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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.

Keywords: Cooperation, intertemporal trade, experiments, social norms.
JEL codes: C70, C90, D03, E02

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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.

	Treatment			
Variable	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	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.

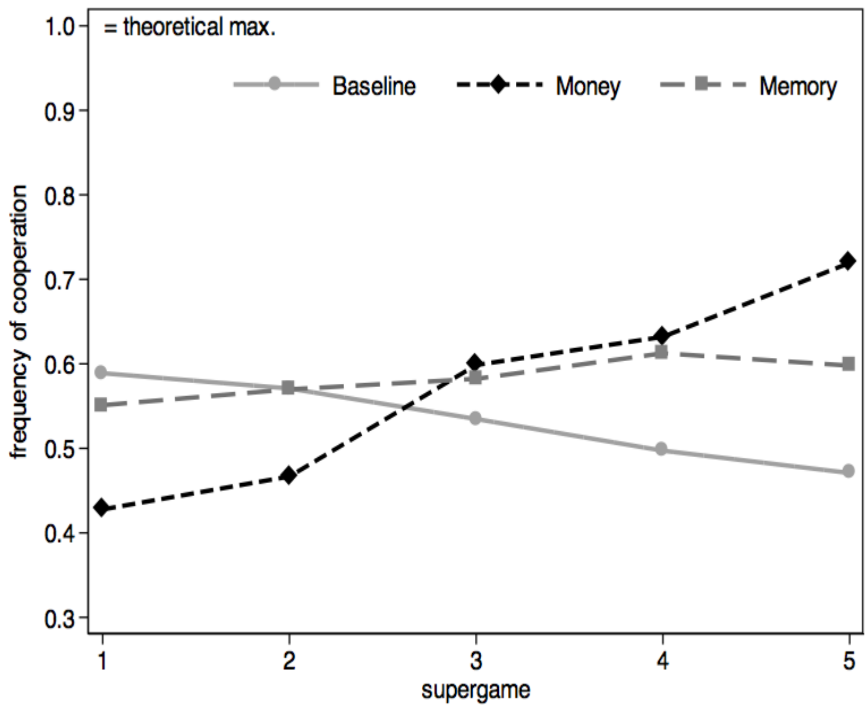

Figure 1: Relative frequency of cooperation by treatment

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:	Model 1		Model 2	
Individual rate	(Baseline)		(All treatments)	
of cooperation	Estimate	S.E.	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:	Supergame 1		Supergame 5	
Individual frequency				
of cooperation	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

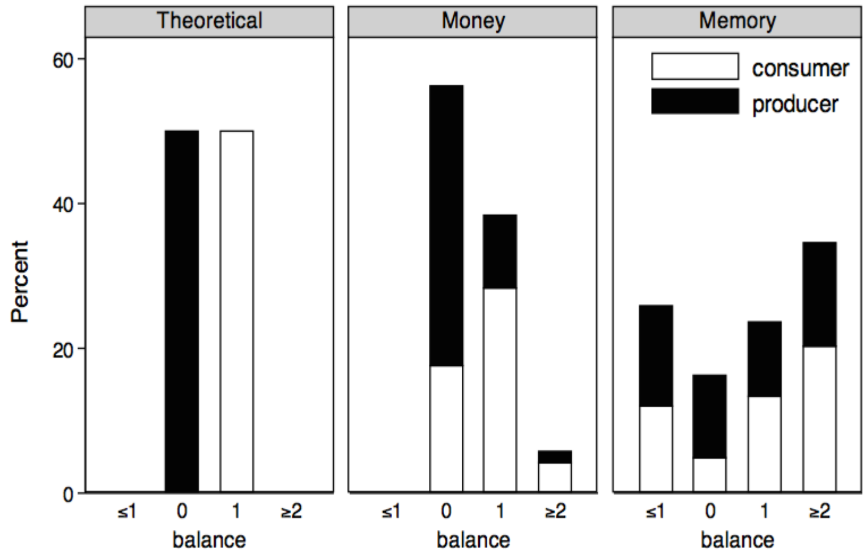

Figure 2: Distribution of balances in MONEY and MEMORY

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

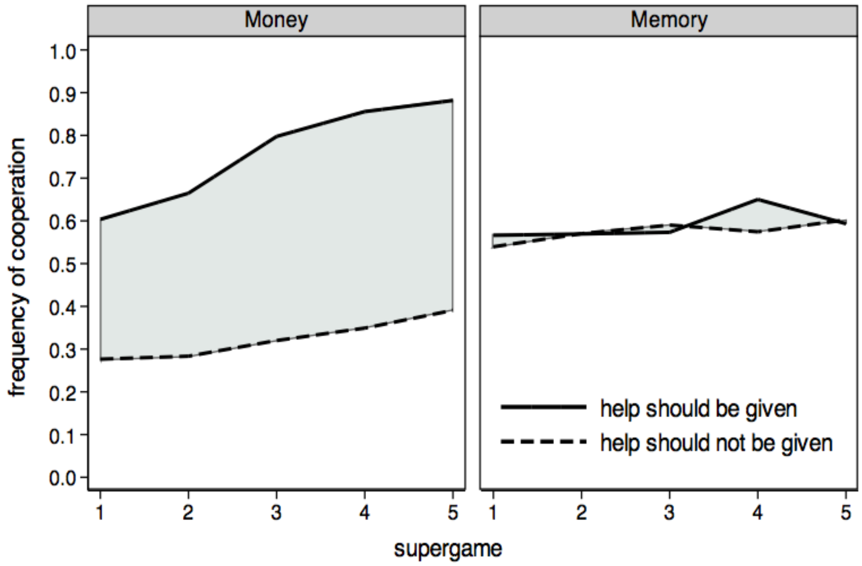

Figure 3: Trade emerges in Money but not in Memory.

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

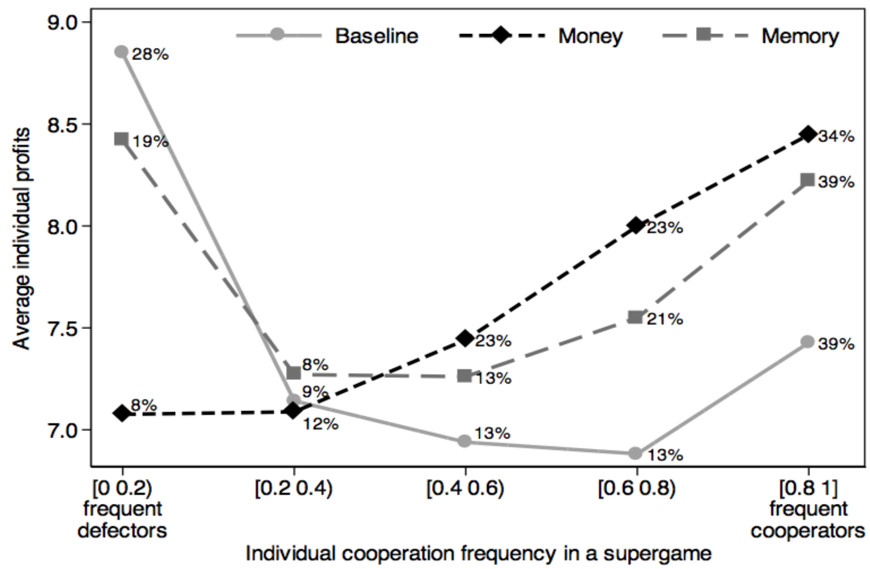

Figure 4: Cooperation frequency and profits

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.

References

Bigoni, M., Fridolfsson, S. O., Le Coq, C., and Spagnolo, G. 2012. Fines, Leniency and Rewards in Antitrust. *The RAND Journal of Economics*, 43(2), 368-390.

Binmore, K. 2005. *Natural Justice*, Oxford University Press.

Bohnet, I. and Huck, S. 2004. Repetition and reputation: Implications for trust and trustworthiness when institutions change. *The American Economic Review*, 94(2), 362-366.

Bolton, G. E., Katok, E., and Ockenfels, A. 2005. Cooperation among strangers with limited information about reputation. *Journal of Public Economics*, 89(8), 1457-1468.

Bowles, S. and Gintis, H., 2011. *A Cooperative Species: human reciprocity and its evolution*. Princeton University Press.

Camera, G. and Casari, M. 2009. Cooperation among strangers under the shadow of the future. *The American Economic Review*, 99(3), 979-1005.

Camera, G. and Casari, M. 2014. The Coordination Value of Monetary Exchange: Experimental Evidence. *American Economic Journal: Microeconomics*, 6(1), 290-314.

Camera, G., Casari, M., and Bigoni, M. 2013. Money and trust among strangers. *Proceedings of the National Academy of Sciences*, 110(37), 14889-14893.

Cooper, D. J. and Kuhn, K.-U. 2014. Communication, Renegotiation, and the Scope for Collusion. *American Economic Journal: Microeconomics*, 6(2), 247-78.

Dal Bó, P. 2005. Cooperation under the Shadow of the Future: Experimental Evidence from Infinitely Repeated Games. *American Economic Review*, 95(5), 1591-1604.

Dal Bó, P. and Fréchette, G. 2011. The Evolution of Cooperation in Infinitely Repeated Games: Experimental Evidence. *American Economic Review*, 101(1), 411-429.

Deck, C. A., McCabe, K. A., and Porter, D. P. 2006. Why stable fiat money hyperinflates: Results from an experimental economy. *Journal of Economic Behavior & Organization*, 61(3), 471-486.

Engle-Warnick, J. and Slonim, R. L. 2006. Learning to trust in indefinitely repeated games. *Games and Economic Behavior*, 54(1), 95-114.

Gächter, Simon, and Benedikt Herrmann. 2011. The limits of self-governance when cooperators get punished: Experimental evidence from urban and rural Russia. *European Economic Review* 55(2), 193-210

Greif, Avner. 2006. The Birth of Impersonal Exchange: The Community Responsibility System and Impartial Justice. *Journal of Economic Perspectives*, 20(2), 221-236.

Kimbrough Erik O., Smith Vernon and Wilson, Bart J. 2008. Historical Property Rights, Sociality, and the Emergence of Impersonal Exchange in Long-Distance Trade. *American Economic Review*, 98(3), 1009-1039

Kocherlakota, N.R., 1998. Money is memory. Journal of Economic Theory, 81, 232-251.

Krugman, Paul. 2013. Bitcoin is Evil. *New York Times*, December 28th edition.

Kurzban, R. and Houser, D. 2005. Experiments investigating cooperative types in humans: A complement to evolutionary theory and simulations. *Proceedings of the National Academy of Sciences*, 102(5), 1803-1807.

McCabe, K. A. 1989. Fiat money as a store of value in an experimental market. *Journal of Economic Behavior & Organization*, 12(2), 215-231.

McCabe, K., Rassenti, S., and Smith, V., 1998. Game Theory and Reciprocity in Some Extensive Form Experimental Games. *Proceedings National Academy of Science*, 93, 13421-13428.

Milinski, M., Semmann, D., Bakker, T. C., and Krambeck, H. J. 2001. Cooperation through indirect reciprocity: image scoring or standing strategy? *Proceedings of the Royal Society of London, Series B: Biological Sciences*, 268, 2495-2501.

North, D.C., 1991. Institutions. *Journal of Economic Perspectives*, 5(1), 97-112.

Nowak, M. A. and Sigmund, K. 1998. Evolution of indirect reciprocity by image scoring. *Nature*, 393(6685), 573-577.

Offerman, T., Potters, J., and Verbon, H. A. 2001. Cooperation in an overlapping generations experiment. *Games and Economic Behavior*, 36(2), 264-275.

Oprea, R. 2014. Survival versus profit maximization in a dynamic stochastic experiment. *Econometrica*, 82(6), 2225-2255.

Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. *American Economic Review* 100, 641-672.

Ostroy, J.M. 1973. The Informational Efficiency of Monetary Exchange. emphAmerican Economic Review, 63(4), 597-610

Palfrey, T.R. and Rosenthal, H., 1994. Repeated Play, Cooperation and Coordination: An Experimental Study. *The Review of Economic Studies*, 61(3), 545-565.

Riedl, Arno, Ingrid M. T. Rohde, and Martin Strobel. 2011. Efficient Coordination in Weakest-Link Games. Ifo Institute Center for Economic Studies (CESifo) Working Paper 3685.

Roth, Alvin E., and Keith Murnighan. 1978. Equilibrium behavior and repeated play of the prisoner's dilemma. *Journal of Mathematical Psychology*, 17, 189-98

Smith, Adam, 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations*. Gateway Editions; First Edition edition (September 1, 1999)

Townsend, R., 1980. Models of money with spatially separated agents. In: Kareken, J., Wallace, N. (eds.) *Models of monetary economies*, 265-303. Minneapolis: Federal Reserve Bank of Minneapolis

Townsend, R., 1987. Economic Organization with Limited Communication. *American Economic Review*, 77 (5), 954-971

Ule, A., Schram, A., Riedl, A., and Cason, T. N. 2009. Indirect punishment and generosity toward strangers. Science, 326(5960), 1701–1704.

R. A. Weber, 2006. Managing Growth to Achieve Efficient Coordination in Large Groups. *Am. Econ. Rev.*, 96(1), 114-126.

Wedekind, C. and Milinski, M. 2000. Cooperation through image scoring in humans. *Science*, 288(5467):850–852.

Appendix A (not for publication)

Details and Proofs of Propositions

1 The model

A group is composed of $N = 2n$ identical players. On the initial period $t = 1$, the population is randomly divided into $n \geq 2$ *consumers* (="blue," in the experiment) and n *producers* ("red"); each player has equal probability of being assigned either role. In all subsequent periods players deterministically alternate between these two roles; producers in period t become consumers in $t + 1$, and vice-versa.

Matching in a period: An exogenous matching process randomly partitions the population into n consumer-producer pairs in each period t. Pairings are random, equally likely, and independent over time. Given that there is an equal number n of consumers and producers, there are $n!$ ways to create n consumer-producer pairs. Let $o_i(t)$ be player i's opponent in period t. Fixing some player $j \neq i$, it holds that $o_i = j$ in $(n-1)!$ of all possible pairs. Hence, in each period any given consumer is matched to any of the n producers with probability $1/n$ (and vice-versa).

Interaction in a pair: In Baseline, only the producer has a choice to make, either Z or Y. If Z is the outcome, then g is the payoff to the consumer and 0 is the payoff to the producer. If Y is the outcome, then d is the payoff to the consumer, while the producer obtains $d - l$ with $-l \leq 0 \leq d < g$; see Figure 1. The outcome Z is called *cooperation* because it generates $g - 2d + l > 0$ surplus, where $g - (d - l)$ is the consumer's share and $-d$ is the producer's share. The outcome Y is called *defection*, as it generates no surplus. The interpretation is that there are gains from specialization and trade: producers have a specialized perishable good, which gives more consumption utility to consumers than producers. Define the (socially) efficient outcome in a match as the one in which total surplus is maximized. Cooperation is efficient but is *not* mutually beneficial. Defection is the unique Nash equilibrium of a one-shot interaction.

The supergame: consider an infinite repetition of the interaction, indexing time $t = 1, 2, \ldots$. Period payoffs are geometrically discounted at rate $\beta = 0.75$ starting from period $T = 20$. Histories are private information, but at the end of each period, players can observe the actions of their opponent and if outcome are identical in all meetings. We call this anonymous public monitoring because it allows public detection of defections on the equilibrium path but it does not allow players to identify opponents. These assumptions imply that players can neither build a reputation nor engage in relational contracting. Payoffs in the repeated game are the sum of expected period-payoffs, discounted starting on period T. In the repeated game, the efficient outcome corresponds to cooperation in each meeting of every period.

Matching across supergames: In each experimental session we created five supergames ensuring that no two subjects could be paired in more than one supergame. Groups are created as follows. In each supergame there are three groups with eight subjects each. Four are of type 1 (beginning producer) and four of type 2 (beginning consumer). Type 1 subjects can only meet type 2 subjects and viceversa. The 24 subjects are partitioned in 6 sets of 4 each: $A = \{1, 2, 3, 4\}$, $B = \{5, 6, 7, 8\}$, . . . , $F = \{21, 22, 23, 24\}$. The sets A through F are fixed for the duration of the session and are paired in each supergame to form groups. During the session subjects are matched to subjects from other sets. The groups can be read in the table below.

	Pair this set...					
	A	B	C	D	E	F
. . . to this set in supergame 1	C	E	A	F	B	D
. . . to this set in supergame 2	B	A	F	E	D	C
. . . to this set in supergame 3	D	C	B	A	F	E
. . . to this set in supergame 4	E	F	D	C	A	B
. . . to this set in supergame 5	F	D	E	B	C	A

That is in supergame 1, group 1 is composed of sets $\{A, C\}$, group 2 of sets $\{B, E\}$ and group 3 of sets $\{D, F\}$, and so on.

2 Existence of a cooperative equilibrium

To support full cooperation as an equilibrium outcome we consider a grim trigger strategy described by a two-state automaton.

Definition 1 (Cooperative strategy). *At the start of any period t, player i can be "active" or "idle," and takes actions only as a producer. As an active producer, player i selects Z, and as an idle producer selects Y. The player starts active on the initial date $t = 1$; in all $t \geq 1$*

(i) *if player i is active, then i becomes idle in $t+1$ only if some producer in the group—not necessarily the producer in $\{i, o_i(t)\}$—chooses Y. Otherwise, player i remains active;*

(ii) *There is no exit from the idle condition.*

We call (full) cooperation the outcome that results when everyone adopts the strategy in Definition 1. If everyone adopts this strategy, then this strategy is called a **social norm**. Intuitively, this norm consists of a rule of cooperation and rule for punishment: (i) Cooperation: if the player is a producer, then he selects Z; (ii) Punishment: if an outcome Y is observed in the group, then the player will always select Y whenever he is a producer. The central feature of this norm is that the entire group participates in enforcing defections but in equilibrium no one ever defects. In what follows we show that, under this social norm, cooperation is a sequential equilibrium if β is sufficiently large.

Proposition 3. *if $\beta \geq \beta^* := \dfrac{d}{g-d+l}$, then the strategy in Definition 1 supports full cooperation in sequential equilibrium.*

The proof is contained in the remainder of this section. Start by calculating equilibrium payoffs. Recall that players deterministically alternate between the two roles of producer and consumer. Hence, in equilibrium players earn g every other period. Discounting kicks in on date T, hence, only payoffs from periods $t = T+1$ (included) are discounted at rate β. Let $v_s(t)$ denote the equilibrium payoff at the start of $t = 1, 2, \ldots$ to an player who is in state $s = 0, 1$, where $0 =$producer and $1 =$consumer.

Lemma 1. *Fix $T \geq 1$ and $\beta \in (0,1)$. In cooperative equilibrium we have $v_1(t) > v_0(t)$ for all $t = 1, 2, \ldots,$ where*

$$v_s(t) := \begin{cases} g \times \dfrac{T-t}{2} + v_s, & \textit{if } \; T-t = 2k \\ g \times \dfrac{T-t+1}{2} + \beta v_s, & \textit{if } \; T-t = 2k-1, \\ v_s, & \textit{if } \; T-t \leq 0, \end{cases} \tag{1}$$

and

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

Proof of Lemma 1. To prove the result we consider the two cases $t \geq T$ and $t < T$ separately.

Let v_s denote the equilibrium payoff at the start of period $t \geq T$ to an player who is in state $s = 0, 1$ (0 identifies a producer). It holds that

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

The payoff is time invariant because of the stationary alternation between states.

Now consider period $t < T$. According to the proposed strategy those who are initial consumers earn g on odd dates ($t = 1, 3, \ldots$) and zero otherwise, while initial producers earn g on even dates ($t = 2, 4, \ldots$) and zero otherwise. Hence, knowing whether $T - t$ is odd or even matters. For $j, k = 1, 2 \ldots$ and $s = 0, 1$ it holds that

$$v_s(t) = \begin{cases} g \times \dfrac{T-t}{2} + v_s & \text{if } T - t = 2k \\ g \times \dfrac{T-t+1}{2} + \beta v_s & \text{if } T - t = 2k - 1. \end{cases}$$

The continuation payoff $v_s(t)$ has two components. The first sums up the period payoffs for all $t \leq T - 1$. The second sums up the period payoffs for all $t \geq T$. It should be clear that $v_s(t)$ is increasing in T for $s = 0, 1$ and it achieves a minimum when $T - t = 1$.

Consequently, the equilibrium payoff to an player in state $s = 0, 1$ on any date $t \geq 1$ is given by (1). We have $v_1(t) > v_0(t)$ for all t because $v_1 > v_0$ for all $\beta \in (0, 1)$. □

The equilibrium payoff is found simply by substituting $t = 1$ in (1).

2.1 Incentives in and off equilibrium

To determine the optimality of the cooperative strategy we must check two items: (i) In equilibrium no producer has an incentive to defect; (ii) out of equilibrium no producer has an incentive to cooperate. We let $\hat{v}_s(t)$ denote the continuation payoff to an player in state s on date t, off equilibrium.

In equilibrium no producer defects: Conjecture that the strategy in Definition 1 is a social norm. Consider a generic producer in a period $t \geq 1$; choosing Z is a best response if

$$v_0(t) \geq \hat{v}_0(t). \tag{2}$$

The left-hand-side of the inequality denotes the payoff to a producer who cooperates in the period, choosing Z. The right-hand-side denotes the continuation payoff on date t if the producer defects in equilibrium (reverting back to playing the social norm in the following period), given that off-equilibrium everyone follows the group punishment rule prescribed by the social norm. Hence, if a defection occurs on t, then every producer selects Y from $t+1$ because equilibrium defections are public.

It should be clear that

$$\hat{v}_0(t) = \hat{v}_0 := \frac{d + \beta(d-l)}{1-\beta^2} \qquad \text{if } t \geq T.$$

For $k = 1, 2, \ldots$, the continuation payoff off-equilibrium satisfies

$$\hat{v}_0(t) := \begin{cases} (d + d - l) \times \dfrac{T-t}{2} + \hat{v}_0 & \text{if } T - t = 2k \\ (d + d - l) \times \dfrac{T-t+1}{2} + \beta\hat{v}_0 & \text{if } T - t = 2k-1, \\ \hat{v}_0 & \text{if } T - t \leq 0. \end{cases} \tag{3}$$

Off equilibrium payoffs are independent of the size of the group N since producers defect forever after seeing a defection.

Lemma 2. *Fix $T \geq 1$ and $\beta \in (0,1)$. If*

$$\beta \geq \beta^* := \frac{d}{g-d+l},$$

then $v_0(t) \geq \hat{v}_0(t)$ for all $t = 1, 2, \ldots$.

Proof of Lemma 2. The result is obtained by manipulation of the equations in (3). Note that

$$v_0 - \hat{v}_0 = \frac{\beta}{1-\beta^2} \times g - \frac{d+\beta(d-l)}{1-\beta^2} = \frac{\beta}{1-\beta^2} \times (g-2d+l) - \frac{d}{1+\beta}$$

Now define

$$\begin{aligned}\Delta_0(t) &= v_0(t) - \hat{v}_0(t) \\ &= \begin{cases} (g-2d+l) \times \dfrac{T-t}{2} + v_0 - \hat{v}_0 & \text{if } T-t = 2k \\ (g-2d+l) \times \dfrac{T-t+1}{2} + \beta(v_0 - \hat{v}_0) & \text{if } T-t = 2k-1, \\ v_0 - \hat{v}_0 & \text{if } T-t \leq 0. \end{cases}\end{aligned}$$

It is immediate that $\Delta_0(t = T-2k) > \Delta_0(t \geq T)$; simply note that $g-2d+l > 0$ by assumption. Also, $\Delta_0(t = T-2k+1) > \Delta_0(t \geq T)$; to prove it insert $k = 1$ (the most stringent case), rearrange the inequality, and then insert the expression for $v_0 - \hat{v}_0$, to obtain the inequality $g - 2d + l > -d$.

Given that the minimum value of $\Delta_0(t)$ is achieved for $T - t \leq 0$, then (2) holds for all t whenever

$$
\begin{aligned}
0 \quad &\leq \quad v_0 - \hat{v}_0 = \frac{\beta}{1-\beta^2} \times (g - 2d + l) - \frac{d}{1+\beta} \\
&\Leftrightarrow \quad \beta \geq \beta^* := \frac{d}{g-d+l}.
\end{aligned}
$$

Note that $\beta^* < 1$ because $g - 2d + l > 0$ by assumption.[13] $\square$

Out of equilibrium no producer cooperates: given that everyone else follows the candidate strategy in Definition 1, it is always individually optimal to punish out of equilibrium. A producer optimally selects Y out of equilibrium, since Y is the dominant action when everyone forever defects. If a producer selects Z instead of Y out of equilibrium—and reverts to play Y afterward—he earns 0 and the continuation payoff is $\beta\hat{v}_1(t)$, because he starts next period as a producer, off-equilibrium. By selecting Y this period, as required by the social norm, he earns $d > 0$ and the continuation payoff is $\beta\hat{v}_1(t)$.

Note that $\hat{v}_s(1)$ is the payoff associated to infinite repetition of the static Nash equilibrium (every producer always chooses Y), which is always an equilibrium of the repeated game. The condition $\beta \geq \beta^*$ is therefore necessary and sufficient for existence of a cooperative equilibrium because it ensures that players earn payoffs above those guaranteed by defecting at any point in time. The condition $\beta \geq \beta^*$ does not guarantee that cooperation will be realized because many equilibria exist in the game. Given the experimental parameters, we have $\beta^* = 3/8 = 0.375$. It follows that the fully cooper-

[13] The producer's payoff from cooperating is normalized to zero. For generality, let it be $c < d$, instead. In this case it is easy to demonstrate that we have $\beta^* := \dfrac{d-c}{g-d+l}$ because $v_0 = \dfrac{c+\beta g}{1-\beta^2}$.

ative equilibrium exists in the Baseline condition because in the experiment $\beta = 0.75$. Furthermore this equilibrium exists in all treatments because tokens and balances are intrinsically worthless, do not restrict the action set, and can always be ignored.

3 Existence of monetary equilibrium

Consider the Money treatment. Each of the $N/2$ initial consumers is initially endowed with one indivisible, intrinsically worthless token. The supply of tokens is fixed at $M = N/2$. It is assumed that token holdings are partially observable by the opponent: in each pair, each player can verify whether the opponent has either 0 or at least one token; the exact number is unobservable. Consider the following strategy.

Definition 2 (**Monetary trade strategy**). *In any period t, after any history, if the player is*

- *without tokens: she has no action to take as a producer; chooses Z conditional on receiving a token, as a consumer;*
- *with tokens: as a consumer she transfers one token to the producer conditional on Z being the outcome; as a producer she selects Y.*

We call *monetary trade* the outcome that results when everyone adopts the strategy in Definition 2. Under monetary trade help is given quid-pro-quo in exchange for a token. Otherwise, help is not given and each player exits the match with their initial endowment. Monetary trade is an equilibrium that sustains the socially efficient allocation on the same parameter set as the use of the social norm. The reason is that in monetary equilibrium all meetings lead to a trade due to the deterministic alternation between consumption and production opportunities. This is demonstrated in what follows.

Proposition 4. *If $\beta \geq \beta^*$, then the monetary trade strategy in Definition 2 supports full cooperation in equilibrium.*

Proof of Proposition 2. Conjecture that monetary trade is an equilibrium. Consider an player with token balance $s = 0, 1$ at the start of a period. In equilibrium, a consumer has a token and a producer has none. Hence, the probability that a consumer with a token meets a producer without tokens is 1. Denote by $v_s(t)$ the equilibrium continuation payoff. Because the consumption pattern is the same as under the social norm, in monetary equilibrium it holds that $v_s(t)$ corresponds to the functions defined in (1).

Now consider deviations. We start by proving that a consumer does not deviate in equilibrium, refusing quid-pro-quo exchange for Z. In period $t \geq 1$ let $\beta_t = 1$ if $t < T$ and $\beta_t = \beta$ otherwise. Denote by $\tilde{v}_1(t)$ the payoff in t to a consumer who defects by refusing to spend money in t. Using recursive arguments we have

$$\begin{aligned} \tilde{v}_1(t) &= d - l + \beta_t[d + \beta_{t+1} v_1(t+2)] \\ &< g + \beta_t[0 + \beta_{t+1} v_1(t+2)] = v_1(t). \end{aligned}$$

The inequality holds for any β_t because $g > d + d - l$ by assumption. To understand the inequality consider the first line. Defecting in t generates payoff $d - l$ instead of g, and in $t+1$ the player will be a producer *with* money, reverting back to playing the monetary strategy (unimprovability criterion). Hence, she will refuse to sell for another token because she already has one; this is optimal because (i) acquiring an additional token costs her d and (ii) she has already one token to spend. hence, in $t+2$ the player becomes a consumer with money and the distribution of tokens is back at equilibrium. In summary, following a unilateral deviation in t by a consumer, the group is back on the equilibrium path in period $t+2$.

Now we prove that if $\beta \geq \beta^*$, then a producer in equilibrium would not want to deviate in any t, refusing to help for a token. Denote by $\tilde{v}_0(t)$ the payoff in t to a producer who defects by refusing to accept money in t. Using recursive arguments, we have

$$\begin{aligned} \tilde{v}_0(t) &= d + \beta_t[d - l + \beta_{t+1} v_0(t+2)] \\ &< 0 + \beta_t[g + \beta_{t+1} v_0(t+2)] = v_0(t). \end{aligned}$$

The inequality holds for any $\beta_t \geq \beta^*$ because $g > d + d - l$ (if $\beta_t = 1$) and if $\beta_t = \beta$ then we simply need $\beta \geq \beta^*$. The first line of the inequality shows that defecting in t generates payoff d instead of 0. In $t+1$ the player is a consumer *without* money; she is unable to buy help—since everyone follows the monetary strategy—and earns $d - l$. In $t+2$ she is a producer without money and the distribution of tokens is back at equilibrium. Hence, after a unilateral deviation in t by a producer, the group is back in equilibrium in period $t+2$. □

4 Equilibrium with record-keeping

Consider the MEMORY treatment. Each player is initially assigned a balance, "1" if consumer and "0" if producer, which is automatically updated at the end of each period. The player's balance may increase or decrease by one unit, or may remain the same, depending on the outcome in the pair. Balances in a pair are unchanged if Y is the outcome. Otherwise, if Z is selected, then the producer's balance increases by 1 and the consumer's balance decreases by 1. Consequently, the sum of all balances is fixed at $N/2$ in each period and over the course of the game the individual balance may take negative or positive integer values. It is assumed that player sees whether the opponent's balance is L (="0 or below") or H (="1 or above"). The exact balance is private information. Balances allow players to replicate the monetary trade without the need to exchange objects.

Definition 3 (**Trade strategy**). *At the start of any period t and after any history, if player i is a consumer, then he has no action to take. If player i is a producer with balance L, then she chooses Z only if the consumer has a balance H; she selects Y in all other circumstances.*

It is therefore immediate that if $\beta \geq \beta^*$ then the strategy in Definition 3 supports the fully cooperative equilibrium. The same analysis done for the monetary trade strategy can be used here. As in the case of monetary trade, if a producer deviates from equilibrium, then the group recovers the equilibrium distribution of balances in two round of play, as seen before.[14]

[14] To see this, suppose player j on period t is a producer who deviates, in equilibrium. As a consequence, his balance remains zero. Next period, player j is a consumer with 0 balance and has no action to take. The producer who meets j on date $t+1$ does not cooperate, so j enters next period still with 0 balance, as a producer. On $t+2$ player j, having reverted to playing the equilibrium strategy, cooperates. We are thus back on the equilibrium path.

Appendix B (not for publication)

Design and Results: Additional Information

1 Design specifics in Money and Memory

We call Token an electronic object that is intrinsically worthless because holding it yields no extra points or dollars, and it cannot be redeemed for points or dollars at the end of any supergame. Tokens can be carried over to the next period but not to the next supergame. Tokens can be transferred from consumer to producer, one at a time. There is no upper bound on token balances and there is a lower bound of zero. Because outcome and actions are observed only at the end of each meeting, subjects cannot signal their desire to cooperate by requesting or offering a token. These same considerations apply to Memory with the difference that there is no lower bound on balances and that consumers are always passive.

The spontaneous use of tokens as money

In a meeting, consumer and producer make simultaneous selections from their choices sets, without prior communication. Choices are observable at the end of the meeting, to speed up learning in the game. Choices that are incompatible lead to the status quo. This design ensures that subjects can neither incur involuntary losses, nor can garnish their opponent's token holdings or earnings. If subjects choose to conditionally trade help for a token, then this would suggest that tokens have acquired value endogenously.

Second, to avoid biasing the results in favor of the emergence of monetary exchange the design includes actions that are antithetical to monetary 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* the choice Z. Hence, tokens may take on a negative connotation as subjects could use them to tag producers who do not provide unconditional help. Given this richer action set, the addition of tokens might increase coordination problems relative to BASELINE.

The actions Z *for* 0 and 1 *for* Y are antithetical to monetary exchange. The outcome function specifies that a producer executes Z only if the consumer keeps her token, while the consumer keeps her token only if the producer unconditionally helps. These actions are consistent with money having a negative connotation because they allow subjects to tag opponents as defectors. To see this consider that there are two types of players in each period, A (who starts the supergame as consumers with one token) and B (who starts as a producer without a token). A-consumers can tag as defectors B-producers by giving them a token if they do not help. Consequently, B-producers "help" only if their opponent keeps her token. On the other hand, A-consumers are identified as cooperators only if they *do* have a token, hence would ask for a token if they are producers without one; in that match, a B-consumer would gladly get rid of her token. Within this richer choice set, subjects have more trouble in discovering the potential use of tokens as money.

Possible and impossible trades

Token transfers could not take place in every circumstance off equilibrium. Trade is possible when the consumer has at least 1 token. Otherwise, trade is impossible, in which case consumer and producer have a restricted choice set. In the experiment, a consumer with 0 tokens had no action to take (=do nothing), and his producer opponent could only choose between Y and Z. Subjects were informed whether trade was possible before making a choice

	Token holdings	
Period	**Producer**	**Consumer**
t=1	0	1
t=2	1	0
t=3	0	1
t=4	1	0
⋮	⋮	⋮

Table B.1: Using tokens to tag defectors

in a way that minimized the chance that such information would indirectly reveal identities. Each player observed whether his opponent had either 0 or "1 or more tokens." Providing information about token holdings reduces the cognitive load for participants when making a decision and when interpreting the outcome.

Monitoring of past actions

In all treatments subjects could observe on their screens the results of every past period of the supergame. The information included the outcome of the encounter, Y or Z, and whether the outcomes were identical in every pair of the group. In Money, subjects also observed whether a token was transferred in the encounter. This information was also visible at all times on the screen and included all past periods. Each subject had also a pen and a sheet of paper to fill in with the results. Requiring manual writing is a standard procedure in experimental economics for the purpose of maintaining participants alert to the ongoing session and to make sure that subjects are aware of the outcome of interactions as the experiment unfolds. The same procedure was followed in all treatments. If subjects wanted to rely on history-dependent strategies, such as trigger strategies, they could easily access information about past outcomes either on the screen or on paper. This design feature could have biased the results against the use of tokens as money.

2 Additional Tables and Figures

In the experiment, producers conditioned help on the opponent's balance, L or H (Table B.2). In Money and Memory treatments consumers with a balance H receive more help than those with balance L. However, in Money producers with a positive balance helped less frequently than producers with a balance of 0 or less. On the other hand, in Memory this gap is less pronounced.

	Consumers' balance		
Producers' balance	L	H	Total
Money			
L	0.299	0.774	0.634
H	0.169	0.491	0.337
Total	0.258	0.726	0.569
Memory			
L	0.477	0.592	0.567
H	0.486	0.683	0.605
Total	0.482	0.623	0.583

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

Table B.2: Frequency of cooperation by subjects' balance (inexperienced sessions).

2.1 Experienced subjects

Dependent variable: *Individual frequency of cooperation*	Model 1 (Baseline)		Model 2 (All treatments)	
	Estimate	S.E.	Estimate	S.E.
Supergame	-0.038***	0.012	-0.038***	0.011
Money			0.369***	0.066
Money x Supergame			0.045***	0.016
Memory			0.132*	0.068
Memory x Supergame			0.007	0.016
Constant	0.699***	0.238	0.670***	0.111
N. of obs. (N. of subjects)	120 (24)		360 (72)	
R-squared within	0.098		0.064	
R-squared between	0.115		0.728	
R-squared overall	0.104		0.520	

Notes: One observation per subject per supergame. All supergames included. 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= 0.002). The estimated coefficients for *Money x supergame* and *Memory x supergame* are significantly different at the 5% level (p-value= 0.017). The sum of the coefficients *Supergame* and *Memory x supergame* is significant at the 1% level (p-value = 0.005). The sum of the coefficients *Supergame* and *Money x supergame* is not significant (p-value > 0.1). *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).

Table B.3: Cooperation frequency (experienced sessions).

Dependent variable: *Individual frequency of cooperation*	Supergame 1		Supergame 5	
	Estimate	S.E.	Estimate	S.E.
Money	0.586***	0.025	0.666***	0.008
Memory	0.245**	0.055	0.210**	0.030
Constant	0.511	0.229	0.385***	0.028
Controls	Yes		Yes	
N. of obs. (N. of subjects)	72 (72)		72 (72)	
R-squared	0.511		0.760	

Table B.4: Treatment Effects on Cooperation in Supergames 1 & 5 (experienced sessions).

Notes: One observation per subject. Experienced 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 5% level (p-value: 0.042). In supergame 5 the estimated coefficients for *Money* and *Memory* are significantly different at the 1% level (p-value: 0.005). *Controls* include the following individual characteristics: gender, major, and two measures of understanding of the instructions (response time and number of wrong answers in the quiz).

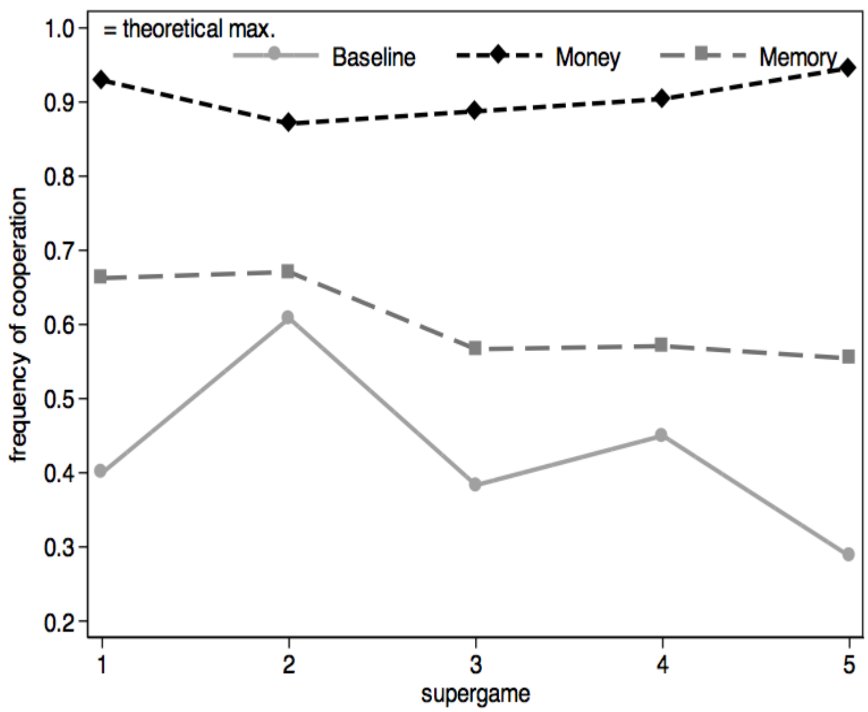

Figure B.1: Cooperation frequency by treatment (experienced sessions)

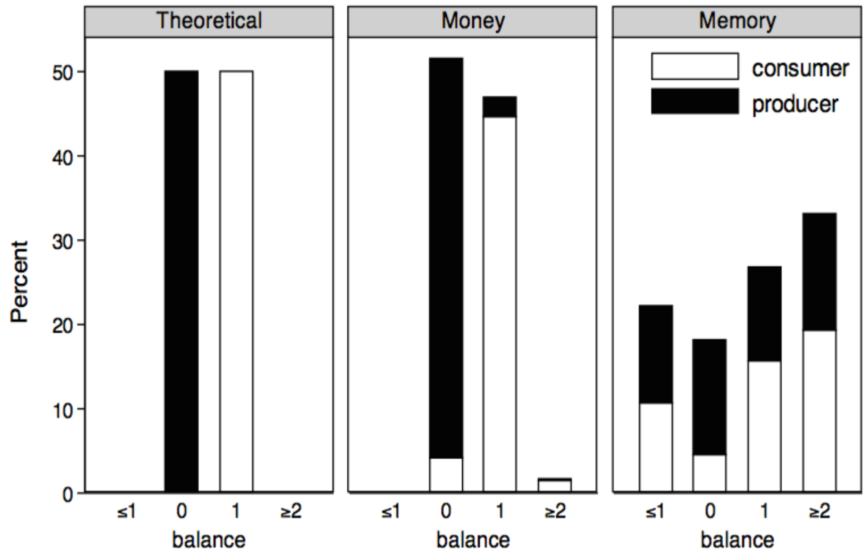

Figure B.2: Distribution of balances in MONEY and MEMORY (experienced sessions)

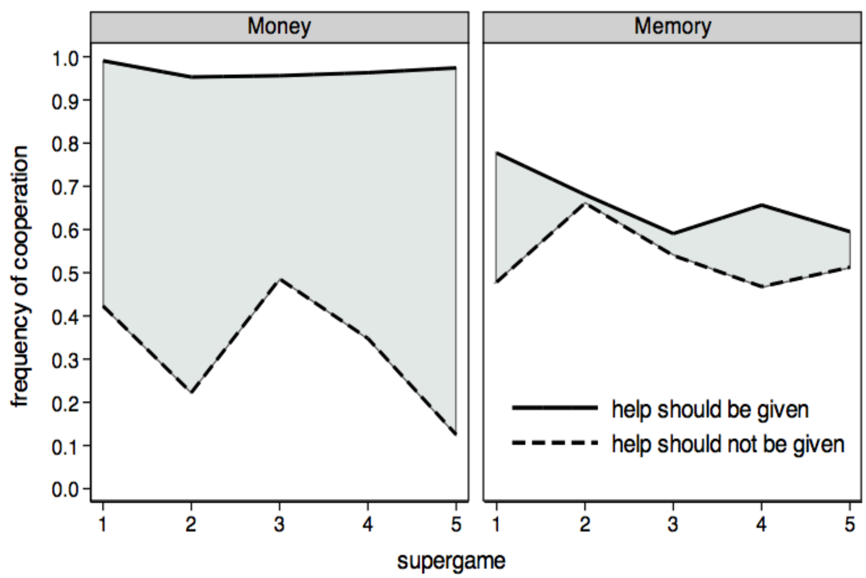

Figure B.3: Trade emerges in MONEY but not in MEMORY.

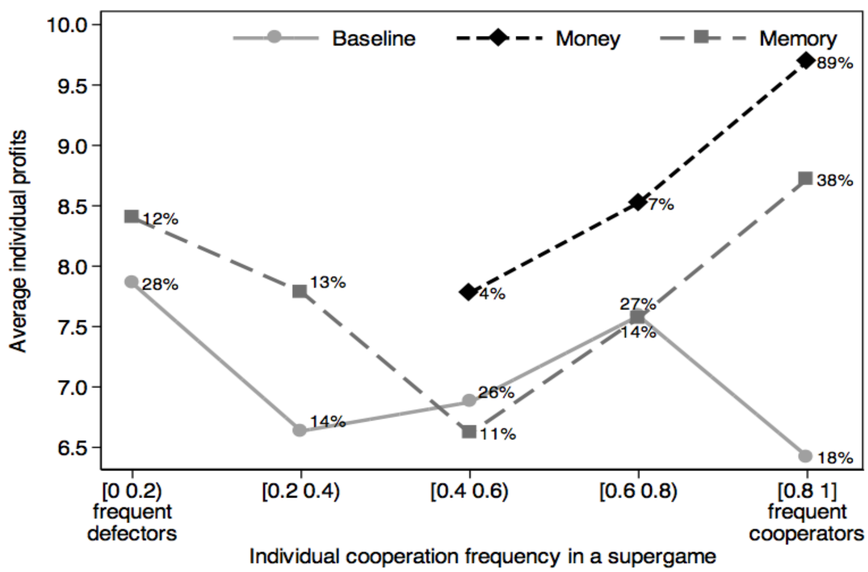

Figure B.4: Cooperation frequency and profits (experienced sessions)

2.2 Treatment Money Unconstrained

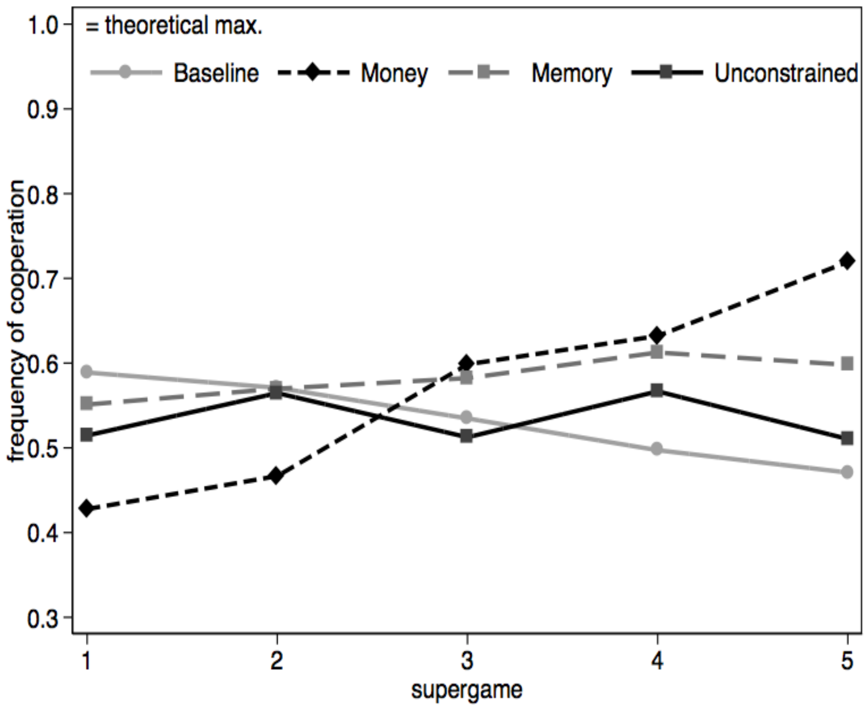

Figure B.5: Cooperation frequency by treatment

Dependent variable: *Individual frequency 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			-0.273***	0.068
Money x Supergame			0.106***	0.018
Memory			-0.103*	0.062
Memory x Supergame			0.045***	0.016
Unconstrained			-0.183***	0.057
Unconstrained x Supergame			0.030**	0.013
Constant	0.308**	0.127	0.423***	0.093
Controls	Yes		Yes	
N. of obs. (N. of subjects)	360		1440	
R-squared within	0.064		0.109	
R-squared between	0.259		0.188	
R-squared overall	0.179		0.152	

Table B.5: Cooperation frequency.

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 *Unconstrained* and *Memory* are significantly different at the 5% level (p- value= 0.014). The estimated coefficients for *Unconstrained x Supergame* and *Memory x Supergame* are significantly different at the 10% level (p- value$<$ 0.091). The sum of the coefficients *Supergame* and *Unconstrained x Supergame* is not statistically significant (p-value $>$ 0.1). *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:	Money Unconstrained	
Cooperation outcome in a pair	Estimate	S. E.
Supergame	0.141***	0.041
Period	-0.007***	0.002
Balance		
Producer, Consumer		
L, H	0.057***	0.016
H, L	0.001	0.012
H, H	0.220***	0.068
Controls	Yes	
N. of obs. (N. of subjects)	2400 (48)	

Table B.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, and two measures of understanding of the instructions (response time and number of wrong answers in the quiz).

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