Money is more than memory*

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Abstract

Impersonal exchange is the hallmark of an advanced society and money is one key institution that supports it. Economic theory regards money as a crude arrangement for monitoring counterparts' past conduct. If so, then a public record of past actions—or *memory*—should supersede the function performed by money. This intriguing theoretical postulate remains untested. In an experiment, we show that the suggested functional equivalence between money and memory does not translate into an empirical equivalence. Monetary systems perform a richer set of functions than just revealing past behaviors, which are crucial in promoting large-scale cooperation.

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1 Introduction

People have an inclination for cooperation (Bowles and Gintis, 2011), but such predisposition is weakened when the sphere of interaction expands from personal to *impersonal* (North, 1991) as it happens in advanced societies, where interactions primarily take place among strangers (Binmore, 2011; McCabe et al., 1998; Ostrom, 2010). These cooperation challenges have led to the creation of a variety of institutions (Greif, 2006; Kimbrough et al., 2008).

Our focus is on money, an institution that is ubiquitous across regions, cultures and historical periods, but whose nature continues to be enigmatic. While theory and empirical evidence indicate that monetary exchange grants efficiency gains compared to barter or gift-exchange, the mechanism behind this result remains open to debate and little is known about whether superior alternatives to money exist. Understanding it can generate valuable insights into the function and (in)stability of traditional monetary systems and of the usefulness of the alternatives presented by digital networks such as Bitcoin (e.g., see Krugman, 2013).

Here we present a laboratory experiment designed to fill these important gaps. Theory views money as a crude monitoring system—a type of ”public memory”—which has no role to play when individuals can rely on shared knowledge of past conduct. An important implication of these theories is that money is subordinate to public monitoring systems, which, if available, would be used to replicate or improve upon monetary trade (Kocherlakota, 1998; Ostroy, 1973; Townsend, 1987). Our study is the first empirical test of this broad theoretical concept and is not tied to any specific monetary model. We find evidence that money performs a richer set of functions than just revealing past behaviors. In a set-up where multiple equilibria coexist, we show that the institution of monetary trade is more powerful than reputation-based systems in enabling coordination on more efficient outcomes.

The experiment consists of a cooperative task involving subjects who interact as strangers for an indefinite number of periods. In each period, subjects meet in pairs, where one has the option to help the other at a cost. Everyone has repeated opportunities to help and to receive help because roles alternate over time. Cooperation requires trusting that help given to a stranger will be returned by a stranger later in the game.

There are four treatments, one of which serves as a control. In all treatments, indefinite repetition gives rise to a social dilemma with two conflicting elements: opportunism, due to the short-run temptation to avoid helping others, and coordination, because any cooperation levels-from zero to one-hundred percent-can be theoretically attained. In the Money treatment, we add fixed balances of intrinsically worthless electronic tokens, which participants can choose to exchange for help. In the Memory treatment, we add a record-keeping system based on numeric balances, which rise for those who give help and fall for those who receive it. By design, tokens and record-keeping do not expand the theoretical efficiency frontier with respect to self-enforcing norms alone. Money and Memory allow help to be based on balances in the pair. In this sense, tokens and record-keeping are theoretically affine: record-keeping can be employed to replicate a pattern of monetary trade without transferring tokens, while tokens can communicate individual past conduct without the need to rely on record-keeping. Through this design we can uncover behavioral differences between monetary systems and systems for collecting and sharing information about past conduct.

We report four main findings. First, control groups struggled to sustain long-run cooperation, which according to theory is an equilibrium outcome.

Second, tokens and record-keeping each significantly boosted long-run cooperation, when in fact theory asserts they should not play a role. In Money subjects traded help for intrinsically worthless tokens, which endogenously became money. In Memory help was also conditioned on balances in the pair, but not in a manner that superseded the function performed by tokens. In fact, record-keeping was not employed to replicate monetary trade. This leads to our third finding: long-run cooperation was significantly higher in Money than in Memory. Tokens encouraged cooperation because subjects took turns at trading them for help, without hoarding them. This alternation did not emerge in Memory, where some subjects accumulated large numeric balances, thus allowing free-riders to run large deficits. This suggests that the tokens' superior performance is tied to the presence of external "liquidity" constraints, which facilitate the task of coordinating on credible, incentive-compatible trade patterns. To test it, in the Money Unconstrained treatment we removed liquidity constraints, so that—as in Memory—help could always be rewarded with a symbolic object. Here, outcomes and patterns of behavior matched those seen in Memory, with some subjects hoarding tokens even if this was inconsistent with payoff maximization (see also Oprea, 2014).

Previous work on finite-horizon games provides evidence that the provision of information on opponents' past actions fosters reciprocity and conditional cooperation (Gächter and Hermann, 2011; Milinski et al, 2001; Ule et al, 2009). A tendency toward positive reciprocity has also been observed in infinite horizon social dilemmas (Camera and Casari, 2009). Our experiment provides unique evidence that the external addition of systems for collecting and sharing information about past conduct provided weaker dynamic incentives to cooperate compared to the monetary trading system that *endogenously* emerged when tokens were available. In fact, although there is evidence for positive reciprocity in each of these conditions, punishment of free-riders was more frequent when tokens were available, compared to when they were not but information about past conduct was provided. This suggests that monetary systems are behaviorally more effective at promoting cooperation and efficiency compared to record-keeping systems that do not include information designed to support the sanctioning of non-punishers (e.g., the so-called "second-order information" in Bolton et al., 2005; Ule et al, 2009). Liquidity constraints are crucial for this result. If the only way of having a positive balance is to help someone who has a positive balance, then this automatically implies a sanctioning of free riders (who have zero balance) *and also* of those who help them (whose balance remains zero). This second sanctioning mechanism is only built into monetary trade, because in the other treatments a positive balance can be obtained also by helping free riders.

The paper proceeds as follows. Section 2 describes the design. Section 3 presents the theory, and Section 4 reports the main results. Section 5 puts the paper in the context of the experimental literature, and Section 6 offers a concluding discussion.

2 Experimental design

The experiment has three main treatments: Baseline, Money and Memory (Table 1). There is an additional treatment, called Money Unconstrained, which serves as a robustness check and will be discussed in Section 4.2. In all treatments subjects face a cooperative task that is repeated an indefinite number of periods, where every period subjects encounter a random counterpart and play in pairs. Interactions are anonymous, and any form of communication is ruled out. The design in Baseline is described next.

Variable	Treatment: Baseline	Money	Memory	Money Unconstr.
Group size	8	8	8	8
Token supply	0	4	0	≥ 4
Record-keeping	No	No	Yes	No
Sessions	4	4	5	2
Subjects	96	96	120	48
Supergames	20	20	25	10
Periods (avg.)	111.5	116.2	117.6	110.0

Table 1: Sessions and treatments

Notes: The last four rows report the number of observations. Sessions' dates (dd-mm-yy): Baseline, 6-2-12 (two), 24-1-14, 20-2-12; Money, 7-2-12 (two), 24-1-14, 16-2-12; Memory, 13-2-12 (two), 21- & 23-1-14, 27-1-14; Money Unconstrained, 12-6-14 (two). The 2012 sessions were run at Purdue University, in the VSEEL lab. The 2014 sessions were run at Chapman University, in the ESI lab. The sessions on 20-2-12, 16-2-12, and 27-1-14 were run with experienced subjects (=experienced sessions): subjects were informed that all session participants had previously participated in a session with the same treatment.

2.1 Interaction in a period

Each period subjects meet in pairs and play a "helping game" (Table 2). In this game, one subject is a producer, and the other is a consumer. The producer has a good, which he can consume or transfer to the consumer, who values it more. In this case, we say that the producer "helps" the consumer. The consumer has no action to take. Hence, it is an individual decision problem.

	Producer Y	**Producer** Z
Consumer	$d-l, d$	$g, 0$

Table 2: Payoffs in the stage "game" in Baseline and Memory

Notes: In the experiment d=6, l=2, g=20.

In Baseline the consumer has no action to take (Table 2). The producer chooses either outcome Z (=*Help*) or Y (= *Do not help*). Payoffs to consumer and producer are, respectively, g and 0 if the producer helps; otherwise, they are $d-l$ and d, with $g > 2d-l > 0$. In the experiment $d = 6$, $l = 2$, $g = 20$ and each point is worth \$0.03. Surplus in a pair is maximum when the producer helps, which generates $g - (2d - l) = 10$ points. We refer to this outcome as the (socially) efficient outcome or, alternatively, *cooperation*. The dominant strategy is not to help, which we call *defection*. At the end of the interaction actions and outcome in the pair are observed by both agents.

2.2 The supergame

A session is divided into five separate supergames. In a supergame, subjects interact within a fixed group of eight subjects, for an indefinite number of periods. A group is comprised of four producers and four consumers with deterministically alternating roles. At the start of every period each consumer meets a producer at random. According to this matching protocol, there is only a 0.25 probability to be in the same pair in two consecutive periods.[1] Participants can never identify their opponent. Hence, subjects interact as strangers because opponents change at random and are anonymous.

The duration of the supergame is determined by a random continuation rule (Roth and Murnighan, 1978). A supergame has 20 fixed periods after which the game continues into an additional period with probability 0.75, which we interpret as the discount factor of a risk-neutral subject. The design guarantees an interaction of finite but uncertain duration. The expected duration of a supergame is 23 periods; from period 20, in each period the

[1] There are 4! ways to match four producers to four consumers; in 3! of such pairings consumer j meets producer i. In each period one pairing is chosen with equal probability.

supergame is expected to go on for 3 additional periods. In the experiment a computer randomly selects an integer number between 1 and 100, using a uniform distribution, and the supergame ends when a number greater that 75 is selected. At the end of each period all participants in the group observe the number drawn, which informs them about the end or continuation of the supergame, and can also serve as a public coordination device. Subjects also observe whether or not outcomes were identical in all four pairs (a binary variable, "yes" or "no;" see Instructions). This second statistic provides a form of anonymous public monitoring, which is introduced to ensure that the minimum discount factor that supports full cooperation in sequential equilibrium remains constant across treatments (see Section 4).[2]

Every experimental session involves twenty-four subjects, who were divided into three groups in each supergame for a total of fifteen groups per session. Supergames terminate simultaneously for all groups. Each group is constructed so that no two subjects can interact in more than one supergame.[3]

2.3 Money and Memory treatments

The Money treatment adds indivisible, intrinsically worthless electronic objects called "tokens," which neither yield nor can be redeemed for points or dollars. In period 1 of each supergame, every consumer is endowed with one token, hence there are four tokens per group; this supply is known and remains fixed throughout the supergame. Tokens can be transferred from consumer to producer, one at a time, and can be carried over to the next period but not to

[2]The design uses a form of public monitoring that may also simplify coordination tasks compared to other forms, such as revealing the frequency of actions in the group. A red flag is a signal less open to interpretation than a frequency-based signal.

[3]Subjects are informed about this predetermined matching protocol.

the next supergame. Participants can hold any positive balance of tokens.[4]

The introduction of tokens expands the actions sets relative to Baseline because the stage game now includes the possibility to *trade* using a direct mechanism; Table 3 explains how. A consumer can either keep her tokens (=*give* 0), transfer one to the producer (=*give* 1), transfer one conditionally on receiving help (=1 *for* Z) or on *not* receiving it (=1 *for* Y). The producer can still help (= Z) or not (= Y), but now can also choose to help conditionally on receiving either one (=Z *for* 1) or no tokens (=Z *for* 0). Each pair of choices is associated with a unique outcome, which is reported in Table 3 along with the relevant payoffs.[5] Subjects choose simultaneously and without prior communication, hence, they cannot signal a desire to cooperate by requesting or offering a token. In particular, nothing prevents producers from unilaterally providing help, if they wish to do so.

Several remarks are in order. First, the possibility of conditioning the outcome on the counterpart's choice might facilitate coordination on cooperation. The producer can choose to help conditional upon receiving a token, and the consumer can choose to transfer one token conditional upon being helped. Helping only in return for a token is a form of monetary exchange, which can also be achieved by choosing the actions Z and *give* 1.

Second, to avoid biasing the results in favor of the emergence of monetary exchange the design includes actions that are antithetical to monetary

[4]In contrast with Camera et al. (2013) and Camera and Casari (2014) here subjects deterministically alternate between the roles of consumer and producer (rather than randomly), and their token holdings are unrestricted (instead of being bounded). This simplifies the experimental tasks relative to the earlier design, it facilitates coordination on cooperation and it makes monetary exchange consistent with full efficiency.

[5]The instructions (see Appendix C) explicitly discuss the outcomes resulting from each choice combination. After reading the instructions and before starting the experiment, all subjects had also to correctly answer twenty-five multiple-choice questions, including questions about the association between choices and outcomes (answers were not incentivized).

		Producer			
		Y	*Z*	*Z for* 1	*Z for* 0
	give 0	$d-l, d$	$g, 0$	$d-l, d$	$g, 0$
Consumer	*give* 1	$d-l, d^{\star}$	$g, 0^{\star}$	$g, 0^{\star}$	$d-l, d^{\star}$
	1 *for Z*	$d-l, d$	$g, 0^{\star}$	$g, 0^{\star}$	$d-l, d$
	1 *for Y*	$d-l, d^{\star}$	$g, 0$	$d-l, d^{\star}$	$d-l, d^{\star}$

Table 3: The augmented stage game in MONEY

Notes: The notation $\star$ indicates that the producer receives a token from the consumer. In the experiment d=6, l=2, g=20.

exchange. By choosing *Z for* 0, the producer commits to execute Z only if the consumer chooses *give* 0. By choosing 1 *for Y*, the consumer commits to transfer a token if the producer *avoids Z*. Hence, tokens may take on a negative connotation as subjects could use them to tag defectors by giving tokens to those who do not help. Given this richer action set, the addition of tokens might increase coordination problems, relative to BASELINE.

Third, subjects cannot create or borrow tokens. Hence, a consumer without tokens has no action to take, as in BASELINE. Such possibility of being "liquidity constrained" is at the heart of monetary economics. It is also central to our study because it allows us to investigate whether removing such constraints through record-keeping helps to improve overall efficiency. Subjects are informed whether a token transfer is feasible in their pair; the design minimizes the chance that such information might indirectly identify the opponent.

Before making a choice, subjects can see if the opponent's balance of tokens is positive or zero, but not the number of tokens held. The restriction to transfer one token at a time is not theoretically binding in monetary equilibrium.

Finally, though subjects can hold any number of tokens, a balance of one token per consumer is all that is needed for the monetary system to function efficiently because with deterministic alternation of roles there is no precautionary motive to hold tokens (see Section 4). This explains our choice for the tokens' supply: with less than four tokens monetary exchange would be sometimes unfeasible; adding tokens cannot increase the cooperation frequency, and in fact would undermine it by reducing the endogenous value of tokens.

The Memory treatment retains the Baseline stage game and adds an information-sharing system called (*public*) *record-keeping.* The system assigns to each subject a numeric *balance* ("personal index," in the experiment), which tallies the help given and received in the past. The initial balance is 1 for consumers, 0 for producers. As in Money, balances are intrinsically worthless and subjects only see if the opponent's balance is positive or not. The difference with Money is that balances are automatically updated at the end of each interaction, based only on the producer's action. If Y is chosen, then balances in the pair do not change. If Z is chosen, then the producer's balance increases by one and the consumer's falls by one; balances can be negative. If subjects condition their help on balances in their pair, then Memory simplifies coordination tasks relative to Money because choice sets are smaller (as in Baseline) and balance updates are automatic.

Considering all treatments, we recruited 360 subjects through announcements in undergraduate classes, at Purdue University and at Chapman University. The experiment was programmed and conducted with the software z-Tree

(Fischbacher, 2007). Instructions (a copy is in Appendix C) were read aloud at the start of the experiment and left on the subjects' desks. A 25-question comprehension quiz was administered electronically after the instruction period. No eye contact was possible among subjects. Average earnings were \$28.25 per subject (min $=$ \$18.84, max $=$ \$40.94. On average, a session lasted 115 periods for a running time of about 85 minutes (min = 72 minutes, max = 108 minutes excluding instruction reading, a quiz, and payments (Table 1).

3 Theoretical considerations

Here we show that full cooperation is an equilibrium outcome in all treatments. It can be supported either by adopting a social norm of cooperation or, alternatively, by using tokens or record-keeping. The Appendix A reports proofs and mathematical details. Consider the following strategy:

Definition 1 (**Cooperative strategy**). *As a producer, the player* cooperates *(selects Z) as long as she has not observed a* defection *(Y). If a defection is observed, then the player defects forever after.*

If everyone adopts this strategy, then we call it a *social norm.* This norm consists of a rule of cooperation and a rule of punishment that sanctions any uncooperative action with permanent defection by the entire group. If players are sufficiently patient, then the punishment threat can adequately deter *any* defection from ever occurring and full cooperation is a sequential equilibrium.

Proposition 1. *If* $\beta \geq \beta^* := \dfrac{d}{g-d+l}$, *then the strategy in Definition 1 supports full cooperation in sequential equilibrium.*

The threshold value β^* is the cost-benefit ratio of cooperating: the producer's cost from helping is divided by the consumer's surplus from being helped. The condition $\beta \geq \beta^*$ is sufficient and necessary for existence of cooperative equilibrium but does not guarantee that it will be realized instead of another outcome with lower efficiency. In fact, thanks to public monitoring of defections, multiple equilibria exists ranging from full defection to full cooperation. Full defection is always an equilibrium because it consists of an infinite repetition of the static Nash equilibrium strategy (Y). Full cooperation is socially efficient because it maximizes surplus in all meetings.

To prove that full cooperation is an equilibrium two conditions must be checked. First, in equilibrium, no producer should prefer to defect. Second, given that everyone else follows the candidate strategy in Definition 1, out of equilibrium no producer should prefer to cooperate. The latter condition is immediately verified: any equilibrium defection is publicly observed, hence, everyone defects forever after and there is no longer a reason to cooperate. The first condition requires checking that a producer cannot improve her payoff by moving off equilibrium (unimprovability criterion). Discounting starts on period $T = 20$, which is when the incentives to cooperate are the smallest. Hence, it is sufficient to consider continuation payoffs at the start of any period $t \geq T$. Denote v_s the equilibrium payoff to an individual in state $s = 0, 1$ ($0 =$ producer, $1 =$ consumer). It holds that $v_1 > v_0$ with

$$v_s := \frac{\beta^{1-s}}{1-\beta^2} \times g \qquad \text{for } s = 0, 1,$$

given the alternation between production (earn 0) and consumption (earn g).

To show that producers do not want to move off equilibrium, suppose a producer defects in period $t \geq T$. Her payoff satisfies

$$\hat{v}_0 := \frac{d + \beta(d - l)}{1 - \beta^2}$$

because she earns d today (instead of 0) but causes cooperation to forever stop from $t+1$ on. It follows that $v_0 \geq \hat{v}_0$ for all $\beta \geq \beta^*$. The design parameters yield $\beta^* = 0.375$, so under reasonable assumptions about subjects' risk attitudes cooperation is an equilibrium in every treatment because in the experiment the continuation probability from period 20 on is 0.75.

3.1 Equilibrium with tokens

Adding tokens expands action and strategy sets, and the set of outcomes. In Money subjects can exchange tokens and see if the opponent's balance of tokens is positive or not. This does not eliminate *any* of the equilibria possible in Baseline because players can always adopt strategies that ignore tokens, since tokens have no intrinsic value. Yet, there are ways in which tokens can be used to support full cooperation. Following the insights from monetary theory, we focus on a strategy that conditions actions on the observable *balances* in the pair, identified by the letters H (=positive) and L (=zero).

Definition 2 (**Monetary trade strategy**). *In any period and after any history: as a consumer, the player transfers one token conditional on receiving help only if her balance is H—otherwise she has no action to take. As a producer, the player helps conditional on receiving a token only if her balance is L—otherwise she does not help.*

If everyone adopts this strategy, then tokens are exchanged quid-pro-quo for help, becoming a medium of exchange. The resulting outcome is called *monetary trade*. In equilibrium all encounters are *trade meetings* in which the consumer "buys" help by giving the only token she has to a producer without tokens, as in a Turnpike model (Townsend, 1980). The monetary trade strategy is cognitively simple: it is history-independent and does not require any change in behavior as a reaction to a defection. Off-equilibrium a producer may have tokens or a consumer may have none, in which case tokens are not exchanged and help is not given.

Monetary trade does not expand theoretical efficiency. Hence, according to theory tokens are irrelevant because the theory implicitly assumes that agents coordinate on the best available equilibrium.[6] Consumption patterns in monetary equilibrium mirror those under the social norm—so payoffs coincide with v_0 for a producer and v_1 for a consumer—and is supported on the same parameter set of the social norm.

Proposition 2. *If $\beta \geq \beta^*$, then monetary trade supports full cooperation as an equilibrium.*

In monetary equilibrium a producer who refuses to help is "punished" by not receiving a token. The player will not be able to consume next period, much as it happens under the social norm, albeit for different reasons. This explains why the lower bound β^* is the same as under the social norm.

To prove Proposition 2 consider payoffs at the start of any period $t \geq T$, without loss of generality. We need to show that in a trade meeting the consumer prefers to spend her token to receive help, and the producer prefers to help to receive a token. The first part of the statement is always true because the consumer earns some surplus from trading. The latter part of the statement is true only if the producer—who sustains a cost d to help—can spend the token fairly soon or, equivalently, is sufficiently patient.

To formalize this intuition consider one-time unilateral deviations. Off-equilibrium payoffs are calculated adopting recursive arguments, exploiting the fact that the monetary trade strategy is history-invariant; hence, equilibrium deviations temporarily alter the tokens' distribution but never trigger a switch

[6]In monetary theory, tokens are said to be theoretically relevant (or, essential) only if monetary trade allows players to achieve allocations that would otherwise not be achievable (e.g., see Kocherlakota, 1998, p. 232).

in behavior. Monetary trade thus allows players to easily re-coordinate on equilibrium play two periods after a unilateral deviation occurs.

Consumer i has an incentive to trade a token for help if

$$d - l + \beta(d + \beta v_1) < v_1 = g + \beta(0 + \beta v_1),$$

which always holds because $g > d + d - l$. To interpret the inequality note that defecting in t gives payoff $d - l$ (instead of g) to consumer i; she enters period $t + 1$ as a producer *with* money and reverts back to following monetary trade. Hence, the defection changes the distribution of tokens only temporarily: two periods after consumer i deviates the tokens' distribution is back at equilibrium. In $t+1$ player i is a producer who refuses to help because it would costs her d and she has already one token to spend in $t+2$. In $t+2$ the distribution of tokens is back at equilibrium since all consumers have money (player i is one of them) and producers have none.

Producer i has an incentive to help in exchange for a token if

$$d + \beta(d - l + \beta v_0) < v_0 = 0 + \beta(g + \beta v_0),$$

which holds whenever $\beta \geq \beta^*$. Defecting in t generates payoff d instead of 0, and in $t + 1$ the player becomes a consumer *without* money. Being unable to buy help she earns $d - l$ and enters $t + 2$ as a producer without money. Hence, in $t + 2$ the tokens' distribution is back at equilibrium.

3.2 Equilibrium with record-keeping

Adding record-keeping leaves unaltered the action sets compared to Baseline. It enriches the strategy sets because producers can now condition actions on observed balances, denoted L (0 or below) and H (1 or above). This eliminates none of the equilibria that are possible in BASELINE because players can always adopt strategies that ignore balances. Yet, there are ways in which balances can be employed to support full cooperation. In particular, subjects can replicate the monetary trade strategy without the need to exchange symbolic objects. Hence, outcomes exist in which balances convey the same information about past actions as under monetary exchange.[7]

Definition 3 (**Trade strategy**). *In any period and after any history, the player takes an action only as a producer. If her balance is L, then she helps only consumers with balance H. In all other circumstances, she does not help.*

This strategy supports full cooperation because, as in Definition 2, help is *conditioned* on balances in the pair. Producers help only to increase their balance above zero, and do so only if the consumer's balance is H. It immediately follows that the trade strategy supports full cooperation when $\beta \geq \beta^*$, and record-keeping is as theoretically irrelevant as tokens.

There are two important behavioral differences between using balances to support trade in MONEY and in MEMORY. First, the record-keeping system simplifies coordination on efficient trading because only producers make choices and balances are automatically updated if help is given. In contrast, in a monetary system, producer and consumer must coordinate on the exchange of tokens in every meeting. Second, producers should not help consumers with balance L, but the incentives to do so differ across treatments. They are strong under monetary trade because producers cannot increase their balance

[7]Not all outcomes convey the same information. The statistics L and H provide information about past actions that *might* differ across treatments because in MEMORY producers can always increase their balance by helping *any* consumer. For instance, in MEMORY a consumer with balance L surely did not help in the past, but this might not be so in MONEY—she might have helped without receiving a token. Considering all possible ways to sustain cooperation with record-keeping is not our objective. Our goal is to understand whether or not tokens are employed purely as a tool to communicate past conduct—as theory suggests—or if they play a richer function.

by helping consumers without tokens. This is not so in Memory since helping always increases the producer's balance. Hence, producers with balance L may be tempted to help someone they should in fact punish.

4 Results

We report six main results that address the following questions: if defections are public, is full cooperation easy to sustain? When monetary trade is possible, do subjects attain different cooperation rates than when it is not? Does a system designed to maintain and share information about past conduct supersede the function performed by money?

All analyses consider only the first twenty periods in each supergame and take as unit of observation, unless otherwise noted, the average choice of each subject in a supergame. All results rely on sessions run with inexperienced subjects, except Result 6 that explicitly addresses the issue of experience.

Result 1. *Cooperation was difficult to support in the* Baseline *treatment.*

Support for Result 1 is provided by Figure 1 and Table 4. Average cooperation (rates) in the Baseline treatment range from 59% in the first supergame to 47% in the last supergame.[8] By design, aggregate efficiency is proportional to average cooperation. The levels achieved in Baseline are well below full efficiency and present a declining trend as the subjects gain experience across supergames (Figure 1). This declining trend is statistically significant at the 5% level as illustrated by the panel regression in Table 4, model 1. The dependent variable is the average cooperation frequency of a subject in a supergame and the regression controls for individual characteristics. The message is that

[8]The minimum and maximum cooperation rates observed in a supergame are as follows 10% and 85% in Baseline; 23% and 95% in Money; 19% and 100% in Memory. Inexperienced subjects only.

subjects did not trust that strangers would return a gift of help in the future. There is scope for institutions to promote cooperation.

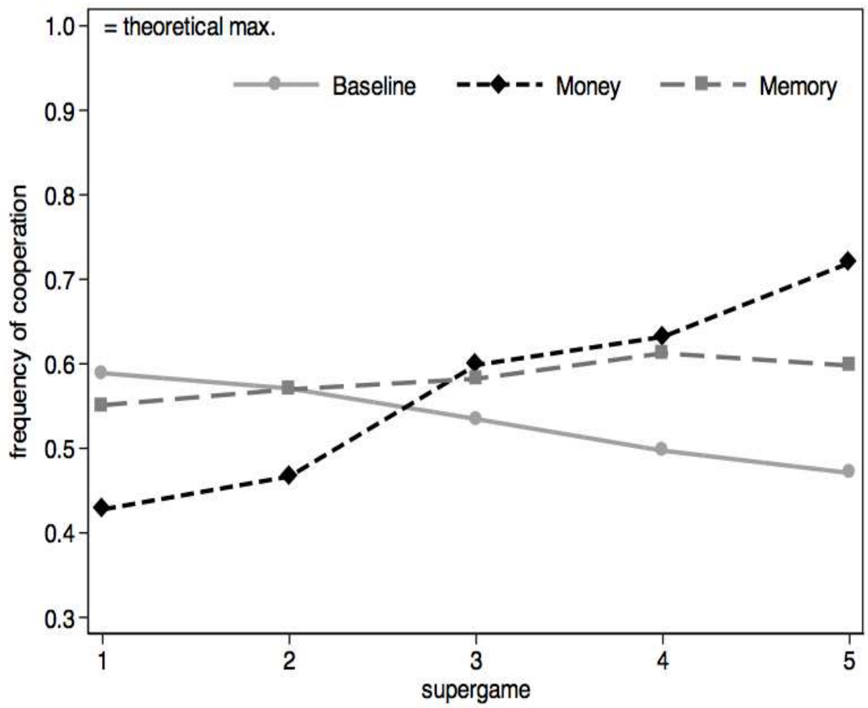

Figure 1: Relative frequency of cooperation by treatment

Result 2. *In the long-run, cooperation and efficiency were greater in* Money *and* Memory *compared to* Baseline*.*

Support for Result 2 is provided by Figure 1 and Tables 4-5. In the last supergame, average cooperation is 72% in Money and 60% in Memory. The differences in cooperation with Baseline are statistically significant according to a linear regression (1% and 5% level, respectively; Table 5). Contrary to the Baseline treatment, in Money there is a significant positive trend with experience (Table 4, model 2). The Memory treatment exhibits a weaker positive trend (significant at a 10% level).

Dependent variable: *Individual rate of cooperation*	Model 1 (Baseline) Estimate	S.E.	Model 2 (All treatments) Estimate	S.E.
Supergame	-0.031**	0.016	-0.031**	0.013
Money			-0.266***	0.069
Money x Supergame			0.106***	0.018
Memory			-0.102	0.063
Memory x Supergame			0.045***	0.016
Constant	0.308**	0.127	0.438***	0.103
Controls	Yes		Yes	
N. of obs. (N. of subjects)	360 (72)		1200 (240)	
R-squared within	0.064		0.126	
R-squared between	0.259		0.212	
R-squared overall	0.179		0.172	

Table 4: Cooperation rate.

Notes: One observation per subject per supergame. Inexperienced sessions, all supergames. Panel regression with random effects at the individual level and robust standard errors (S.E.) adjusted for clustering at the session level. The estimated coefficients for *Money* and *Memory* are significantly different at the 1% level (p- value$<$ 0.001). The estimated coefficients for *Money x Supergame* and *Memory x Supergame* are significantly different at the 1% level (p- value$<$ 0.001). The sum of the coefficients *Supergame* and *Memory x Supergame* is significant at the 10% level (p-value = 0.099). The sum of the coefficients *Supergame* and *Money x Supergame* is significant at the 1% level (p-value $<$ 0.001). *Controls* include the following individual characteristics: gender, major, two measures of understanding of the instructions (response time and number of wrong answers in the quiz) and session location (Purdue, Chapman).

Dependent variable: *Individual frequency of cooperation*	Supergame 1		Supergame 5	
	Estimate	S.E.	Estimate	S.E.
Money	-0.151*	0.069	0.307***	0.078
Memory	-0.059	0.065	0.132**	0.047
Constant	0.342*	0.155	0.456***	0.069
Controls	Yes		Yes	
N	240		240	
R-squared	0.212		0.207	

Table 5: Treatment Effects on Cooperation in Supergames 1 & 5.

Notes: One observation per subject. Inexperienced sessions. Robust standard errors (S.E.) adjusted for clustering at the session level. In supergame 1 the estimated coefficients for *Money* and *Memory* are significantly different at the 1% level (p-value: 0.002). In supergame 5 the estimated coefficients for *Money* and *Memory* are significantly different at the 5% level (p-value: 0.014). *Controls* include the following individual characteristics: gender, major, two measures of understanding of the instructions (response time and number of wrong answers in the quiz) and session location (Purdue, Chapman).

One may be tempted to chalk up Result 2 as an artifact of subjects being in the habit of relying on record keeping and monetary exchange in everyday life. Yet, two observations suggest this result has a deeper connotation. First, the design in Money and Memory neither expands the efficiency frontier—the efficient outcome is attainable in Baseline—nor constrains subjects to adopt a trade strategy, nor precludes cooperation through a social norm. In fact, adding tokens and balances expands action set, strategy sets, and the equilibrium set relative to Baseline. Hence, if anything, the enriched stage games in Money and Memory should increase coordination difficulties, not reduce them (Riedl at al., 2011; Weber, 2006).

Second, Money and Memory supported lower overall cooperation than Baseline in the short-run (Table 5). This lower performance at the start of the sessions suggests that pre-existing "monetary" habits are not the primary reason for the experimental results. In fact, it suggests that subjects *purposefully developed* a monetary trade convention over the course of the session, with the intent to coordinate on a cooperative outcome.

Result 3. *In the long-run* Money *supported higher cooperation and efficiency than* Memory*.*

Support for Result 3 is provided by Figure 1 and Tables 4-5. In the last supergame the average cooperation level in the Money treatment is significantly different from the Memory treatment (Table 5).

In the experiment, tokens became a fiat money in a manner consistent with monetary equilibrium. This finding about the endogenous emergence of monetary systems is in line with studies in Camera and Casari (2014); Camera et al. (2013). Tokens were by design intrinsically worthless, and—unlike the transfer of balances in the Memory treatment—their exchange was not forced. It is important to note that tokens could change hands in a way *opposite* to monetary trade. Consumers could transfer a token only to a producer who *refused* to help (Section 2), but this behavior was not observed. Many producers offered help only in exchange for a token (63%) and consumers offered a token only in exchange for help (82%).[9] On the other hand, when consumers had no tokens to give, producers refused help 72% of the times.

One cannot exclude that the behavior in Memory is consistent with some equilibrium being played. Indeed, the design admits multiple equilibria, with frequencies of cooperation ranging from 0 to 100 percent due to public monitoring. What we do observe is that efficiency is lower in Memory than in Money even if subjects could easily adopt a trade strategy in both treatments. A possible explanation for Result 3 is that subjects were unable to exploit record-keeping to replicate a monetary trade pattern.

[9]These data refer only to encounters in which the exchange of tokens was feasible.

Result 4. Money *supported trade but* Memory *did not.*

Support for Result 4 comes from Figures 2-3 and Table 6. Full cooperation in Money and Memory can be achieved through trade as defined in the previous section. This means that after any history, in either treatment a producer with a low balance (=L) helps only a consumer with a high balance (=H). If everyone adopts this trade strategy, subject alternate deterministically between giving help and receiving help. Therefore, subjects would alternate between a balance of 0 as producers and 1 as consumers (Figure 2, left panel). In the experiment, the distribution of balances approximates the 50/50 theoretical distribution only in Money, where about 56% of subjects hold 0 tokens and 38% hold 1 token (Figure 2, center panel). This distributional pattern completely breaks down in Memory, where only 16% of subjects have a 0 balance and 23% have a unit balance (Figure 2, right panel).

Another indicator of the adoption of the trade strategy is provided in Figure 3. The trade strategy implies that help should be given in every equilibrium encounter. However, this is not so off-equilibrium, where help should be given only in some encounters but not in others. The trade strategy implies that help should be given only in *trade meetings*, where the producer's balance is L and the consumer's is H, and should not be given in all other meetings and, in particular, if consumers have balance L. Figure 3 shows the empirical frequency of cooperation when help should and should not be given under the trade strategy (solid vs. dashed line). Theoretically, the solid line should be at 100%, and the dashed line at 0%, if everyone followed the trade strategy. In the Money treatment (Figure 3, left panel), the aggregate cooperation frequency is consistent with the widespread adoption of the trade strategy: the distance between the two lines in Figure 2, solid vs. dashed, amounts

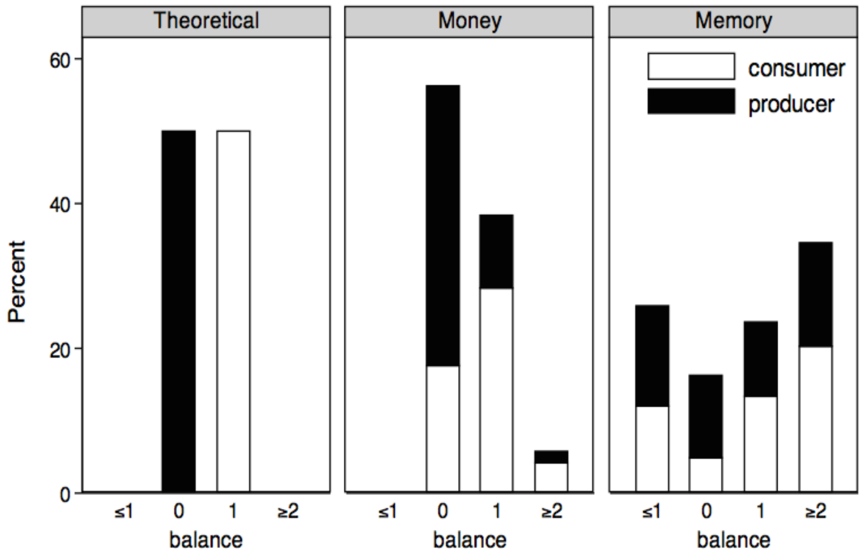

Figure 2: Distribution of balances in Money and Memory

Notes: Based on periods 15-20 of each supergame.

to 49 percentage points in the last supergame. No such evidence emerged in Memory treatment, where there is a minimal difference between lines, even in the last supergame (1 percentage point, Figure 3, right panel).

The data reveal that subjects do not use record-keeping in the same manner they use tokens. Producers do help more frequently consumers with balance H rather than L. However, in Memory producers do not condition their help on their own balance as they should following a trade strategy, while in Money they do, helping more frequently if *their* balance is L rather than H.

Table 6 reports the marginal effects of balances in a pair on the probability of observing cooperation in the pair, in the two treatments. If subjects adopt the trade strategy in each treatment, then the probability of observing cooperation should be higher in *trade meetings*—where the producer's balance is L and the consumer's is H—than in all other meetings. The Money treatment

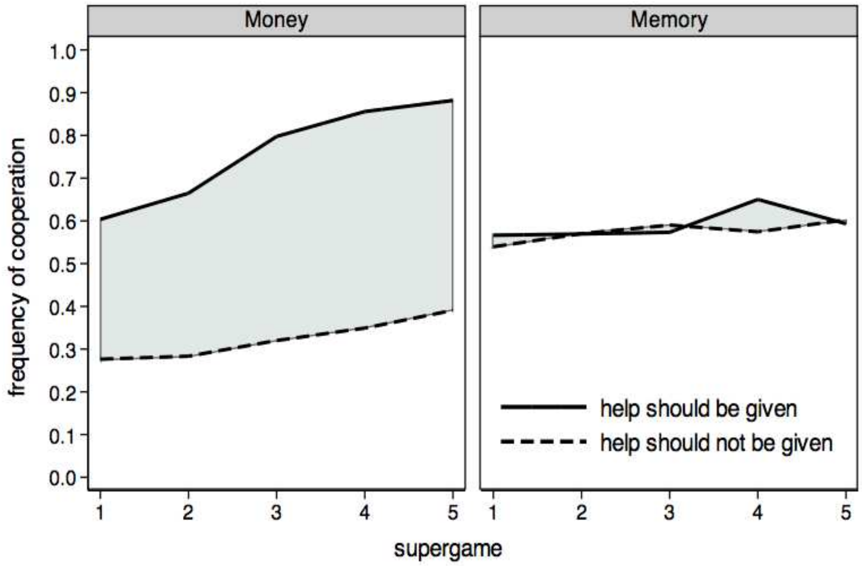

Figure 3: Trade emerges in MONEY but not in MEMORY.

is in line with this prediction: we observe that the probability of observing help being given is significantly higher in trade meetings than in all others (p-value < 0.001 for all comparisons). However, this is not so in MEMORY, where the estimated marginal effect of being in a trade meeting is significantly smaller than the estimated marginal effect when both producer and consumer have balance H (p-value $= 0.003$). In addition, the estimated marginal effect of being in a trade meeting is much smaller in MEMORY than in MONEY (p-value < 0.001 in a regression with pooled data from both treatments). This is evidence that the trade strategy is used in MONEY but not in MEMORY.

Result 4 is especially significant in light of the fact that trade in MEMORY requires less coordination than trade in MONEY, where trade can occur only if consumer and producer coordinate their actions in the pair. This is not so in MEMORY, because only the producer takes an action, while balances are

Dependent variable: *Cooperation outcome in a pair*	Money		Memory	
	Estimate	S. E.	Estimate	S. E.
Supergame	0.099***	0.016	0.138***	0.029
Period	-0.002***	0.001	-0.005***	0.002
Balance: Producer, Consumer				
L, H	0.440***	0.035	0.095***	0.016
H, L	-0.118**	0.055	-0.006	0.032
H, H	0.203***	0.063	0.191***	0.024
Controls	Yes		Yes	
N. of obs. (N. of subjects)	3600 (72)		4800 (96)	

Table 6: How balances in a meeting affect cooperation.

Notes: One observation per subject per period. Inexperienced sessions. Marginal effects from a logit regression. Robust standard errors (S.E.) adjusted for clustering at the session level. *Controls* include the following individual characteristics: gender, major, two measures of understanding of the instructions (response time and number of wrong answers in the quiz) and session location (Purdue, Chapman).

automatically adjusted. So, why did trade emerged in Money and not in Memory?

Result 5. Money *removed the incentives to free ride but* Memory *did not.*

Support for Result 5 comes from Figure 4. It shows that the introduction of Money and Memory altered the distribution of earnings because it redistributed surplus from frequent defectors to frequent cooperators.

In each supergame, we classified subjects into five categories according to the frequency of cooperative outcomes in periods in which they were producers (horizontal axis) and computed the associated average earnings across all periods, regardless of their role, consumer or producer (vertical axis). In Baseline, about 39% of subjects are frequent cooperators and 28% are frequent defectors; those who earned the most on average are the frequent defectors (Figure 4, solid line). Introducing the record keeping technology lowered the incentives to defect relative to cooperation. The association between income

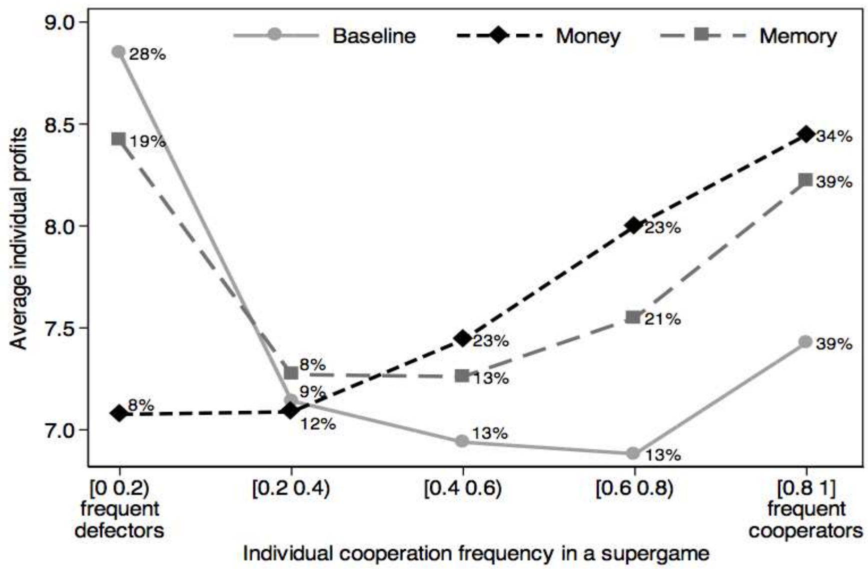

Figure 4: Cooperation frequency and profits

Notes: The percentages show the share of subjects in each category by treatment.

and cooperation remained U-shaped and frequent defectors still earn the most (Figure 4, dashed line with squares). In contrast, the use of tokens as money generates a dramatic shift in incentives: average individual earnings and cooperation frequency exhibit a positive, monotone association (Figure 4, dashed line with diamonds). Frequent defectors are now the category that earned the least, and account for only 8% of the subject population.[10] In short, a monetary system endogenously emerged in the Money treatment and the use of money removed the incentives to free ride. In contrast, in the Memory treatment subjects failed to remove incentives to free-ride, which is a likely reason why efficiency is lower in Memory than in Money.

[10]This result confirms previous findings reported in (Camera and Casari, 2014)

4.1 The effect of experience

Experience with the task is relevant for cooperation, as Figure 1 suggests. The open question is, therefore, whether Memory could outperform Money in cooperation frequency when subjects have gained enough experience. All of the results above are based on the behavior of subjects that had no previous experience with the game. Result 6 below, instead, presents evidence from subjects who had previously participated in a session of the same treatment.

Result 6. *The behavior of experienced subjects confirms and reinforces Results 1-5.*

Support for Result 6 is in Appendix B and is based on sessions where subjects had previously participated in an experiment under the same treatment. By the last supergame of the experienced sessions, cooperation in Baseline had fallen to 28.8%, in Money had risen to 94.6%, and in Memory had reached 55.4%. These levels are significantly different one from another according to a probit regression (see Appendix B). These additional data confirm and reinforce Results 1, 2 and 3.

Experience with the task helps to firmly establish the use of trade strategy in Money but not in Memory, which strengthens the finding for inexperienced subjects (Result 4). Consider the distance between the solid and dashed lines in a graph made with data from experienced sessions and similar to Figure 3. By the last supergame, there was a distance of 85 percentage points in Money and of 8 points in Memory (see Appendix B). Experience also wiped out free riding behavior in Money in line with Result 5 for inexperienced subjects. About 89% of subjects were frequent cooperators and there was nobody with an average cooperation rate less than 40%.

4.2 A robustness check

Subjects had the possibility to adopt identical strategies in Money and in Memory, but they did not. In Money cooperation was based on monetary trade, which is self-enforcing by design. A producer has an incentive to help for a token—to avoid being "liquidity constrained" in the future—and has nothing to gain from helping free-riders, who have nothing to offer in exchange. This contrasts with the record-keeping system in Memory because opportunistic consumers can always "pay" by accumulating negative balances. Here, cooperation is self-enforcing if no producer helps opportunistic individuals, yet there is a temptation to do so because the producer "gets paid" after all. A failure to punish is the source of a negative externality, which magnifies free riders' opportunistic motivations and displaces cooperation. In Memory, subjects failed to fully appreciate this externality and often failed to punish. In contrast, token exchange in Money internalized this externality, precisely because they were liquidity constrained.

To provide additional evidence in favor of this interpretation, we ran the treatment Money Unconstrained, which modifies the Money treatment by removing all liquidity constraints. A consumer who wanted to trade but was without a token, could freely produce one token for the producer; hence, trade was always feasible and balances could be negative—as in Memory.

Result 7. Money Unconstrained *supported lower cooperation and efficiency than* Memory*.*

Figure B.5 and Table B.5 (in Appendix B) provide evidence for Result 7. The data reveal that subjects did not adopt the trade strategy in the Money Unconstrained treatment. While we do find a tendency to help more frequently consumers who have tokens, we also find evidence that producers *did* *not* condition help on their own balance—in contrast with what we would expect if they had adopted the trade strategy. This behavior is in line with what was observed in MEMORY (see Table B.6 in Appendix B), but is in sharp contrasts with behavior observed in the MONEY treatment, where producers without tokens helped more frequently, instead (Table 6).

5 Related studies

Our work is related to experimental studies of cooperation in repeated social dilemmas and, in particular, to indefinitely repeated dilemmas—which support a richer set of equilibria compared to games that are one-shot or with a commonly known number of periods (Dal Bó, 2005; Palfrey, 1994). These related studies differ in the type of stage game, matching protocol, and informational conditions that are considered.

Most of the experiments on indefinitely repeated games have focused on tasks in which all subjects make a decision in every period, e.g., prisoners' dilemmas, voluntary contribution mechanisms, Bertrand duopolies, or trust games (see Bigoni et al., 2012; Engle-Warnick and Slonim, 2006; Kurzban and Houser, 2005; Roth and Murnighan, 1978). In contrast, the stage game in our design is a cooperative task known as helping or gift-giving game, in which one subject makes a decision and the other is passive (Nowak and Sigmund, 1998). The game is at the core of a large class of decentralized trade models in macroeconomics (Kocherlakota, 1998). The task is simple and directs subjects' attention to the possibility of an intertemporal exchange of favors, which is at the core of the present study.

The typical matching protocol in indefinitely repeated experiments involves fixed pairs (e.g., Dal Bó and Fréchette, 2011), which is suitable to study cooperation in small societies, where interaction is characterized by repeated encounters with known individuals. Instead, we adopt a strangers' matching protocol, which prevents subjects from relying on reciprocity. Such protocol allows us to study institutions that promote large-scale cooperation, which is central to understanding outcomes in contemporary societies where there is less scope for reciprocity because social interactions are fragmented. There is a related literature on this theme, which has mostly focused on personal punishment and information-sharing institutions such as communication (Camera and Casari, 2009; Cooper and Kuhn, 2014). Our unique contribution is to concentrate on the institution of money.

Our paper studies how knowledge of others' past actions affects trust and cooperation in a helping game. A correspondence exists with the literature on scoring systems, which mostly adopts helping games, albeit with a known ending.[11] The information-sharing system generally adopted in this literature differs from the one in the MEMORY treatment along several dimensions. First, individuals can observe a summary of only the most recent decisions of their opponents (e.g., Ule et al, 2009); we instead give a summary of *all* past decisions of opponents. Second, scores typically account only for the help given, ignoring the help *received*—unlike our experiment. Third, our design differs from experiments on "second order" information (e.g., Bolton et al., 2005; Milinski et al, 2001) as the information summaries provided in our experiment are not designed to reveal possible motives behind an individual's refusal to help (e.g., to discover if it is a reaction to defections by someone else).

[11] There is also a literature that has adopted indefinite horizon games of a different type, mostly prisoners' dilemmas or trust games to study the connection between knowledge of opponents' histories and cooperation (e.g., Bohnet and Huck, 2004; Camera and Casari, 2009). A hybrid design is in Offerman et al (2001), where subjects plays a one-shot, one-side giving problem, in a sequence of unknown length.

By studying indefinitely repeated games where subjects may exchange symbolic objects we contribute to an experimental literature about the endogenous emergence of fiat monetary systems (Camera and Casari, 2014; Camera et al., 2013). We have built upon these earlier studies, introducing two main changes to the design. First, role alternation is deterministic, which implies that the trade strategy supports full efficiency. Second, we added the MEMORY treatment, to offer a direct test of the theoretical assertion that the fundamental role of money in a society is to reveal past behaviors. Such a test represents a unique contribution to monetary economics and also to the experimental literature on fiat money (e.g., Deck et al, 2006; McCabe, 1989).[12]

Camera et al. (2013) offer an evolutionary model based on replicator dynamics of three types of players: defectors, who never help, cooperators, who always help, and traders, who exchange help for a token. Without tokens, only defectors would survive; in contrast, cooperation can emerge with tokens because monetary exchange gives an evolutionary advantage to traders. This advantage is lost with MEMORY and MONEY UNCONSTRAINED because here defectors can increase their fitness at the expense of all other players because they are as likely as anyone else to receive help from cooperators, but also from traders, by simply accumulating increasingly negative balances.

6 Conclusion

At the heart of economics lies the notion that specialization and trade hold the key to economic development. Yet, broadening the scope of commerce from a personal to an impersonal domain presents hurdles because reputation, trust and other motivational mechanisms can no longer be leveraged to deter

[12] A broader review of the experimental literature on money is in Camera and Casari (2014).

opportunistic behaviors. Many institutions have emerged over the course of history to assist impersonal exchange (Greif, 2006; North, 1991; Ostrom, 2010), including money, which remains "the universal instrument of commerce" today much as it was more than two centuries ago when Adam Smith wrote those words (Smith, 1776, Chapter 4).

Through an experiment, we have analyzed the behavioral role of money in comparison to an institution for maintaining and sharing information about past conduct, which monetary economists call "memory." Theory asserts that money has no role to play when individuals can rely on shared knowledge of past conduct to reproduce patterns of monetary exchange. We constructed economies in which strangers—who by design cannot engage in relational contracting—can derive significant benefits from cooperating over the long haul. We find that the suggested theoretical affinity between money and memory does not empirically translate into a functional equality. The differences in long-run efficiency, strategies and distribution of earnings in the MONEY and MEMORY treatments demonstrate that money performs a richer set of functions than just revealing past behaviors.

Cooperation was significantly greater in MONEY compared to MEMORY, a difference that becomes increasingly evident as subjects gain experience. In both treatments producers conditioned their choice to help others on balances in their pair, but did so in a dissimilar manner. In MEMORY, many helped even when their own balance was already positive, which set the wrong incentives for free riders—who continued to behave opportunistically. On the contrary, this pattern is rare in MONEY, and this was instrumental to its success.

Fundamentally, this occurs because groups of strangers are unable to coordinate on collective punishment schemes. This is already evident in the BASELINE treatment (Result 1) where subjects observe whether there are free-riders in the group without being able to identify them. Cooperation can be self-enforcing only if the group adopts a *common* punishment scheme, but groups seem unable (or unwilling) to do so, possibly due to heterogeneity in beliefs, cognitive skills, or emotional reactions. The addition of record-keeping in Memory lessens this fundamental behavioral problem (Result 2) by providing individual-specific information on past conduct, but does not fully solve it. Subjects *can* identify individuals as being free-riders—based on their balances—but still do not consistently sanction them (Result 5). The exchange of tokens in Money bypasses this coordination issue because punishment is built into the system (Result 4).

In the Money treatment, monetary trade is self-enforcing because of the presence of liquidity constraints. A producer has an incentive to help for a token—to avoid running out of tokens in the future—and has nothing to gain from helping free-riders, who have nothing to offer in exchange. On the other hand, in Memory and Money Unconstrained opportunistic consumers can always "pay" by accumulating negative balances. Cooperation would be self-enforcing if no one helped opportunistic individuals, but the incentive to do so is too weak because producers who help "get paid" in any case. It is precisely this lack of punishment that generates a negative externality, which magnifies free riders' opportunistic motivations and displaces cooperation. As a result—although liquidity constraints are generally considered a source of inefficiency—relaxing them in the experiment (as we do in Memory and Money Unconstrained) lowers long-run efficiency (Results 3 and 7). In our laboratory economies liquidity constraints impose discipline on sanctioning behavior, which channels the group toward cooperation.

The findings suggest that in order to bypass the hurdle of coordinating on a sanctioning rule, one must introduce institutions *in addition* to record-keeping.

For example, consider a system that updates balances *only if* the producer helps when she should, i.e., when meeting a consumer with a positive balance. Such *ad-hoc* manipulation of action histories would amount to *imposing* a form of monetary trade. In contrast, in the Money treatment the institution of monetary trade emerges endogenously, it is neither imposed nor based on ad-hoc manipulation of histories.

Could more extensive public records bring cooperation in Memory closer to the levels observed in Money? A broader information disclosure, such as making public all identities and all past actions, is known to have a powerful behavioral effect on cooperation because it enables relational contracting (e.g., Camera and Casari, 2009). But such disclosure would fundamentally change the nature of this study, which is to take on the bigger challenge of investigating how to sustain cooperation among *strangers*, when relational contracts are unavailable. The design supplies public information at a level that equally supports full cooperation in all treatments—without the need of additional institutions—while carefully ensuring that interactions remain impersonal. Subjects are informed whether someone defected in their group, without being able to single the offender out. Record-keeping augments this anonymous public monitoring system with a summary of the opponent's past history in the form of a concise balance (L or H); according to theory, this is sufficient to facilitate cooperation by replicating a monetary trade pattern, while maintaining interaction impersonal. An alternative design with precise numeric balances has the drawback of allowing identification of past opponents—altering the nature of the interaction from impersonal to personal.

The experimental evidence we provide reinforces the long-held view that monetary systems are key to support impersonal exchange, intertemporal trade and, consequently, large-scale cooperation. It also highlights original aspects of the institution of money that were previously ignored or little understood. The analysis demonstrates that the use of money imposes a discipline on what individuals are willing to do in order to keep the economy on a cooperative track. Such findings suggest that well-functioning monetary systems are not simply rudimentary arrangements for monitoring past conduct in society, but play a richer role than previously thought.

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