The coordination value of monetary exchange: Experimental evidence[*]

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Abstract

What institutions can sustain cooperation in groups of strangers? Here we study the role of monetary systems. In an experiment, subjects sometimes needed help and sometimes could incur a cost to help an anonymous counterpart. In the absence of money, the intertemporal exchange of help, which could be supported by a norm of community punishment of defectors, did not emerge. Introducing intrinsically worthless tokens substantially altered patterns of behavior. Monetary trade emerged, which increased predictability of play and promoted cooperation when strangers could trade help for a token.

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Impersonal exchange—trading with complete strangers instead of well-known individuals—is a fundamental trait of developed market economies (Granovetter, 1985; North, 1990; Seabright, 2004). It expands the set of trade opportunities because—unlike personal exchange—it does not require high levels of information about others' past behavior. If trade frictions hinder impersonal exchange, then opportunities for mutual gain may be lost.[1] Consequently, many institutions have been developed over the course of history to overcome frictions and facilitate impersonal exchange.

This paper is an experimental study about one of the oldest institutions designed to facilitate impersonal exchange: money. Monetary exchange is a defining feature of virtually every economy. Yet, money plays no role in most economic models: the basic insights from theories of growth, business cycles, asset pricing, or unemployment for instance, emerge from models where money is not an essential element. So, what is the value of (fiat) money to a society?

Current thinking in monetary theory revolves around the notion that money matters *only if* it expands the efficiency frontier by overcoming trade frictions. The implicit hypothesis here is that if an efficient, non-monetary equilibrium exists, then agents would select it, and introducing money would neither affect trade patterns nor social welfare. Put simply, money matters only if it enables transactions that *could not* otherwise occur, in equilibrium, through impersonal exchange (see the survey in Ostroy and Starr, 1990).

This paper studies the aforementioned hypothesis through an experiment in which groups of strangers faced a cooperative task over time. The resulting data reveals an additional reason for why money matters, a reason that the literature

[1] For example, obstacles to trade are a key feature of "frictional" macroeconomic models, which include explicit obstacles to the realization of mutually beneficial exchanges, such as lack of information about identities and past behaviors of others, difficulties in coordinating trade, or limitations in enforcement and punishment. E.g., see Diamond (1982).

has overlooked: in the intertemporal giving and receiving of goods, money helps strangers to *coordinate* on cooperative outcomes. This behavioral role of money could be a reason for its widespread adoption in the field.

We model impersonal exchange through a design that makes transparent the intertemporal dimension of cooperation among strangers and the trading frictions. An economy comprises a stable population of four anonymous subjects who interact in pairs with changing opponents. Every encounter consist of a helping game, where one subject owns a good and can consume it (defect or autarky), or transfer it to her opponent who values it more (cooperate or help). The economy had a long-run horizon, implemented through a random stopping rule. Social efficiency requires that in every period, everyone with a good transfers it to others. Subjects are strangers in the sense that they cannot observe the opponent's identity and are randomly re-matched after each encounter; hence, building a reputation is impossible. In this environment there is no possibility of direct reciprocation, yet subjects can sustain the efficient outcome through a social norm of cooperation based on community enforcement of defections.

Indefinite repetition of the game induces multiple equilibria ranging from full defection to full cooperation (=efficient outcome). According to Folk Theorem-type results, self-regarding individuals can overcome opportunistic temptations and attain the efficient outcome by threatening permanent autarky through a decentralized punishment scheme that spreads by contagion (Kandori, 1992, Ellison, 1994). The theoretical literature often implicitly assumes that agents coordinate on the best available equilibrium. In this case, institutions such as money are seen as useless if social efficiency can be achieved through decentralized enforcement (e.g., Milgrom et al., 1990), as it is the case in our experimental economies.

By experimentally controlling informational flows and matching process, our laboratory economies capture trade frictions typically observed in larger economies without the need for hundreds of people to interact together. Our design precludes relational contracts and direct reciprocity, thus removing strong and empirically relevant motivational forces for cooperation in society (Fehr and Gaechter, 2000). Even if social efficiency is within theoretical reach, achieving it in practice is especially difficult when individual reputations are absent (Ostrom, 2010). Moreover, experimental evidence from indefinitely repeated prisoners' dilemmas has documented that fully overcoming the complexities of community enforcement is difficult even in groups of four agents (Camera and Casari, 2009). Embedding an individual decision problem—as opposed to a strategic interaction—within an indefinitely repeated game is what sets this study apart from previous cooperation experiments based on social dilemmas (e.g., Engle-Warnick and Slonim, 2006). In our model, cooperation amounts to engaging in an inter-temporal giving and receiving of anonymous gifts.

In order to study fiat money in a controlled environment, the experiment allowed subjects to hold and transfer *intrinsically worthless* electronic objects called "tickets." The introduction of tickets changes the equilibrium set, but neither removes any equilibria, nor adds Pareto-superior equilibria. In fact, by design tickets could not be exchanged in every meeting, so the efficiency frontier would *decline* if subjects based their cooperation only on the exchange of tickets. The rationale behind this design choice is simple: we intend to discover whether monetary exchange plays a role *other than* improving efficiency (=essentiality). This experiment is not a test of whether money improves efficiency.

Remarkable cooperation patterns emerged in economies with tickets. First, intrinsically worthless tickets endogenously acquired value as money, emerging as an effective tool for the intertemporal exchange of help. The adoption of monetary exchange promoted stable and predictable behavior. Participants trusted that help would be reciprocated by transferring a token. Second, the possibility to give help for a ticket profoundly altered subjects' behavior. The presence of tickets affected the type of equilibrium subjects played: they traded tickets for help when this was possible, but denied help otherwise. Third, the emergence of monetary exchange resulted in a redistribution of surplus from frequent defectors to frequent cooperators when compared to the baseline treatment.

What generated these cooperative patterns? Monetary trade has a behavioral advantage over alternative self-enforcing cooperation mechanisms. It is built around a straightforward punishment scheme: a single defection does not trigger a generalized switch to uncooperative behavior—only the subject who is cheated punishes the defector, by simply not giving her money. Without money, instead, the entire community must respond to a defection, by switching to some form of punishment scheme. In practice, however, coordinating on such forms of community punishment is challenging, especially when subjects cannot communicate their intentions.

The evidence reported in this study shows that the value of money goes beyond expanding the efficiency frontier. Our findings also offer new insights about a fundamental question in game theory: under what conditions can cooperation be sustained in a network of strangers engaging in anonymous, long-term interactions (e.g., Binmore, 2005). The existing evidence is largely limited to two-person economies (e.g., Dal Bó and Fréchette, 2011). In addition, the study contributes to a theoretical literature on institutions designed to sustain intertemporal trade under limited commitment (e.g., Krasa and Villamil, 2000), on the use of money as a substitute for social norms under impersonal exchange (Araujo, 2004, Aliprantis et al., 2007, Araujo and Guimaraes, 2011), and, more generally, a large theoretical literature that has adopted repeated games or random matching economies as a platform for micro- and macro-economic analysis. For example, consider models of unemployment (Diamond, 1982), of economic governance (Dixit, 2003), of the organization of commerce (Milgrom, et al. 1990), and of money (Kiyotaki and Wright, 1989). Experiments with anonymous economies provide much needed empirical evidence to assess the validity of such theories.

The paper proceeds as follows. Section 2 illustrates the related literature while Section 3 presents the experimental design. Section 4 includes theoretical considerations. Section 5 illustrates the results while Section 6 offers some conclusions.

I. Related experimental literature

This study contributes to three streams of experimental literature: cooperation and reciprocity, infinitely repeated games, and experiments on money.

We study cooperation though a social dilemma known in the literature under various labels: gift-giving game, helping game, altruism game, or donor-recipient game (e.g. Johnson et al., 2001, Nowak and Sigmund, 2005). The novel aspect is the *indefinite* repetition of this gift-giving game, which generates a multiplicity of equilibria, ranging from autarky to full cooperation. This key feature sets the present study apart from experiments on one-shot or finitely repeated games, where there is a unique equilibrium with defection. Experimental studies based on infinitely repeated games adopt a random continuation rule (e.g., as in Palfrey and Rosenthal, 1994, Dal Bó, 2005). In most studies direct reciprocity is possible (e.g., Engle-Warnick and Slonim, 2006, Dal Bó and Fréchette, 2011). Those studies where reciprocity is impossible focus on environments without institution in place to help cooperation, or consider personal punishment (Fehr and Gaechter, 2000, Camera and Casari, 2009), reputation (Stahl, 2009, Duffy et al. 2011), or communication (Camera, Casari, and Bigoni, forthcoming).

The experimental literature on money can be categorized according to studies about the three functions used to *describe* money. Money serves as (i) a unit of account, which simplifies the price system; (ii) a medium of exchange that facilitates trade by eliminating the need to barter; (iii) a store of value because money earned today can be spent on future consumption. Some experiments have also considered money purely as a unit of account (e.g., Fehr and Tyran, 2001). Experiments that have considered the medium of exchange function of money have done so by introducing tokens that have redemption value (e.g., Lian and Plott 1988). In contrast, ours is a study of *fiat* money, which has neither intrinsic nor redemption value. A recent paper (Duffy and Puzzello, 2011) follows in the footsteps of the present study by adding a centralized market after playing the gift-giving game, to test the theory developed in Aliprantis et al. (2007). Our focus, instead, is to understand the dynamics of cooperation in *decentralized* interactions.

The store of value function of money has been studied through experiments lasting a fixed and known number of periods (e.g., McCabe, 1989, Camera et al. 2003, Deck et al., 2006). In contrast, in the present design subjects interact *indefinitely*. Yet other studies have compared the relative efficiency of money versus barter in models with "double coincidence of wants" (e.g., Brown, 1996, Duffy and Ochs, 2002), where subjects earn payoffs *only if* they barter or trade. By design, in these experiments subjects face complex storage problems involving multiple goods and money *must* be used to expand the efficiency frontier. The gift-giving design we consider removes these confounds by eliminating the need to barter or trade to earn payoffs. This allows subjects to focus on the *inter-temporal* dimension of cooperation, a dimension that is considered central to the theory of money at least since Keynes.[2] Because such a design lifts the bias toward employing money only to maximize social efficiency, it allows us to *explain* why a monetary system emerges, as opposed to simply *describe* what money does in the experiment.

[2] Indeed, the major paradigms of monetary theory exclude barter (e.g., Samuelson,1958, Lucas, 1982).

II. Experimental design

The experiment has two treatments: *Baseline* and *Tickets* (Table 1). In all treatments the interaction was anonymous and local: subjects observe only the outcome in their pair, not in the rest of the economy.

The stage game in the Baseline treatment. Consider an individual decision problem based on a helping (or gift-giving) game: there is a seller who can consume a good in her possession or transfer it to a buyer who values it more than the seller. This trading mechanism is at the core of a large class of models of decentralized trade (Kocherlakota, 1998), such as overlapping generation, turnpike, and random matching models of exchange.

The seller (called "Red" in the experiment) chooses one of two actions: outcome Y (a choice called *defection* or *autarky*) and outcome Z (a choice called *cooperation* or *help*). The buyer (called "Blue" in the experiment) has no action to take. The payoffs for seller and buyer are, respectively, (a, a) if Y occurs and (d, u) if Z occurs. Here $a>0$ is the autarky payoff, while $d \in (0, a)$ and $u > 2a - d$ are payoffs under cooperation. In the experiment $d=2$, $a=8$, $u=20$. The dominant strategy for the seller is autarky, Y. Total surplus is maximum when the seller cooperates, i.e., Z is the outcome and surplus in a pair is 6 points (22 minus 16). We refer to this outcome as the (socially) *efficient* or fully cooperative outcome. If all sellers in the economy always select Y, then we say that the outcome is *autarky*.

The supergame. We consider economies composed of four players who interact for an indefinite number of periods. In each period players first randomly meet an opponent and then are randomly assigned a role, either seller or buyer, to play the gift-giving game described above (shaded area in Table 2). This interaction describes a situation where strangers can engage in an inter-temporal giving and receiving of goods.

A supergame or *cycle* consists of an indefinite interaction among subjects achieved by a random continuation rule, as in Roth and Murnigham (1978). A supergame that has reached a period continues into the next with a probability $\delta = 0.93$ so the interaction is with probability one of finite but uncertain duration. We interpret the continuation probability δ as the discount factor of a risk-neutral subject. The expected duration of a supergame is $1/(1-\delta)$ periods, so in each period the supergame is expected to go on for 13.28 additional periods. In our experiment the computer drew a random integer between 1 and 100, using a uniform distribution, and the supergame terminated with a draw of 94 or of a higher number. All session participants observed the same number, and so it could have also served as a public randomization device.

The experimental session. Each experimental session involved twenty subjects and five cycles. We built twenty-five economies in each session by creating five groups of four subjects in each of the five cycles. This matching protocol across supergames was applied in a predetermined fashion. In each cycle each economy included only subjects who had neither been part of the same economy in previous cycles nor were part of the same economy in future cycles. For the entire cycle a subject interacted exclusively with the members of her economy. Subjects were informed that no two participants ever interacted together for more than one cycle, though were not told how groups were created. Adding other cycles beyond five, would have introduced the possibility of contagion across economies because some participants would have interacted together for multiple cycles. Cycles terminated simultaneously for all economies.

Participants in an economy interacted in random pairs according to the following matching protocol within a cycle.[3] At the beginning of each period, the economy was randomly divided into two pairs of participants, i.e., each subject

[3] For comparison purposes, a "partner" treatment differs from our treatments in the matching protocol (fixed pairings instead of random), may differ in anonymity (subject IDs may be observable), and is otherwise informationally identical to our *Baseline* treatment. Of course, in cycles 3, 4 or 5, a subject *i* may meet someone who in past cycles met a previous opponent of *i*.

randomly met one opponent (called "match" in the experiment). There are three ways to pair four participants in an economy. In each period one pairing was randomly chosen with equal probability, so a subject had one third probability of meeting anyone else from their economy in each period of a cycle. Once pairs were formed, in each pair a computer-determined coin flip assigned to one player a seller role (red) and a buyer role to the other (blue). This random assignment implied that subjects could change role from period to period and in each period every economy had two buyers and two sellers.[4]

Table 1

Tickets treatment. In each economy there was a constant supply of four tickets. We call "ticket" an electronic object that is *intrinsically* worthless because holding it yielded no extra points or dollars, and it could not be redeemed for points or dollars at the end of any cycle. In period 1 of each cycle, each buyer was endowed with two tickets. Tickets could be carried over to the next period but not to the next cycle.

Tickets could be transferred from buyer to seller, one at a time, and subjects could hold at most two tickets. As illustrated in Table 1, a buyer could either keep the tickets (action 0), unconditionally transfer one ticket to the seller (action 1), or transfer one conditional on the outcome being Z (action $1|Z$); hence, the action set of the buyer is $\{0, 1, 1|Z\}$. The seller could either choose to execute outcome Y, execute outcome Z, or execute outcome Z conditional on receiving one ticket from the buyer (action $Z|1$). Hence, the action set of the seller is $\{Y, Z, Z|1\}$. These choices were made simultaneously, without prior communication and were private information, i.e., only the outcome could be observed but not the opponent's choice. If the choices were incompatible, then the outcome was Y

[4] The random role assignment helps to implement impersonal interaction as it restricts knowledge of the opponent's history as opposed to random matching with fixed roles or deterministic alternation in roles. The latter design most likely favors cooperation.

(Table 2). Because only the outcome was observed, not the action, subjects could not signal their desire to cooperate by requesting or offering a ticket.[5]

As seen above, the strategy sets include conditional and unconditional actions. The seller can choose to implement outcome *Z* conditional upon receiving a ticket. The buyer can choose to transfer one ticket conditional upon *Z* being implemented. If subjects attach value to tickets, then conditional actions facilitate coordination on the outcome where there is cooperation only in return for one ticket. This outcome can also be achieved through other actions, in particular choosing *Z* and choosing to transfer a ticket unconditionally. The typical monetary model assumes that exchange is *quid-pro-quo*: buyer and seller make simultaneous proposals and only compatible proposals are implemented. Incompatible proposals lead to autarky. This requires the availability of conditional actions. Our design captures this key theoretical aspect without favoring the emergence of monetary exchange. The design ensures subjects can neither incur involuntary losses, nor can garnish their opponent's endowment or earnings. With conditional strategies, a seller is "compensated" with one intrinsically worthless ticket for implementing *Z* if and only if the buyer is compensated for her ticket with a cooperative outcome. Non-compliant opponents are immediately sanctioned with autarky: cooperation is withheld from buyers who do not transfer a ticket and no ticket is given to sellers who choose *Y*. The choice to conditionally transfer a ticket and to conditionally implement Z would thus suggest that tickets have acquired value *endogenously*.

For tractability reasons, some constraints on ticket transfers had to be

[5] In a pilot session run on April 17, 2007, buyers had four options available, including two conditional strategies: offer 1 ticket in exchange for Y and offer 1 ticket in exchange for Z. Buyers overwhelmingly chose the latter strategy (the relative frequency is 17 times greater). Given this evidence, not all possible conditional choices were included in the design either because they are theoretically redundant (e.g., offer *Y* in exchange for 0 tickets, or offer 0 tickets, in exchange for *Y*), or to minimize subjects' confusion (e.g., offer *Z* in exchange for 0 tickets, or offer a ticket in exchange for *Y*). This design precludes using tickets as markers of negative behavior.

imposed. Subjects could not borrow (short sell) tickets—a standard assumption in monetary models. No subject could hold more than two tickets to avoid having someone accumulating all tickets. Because each subject could hold 0, 1, or 2 tickets, ticket transfers could not take place in every circumstance. A ticket transfer is *feasible* when the buyer has 1 or 2 tickets and the seller has 0 or 1 tickets. A transfer is *unfeasible* either when the buyer has 0 tickets or when the seller has 2 tickets. Consequently, buyer or seller may have a restricted choice set when a ticket transfer is unfeasible. In the experiment, a buyer with 0 tickets had no action to take, while a seller with 2 tickets could only choose to execute outcome *Y* or *Z*. Before making a choice, subjects received some information about the opponent's ticket holdings. The seller was told whether the buyer had either 0 or some tickets; the buyer saw whether the seller had either 2 or less than 2 tickets. Hence, subjects were informed whether a ticket transfer was feasible in their match, in a manner that minimized the chance that such information would indirectly reveal identities. Table 2 reports all possible outcomes and payoffs for the *Tickets* treatment, when ticket transfers are feasible and not.

In our experimental design, monetary trade is not always possible (= unfeasible matches), which is a defining feature of decentralized monetary exchange models (Kocherlakota, 1998, Camera and Corbae, 1999), e.g., as when traders experience liquidity shocks. This feature is also relevant for our research questions because it enables us to judiciously constrain the efficiency frontier under monetary exchange. In this manner we can discover whether monetary exchange plays a role other than improving efficiency.[6]

A supply of four tickets is ideal because it balances two aspects. With less tickets, the fraction of unfeasible matches increases, which is undesirable. It is important that tickets are sufficiently scarce in the economy because, with more

[6] Such feature can be easily removed—while maintaining the inessentiality of money—by moving to a turnpike environment or, alternatively, by adding sequential trades and centralized markets.

tickets, their endogenous value falls, which can undermine the existence of a monetary equilibrium (see Section 4). Fixing a two-unit upper bound for ticket holdings simplifies the subjects' task to formulate a prediction on the distribution of ticket holdings. Removing this bound does not change the fraction of unfeasible matches in monetary equilibrium because the *endogenous* bound on ticket holdings is 2 (see Section 4). In addition, removing the two-unit bound cannot increase the fraction of feasible matches relative to our setup.[7]

Table 2

Considering all treatments, we recruited 80 subjects through announcements in undergraduate classes, half at Purdue University and half at the University of Iowa. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007). Instructions (a copy is in the Appendix) were read aloud at the start of the experiment and left on the subjects' desks. No eye contact was possible among subjects. Average earnings were $18 per subject. On average, a session lasted 73.5 periods for a running time of 2 hours, including instruction reading and a quiz.[8] Details about the number and length of sessions are provided in Table 1 (each session had 20 participants and 5 cycles).

III. Theoretical considerations

In the one-shot gift-giving game the dominant strategy for the seller is autarky, which is socially inefficient. A main goal of this section is to prove that in all treatments of the indefinitely repeated game the equilibrium set includes 100 percent cooperation, which is the socially efficient outcome because it maximizes

[7] Intuitively, if one subject holds all four tickets, then at least one buyer has no tickets. If one subject holds three tickets, then there is only one ticket for all other subjects. To verify the empirical validity of this intuition, we run a follow-up session run on Feb 4th, 2010 where we removed the upper bound on ticket holdings. The fraction of feasible matches did not increase (67.6 percent, cycles 1-2, vs. 67.3 percent in this experiment) because only 6.4 percent of the subjects chose to hold more than two tickets.

[8] Subjects were recruited for three hours in order to ensure that, given the random termination protocol, the time constraint would not be binding.

joint payoffs. The analysis is based on the works in Kandori (1992) and Ellison (1994), under the assumption of identical players, who are self-regarding and risk-neutral. The payoff in the repeated game is the (ex-ante) expected discounted stream of payoffs in the one-shot games.

The *Baseline* treatment is characterized by two informational frictions. Players can only observe the outcome in their pair (private monitoring). They can neither observe identities of opponents (anonymity), nor communicate with them, nor observe action histories of others. Hence, participants cannot track others' reputations. The worse outcome is a sequential equilibrium under the strategy "defect forever." Clearly, Y is a best response to all sellers playing Y in all periods. In this case the payoff in the repeated game is the value of autarky forever, $a/(1-\delta)$.

If δ is sufficiently high, then the efficient outcome can also be sustained as a sequential equilibrium. To prove it, conjecture that players behave according to actions prescribed by a social norm, which is a rule of behavior that identifies "desirable" play and a sanction to be triggered if a departure from the desirable action is observed. For a seller, we identify the desirable action with Z and the sanction with Y, hence we define the following strategy.

Definition 1 (grim trigger strategy). *As a seller, the player cooperates as long as she has never experienced an outcome Y, and otherwise defects forever after whenever she is a seller.*

According to this strategy, deviations are policed in a decentralized manner. Anyone who experiences outcome Y (as a buyer or a seller) triggers a contagious process of defection as soon as she is a seller, which eventually leads to permanent autarky. We have the following result.

Proposition 1. *In the indefinitely repeated gift-giving game there exists a non-trivial interval $(\delta_L,\delta_H)\subset[0,1]$ for the discount factor, such that if $\delta\in(\delta_L,\delta_H)$, then the grim trigger strategy supports the efficient outcome as a sequential* *equilibrium.*

The proof, in the Appendix, is based on the extension of the Folk Theorem in repeated games to random matching environments (Kandori 1992, Ellison 1994). Here, we provide intuition. In each period payoffs for (seller, buyer) are (u, d), if cooperation is the outcome, and (a, a), if autarky is the outcome. If everyone adopts the grim trigger strategy, then on the equilibrium path every seller cooperates so everyone's payoff is the expected discounted utility from buying or selling with equal probability, $(u+d)/[2(1-\delta)]$. However, a seller might be tempted to defect to earn $a>d$. Since $a<(u+d)/2$ is assumed, the threat of autarky forever can remove such a temptation. A seller deviates in several instances: in equilibrium, if she has not observed play of Y in the past but chooses Y currently, i.e., she "cheats," and second, off-equilibrium, if she has observed play of Y in the past but chooses Z currently, i.e., she does not punish as she should.

Consider one-time deviations by one seller. Cooperating when no defection has been observed is optimal only if the agent is sufficiently patient. The future reward from cooperating today must be greater than the extra utility generated by defecting today (unimprovability criterion). Instead, if autarky occurs and everyone plays grim trigger, then everyone eventually ends up in autarky since the initial defection will spread by contagion. Contagion to 100 percent autarky in our experimental economies occurs quickly because there are only four players.

Cooperating after observing autarky should also be suboptimal. Choosing Z can delay the contagion, but cannot stop it. To see why, suppose a player observes Y. If the next period he is a seller and chooses Z, then this yields an immediate loss because he earns d instead of a. Hence, the player must be sufficiently impatient to prefer playing Y than Z. The incentive to play Y increases in a and decreases in d. Our parameterization ensures this incentive exists for all $\delta\in(0,1)$ so it is optimal to play Y after observing (or selecting) Y. For the efficient outcome to be an equilibrium, we need $\delta>\delta_L=0.808$ and $\delta<\delta_H=1$. In our experimental design $\delta=0.93$.

Proposition 2. *In the Baseline treatment the equilibrium set includes permanent autarky and the efficient outcome. In the Tickets treatment, the addition of tokens does not eliminate any equilibria of the Baseline treatment.*

To prove the first part of the statement, simply note that, due to indefinite repetition, if all subjects adopt the grim trigger strategy, then the efficient outcome can be sustained as a sequential equilibrium.[9] Permanent autarky is also an equilibrium because autarky is always a best response to play of autarky by the opponents. The second part of the statement immediately follows because intrinsically useless tokens can always be ignored. Put differently, all strategies available in the *Baseline* treatment are available in the *Tickets* treatment. Hence, the *Tickets* treatment does not introduce Pareto-superior equilibria and the efficient outcome can be supported in both treatments. However, additional strategies and outcomes are available in the *Tickets* treatment. The presence of tickets changes the equilibrium set but does not expand the efficiency frontier—the efficient outcome is already attainable—so it might actually increase coordination problems relative to the Baseline treatment, because the possibility to transfer tokens adds choices. In particular, a strategy that is the basic building block in monetary economics becomes available.

Definition 2 (fiat monetary exchange strategy). *After any history, a player who is: a seller with less than two tickets chooses to cooperate conditional on receiving a ticket; a buyer with tickets chooses to transfer one conditional on cooperation*

[9] T-periods punishment strategies, which are feasible in experiments among partners, cannot support the efficient outcome as an equilibrium in our experiment, due to private monitoring. Suppose a pair of agents starts to punish for T periods, following a defection in the pair. Due to random encounters, this initial defection will spread at random throughout the economy. Hence, over time different agents in the economy will be at different stages of their T-periods punishment strategy, which does not allow agents to simultaneously revert to cooperation after T periods have elapsed from the initial defection.

being the outcome; a seller with two tickets chooses to defect, and a buyer with no tickets has no action to take.

The fiat monetary exchange strategy prescribes cooperation for the seller and the transfer of one ticket for the buyer; this is the standard definition of behavior under monetary exchange. A deviation from this strategy leads to autarky *in the period*. The modifier “fiat” emphasizes that tickets are intrinsically useless, i.e., they cannot be redeemed for points. Monetary exchange can be implemented using conditional strategies *Z*|1 for the seller and 1|*Z* for the buyer, both in and out of equilibrium; this reflects the *quid pro quo* nature of monetary exchange (see the survey in Ostroy and Starr, 1990). Because exchange is conditional on a given outcome, cheating generates no loss of points to the seller and no loss of tickets to the buyer; hence, issues of distrust are minimized. An alternative is to use unconditional strategies, i.e., *Z* for the seller and 1 for the buyer (Table 1). If subjects attribute value to intrinsically worthless tickets, then the use of unconditional strategies generates strategic risk by exposing subjects to the risk of a loss. A seller may not be compensated with a ticket for choosing *Z*. A buyer may not be compensated with *Z* for transferring a ticket.

Our design exhibits another typical feature of monetary economies.

Definition 3 (feasibility of monetary exchange). *Monetary exchange is said to be feasible in a match if a buyer has at least one ticket and the seller has less than two tickets.*

Not all matches admit monetary exchange because sometimes the buyer is without tickets or the seller has two.[10] With random selection of seller and buyer roles, there is a strictly positive probability that ticket transfer is unfeasible because an agent may take on the same role in more than two consecutive

[10] The parameterization ensured that the constraint on holding at most 2 tickets is not binding in monetary equilibrium. Rational sellers with 2 tickets would not choose Z in exchange for one additional ticket.

periods.[11] Use of the monetary exchange strategy leads to the following outcome in the period: If monetary exchange is feasible, then the outcome is *Z*, cooperation. If it is unfeasible, then the outcome is *Y*, autarky.

The introduction of tickets expands the strategy set relative to the *Baseline* treatment. This change in the stage game could increase coordination difficulties (Riedl et al., 2011; Van Huyck et al., 1990) but it *neither constrains* subjects to employ the monetary exchange strategy, *nor precludes* the use of social norms based on decentralized enforcement. For example, sellers could cooperate unconditionally when a ticket transfer is unfeasible, and otherwise cooperate only for a ticket. Given this expanded strategy set, it is meaningful to quantify the theoretically efficiency level granted by monetary exchange.

Proposition 3. *Monetary exchange cannot support 100 percent cooperation. In the long-run, the economy has an efficiency loss of 42.8 percent.*

The proof of Proposition 3 is in the Appendix. This inefficiency result is standard in distributional models of money (e.g., Camera and Corbae, 1999). In economies with a stable population of four agents and a constant supply of four tickets there can be three possible distributions of tickets: (2,2,0,0), (2,1,1,0) and (1,1,1,1). The fraction of matches in which a ticket transfer is feasible depends on the initial distribution of tickets in a period. Moreover, the transition from a state of the economy from one period to the next depends on the random matching of subjects in pairs, the random assignment of buyer and seller roles as well as subjects' choices. The result in Proposition 3 is obtained by first calculating the unconditional (long-run) probability distribution of aggregate states, then the associated long-run fraction of matches in which monetary exchange is feasible.[12]

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[11] As an example, suppose someone is a buyer in periods 1, 2, and 3, which happens with probability 1/8. The buyer starts with an endowment of two tickets; if he transfers tickets in periods 1 and 2, then he has no tickets in period 3. There exists an analogous example for a seller.

[12] Proposition 3 is not a statement about existence of monetary equilibrium. In the Appendix, we prove that monetary exchange is a long-run equilibrium in our economies. Given the long-run

Adoption of the monetary exchange strategy does not support the efficient outcome because the transfer of a ticket is sometimes unfeasible, in which case the outcome is *Y*. In the long-run, 42.8 percent of matches do not admit monetary exchange. The efficiency loss measures the social cost of monetary exchange in relation to the maximum surplus, which is 12 points per economy. The *efficiency loss* is 1 minus the realized surplus over the maximum surplus.

In monetary theory, money is said to be "essential" if removing it from the economy reduces the set of possible equilibrium outcomes (Huggett and Krasa, 1996). In our design, money is not essential. In the *Tickets* treatment, the efficient outcome can be attained using the grim trigger strategy (Proposition 2); monetary exchange sustains a Pareto-inferior outcome (Proposition 3).

To sum up, coordinating on strategies that support the efficient outcome is likely to be difficult because of the equilibrium multiplicity. Introducing intrinsically worthless tickets changes the set of actions and outcomes but cannot expand the efficiency frontier relative to the *Baseline* treatment. In fact, their use might simply lower the efficiency frontier. It is an open question whether tickets endogenously acquire value and, if they do, how their presence alters cooperation patterns relative to the *Baseline* treatment.

IV. Results

There are four key results: Result 1 is a benchmark for the performance in the *Tickets* treatment reported in Results 2-4. Unless otherwise noted, in the empirical analysis the unit of observation is an economy, 4 subjects interacting in a cycle. There are 50 observations per treatment.

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ticket distribution associated to monetary exchange, we calculate the expected value of holding zero, one and two tickets as an unconditional expectation. A monetary equilibrium exists if, given that everyone plays a monetary exchange strategy, sellers with zero or one ticket prefer to implement cooperation, *Z*, in exchange for one ticket, instead of implementing *Y*. The key requirement is that the discount factor δ be sufficiently high; the parameters selected ensure this is the case.

Result 1. *In the Baseline treatment, the realized efficiency frontier (48.2 percent) was below the theoretical efficiency frontier.*

Tables 3-4 and Figure 1 provide support for Result 1. When averaging across all periods, the rate of cooperation was 48.2 percent. Only 4 percent of economies reached the efficient allocation, i.e., every seller always cooperated in each period of a cycle. Only 2 percent of economies coordinated on autarky. Considering only period 1 of each cycle, the average cooperation rate was 51.0 percent; about 30 percent of the economies started with full cooperation and 28 percent with full autarky so we cannot rule out that subjects attempted to coordinate on autarky. Subjects who observed a defection exhibited a very strong response in the form of a long-lasting sequence of defections.[13]

Figure 1, Tables 3 and 4

What made cooperation challenging? On the one hand, the design precludes relational contracts, direct reciprocity and reputation-building so removes strong motivational forces for cooperation (Nowak, 2005, Ostrom 2010). On the other hand, cooperation is not easily sustained in practice because of the complexities of community enforcement (Camera and Casari 2009). In what follows, we thus investigate whether a monetary system has a role to play in these economies with frictions.

Result 2. *Tickets affected cooperation patterns: the realized efficiency increased relative to the Baseline treatment when a ticket transfer was feasible (61.4 percent) and decreased when unfeasible (12.5 percent).*

Tables 3-5 provide support for Result 2. In the Tickets treatment, the average cooperation rate was 46.8 percent overall, 61.4 percent when a ticket transfer was feasible, and 12.5 percent when it was unfeasible. The difference in cooperation

[13] Evidence on this point is in Table 7, which is discussed after Result 4.

rates when a ticket transfer was feasible or unfeasible is significant (Wilcoxon signed-rank test, p-values 0.0000, n=43; 7 economies are dropped because all matches were feasible).[14] The overall average cooperation rate of 46.8 percent—see Table 3—is not significantly different from the *Baseline* treatment (see the probit regression in Table 7, col. 2, and Mann-Whitney test, p-values 0.78, n1=n2=50). However, average cooperation in period 1—see Table 4—was 71.0 percent, which is significantly higher than in *Baseline* (see the probit regression in Table 7, col. 1, and Mann-Whitney test, p-values 0.008, n1=n2=50).

The central observation is that the efficiency frontier in the *Tickets* treatment was no different than in the *Baseline* treatment. Yet, cooperation patterns exhibited a marked change. The data show cooperation patterns compatible with the use of the monetary exchange strategy. A primary reason for the (in)efficiency result is that by design monetary trade was not always feasible. Under monetary exchange, there is a theoretical prediction about the long-run distribution of ticket holdings (Section 4). The distribution of tickets in the data is consistent with the theoretical prediction of positive mass on 0, 1 and 2 ticket holdings and symmetry between 0 and 2.[15] Sellers held 2 tickets with a frequency of 21.3 percent, which made them unable to accept another ticket. Buyers held 0 tickets with a frequency of 21.7 percent, which made them unable to offer a ticket. As a consequence, monetary trade was not possible in every encounter: on average in an economy a ticket transfer was not feasible in 32.7 percent of matches (Table 5). Put differently, the monetary exchange strategy could sustain *at most* 67.3 percent

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[14] The results of the statistical tests in the paper rely on the assumption that all observations are independent.

[15] In a large economy, theory predicts that the stationary distribution of ticket holdings is uniform over 0, 1, and 2. In our small economy, the distribution of tickets cannot be stationary but we can still calculate unconditional probabilities of holding 0, 1 and 2 tickets. Theoretically the probability of holding 0 tickets is about 32.1 percent, it is the same for 2 tickets and it is 35.7 percent for 1 ticket. In the data, the probability of holding 0 tickets was 31.5 percent, it was identical for 2 tickets, and it was 37.1 percent for 1 ticket. Given the *empirical* distribution of tickets (Table 5), monetary exchange is a theoretical equilibrium. The proof is in the Appendix.

cooperation.

Table 5

The next result puts forward more direct evidence that subjects employed the monetary exchange strategy.

Result 3. *Fiat monetary exchange emerged. The exchange of tickets was instrumental to achieve cooperation.*

Support for Result 3 is in Tables 6, 7 and in Figure 2. In the experiment tickets endogenously emerged as fiat money, an intrinsically useless object valued by subjects because it facilitated the intertemporal giving and receiving of cooperation. In the Tickets treatment, there was a ticket transfer in 43.3 percent of matches (67.5 percent when considering only matches where transfers were feasible). Subjects traded on average 0.87 tickets per period and 1.44 when considering only period 1.[16] The data show that the transfer of tickets was instrumental to achieve cooperation, even if cooperation could be supported without ticket transfers (Proposition 2). When feasible, a ticket was transferred in 99.8 percent of matches with a cooperative outcome as opposed to 7.8 percent of matches with an autarky outcome (here, buyers unconditionally transferred a ticket either for redistributive purposes or because they simply did not care for it).

As explained below, the data exhibit patterns of behavior coherent with the typical description of a monetary economy: trade was based on a quid pro quo exchange of cooperation for tickets, and tickets had a decreasing marginal value. There is overwhelming evidence that, when monetary trade was feasible, subjects adopted *conditional* strategies and rarely cooperated unconditionally (Table 6). Buyers were not willing to give a ticket unless they were sure to be compensated with cooperation. Sellers were not willing to cooperate unless they were sure to receive a ticket. This evidence suggests that subjects attributed value to

[16] If all subjects followed the monetary exchange strategy and there were no issues of feasibility of ticket exchange there would be two tickets exchanged every period.

intrinsically worthless tickets. A ticket was transferred *and* cooperation was the outcome in 61.2 percent of matches. In those matches, both subjects used conditional strategies in 83.3 percent of cases, while both used unconditional strategies only in 0.3 percent of cases.

Table 6

Adoption of the monetary exchange strategy greatly facilitated the intertemporal giving and receiving of goods in meetings where a ticket transfer was feasible.[17] In sum, there is evidence that tickets in the experiment became a fiat money, an intrinsically useless object valued by subjects because it facilitated the intertemporal giving and receiving of cooperation. In a way, subjects self-insured against future cooperation needs by holding tickets.

If subjects did value tickets, then why were tickets not always traded when feasible? A possible reason is that some subjects may have simply not employed the monetary exchange strategy. A second reason is the existence of wealth effects for those who employed the monetary exchange strategy. Following a standard result in monetary theory, wealth effects lower the incentive to cooperate for sellers who have already one ticket. If subjects attach value to tickets, then the marginal value of a second ticket is less than the first.[18] As a consequence, the incentive to cooperate is lower for sellers who already have one ticket than for those who have none. Diminishing incentives should translate into diminishing cooperation rates, which we do find in the data (Figure 2). In the experiment, sellers with 1 ticket cooperated substantially less than sellers with 0 (69.8 vs. 49.0 percent in feasible matches; 67.4 vs. 43.0 percent in all matches).

Figure 2

[17] A probit regression confirms a high and significant effect of ticket exchange on cooperative outcomes (Table 7, cols. 4-5).

[18] With geometric discounting, the value from the future cooperation "bought" with the second ticket is at best $\delta^2 \times 20$ as opposed to $\delta \times 20$ for the first ticket. This result is not an artifact of limiting ticket holdings to 2 (see Camera and Corbae, 1999).

This last consideration also allows us to discern whether *indirect* reciprocity is the primary reason behind the use of tickets. The experimental literature has identified indirect reciprocity as an important mechanism behind cooperation (e.g., Fehr and Gaechter, 2000). Tickets allow strategies based on indirect reciprocity (not direct reciprocity, given anonymity and private monitoring), which are more selective in punishment than the grim trigger strategy. A seller could cooperate only with those buyers who cooperated with others in the past and could defect with those who have defected with others in the past. Owning one or two tickets is statistical evidence of past cooperative behavior. Therefore, an indirectly reciprocal seller should cooperate when the buyer has a ticket. The evidence suggests indirect reciprocity is not what primarily drives the transfers of tickets. According to reciprocity, the subject responds in kind to past cooperation even if no material gains can be expected. Hence, sellers' cooperation rates should be invariant to *their* ticket holdings, but in the data sellers' cooperation rates declined in their ticket holdings (Figure 2). The data also show that sellers significantly lowered their cooperation rates when they could not acquire a third ticket, even if the buyer had one (cooperation was the outcome in 15.0 percent of cases if the buyer had one or two tickets and 11.7 percent otherwise). This is evidence of forward looking behavior and not of indirectly reciprocal, backward-looking behavior.

To sum up, the data exhibit patterns of behavior coherent with the typical description of a monetary economy: the inter-temporal giving and receiving of goods was based on a *quid pro quo* exchange of cooperation for tickets, and tickets had a decreasing marginal value. The next result offers a reason why monetary exchange emerged in the *Tickets* treatment.

Result 4. *Monetary exchange redistributed surplus from frequent defectors to frequent cooperators and promoted stable and predictable behavior, which simplified coordination tasks.*

Recall that monetary exchange cannot expand the efficiency frontier; it can only lower it (Proposition 3). In the experiment, the monetary exchange strategy was adopted and though it did not empirically raise overall cooperation rates (Result 2), it did affect patterns of cooperation because it lead to the selection of an outcome where there is cooperation only in return for a ticket (Result 3). We argue that these results are the consequence of two effects of monetary exchange: a simplification of coordination tasks and a redistribution of surplus from frequent defectors to frequent cooperators.

Monetary exchange simplified coordination tasks and it enabled cooperation among a subset of participants in a four-person experimental economy. These participants trusted that cooperation would be reciprocated through the transfer of a ticket. Supporting the efficient outcome via decentralized community enforcement is theoretically feasible in our economies but it requires a uniform convention of behavior. *Everyone* in the economy must follow the same strategy both in equilibrium as well as out-of-equilibrium. This is so because subjects have many punishment strategies to choose from, not only grim trigger. Monetary trade solves the off-equilibrium coordination problem because it removes entirely the need to conform to a common punishment strategy to discourage defections. The seller who does not cooperate simply does not receive a ticket due to the *quid pro quo* nature of trade. As a consequence, subjects following a monetary exchange strategy only have to coordinate on equilibrium behavior. Moreover, not everyone in the economy ought to adhere to the same convention. For instance, a pair of subjects can adopt monetary exchange regardless of what others do. This is especially important when there is heterogeneity in strategy adoption, as it is often the case in experimental economies (Camera, Casari, and Bigoni, 2012). With heterogeneity in strategies, decentralized community enforcement is likely to fail in sustaining the efficient outcome. Consider for instance an economy where everyone follows a grim trigger strategy except one subject, who starts defecting and then follows grim trigger.

The experimental literature has identified trust as an important mechanism behind cooperation (Ostrom, 2010). When individuals face incentives to behave opportunistically (as in our design), they are more likely to cooperate if trust can be increased that others will reciprocate. Monetary exchange can help to build trust by making cooperation *quid pro quo*: subjects may trust that cooperating today for a ticket will be reciprocated tomorrow by giving the ticket. Consistent with the above interpretation, the data show a reduction in strategic risk. Higher predictability of actions is evidence of lower strategic uncertainty, and of trust that sellers cooperate when tickets are offered.

The supporting empirical evidence is in Table 7, which reports the results from a probit regression that explains the seller's choice to cooperate (1) or not (0) overall and by treatment. The regression includes the subject's choices only in those periods in which she is a seller. We introduce several dummy variables that control for fixed effects (cycles, periods within the cycle), for demographic characteristics such as gender and major, and for the duration of the previous cycle. A set of regressors is also included to trace the response of the representative subject in periods *after* he has seen a defection *and* he is a seller. For simplicity, we focus on the first two instances of such occurrence.[19] We find that the subject's behavior is much more predictable in the Tickets treatment—especially when a ticket transfer is feasible—as opposed to the Baseline treatment. The pseudo-r2 statistic for the *Tickets* treatment is 51.1 percent, which

[19] There are several ways to choose regressors to trace strategies. The specification selected has the advantage of detecting whether subjects followed strategies that are either theoretically or behaviorally relevant, such as grim trigger (Kandori, 1992) or tit-for-tat (Axelrod, 1984). We include a "grim trigger" regressor, which has value 1 in *all* periods following the first match in which *Y* was the outcome, and value 0 otherwise. We also include "Lag" regressors, which consider only the periods—after suffering a defection—in which the subject has an opportunity to punish. The "Lag 1" regressor takes value 1 at the first opportunity to punish and 0 otherwise. The "Lag 2" regressor takes value 1 at the second opportunity to punish and 0 otherwise.

grows to 68.8 percent when considering only matches with feasible ticket transfers. In contrast, the *Baseline* treatment scores 7.3 percent. Similar results are obtained in probit regressions along the lines of the one in Table 7 where we drop demographic independent variables that subjects could not observe (interaction was anonymous) and control for individual characteristics (not reported).

Table 7

There are also interesting results on the use of strategies of community enforcement of defections. If the representative subject switched from a cooperative to a punishment "mode" after seeing autarky, then the estimated coefficient of at least one of the three strategy regressors should be negative. For instance, if subjects punished by choosing *Y* only the first time they became sellers after a defection, then the sum of the estimated coefficients of the grim trigger regressor and the Lag 1 regressors should be negative for the first occurrence following a defection, and zero afterwards. The data are not consistent with the use of tit-for-tat, which is not an equilibrium strategy. The grim trigger marginal effect estimate of -0.413 is significantly different than zero at a 1 percent level, while all other strategy marginal effects are not significant (Table 7, col. 3). These results are consistent with the notion that there was an attempt to adopt a common informal sanctioning scheme based on the grim trigger strategy. The data show a sizable and persistent decline in cooperation of the average subject following an autarky outcome.[20]

Monetary exchange also promoted a redistribution of surplus from frequent defectors to frequent cooperators. Given heterogeneous behavior, tickets can become a powerful device to ensure that subjects who do not want to cooperate

[20] The probit regression in Table 7 provides evidence for demographic effects. Male subjects are significantly more likely to cooperate than female subjects in all treatments when controlling for major, location, and risk attitude (the marginal effect is 0.15 in col.2). This is interesting because the literature has sometimes reported that women are more generous than men (e.g. Andreoni and Vesterlund, 2001, Ortmann and Tichy, 1999).

cannot free ride. If offering a ticket is statistical evidence of being a cooperator, then subjects who wish to cooperate may choose to do so only in return for a ticket. An important consequence of monetary trade is that the probability of a cooperative outcome improves only for those who hold tickets and falls for everyone else, so that the use of tickets redistributes surplus in an incentive-compatible way, from defectors to cooperators. Figure 3 shows how adopting the monetary exchange strategy redistributed earnings. Subjects who cooperated less than 40 percent as sellers earned significantly less than in the *Baseline* treatment (Mann-Whitney tests, p-value=0.003, N1=78, N2=66). Subjects who cooperated 40 percent or more earned significantly more (p-value=0.001, N1=88, N2=104).[21] When comparing earnings distributions in *Baseline* vs. *Tickets*, there is a difference in the relative incentives to cooperate as opposed to defect.

Figure 3

V. Discussion and conclusions

This study provides behavioral evidence for why money matters in economies where interaction is decentralized and subject to frictions. In an experiment, intrinsically worthless tickets acquired value as they favored a coordination on the inter-temporal giving and receiving of goods in ways that subjects were not able to sustain through decentralized community enforcement.

We designed an experiment in which a stable population of strangers interacted in a decentralized manner. The interaction consisted of an indefinite sequence of helping or gift-giving games; in each game, subjects could either give or receive a good as help. The subject without the good valued it more than the subject possessing it, so that providing help unconditionally maximized joint payoffs. The interaction was anonymous; hence, subjects could not rely on direct reciprocity or

[21] Earnings were adjusted to account for the uneven frequency of a subject's buyer and seller role. Figure 3 does not qualitatively change when using raw average profits.

engage in relational contracts. In some economies, subjects could transfer intrinsically worthless tickets, thus expanding the set of equilibria but not the efficiency frontier. In all economies, subjects could attain the socially efficient outcome through a trigger strategy based on decentralized community enforcement.

Two findings stand out. First, when feasible, tickets were actively transferred in return for help. This is remarkable because the design ensured that (i) the socially efficient outcome could be sustained through a social norm of gift-exchange and (ii) helping only conditional on the transfer of tickets substantially lowered the efficiency frontier. Second, tickets became fiat money; the data exhibit patterns of behavior consistent with those of a monetary economy. Tickets acquired value endogenously even if they had no redemption value; cooperation was traded for tickets in a *quid pro quo* manner; the distribution of ticket holdings in the economy was close to the theoretical prediction for a monetary economy.

Based on the findings reported in this paper, we argue that money deeply affects behavior in economies that rely on impersonal exchange. In the experiment, the emergence of a monetary system affected behavior through various channels. First, it had a fundamental behavioral role in facilitating *coordination* of play in decentralized interactions. The use of money in the experiment simplified subjects' task to adopt a common self-enforcing cooperation mechanism: it allowed them to directly sanction defectors, without the need to rely on decentralized, contagious forms of punishment like grim trigger. More precisely, monetary trade solves the *on-equilibrium* coordination problem in the economy because it enables a subset of the population to cooperate even if not everyone is interested in doing so. This is especially important in heterogeneous populations and in economies of more than two subjects such as in our experiment. For instance, monetary trade can sustain some cooperation even if just two or three subjects in the economy follow this strategy, independently of the behavior of others. Instead, grim trigger may not guarantee cooperation unless its adoption is universal. In addition, monetary trade solves the *off-equilibrium* coordination problem because it entirely removes the need to select punishment mechanisms based on community enforcement. Under monetary trade, sellers who do not cooperate simply do not receive a ticket.

Second, the emergence of monetary trade substantially raised the *predictability* of cooperative outcomes: the strategic uncertainty of impersonal exchange was substantially reduced in the Tickets treatment. Subjects trusted that giving a gift today would grant them a gift at some point in the future in return for a ticket. One can see from the data that the presence of tickets altered which equilibrium subjects expected to play, and hence it affected their behavior.[22] For instance, we see that cooperation in period 1 of each supergame jumped from 51 to 71 percent when tickets were present, which implicitly reveals the impact of tickets on subjects' expectations of play.

Third, tickets supported a *redistribution* of surplus from frequent defectors to frequent cooperators. In the absence of tickets, frequent defectors obtained the highest average earnings; this was no longer true when tickets became available. This is why—despite a modest difference in aggregate earnings between treatments—subjects interested in cooperation still had a substantive motive to adopt a monetary exchange strategy.

In conclusion, this study opens a new avenue of research at the intersection between macro- and micro-economic theory, and experimental economics. Monetary trade is a defining feature of virtually every economy and yet money plays no role in most economic models. What the literature has largely ignored, and this study has uncovered, is a role for fiat money as a tool for coordination on self-sustaining, cooperative outcomes among strangers.

[22] We thank an anonymous referee for suggesting this interpretation.

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Tables and Figures

	Baseline		Tickets	
Information	Private monitoring		Private monitoring	
Action sets:	Seller {*Y*, *Z*}	Buyer No action	Seller {*Y*, *Z*, *Z*|1}	Buyer {0, 1, 1|*Z*}
Grim trigger supports the efficient outcome	Yes		Yes	
Session dates, location, # of periods	21.9.08, Purdue, 43 7.9.08, Iowa, 58		21.9.08, Purdue, 82 10.9.08, Iowa, 111	

Table 1: Experimental treatments

Notes: Seller was called Red in the experiment and buyer was called Blue. The date format is day.month.20xx.

(a) Baseline treatment

		Buyer
Seller	**Y**	*Y* (8, 8)
	Z	*Z* (2, 20)

(b) Tickets treatment

		Buyer: **0**	**1**	**1|Z**	**No Action**
Seller	**Y**	*Y*, No Transfer (8,8)	*Y*, Transfer (8,8)	*Y*, No Transfer (8,8)	*Y*, No Transfer (8,8)
	Z	*Z*, No Transfer (2,20)	*Z*, Transfer (2,20)	*Z*, Transfer (2,20)	*Z*, No Transfer (2,20)
	Z|1	*Y*, No Transfer (8,8)	*Z*, Transfer (2,20)	*Z*, Transfer (2,20)	*Y*, No Transfer (8,8)

Table 2: Actions, Outcomes, and Payoffs in a Pairwise Encounter

Notes: Payoffs in points are reported for (seller, buyer). Conversion rate: 10 point = $0.25. In the Baseline treatment, an outcome is a value x=Y, Z. In the Tickets treatment, an outcome is a pair x, y where x=Y, Z and y=Transfer, No Transfer. A buyer who has no tickets has no action to take. The Z|1 action is not available to a seller who has two tickets. Ticket transfer or possession generates neither earnings nor losses.

	Treatment			
	Baseline	**Tickets**		
Cycle		All matches	Feasible	Unfeasible
1	0.475	0.527	0.615	0.167
2	0.441	0.494	0.612	0.074
3	0.563	0.442	0.582	0.122
4	0.487	0.506	0.690	0.178
5	0.446	0.371	0.570	0.094
Overall cooperation	**0.482**	**0.468**	**0.614**	**0.125**
Net surplus (points)	5.78	5.62	--	--
Gross surplus (points)	5.78	7.53	--	--
Maximum theoretical surplus	12	12	--	--

Table 3: Average cooperation frequency: all periods

Notes: 1 obs. = 1 economy (10 obs. per cycle, per treatment). Consider an economy k=1,..,50. The mean cooperation level for an economy k=1,..,n is measured by defining the action $a_{it}^{k} \in \{0,1\} \equiv \{Z, Y\}$ *of a seller (red subject) i=1,2 in period t=1,..,*T^k *of the economy as an element. A cooperative action is coded as 1, and a defection is coded as 0. Therefore, average cooperation in an economy k is* $c_k = (1/2T^k)\sum_{t=1}^{T^k}\sum_{i=1}^{2} a_{it}^{k}$ *between zero and one, and across economies is* $c = (1/n)\sum_{k=1}^{n} c_k$ *. Thus, although economies have different length* T^k*, they are given equal weight in our measure c of average cooperation, since we consider each economy a unit of observation. The "feasible" (resp. "unfeasible") column calculates average cooperation using only matches in each period in which exchange of a ticket was feasible (resp., unfeasible).*

	Treatment	
Cycle	**Baseline**	**Tickets**
1	0.40	0.40
2	0.30	0.75
3	0.55	0.70
4	0.55	0.85
5	0.75	0.85
Overall frequency of cooperation	**0.51**	**0.71**
Fraction of economies with 100% cooperation	0.30	0.58
Fraction of economies with 100% defection	0.28	0.16

Table 4: Average cooperation frequency: period 1 of each cycle

Buyers	Sellers			
	0 tickets	1 ticket	2 tickets	*Total*
0 tickets	0.031	0.083	0.103	*0.217*
1 ticket	0.075	0.213	0.079	*0.367*
2 tickets	0.307	0.079	0.031	*0.417*
Total	*0.413*	*0.375*	*0.213*	*1.001*

Table 5: Empirical distribution of ticket holdings in the average economy

Notes: N=50 economies. We first compute the frequency of each occurrence by economy and then take the mean across economies. The shaded area includes cells where ticket exchange is unfeasible. In period 1 buyers received 2 tickets while sellers received none.

Buyers	Sellers			
	Defect	***Cooperate***	***Cooperate* if 1 ticket is transferred**	Total
No action available:				
feasible	--	--	--	--
unfeasible	51.6	7.0	7.7	66.3
Transfer 0				
feasible	2.3	0.1	3.5	5.9
unfeasible	12.7	2.9	0.0	15.6
Transfer 1				
feasible	2.2	0.2	1.9	4.3
unfeasible	1.6	0.3	0.0	1.9
Transfer 1 if the outcome is *Cooperate*:				
feasible	30.6	8.1	51.0	89.7
unfeasible	13.9	2.4	0.0	16.3
Total:				
feasible	35.1	8.4	56.4	100
unfeasible	79.8	12.6	7.7	100

Table 6: Frequency distribution of players' actions and feasibility of ticket exchange

Notes: All numbers are in percent. Feasible (unfeasible) refers to matches where ticket transfer is feasible (unfeasible). The shaded cells refer to feasible matches where there is a cooperative outcome and a ticket transfer. Y= defect and Z= cooperate

Dependent variable: 1=cooperation 0=defection	**All Treatments** (1) Periods 1 only	(2)	**Baseline** (3)	**Tickets** (4)	(5) Feasible matches only
Ticket treatment	0.213***	-0.025			
	(0.075)	(0.031)			
Duration of previous cycle	0.009**	0.003***	0.007***	0.005***	0.004***
	(0.004)	(0.001)	(0.001)	(0.000)	(0.000)
Cycle dummies:					
Cycle 2	0.123	-0.060***	0.092**	-0.194***	-0.206**
	(0.162)	(0.022)	(0.037)	(0.014)	(0.082)
Cycle 3	0.234	-0.034	0.168***	-0.154***	-0.213
	(0.184)	(0.042)	(0.038)	(0.053)	(0.144)
Cycle 4	0.218	0.011	0.152**	-0.159***	-0.185**
	(0.161)	(0.029)	(0.063)	(0.004)	(0.086)
Cycle 5	0.293***	-0.119*	-0.055	-0.234***	-0.169***
	(0.088)	(0.061)	(0.107)	(0.054)	(0.059)
Strategy coding:					
grim trigger		-0.343***	-0.413***	-0.286***	-0.154**
		(0.043)	(0.046)	(0.080)	(0.069)
Lag 1		0.129***	0.103	0.074*	0.025
		(0.034)	(0.113)	(0.039)	(0.033)
Lag 2		0.034	-0.005	0.074*	0.005
		(0.026)	(0.026)	(0.038)	(0.006)
Male	0.206***	0.150***	0.094**	0.272***	0.218***
	(0.037)	(0.023)	(0.048)	(0.009)	(0.010)
Business major	-0.243	-0.179**	-0.147	-0.256***	-0.309***
	(0.161)	(0.085)	(0.270)	(0.001)	(0.032)
Engineering, Science, and Mathematics major	-0.208	-0.170*	-0.182	-0.194***	-0.232***
	(0.141)	(0.089)	(0.215)	(0.046)	(0.005)
Risk neutral or low Risk aversion (questionnarie)	-0.273***	-0.097**	-0.075	-0.057	-0.148**
	(0.071)	(0.045)	(0.144)	(0.099)	(0.074)
High Risk aversion (questionnarie)	-0.030	0.009	0.093	-0.042***	-0.104***
	(0.073)	(0.072)	(0.101)	(0.006)	(0.014)
A ticket was transferred				0.795***	0.881***
				(0.016)	(0.059)
Observations	200	2940	1010	1930	1151
Pseudo-R2	0.171	0.069	0.073	0.511	0.688

Table 7: Probit regression on individual choice to cooperate – marginal effects

*Notes: Marginal effects are computed at the mean value of regressors. Robust standard errors for the marginal effects are in parentheses computed with a cluster on each session; * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent. For a continuous variable the marginal effect measures the change in the likelihood to cooperate for an infinitesimal change of the independent variable. For a dummy variable the marginal effect measures the change in the likelihood to cooperate for a discrete change of the dummy variable. Period fixed effects are included (except in the first column) but not reported in the table (periods 2-5, 6-10, 11-17, 18-25, >25). Duration of previous cycle was set to 14.3 periods for cycle 1. Each observation refers to a seller in a pair, i.e. half of the population in each period.*

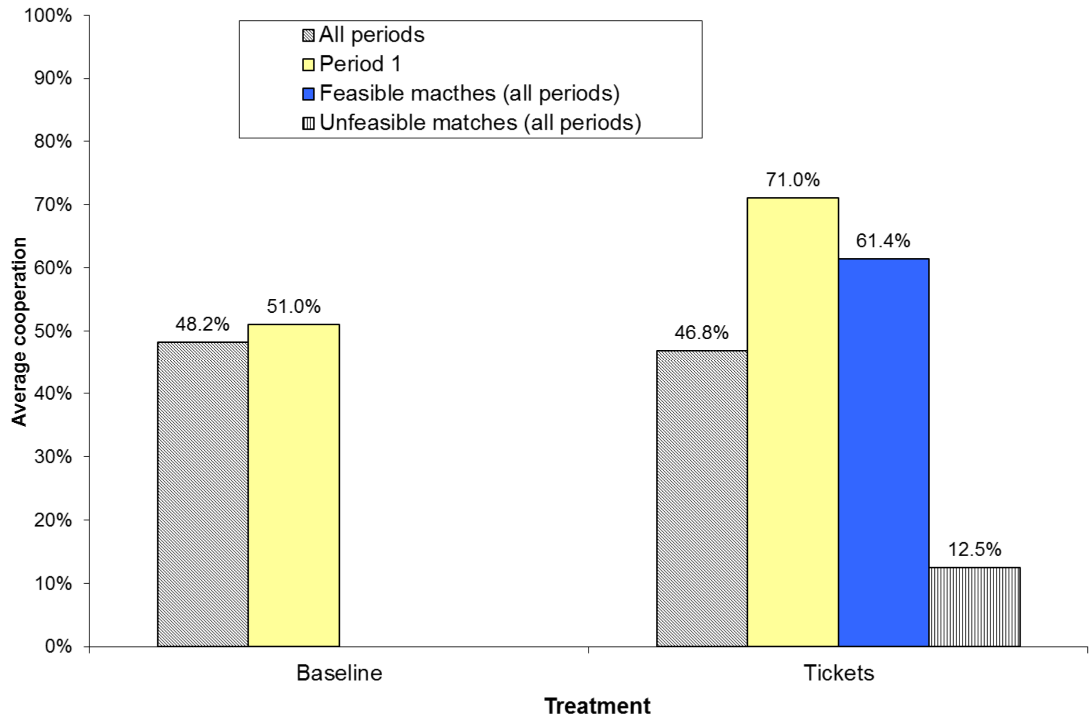

Figure 1. Cooperation by treatment

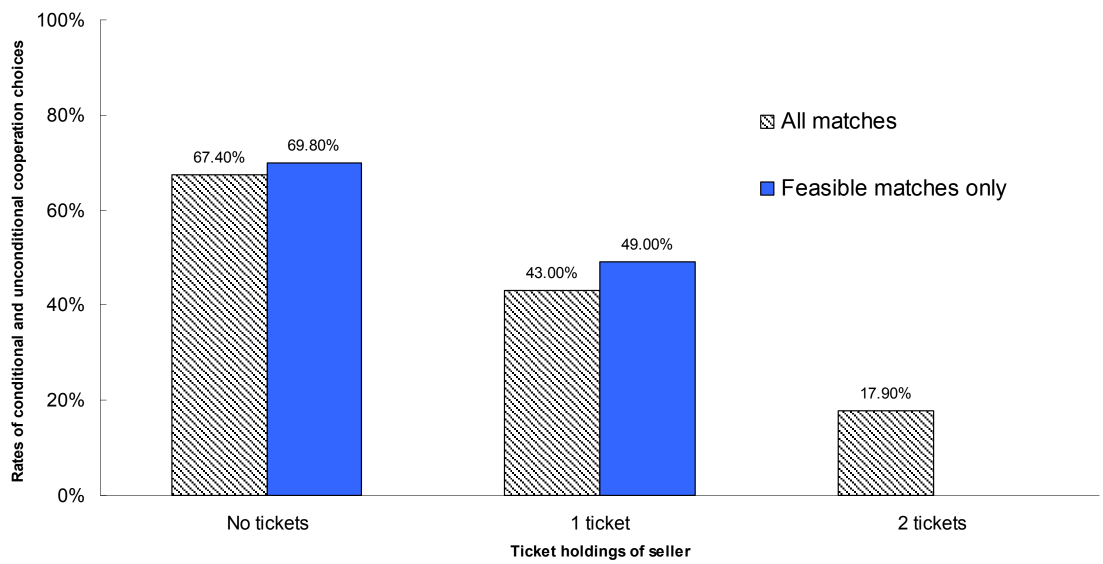

Figure 2. Cooperation rates by seller's ticket holdings

Notes: N=1930, 1151; 1 obs.=seller's choice in a period. The cooperation rate refers to the sum of unconditional and conditional cooperation choices observed (Z and Z|1).

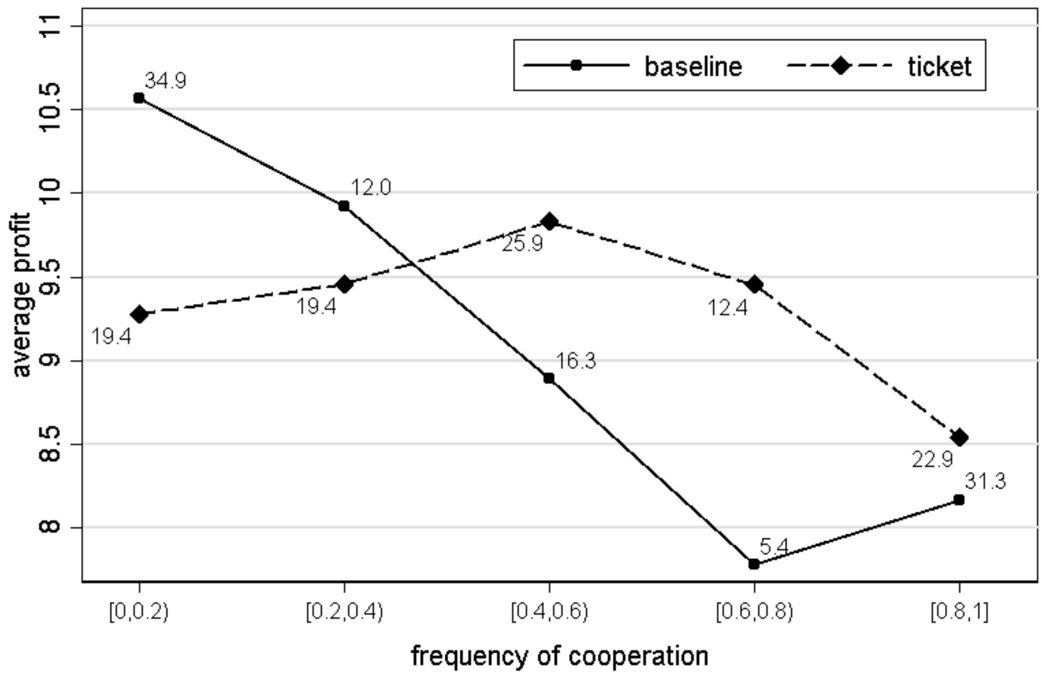

Figure 3. Cooperation rates and earnings

Notes: N=166 for Baseline and N= 170 for tickets; only obs. where subjects switch roles within the cycle are included. Average profits were adjusted to account for the frequency of roles: we separately computed average profits as buyer and as seller and then took their arithmetic average. Average profit is 11 when Z is the outcome, i.e., (20+2)/2; it is 8 when Y is the outcome, i.e., (8+8)/2. Next to each data point, we report the associated percentage of observations.