A \end{cases}$$

where $0 < x \leq \overline{Y}$. For instance, an agent in state C behaves as follows. In the decentralized meeting, he agrees to trade. In the centralized meeting he contributes production x to the trading post and then bids for amount x at the trading post. The transition rules are given by

$$\tau_1(w, a_1, a_1') = \begin{cases} C & \text{if} \quad w = C \text{ and } (a_1, a_1') = (\text{yes}, \text{yes}) \\ D & \text{if} \quad w = C \text{ and } (a_1, a_1') \neq (\text{yes}, \text{yes}) \\ w & \text{if} \quad w \in \{D, A\} \end{cases}$$

and

$$\tau_2(w, a_2, p) = \begin{cases} C & \text{if} \quad w \in \{C, D\} \text{ and } p \in \{1, \frac{N-2}{N}\} \\ A & \text{if} \quad w \in \{C, D\} \text{ and } p \notin \{1, \frac{N-2}{N}\} \text{ or } w = A \end{cases},$$

where $p^D = \frac{(N-2)}{N}$ is the price vector in the centralized meeting when $(N-2)$ agents are in state C and the two remaining agents are in state D. For instance, an agent in state C in the decentralized meeting remains in state C only if trade takes place in his match, otherwise he moves to state D. Likewise, an agent in state C in the centralized meeting stays in C if the price he observes belongs to $\{1, \frac{N-2}{N}\}$, otherwise he moves to state A.

Let V_{DM}^* and V_{CM}^* denote the equilibrium value functions (associated with $q > 0$) at the beginning of the decentralized and centralized meetings, respectively. Then

$$V_{DM}^* = \frac{1}{1-\beta}\frac{1}{2}\left(u(q) - c(q)\right) \text{ and } V_{CM}^* = \frac{\beta}{1-\beta}\frac{1}{2}\left(u(q) - c(q)\right) = \beta V_{DM}^*.$$

Let V_{CM}^D denote the (off-equilibrium) value function at the beginning of the centralized meeting when the state is D. Then

$$V_{CM}^D = -x + \beta V_{DM}^*.$$

Note also that in the autarkic state, $V_{CM}^A = V_{DM}^A = 0$.

Now let μ^* be the belief system such that: (i) an agent in state C believes that all other agents are in state C; (ii) an agent in state A believes that all other agents are in state A; (iii) an agent in state D believes that there exists one other agent in state D and the remaining agents are in state C. Clearly, (σ^*, μ^*) is a consistent assessment and σ^* implements the first–best. We have the following result.

Proposition 1 *Let $q > 0$ be a positive amount of production and consumption in the decentralized meeting. Suppose that $c(q) \leq x$, where $0 < x \leq \overline{Y}$. Then there exists a $\delta' \in (0,1)$ such that (σ^*, μ^*) is a sequential equilibrium for all $\delta \geq \delta'$.*

A sketch of the proof is as follows. Consider first an agent in state C in the decentralized meeting. If he is a producer, his flow payoff gain from a one–shot deviation is $c(q)$. However, in the centralized meeting that immediately follows, he exerts effort x and receives 0. Since $c(q) \leq x$ by assumption, the one–shot deviation is not profitable.

Consider now an agent in state C in the centralized meeting. First note that no one-shot deviation leading to $p \in \{1, \frac{N-2}{N}\}$ is profitable. Since any one–shot deviation with $p \notin \{1, \frac{N-2}{N}\}$ triggers permanent autarky, we can then conclude that no one–shot deviation is profitable if the agent is patient enough.

To sum up, on the equilibrium path, agents do not deviate from σ^* in decentralized meetings since a deviation triggers a within-period punishment in the following centralized meeting (agents in state D in the centralized meeting produce x for the post and they get nothing since they bid 0), which in its turn is sustained by the threat of autarky. Similarly, a deviation in the centralized meeting would trigger autarkic behavior.

To finish, we need to show that behavior off the path of play is credible. It is immediate to see that no agent in state A has an incentive to deviate. It is also immediate to see that no agent is ever in state D in the decentralized meeting. Consider then an agent in state D in the centralized meeting. First, it is possible to show that no one-shot deviation which leads to a price vector $p \in \{1, \frac{N-2}{N}\}$ is profitable. Since any one–shot deviation with $p \notin \{1, \frac{N-2}{N}\}$ triggers permanent autarky, we can then conclude that no one–shot deviation is profitable if agents are patient enough.

Thus no agent has an incentive to deviate from σ^* off-the equilibrium path since either a deviation in the centralized meeting would trigger autarky or autarkic behavior is a best response to autarky.

Proof of Proposition

Let V^*_{DM} and V^*_{CM} be the (discounted) lifetime payoffs to an agent in state C before he enters the decentralized and centralized meetings, respectively. Then,

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

Now let V^A_{CM} and V^A_{DM} be the lifetime payoffs to an agent in state A. It is easy to see that $V^A_{CM} = V^A_{DM} = 0$. Finally, let V^D_{CM} be the lifetime payoff to an agent in state D before he enters the centralized meeting. Since an agent in state D in the centralized meeting believes that there are $(N-2)$ agents in state C and one other agent in state D, he believes that the price vector in the centralized meeting will be $\frac{N-2}{N}$. Thus,

$$V^D_{CM} = -x + \frac{0}{\frac{N-2}{N}} + \beta V^*_{\text{DM}} = -x + \beta V^*_{\text{DM}}.$$

We start with incentives in state C. An agent in state C in the decentralized meeting has no profitable one–shot deviation if

$$-c(q) + V^*_{\text{CM}} = -c(q) + \beta V^*_{\text{DM}} \geq -x + \beta V^*_{\text{DM}},$$

which is satisfied since $c(q) \le x$. Consider then an agent in state C in the centralized meeting. Let $a_2 = (y, b) \neq (x, x)$ be the agent's action and denote the corresponding price by p. First, we show that there exists no profitable one–shot deviation by the agent when a_2 is such that $p = 1$. It is immediate to see that $p = 1$ if, and only if, $b = y$. Thus, when $a_2 \neq (x, x)$ and $p = 1$, the agent's flow payoff is 0 which is the same payoff he gets if he chooses (x, x). Since $p = 1$, the continuation payoff is the same. Therefore, there is no profitable one-shot deviation where a_2 is such that $p = 1$. It is easy to check that a deviation where a_2 is such that $p = \frac{N-2}{N}$ is not profitable since it would lead to a lower flow payoff ($-\frac{2x(N-1)}{N-2} < 0$) and the same continuation payoff. It is also easy to see that he has no profitable one–shot deviation when a_2 is such that $p \notin \{1, \frac{N-2}{N}\}$. In that case, an agent would get a lower flow payoff (since b/p is increasing in b) and also a lower continuation payoff since he would trigger autarky. So there is no profitable one-shot deviation.

Next, consider incentives in state D. Given σ^*, an agent is never in state D at the beginning of the decentralized meeting. Consider an agent in state D in the centralized meeting. Let $a_2 = (y, b) \neq (x, 0)$ be the agent's action and denote the corresponding price by $\widetilde{p}^D$. That is, $\widetilde{p}^D = \frac{(N-2)x+b}{(N-1)x+y} < 1$. We need to consider two kinds of deviations: $\widetilde{p}^D = \frac{N-2}{N}$ or $\widetilde{p}^D \neq \frac{N-2}{N}$. In order for $\widetilde{p}^D = \frac{N-2}{N}$, it should be the case that $b = \frac{N-2}{N}(y-x)$. However, such a deviation would lead to the flow payoff since $\frac{b}{\frac{N-2}{N}} - y = -x < 0$, which is not profitable. We next show that if agents are patient enough, a one-shot deviation with $\widetilde{p}^D \neq \frac{N-2}{N}$ is also not profitable. It is easy to check that $\frac{b}{\widetilde{p}^D}$ is increasing in b, therefore $b = y$. Given this, $\frac{y}{\widetilde{p}^D} = \frac{y}{\frac{(N-2)x+y}{(N-1)x+y}}$ is increasing in y, so the best deviation for an agent entails $b = y = \overline{Y}$. Furthermore, recall that $\widetilde{p}^D \neq \frac{N-2}{N}$ triggers autarky. Thus a one-shot deviation is not profitable if

$$-x + \beta V^*_{\text{DM}} \ge -\overline{Y} + \frac{\overline{Y}}{\frac{(N-2)x+\overline{Y}}{(N-1)x+\overline{Y}}} + 0 = \frac{x\overline{Y}}{(N-2)x+\overline{Y}}.$$

That is, after substituting appropriately for the value functions,

$$\beta \ge \frac{\frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}}{\frac{1}{2}\left[u(q)-c(q)\right] + \frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}}. \tag{5}$$

To finish, since state A is absorbing and involves no trade in both the decentralized and centralized meetings, it is immediate to see that no one–shot deviation is profitable in this state. We can then conclude that (σ^*, μ^*) is an equilibrium as long as

$$\beta \ge \frac{\frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}}{\frac{1}{2}\left[u(q)-c(q)\right] + \frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}} = \underline{\beta}. \quad \blacksquare$$

This strategy is a modified version of the one proposed by Araujo et al. (2012) in the linear case.[37] Given our parameterization, the strategy developed in Araujo et al. (2012) would

[37] The strategy discussed by Araujo at al. (2012), however, does not support the first best as a sequential equilibrium given our parameterization. Thus, we have modified it appropriately.

not support the first best as a sequential equilibrium, since the strategy above would not be an equilibrium for $x = \overline{Y}$ (given $\beta = \frac{5}{6}$, expression 5 implies that the highest x under which the strategy above supports the first best as a sequential equilibrium is $x = 17.40$). The lowest discount factor under which positive amounts $q > 0$ can be supported as sequential equilibria is increasing in x, which in turn should satisfy $x \geq c(q)$. Thus, the lowest discount factor under which a positive amount $q > 0$ can be supported as a sequential equilibrium obtains when $x = c(q)$ or $x = q$, given our linearity assumption for $c(q)$. Thus, given our parameterization, the lowest discount factor under which the first best can be supported as a sequential equilibrium is obtained when $x = 6$ and it is equal to $\underline{\beta}_{14}^{CM} = 0.66 < \underline{\beta}_{14}^{DM} = 0.8256$.

Furthermore, since $\underline{\beta} = \frac{\frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}}{\frac{1}{2}[u(q)-c(q)]+\frac{2x\overline{Y}+(N-2)x^2}{(N-2)x+\overline{Y}}}$ is decreasing in $x = q$, under our parameterization, using de l'Hôpital's rule one can show that as $q \to 0$, we have $\underline{\beta} \to 0.4$, and since $0.4 < 5/6$ any positive quantity $0 < q \leq 6$ can be supported as a sequential equilibrium.[38]

Monetary Equilibrium

We focus on a modified version of the Lagos-Wright model where trade in the centralized meeting is arranged via a trading post. Time is discrete and denoted by $t = 1, 2, ...$ The centralized meeting is modeled as a single trading post where money is exchanged for the general good. Agents place bids in terms of fiat money. Each agent's bid cannot exceed his money holdings in the centralized meeting, i.e., for all agents i and each period t, $0 \leqslant b_{it} \leqslant m_{it}^{CM}$.

Let b_{it} denote the bid of agent i in period t in terms of fiat money, and y_{it} the amount of the general good that agent i produces for the trading post. When both the total money bids and the total good contributions are strictly positive, the price is given by $p_t = \frac{\sum b_{jt}}{\sum y_{jt}}$. For all i, consumption in the centralized meeting is determined as follows:

$$X_{it} = \begin{cases} b_{it}\frac{\sum y_{jt}}{\sum b_{jt}} & \text{if} \quad \sum y_{jt} \neq 0 \text{ and } \sum b_{jt} \neq 0 \\ 0 & \text{otherwise} \end{cases}$$

Money holdings are updated as follows

$$m_{it+1}^{DM} = \begin{cases} m_{it}^{CM} + \frac{\sum b_{jt}}{\sum y_{jt}} y_{it} - b_{it} & \text{if} \quad \sum y_{jt} \neq 0 \text{ and } \sum b_{jt} \neq 0 \\ m_{it}^{CM} & \text{otherwise} \end{cases}$$

Note that the price formation mechanism guarantees that demand is equal to supply.

[38] We note that quantities higher than the first best can be supported as sequential equilibria, but we do not incorporate these in the analysis since they are not economically relevant.

The optimization problem in the centralized meeting can be written as follows:

$$\begin{aligned} W_t(m_t) &= \underset{b_t, m_{t+1}, y_t}{Max} \left[U\left(\frac{b_t}{p_t}\right) - y_t + \beta V(m_{t+1}) \right] \\ s.t. \; m_{t+1} &= m_t + p_t y_t - b_t \end{aligned}$$

and, as the population grows large (or as agents act as price takers), we get the same solution as in Lagos and Wright (2005).

Appendix B: Additional Experimental Findings

In the paper we reported on the main finding from our modified experimental design, Finding 9 that welfare is significantly higher in the environment with money than in the environments without it. In this appendix we report on some other findings using the data from our modified experimental design (sessions 18–27) as described in Table 16 of the paper. These results are organized as a number of different findings.

First, paralleling Finding 2 for the original design we have:

Finding 10 *In the modified design, proposals are less likely to be accepted as the quantity requested increases. In the modified money treatment, proposals are more likely to be accepted the higher the number of tokens or the better the terms of trade offered.*

Support for finding 10 comes from Table 21 which reports on a regression analysis similar to that reported in Table 4 for the original design. Under the modified design, both producers and consumers could accept offers depending on the round of bargaining reached up to a maximum of three rounds. Here we focus on the final decision made, either accept or reject, by either the consumer or the producer as a function of the final quantity q and (in the money session) the final token amount d that was "on the table" when a decision to reject or accept was made. The probit regression analysis as reported in Table 21 has dependent variables that are as described in the paper for Table 4. Note that the dummy variable M14 here refers to the four sessions of the modified design where there was money (sessions 18-21) and the new dummy variable NMNC, took on a value of 1 if there was no money *and* no centralized meeting stage as in sessions 26-27 and it was 0 otherwise.

Similar to the findings of Table 4, we find that the introduction of money leads to a significant increase in acceptance frequencies as indicated by the positive and significant coefficient on the dummy variable M14 in the first regression specification using data from all sessions of our modified experimental design. As in our first design, the likelihood that an offer is accepted is decreasing in the period number and in the final quantity proposed, q. In the money treatment sessions, proposals are more likely to be accepted the greater is the amount of tokens offered, d, or the greater terms of trade, d/q. Differently from the first experimental design we find that for our modified design, neither the grim nor the HLscore dummy variables are significant in any regression specification. We attribute this difference to the additional number of bargaining rounds that were present in our modified design.

Next, paralleling Finding 3 and Table 6 of the paper we report a regression analysis of some potential determinants of accepted offers in the decentralized meeting of our modified experimental design in Table 22. The variables are the same as in Table 6 except that we have added the dummy variable NMNC for the two no money sessions (26-27) that don't have a centralized meeting stage and we have also added the number of rounds of bargaining, "RoundsB" before an agreement was struck.

The main finding comes from the first column of Table 22 where we observe that the presence of money has a large impact on accepted quantities raising it from a baseline of 1.81 units to an additional 3.25 units for a sum of 5.06 units. This amount is eroded over time by the period number which largely accounts for the average quantity in the MM14 sessions being just 3.91. Notice however, that traded quantities are increasing (by a small

	Dependent Variable, Accept=1, Reject=0			
	All Sessions	NM Sessions	M Sessions (1)	M Sessions (2)
Constant	0.466	1.817***	0.518	-0.437***
	(0.486)	(0.446)	(0.338)	(0.181)
NMNC	-0.098	0.265*		
	(0.186)	(0.147)		
M14	0.962***			
	(0.378)			
NewSeq	0.345***	0.340*	0.567***	0.520***
	(0.113)	(0.182)	(0.124)	(0.113)
Period	-0.024***	-0.079***	-0.033*	-0.040*
	(0.008)	(0.010)	(0.019)	(0.025)
Grim	0.050	0.020	0.143	0.337
	(0.139)	(0.177)	(0.221)	(0.334)
HLscore	-0.016	-0.030	0.024	0.010
	(0.063)	(0.026)	(0.034)	(0.030)
q	-0.167**	-0.776***	-0.152***	
	(0.077)	(0.177)	(0.045)	
d			0.122**	
			(0.062)	
d/q				1.244***
				(0.253)
m_p			0.015***	0.016***
			(0.004)	(0.005)
m_c			-0.008	-0.041*
			(0.021)	(0.027)
No. obs.	1,449	889	560	541
Log Likl.	-919.99	-486.8	-360.6	-283.2

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 21: Probit Regression Analysis of Proposal Acceptance Decisions in the Modified Design

	All Sessions	M Sessions Only
Dependent Variable:	q	d/q
Constant	1.815***	0.537*
	(0.610)	(0.316)
M14	3.251***	
	(0.278)	
NMNC	-0.189**	
	(0.090)	
NewSeq	0.283	-0.039
	(0.235)	(0.052)
Period	-0.050***	0.032***
	(0.007)	(0.012)
RoundsB	0.166***	0.011
	(0.053)	(0.078)
Grim	-0.214	0.001
	(0.191)	(0.087)
HLscore	-0.144*	0.032
	(0.086)	(0.027)
m_c		0.022**
		(0.009)
m_p		-0.010**
		(0.004)
No. obs.	1,245	350
R^2	.520	.132

*, **, ***, indicate significance at the: 10%, 5%, 1% significance levels.

Table 22: Random Effects, GLS Regression Analysis of Accepted Proposals in the Modified Design

amount, 0.166), in the number of rounds of bargaining, and that over all sessions, a higher Holt–Laury score (indicating greater risk aversion) is marginally significant in reducing the quantity agreed upon for exchange purposes. Note finally that the absence of a centralized meeting opportunity has a small negative impact on the quantity traded as indicated by negative and significant coefficient on the NMNC dummy variable. As for the modified money treatment sessions alone (the second column of Table 22) we observe that the number of rounds of bargaining does not seem to matter for the terms of trade d/q, which are increasing in the period number and in the amount of money that the consumer has on hand and decreasing slightly with the amount of money the producer has on hand. No other variables are significant in explaining accepted terms of trade. We summarize the main findings as follows:

Finding 11 *In the modified design, quantities exchanged are higher with money than without money. Quantities exchanged are also increasing with the number of rounds of bargaining. Finally, the absence of a centralized meeting opportunity results in a small decrease in the quantity exchanged relative to the baseline, no money treatment with a centralized meeting opportunity.*

We next focus on behavior in the centralized meeting stage of our modified experimental design. Table 23 reports participation rates, centralized meeting prices and trade volume for both the modified money and no money sessions that made common use of the same trading post mechanism to determine the price of the homogeneous good.

Session No., Treatment	Particp. Rate	Avg. Centralized Mtg. Price			Avg. Centralized Mtg. Volume		
		1^{st} half	2^{nd} half	All Periods	1^{st} half	2^{nd} half	All Periods
18, MM14	0.90	1.83	1.58	1.70	27.70	25.07	26.32
19, MM14	0.79	1.63	2.48	2.08	32.39	18.25	24.98
20, MM14	0.83	2.46	2.82	2.64	20.21	12.33	16.27
21, MM14	0.97	2.18	1.73	1.95	25.18	21.77	23.48
Avg. 18-21	0.87	2.03	2.16	2.10	26.34	19.33	22.75
22, MNM14	0.83	0.97	0.99	0.98	71.47	95.68	84.10
23, MNM14	0.69	0.98	0.97	0.98	80.18	88.56	84.37
24, MNM14	0.72	0.99	1.00	0.99	116.16	132.83	124.50
25, MNM14	0.86	0.98	0.99	0.99	135.49	180.92	158.20
Avg. 22-25	0.77	0.98	0.99	0.98	100.02	122.56	111.42

Table 23: Participation Rates, Prices and Volume in the Centralized Trading Post of the Money and No Money Sessions of the Modified Design.

We observe that decentralized social norm equilibria, where the centralized meeting is completely avoided, are not selected; participation rates in the centralized trading post meeting were high, averaging 87 percent in the modified money (MM14) sessions and 77 percent in the modified no-money (MNM14) sessions. Using the session level averages reported in

Table 23 a Mann-Whitney test reveals no difference in these participation rates between the MM14 and MNM14 treatments ($p = .19$, two-sided test).[39]

Similarly high participation rates in the centralized meeting, averaging 73 percent, were found for the M14 (money) sessions of the Lagos Wright treatment of our experiment. Indeed, rates of participation in the centralized meeting are indistinguishable between the M14 and MM14 sessions ($p = .25$, two-sided Mann-Whitney test using session-level data from Table 8 in the paper and Table 23). What is different is the high participation rate in the centralized meeting by subjects in the *no money* treatment of the modified experimental design. When the centralized meeting involved the public good mechanism, as in the ACP, no money treatment of our experiment, nearly all subjects learned to contribute zero toward the public good. However, in the modified no money treatment where the centralized meeting involves a trading post mechanism, production and bids for the centralized good are considerably higher. We attribute this finding to differences in the two centralized mechanisms. Under the trading post mechanism of our modified design, if subjects placed bids for good X that were equal to their production of good X, they could always avoid getting a negative payoff (and indeed this is what many subjects chose to do). By contrast, under the binary choice public good centralized mechanism used in the ACP no money treatment of our experiment, agents could earn a negative payoff if they chose to contribute and one or more of the other agents did not. We note that despite these differences, there is no appreciable impact on decentralized trading behavior or on overall welfare.

While the trading post mechanism was held constant, the price and trade volume predictions depend on whether there was money or not. Recall that the monetary equilibrium prediction (in the money treatment) is for a price of 2 and for a trade volume of $4N$, or 28 when $2N = 14$; the latter prediction is the same for the original design involving the Walrasian call market mechanism. The social norm equilibrium prediction for the no-money treatment in the case where the centralized meeting *is* used as a signaling device calls for a price of 1 and allows for any contribution between $c(q) * 2N$ (where $c(q)$ is approximately 1 in the experimental data) and less than or equal roughly to $x * 2N$ where x should satisfy $\frac{\frac{44x+12x^2}{12x+22}}{\frac{1}{2}[7\ln(1+q)-q]+\frac{44x+12x^2}{12x+22}} = \underline{\beta} \leq \frac{5}{6}$.[40] For the MM14 treatment, we find that the mean meeting price of 2.10 is slightly greater than 2, while the mean trade volume of 22.75 units is somewhat less than 28; nevertheless both means are surprisingly close to the monetary equilibrium prediction. For the MNM14 treatment, we find that the mean meeting price of .99 is only slightly less than 1 and trade volume is close to equilibrium predictions. The small departures, especially in prices, might be attributed to less than full participation by all 14 subjects in the centralized meeting which may also account for the lower than equilibrium quantities being bought and sold in the money (MM14) treatment.

In the money (M14) treatment of the original design involving a Walrasian call market, the price in the centralized meeting was also around 2, as reported in Table 8 of the paper. Indeed, a Mann-Whitney test on the session-level centralized meeting price observations (over

[39] As in the analysis of the money and no money treatments in the paper, participation here refers to the submission of an offer to sell and/or a bid to buy units of the homogeneous good.

[40] For instance, for $q = 1.12$ then $\underline{\beta} = \frac{\frac{44x+12x^2}{12x+22}}{\frac{1}{2}(7\ln(2.12)-1.12)+\frac{44x+12x^2}{12x+22}} \leq \frac{5}{6}$ for $x \leq 8.83$. See Appendix A for details.

all rounds) reveals no difference in prices as determined by the Walrasian mechanism of the original money treatment (M14) design or by the trading post mechanism of the modified money treatment (MM14) design (p = .56, two-sided test). Thus there is some evidence that the centralized meeting mechanism is not so important to price determination in the centralized meeting stage. On the other hand we do find that trade volume is significantly greater and closer to the equilibrium prediction of 28 in the modified money treatment design as compared with the original money treatment design, (p = .02, two-sided test.) Summarizing, we have

Finding 12 *In the modified experimental design, there is active participation in the centralized meeting trading post mechanism regardless of whether or not there exists any money. Meeting prices and trade volume are close to or consistent with equilibrium predictions.*

We note further that the active participation and positive trade volume in the centralized meeting of the modified no money experimental treatment (MNM14 sessions 22-25) stands in sharp contrast to the near unanimous decision to contribute zero units toward the public good X in the centralized meeting of the no money treatment (NM14) of our first experiment. Nevertheless, the use of the centralized meeting as a mechanism to signal cooperative behavior does not seem to have resulted in a large quantity of exchange in the decentralized meeting of our modified experimental design.

Finally, we consider again whether subjects in our modified money treatment (MM14 sessions) were using the centralized meeting to re-balance their money holdings. Consistent with finding 7 in the paper we have:

Finding 13 *In the modified money treatment with* $2N = 14$*, the distribution of money holdings at the end of the centralized meeting round is not degenerate. However, we again find evidence that subjects are using the centralized meeting to re-balance their money holdings.*

Support for Finding 13 is found in Figures 4-5 and in Table 24. Figure 4 (like Figure 1 of the paper) shows the distribution of token (money) holdings following the completion of the centralized meeting. Here again we first averaged each subjects' token holdings as of the end of each centralized meeting round over the first and over the second halves of each modified money treatment session. These averages were then rounded up to the nearest token. Figure 4a presents a histogram of these average token holdings while Figure 4b shows the cumulative distribution function (CDF) of these token holdings. Consistent with our findings in the first experiment, Figure 4 reveals that the distribution of money holdings following the centralized meeting is not degenerate at 8 tokens. Using the data illustrated in Figure 4, a two-sided Kolmogorov–Smirnov test indicates that the CDF of money holdings for either the first or second halves of the sessions are both significantly different from the CDF associated with a degenerate distribution of money holdings at 8 tokens ($p < .01$ for both one-sample tests). Nevertheless, mean money holdings are centered around 8 tokens in both the first and second halves of the money sessions.

Further, we again find that subjects used the centralized trading post to re-balance their money holdings (token positions). Figure 5, (which parallels the construction of Figures 2-3 in the paper) and Table 24 (which parallels Table 9 of the paper) provide evidence for

	Dependent variable: $\Delta_{CM}m$			
Treatment,	MM14	MM14	MM14	MM14
Sess. No.	1	2	3	4
Cons	0.000	0.000	0.000	0.013
	(0.216)	(0.281)	(0.212)	(0.202)
$\Delta_{DM}m$	-0.294***	-0.443***	-0.727***	-0.759***
	(0.090)	(0.055)	(0.058)	(0.070)
R^2	0.040	0.178	0.359	0.298

*** indicates significance at the 1% significance level.

Table 24: Regression Evidence of Re-balancing in the Centralized Meeting: Coefficient Estimates and (Standard Errors) from a Regression of $\Delta_{CM}m$ on a Constant and $\Delta_{DM}m$ for each Modified Money Treatment (MM14) Session

this re-balancing. Figure 5 shows for each of the four modified money (MM14) treatment sessions a plot of the change of each individual subjects' money holdings at the end of each decentralized meeting round, $\Delta_{DM}m$, against the change in the same individual's money holdings at the end of the subsequent centralized meeting round, denoted by $\Delta_{CM}m$. Table 24 reports a regression analysis of $\Delta_{DM}m$ and $\Delta_{CM}m$, of the same type reported for the first experiment in Table 9 of the paper. Figure 5 and Table 24 again indicate a strong negative relationship between $\Delta_{DM}m$ and $\Delta_{CM}m$, which is consistent with the use of the centralized meeting for token re-balancing. The fitted (red solid) line shown Figure 5 for each session has a slope coefficient that is negative and significantly different from zero ($p < .01$ for all 4 sessions) as indicated in Table 24.[41] While the equilibrium prediction would call for perfect re-balancing, (i.e., $\Delta_{DM}m = -\Delta_{CM}m$) as indicated by the dashed 45 degree line in Figure 5, the experimental data again suggest that re-balancing was less than perfect in that $|\Delta_{DM}m| > |\Delta_{CM}m|$. More precisely, the regression coefficients on $\Delta_{DM}m$ as reported in Table 24 are always significantly less than 1 according to Wald tests ($p < .01$ for all 4 sessions). As in our first experiment this is indicative of possible precautionary hoarding of money balances relative to monetary equilibrium predictions, but it may also simply reflect out-of-equilibrium behavior in both the decentralized and centralized meetings.

Summarizing, we have provided evidence in this appendix that many of the findings found using our original experimental design are also found in the data collected using our modified experimental design involving up to three rounds of bargaining and the same trading post mechanism in the centralized meeting stage of both the money and no money treatments.

[41] The results reported are from a random effects, GLS regression on data for each money treatment session.

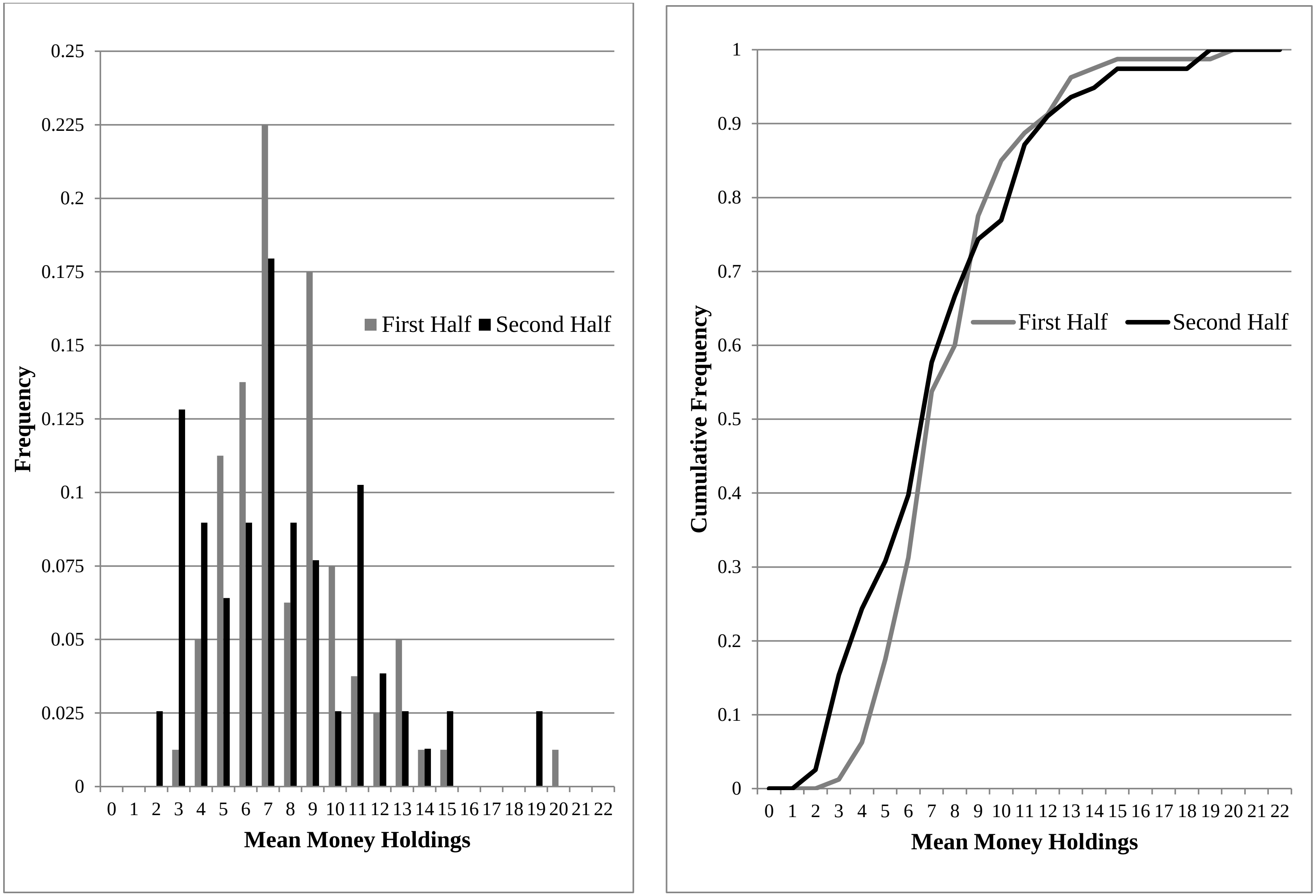

Figure 1: Left Panel Shows the Distribution of Mean Individual Money (Token) Holdings over the First and Second Halves of all Money (M) Treatment Sessions, Right Panel Shows the Cumulative Frequency Distribution of the Same Data.

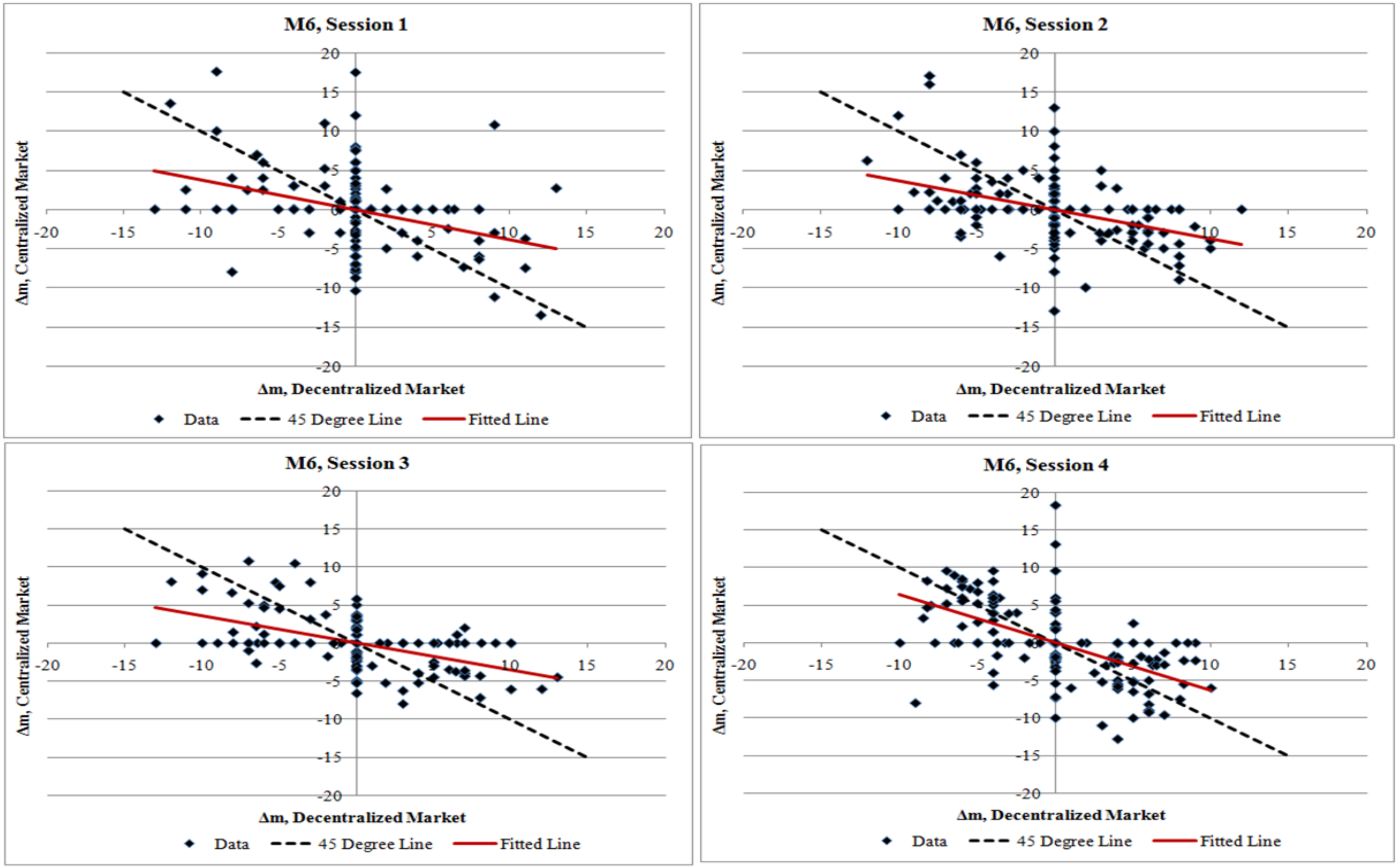

Figure 2: An Individual's Δm in the Decentralized Meeting (Horizontal Axis) Versus That Same Individual's Δm in the Corresponding Centralized Meeting of the Same Period (vertical axis) When There Was a Price (and Trade) in the Centralized Meeting. Notes: All data from each of the four M6 treatment sessions (1-4). The solid line is a linear fit to the data.

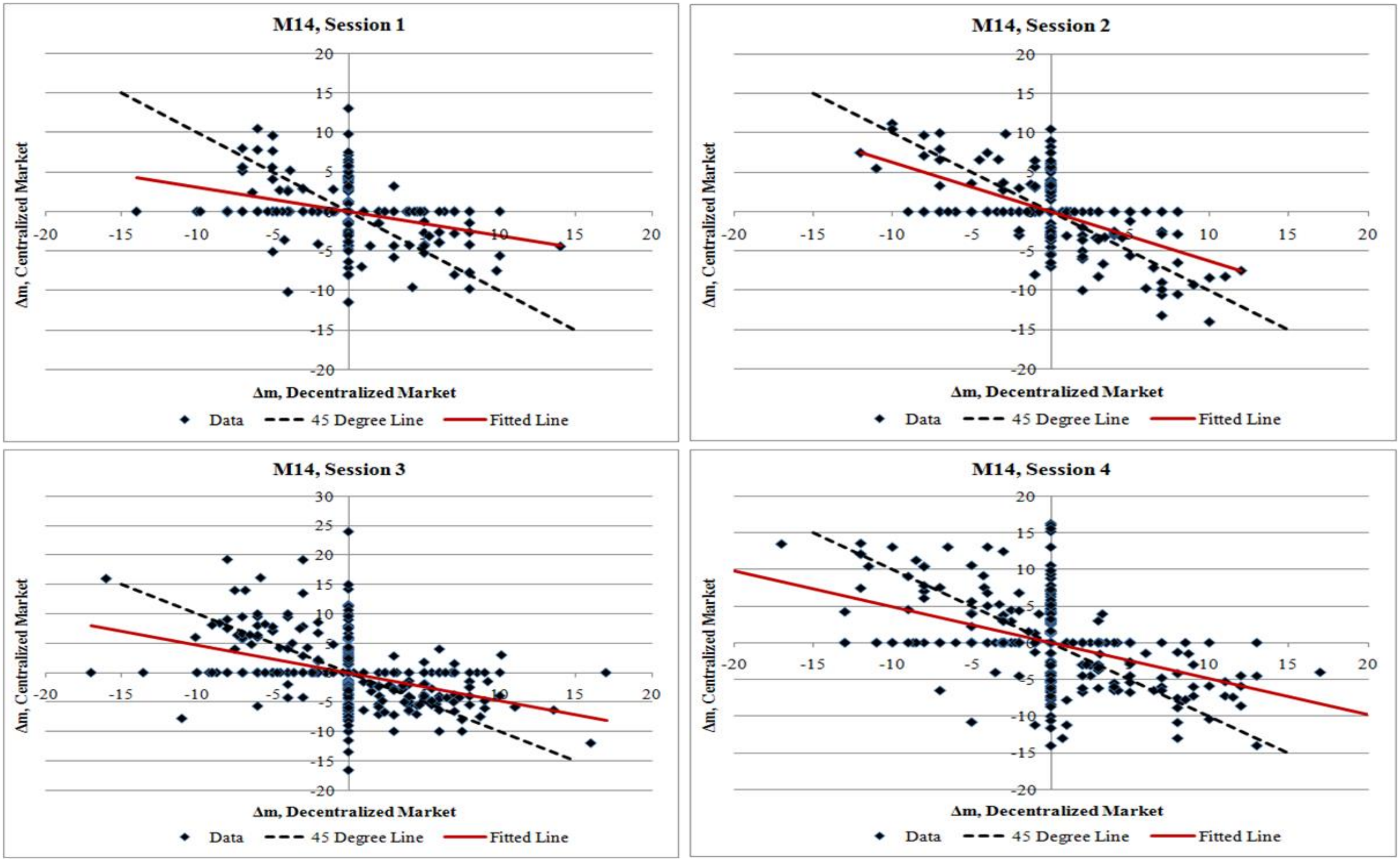

Figure 3: An Individual's Δm in the Decentralized Meeting (Horizontal Axis) Versus That Same Individual's Δm in the Corresponding Centralized Meeting of the Same Period (vertical axis) When There Was a Price (and Trade) in the Centralized Meeting. Notes: All data from each of the four M14 treatment sessions (5-8). The solid line is a linear fit to the data.

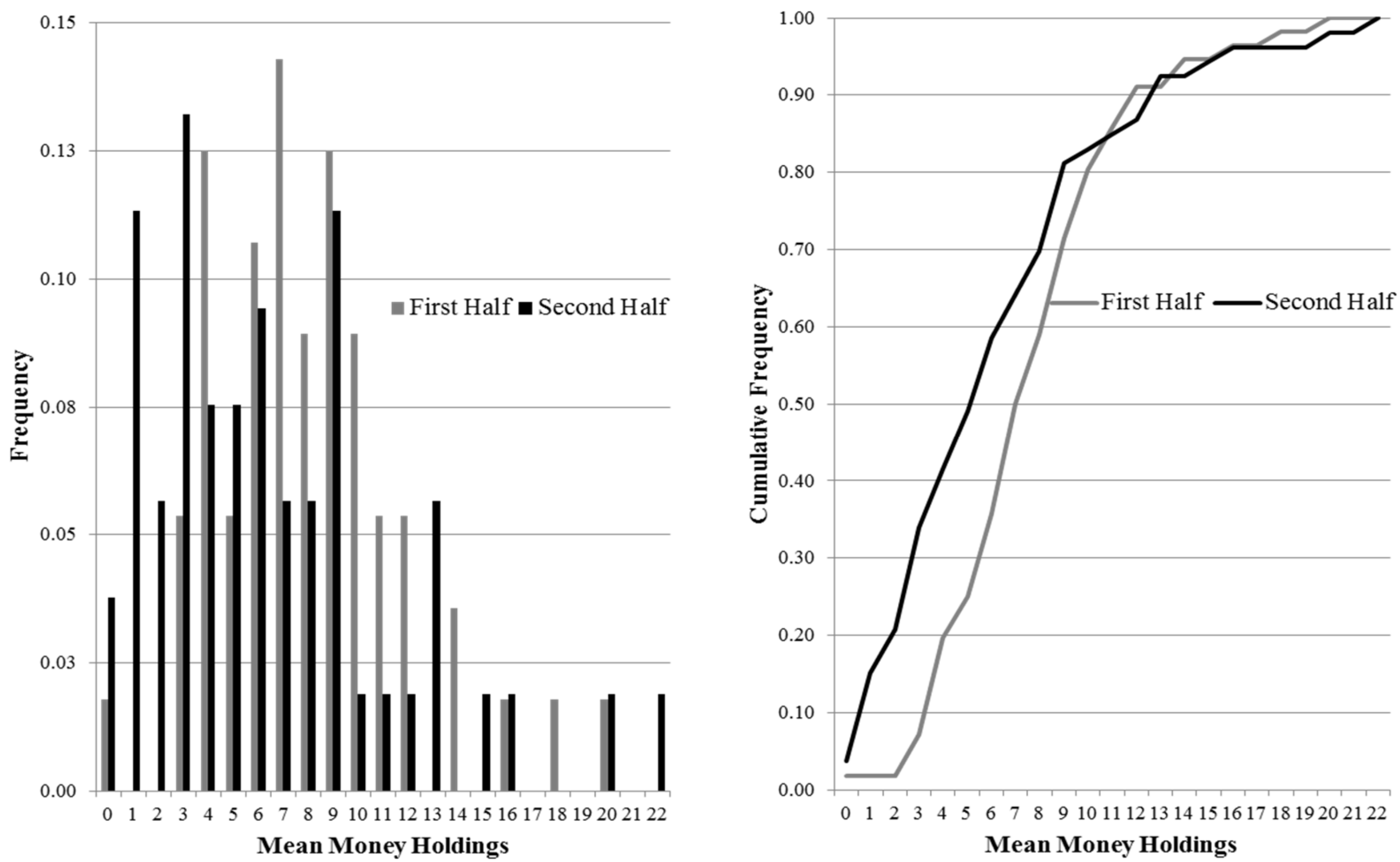

Figure 4: Left Panel Shows the Distribution of Mean Individual Money (Token) Holdings over the First and Second Halves of all four Modified Money (MM) Treatment Sessions (18-21). Right Panel Shows the Cumulative Frequency Distribution of the Same Data.

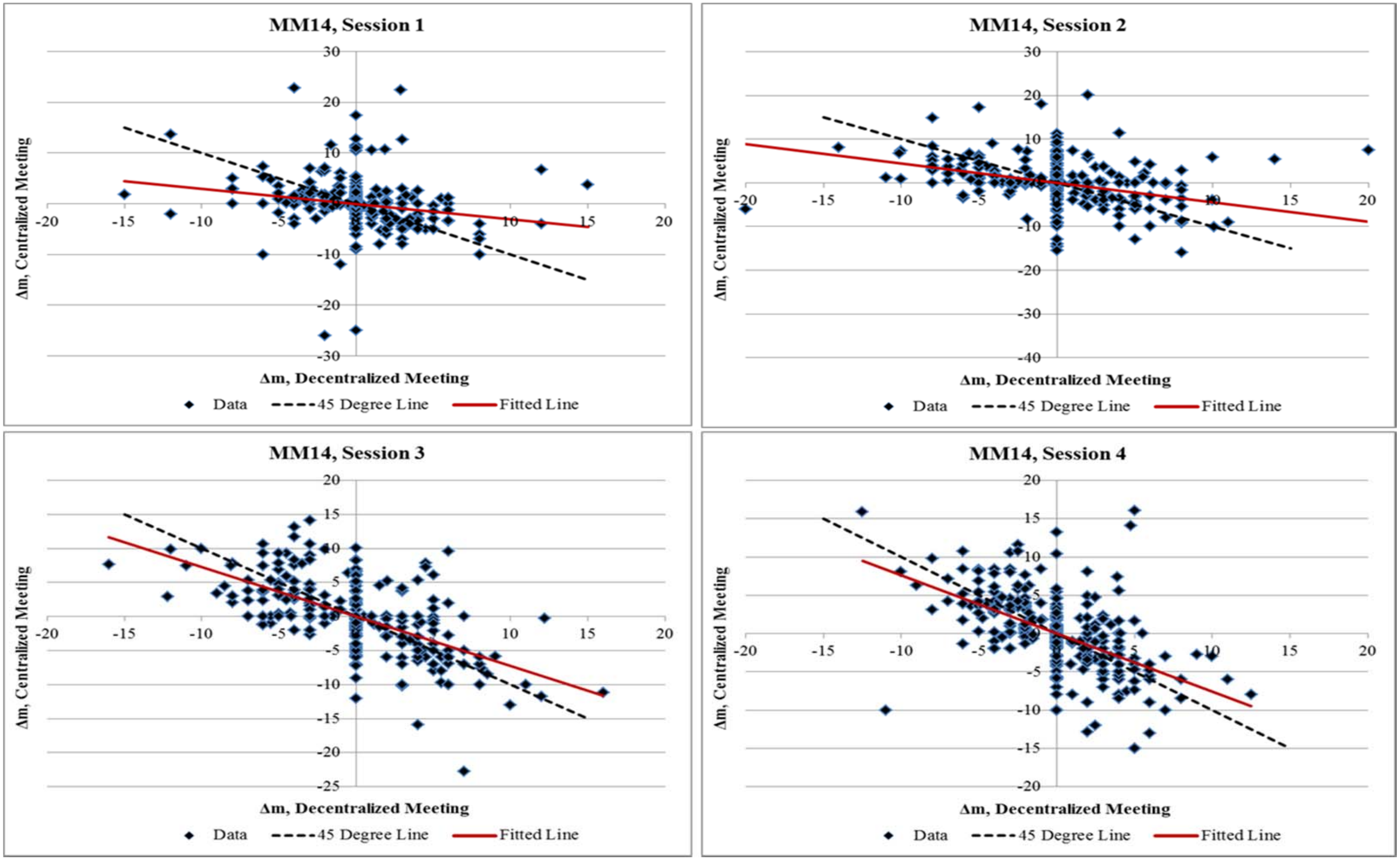

Figure 5: An Individual's Δm in the Decentralized Meeting (Horizontal Axis) Versus That Same Individual's Δm in the Corresponding Centralized Meeting of the Same Period (vertical axis) When There Was a Price (and Trade) in the Centralized Meeting. Notes: All data from each of the four MM14 treatment sessions (18-21). The solid line is a linear fit to the data.