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Trust and trustworthiness in networked exchange ☆

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ABSTRACT

This paper focuses on the interaction between network structure, the role of information, and the level of trust and trustworthiness in 3-node networks. We extend the investment game with one Sender and one Receiver to networked versions — one characterized by one Sender and two Receivers ([1S-2R]) and one characterized by two Senders and one Receiver ([2S-1R]) — under two information conditions, full and partial. We develop a comparative model of trust for the networked exchange environments and generate two hypotheses: (1) what counts as a signal of trust depends on investment behavior along the other link in the network and (2) this type of trust can be leveraged under full information, increasing the rate of cooperation on the side of the exchange with multiple traders. The results generally support our hypotheses: trust is comparative and under full information, the [1S-2R] network shows higher trustworthiness and the [2S-1R] network displays higher trust.

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1. Introduction

It is well known that bilateral exchange under implicit contracts is often efficient and cooperative, even in environments where the equilibrium path favors no exchange at all (Williamson, 1985; Fehr et al., 1993). Bilateral exchange is often embedded in networks: a principal may invest simultaneously in multiple agents, and an agent may represent the interests of more than one principal (Granovetter, 1985; Raub and Weesie, 1990; Kranton and Minehart, 2001; Barabasi, 2002; Jackson, 2008). To execute an exchange, principals trust the agent to take an action that is preferred rather than one that is costly to the principal. There are potential gains from trust — if the agent exhibits trustworthiness, then both parties are made better off than if they had not traded. Since the exchange may be embedded in a larger network, this raises a question: Are the signals of trust sensitive to the surrounding network? If so, then trust is *comparative*: what counts as trusting behavior depends on comparing information about behavior across one's network. If not, then trust is essentially *absolute* and the larger network makes little difference to bilateral exchange.

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In this paper, we focus on the interaction between exogenous network structure and cooperative behavior in two networked versions of the investment game (Berg et al., 1995). The standard investment game is played among two parties, one Sender (the principal) and one Receiver (the agent) and each is endowed with equal starting capital of amount M. Sender decides how much of his capital to invest in Receiver (X) and any amount invested grows by some factor $r > 1$; the Receiver then decides how much to return of rX (Y). Final payoffs are $M - X + Y$ to Sender and $M + rX - Y$ to Receiver. Trust is operationalized by the amount Sender sends to Receiver, and trustworthiness is operationalized by the fraction returned to Sender by Receiver (i.e., $\frac{Y}{rX}$).[1] We extend the investment game to the smallest non-trivial network structure: those with 3-nodes. One such network is characterized by one Sender and two Receivers ([1S-2R]) and the other is characterized by two Senders and one Receiver ([2S-1R]).

We are interested in two main questions. Our first question is about psychological perceptions: what counts as a signal of trust in a networked investment game? Will it simply be the amount invested as in the dyad, or will it also depend, in part, on the investment behavior along the other link in the network? Our first empirical hypothesis can be summarized this way:

Comparative Trust Hypothesis What counts as a signal of "trust" in a network is not simply the amount invested but also depends, in part, on the investment behavior along the other link in the network.

Our second question is about competitive leverage: if trust signals are comparative, can this fact be leveraged to crowd-in cooperation within the network? Our second empirical hypothesis is that comparative trust does get leveraged and the effect on trust and trustworthiness depends on the network structure. It can be summarized this way:

Competition for Cooperation Hypothesis Information crowds in cooperation on the long side of the network — that is, the side of the network with multiple agents.

We develop a framework in which we can formulate these hypotheses and then test experimentally for evidence in support of them in each 3-node network.[2]

We mention three examples of the sorts of environments we aim to better understand. First, suppose a homeowner (the principal) has some renovations to be done. A single contractor (an agent) could take arbitrarily long to finish the various renovations and cost arbitrarily much. Savvy homeowners in this position often enlist multiple contractors simultaneously. This is standard operating procedure for Jeff Lewis, star of Bravo TV's *Flipping Out*. Lewis always has multiple jobs to be done and multiple contractors on hand. He bargains contemporaneously with two contractors, e.g., with one to replace hinges and one to replace latches. He alerts each of them to the terms he is discussing with the other, and sometimes threatens to hire one for both jobs. We want to understand how this sort network impacts the behavior of both the principal and the agents.

A second example: the structure of tipping in small or crowded restaurants. A single waiter (the principal) must decide how to invest his time and energy among multiple tables (the agents) expecting to receive some level of gains at the end of the transaction in the form of a tip.[3] In small restaurants, diners easily observe the level of service waiters provide to other tables — and can easily observe the tips left by diners at those tables.

A third example is familiar to fans of any sport: sports agents often represent the interests of multiple players (the principals) simultaneously and sometimes to the same team when the principals' interests might be in conflict. The players might determine an initial retainer, an investment in the agent, and then the agent sells the player on the free agent market with some of the gains, perhaps negotiated ahead of time but often they are returned to the agent as a bonus. The effort the agent invests for any particular player is observable and widely known among players. Of course, the final terms the agent secures, or fails to secure, for his clients make headlines.[4]

There is a large theoretical and experimental literature focusing on strategic behavior in networks. The scope of issues is broad: the amount of cooperation and coordination achieved in various networked versions in coordination games (Berninghaus and Schwalbe, 1996; Berninghaus and Ehrhart, 1998; Eshel et al., 1998; Axelrod et al., 2002; Cassar, 2007; Corbae and Duffy, 2008); borrowing and repayment behavior in informal credit arrangements (Cassar et al., 2008; Karlan et al., 2009a); different patterns of contagion in financial crises (Cassar and Duffy, 2001; Eisenberg, 1995; Allen and

[1] In one-shot, double-blind experiments with anonymous, randomly matched subjects ($M = \$10$ and $r = 3$), Berg et al. (1995) found that roughly ninety-five percent of Senders sent money to Receivers, with $X = \$5.16$ sent on average, and transfers of $X = \$5$ had an average payback of $Y = \$7.17$. These results suggest that principals trust their agents, and that trust is often reciprocated. Such results deviate from the standard utility-maximization prediction that Receiver will keep all rX and, therefore, Sender will send nothing. There is ample experimental evidence showing that subjects exhibit significant amounts of trust and trustworthiness, both in binary-choice investment games (McCabe et al., 2002, 2003; Chaudhuri et al., 2003; Eckel and Wilson, 2004) and in versions of the investment game (Croson and Buchan, 1999; Ortmann et al., 2000; Glaeser et al., 2000; Burks et al., 2003; Cochard et al., 2004; Chaudhuri and Gangadharan, 2007; Capra et al., 2008; Greig and Bohnet, 2008).

[2] All we mean by "competition" here is that crowding in happens on the side of the network with multiple agents. In [1S-2R], for example, it is natural to think of the Sender as a monopolist and the Receivers as "competitors"; in [2S-1R] it's the reverse.

[3] Conlin et al. (2003) develop a model for the determinants of tipping behavior and investigate whether survey research on tipping behavior is consistent.

[4] Detroit pitcher Kenny Rogers abruptly fired his agent Scott Boras in the 2007 off-season, saying he would rather represent himself. Allegedly, Rogers felt Boras was representing his own interests (or perhaps the interests of some of his other clients) and not Rogers'.

Gale, 2000); employment and inequality in labor markets (Calvo-Armengol and Jackson, 2004; Bayer et al., 2005; Hellerstein et al., 2008); institutional efficiency (Deck and Johnson, 2004); social capital (Karlan et al., 2009b); social learning (Ellison and Fudenberg, 1995; Jackson and Kalai, 1997; Kariv and Gale, 2003); and transmission of information about profitable trade opportunities (Rauch and Casella, 2001; Cassar et al., forthcoming).[5] The research most closely related to ours explores network effects in bargaining environments such as the ultimatum game using laboratory methods (Roth et al., 1991; Charness et al., 2004; Fischbacher et al., 2009). However, unlike this prior research, we focus on a situation in which there are gains from exchange between parties, which is an important feature of the kinds of real-world principal–agent problems we find interesting. Moreover, the structure of the investment game allows us to gain an understanding of network effects on two variables that are economically significant: trust and trustworthiness. Trust is a key ingredient to strong economic performance of a country (Knack and Keefer, 1997; Zak and Knack, 2001). There are clearly enormous benefits to the presence of high trust and trustworthiness in a society, including less need for individuals to spend resources to protect themselves from defection and the government need not divert its resources to the enforcement of contracts (Putnam et al., 1993; La Porta et al., 1997).

Our research is the first to explore the impact network structure has on trust and trustworthiness in bilateral exchange. Our results generally support our two main hypotheses. Signals of trust are comparative and this type of trust gets leveraged to crowd-in cooperation. The rest of the paper is organized as follows.

The next section characterizes the two networked versions of the investment game. Section 3 develops a framework that we use to characterize comparative trust, and discusses two kinds of information flow in the network, full and partial. We then put forward our main hypotheses about the relationship between information flow, comparative trust measures, and rates of trust and trustworthiness in the 3-node networks. Section 4 discusses the experimental design and procedures and Section 5 contains results. The final section concludes.

2. Networked investment games

There are two ways in which exchange may be implemented on a network. The first, *exchange over a network*, is familiar from the evolutionary game theory literature. Here individual interactions remain bilateral, but there is imposed structure on the population from which partners are drawn. For example, agents on a ring interact with their neighbor to their left and to their right, and agents on a lattice interact with their 8 local Moore neighbors or their 4 von Neumann neighbors. In each case, the individual interactions remain bilateral, but the population forces the pairing to be non-random, and this (in the context of an updating rule like the replicator dynamics) can drive the population toward efficient outcomes (Skyrms, 2004; Axelrod et al., 2002; Blume, 1995; Ellison, 1993; Nowak and May, 1993; Eshel et al., 1998).

The other way of implementing exchange on a network — what we call *networked exchange* — changes the topology of the environment itself to model structured interactions for more than two agents. Here the interactions are no longer bilateral and the network structure is part of the strategic environment. We focus on this type of interaction between network and exchange and, in particular, on networked exchange in the investment game.

The standard bilateral investment game is the limiting case of networked exchange: it is a 2-node (dyadic) network, with one node occupied by Sender and the other by Receiver. Sender (S) is paired with Receiver (R), and each is endowed with M. In the first stage, S sends an amount X ($0 \leqslant X \leqslant M$) to R. That investment grows by some factor $r > 1$. In the second stage, R can return any amount Y of rX to S ($0 \leqslant Y \leqslant rX$). The final payoff to S is $M - X + Y$ and the final payoff to R is $M + rX - Y$. We use the 2-node case as a point of comparison, but focus on 3-node (triadic) networked investment games. In the networks we consider, each of the nodes is a different player — either a Sender or a Receiver — and the network is created through the interaction of the players. Moreover, we focus on *directed networks*, where each link represents a directional flow of investments or returns from one player to another player. There are then two unique types of triads: in one the induced competition is on the Receiver's side (i.e., the agent's); in the other the induced competition is on the Sender's side (i.e., the principal's).

The first triadic network structure adds an additional Receiver so that Sender is paired with two Receivers, A and B (see Fig. 1(a)); we call this network structure [1S-2R]. S begins with M, and R_A and R_B both begin with M. In the first stage, S chooses an amount X_A of his endowment ($0 \leqslant X_A \leqslant M$) to send to R_A and an amount X_B ($0 \leqslant X_B \leqslant M$) to send to R_B, where $X_A + X_B \leqslant M$. The invested X_A and X_B are then multiplied by a growth factor, $r > 1$. In the second stage, R_A chooses some amount Y_A of rX_A, and R_B some amount Y_B of rX_B, to return to Sender. In this structure Sender is a monopolist and Receivers A and B are potential competitors for the Sender's investment.

The other triad reverses the asymmetry between Senders and Receivers: two Senders α and β are paired with one Receiver (see Fig. 1(b)); we call this network structure [2S-1R]. S_α and S_β each begin with M, and R begins with M. In the first stage, S_α chooses an amount X_α ($0 \leqslant X_\alpha \leqslant M$) to send to R, and similarly S_β chooses an amount X_β ($0 \leqslant X_\beta \leqslant M$). The invested X_α and X_β are then multiplied by a growth factor, $r > 1$. In the second stage, R then chooses some amount Y_α of rX_α to return to S_α and some amount Y_β of rX_β to return to S_β.[6] In this structure Receiver is a monopolist and there is potential competition between Senders α and β for the Receiver's trustworthiness.

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5 See Kosfeld (2004) for a survey of experimental economics research focusing on the role of networks.

6 Note that R return choices are bounded by the investment made by a particular sender, not by the aggregate investments: R can return some amount Y_i to S_i, where this amount returned is constrained by rX_i (i.e., the gains generated by S_i's investment) and not by $r(X_i + X_j)$.

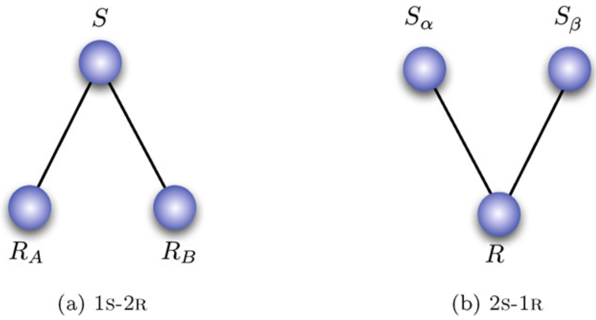

Fig. 1. 3-node networks.

The subgame-perfect equilibrium in the dyadic investment game has S opting out, investing nothing and all players earn only their initial endowments of M. Extending the standard backward induction argument to the triads the predicted result does not change. Independent of whether the power is concentrated in the hands of the Sender in [1s-2r] or the Receiver in [2s-1r], assuming that agents are Bayesian maximizers, Receivers will keep any investment. Under the standard common knowledge assumptions, Senders know this and (preferring more to less) invest nothing. Since the relevant inequalities between utilities are strict, the equilibrium is unique. Thus the equilibrium path in the triads also favors no exchange between Senders and Receivers.

3. Modeling comparative trust and the role of information

What distribution or outcome an agent prefers might depend not only on what the options for distributing the goods are when she makes her choice, but on how she arrived at that set of options. If preferences are understood purely classically, of course, this is problematic. But in the case of personal exchange environments, there is ample experimental evidence of exactly this kind of dynamics of preferences. There are two relevant results. First, cooperative outcomes are chosen by second movers in investment and trust games at different rates (across subjects) depending on different histories of the game leading up to an information set (Croson and Buchan, 1999; Ortmann et al., 2000; Glaeser et al., 2000; Fehr et al., 2002; McCabe et al., 2002; Engle-Warnick and Slonim, 2005; Rigdon, 2009). With an interesting caveat, rates of return increase as a function of investment.[7] Second, if that history involves an opportunity cost for first movers (i.e., the difference between first movers' outside option and the payoff received if the second mover chooses defection is strictly positive), so that the cooperative move by a second mover can be deemed "reciprocal", there is comparably more cooperative play by second movers than if there is no such opportunity cost (McCabe et al., 2003).

Thus there is empirical support for the hypothesis that a significant portion of Receivers in these environments choose cooperatively only when a Sender's action carries a signal of trust. Therefore by giving a more precise characterization of when a Sender's action carries a signal of trust in a networked investment game, we can generate more precise predictions for the conditions under which Receivers reciprocate, and test these predictions in the laboratory.

Trust, in the standard investment game, is measured by how much Sender invests. Given the empirical hypothesis that Receivers respond differentially to different levels of trust, it is then straightforward that what counts as trusting behavior (according to Receivers) is the investment level. Once we have non-trivial networked exchange, a question arises about what counts as trust. In [1s-2r] the question is *trust in whom*? Does trust in Receiver A just equal the amount sent to A, X_A (an *absolute* measure), or does it also depend on the amount sent to the other Receiver, X_B (a *comparative* measure)? In [2s-1r] the question is *trust from whom*? Does trust from Sender α just equal the amount sent from α (an *absolute* measure), X_α, or does it also depend on the amount sent from the other Sender, X_β (a *comparative* measure)? Our first hypothesis, to be refined below, is that what counts as a signal of trust in the networked games will be comparative, depending on the investment behavior along the other link in the network. Our second hypothesis is that if the information conditions are right, that can get leveraged to drive choice behavior toward more efficient play. For our purposes, it is not important to look to any one particular model of comparative trust. Rather, we can assume that *any* reasonable model of comparative trust says that it is some increasing function of differences in amount sent, and then use that as a basis for probing our main empirical hypothesis — whether or not, if the information conditions are right, cooperation is crowded in on the long side of our networked investment games.[8] It is still useful to see some simple models of comparative trust, and so we provide some examples.

Section 3.2 develops a framework for formulating the difference between absolute and comparative trust in [1s-2r] and Section 3.3 develops the framework for [2s-1r]. In each case, we first develop the general framework, then describe two

[7] The caveat is that there is a kink in returns for investment levels in the $(6, 8)$ interval in the standard baseline one-shot investment game.

[8] There are several approaches we could have used as a framework for developing our hypotheses, including mapping our framework into the extensive-form models of Battigalli and Dufwenberg (2009) and Dufwenberg and Kirchsteiger (2004). While potentially very interesting, our aim in this section is to generate a simple set of hypotheses about comparative trust. It is not to distinguish between possible rival explanations of our data.

different ways information can flow in that network, and finally express the empirical hypotheses to be tested in that network. Section 3.1 contains a preliminary discussion of the 2-node case. This is, strictly speaking, not necessary since what we say about the 2-node investment game is a special case of what we say about the [1S-2R] network; but it may be helpful to begin with the limiting case.

3.1. Trust in 2-node networks

In the standard 2-node investment game, the distinction between absolute and comparative trust collapses: the amount sent by Sender (X) is considered a signal of trust. Intuitively, this is because as the investment X gets larger, so does the pie of gains from exchange that Receiver has to divide between them. So Receiver's space of options gets bigger and better while Sender's best-case options get bigger and better but also her *worst-case* option is worse than had she not sent anything at all.

To turn this reasoning into a more precise characterization, we need to describe how agents' preferences can be conditional on the opportunities they face. The idea of "dynamic preferences" — that an agent's preferences over bundles might depend on how she arrives at the choice between bundles — is, of course, not new (see e.g. Sen, 1997). What is new is to use such a characterization of when an action carries a signal of trust to derive predictions for off-equilibrium cooperative behavior by Receivers in the standard investment game and the networked versions. Our characterization of trust in 2-node investment games uses some of the framework from a non-parametric model of preferences by Cox et al. (2008). We depart from and extend the framework to better suit our purposes, providing an interesting set of hypotheses for network environments.[9]

Begin with an n-player extensive form game. The basic idea is that agents can have very different preferences depending on what the set of feasible options is. Thus we condition preferences on such sets. For a given game, let Π be the total set of possible payoff distributions. We will generally assume that this is a compact, convex subset of $\Re^2_+$. Since our interest is in 2-node and 3-node investment games, three types of distributions will be particularly relevant (where w is Sender's payoff and z is Receiver's payoff, and similarly for $z_{A/B}$ and $w_{\alpha/\beta}$):

- 2-node (baseline): $\pi = (w, z)$
- 3-node [1S-2R]: $\pi = (w, z_A, z_B)$
- 3-node [2S-1R]: $\pi = (w_\alpha, w_\beta, z)$

An *opportunity set* F is a non-empty subset of Π. Opportunity sets are thus just feasible budget sets.

Rather than preferences *simpliciter*, we want to talk about an agent's *preferences given an opportunity set*. Given an opportunity set F, i's preferences given F is a well-defined ordering over F that is convex and continuous. What we care about is that player i's preferences given F can be represented by a smooth utility function $u_i(\cdot|F)$ such that $\frac{\partial u_i(\cdot|F)}{\partial \pi_i} > 0$. Two possibilities are noteworthy here. First, it is possible that i (given F) cares about j's payoff: $\frac{\partial u_i(\cdot|F)}{\partial \pi_j} > 0$. Second, it is possible that $u_i(\pi|F) \neq u_i(\pi|F')$ even when $F \subseteq F'$. That is because the shape of i's preferences may well be affected by the set of opportunities she faces. It is convenient to identify what, given an opportunity set F, a maximizing agent i's best outcome is if i is an own-payoff maximizer; here we abuse notation (slightly, and to no harm) and write $\pi^*(i|F)$. This is the maximum feasible payoff to i in opportunity set F.

In the 2-node investment game, then, it is straightforward to say when one of Sender's actions is more trusting than another: just in case it determines a better budget space for Receiver and how much better is not dwarfed by how much better it is for Sender. That is:

Definition 1.

1. Opportunity set G is at least as generous as F, $G \trianglerighteq F$, iff:
   (a) $\pi^*(R|G) \geqslant \pi^*(R|F)$; and
   (b) $\pi^*(R|G) - \pi^*(R|F) \geqslant \pi^*(S|G) - \pi^*(S|F)$
2. G is more generous than F, $G \triangleright F$, iff $G \trianglerighteq F$ and $F \ntrianglerighteq G$

X carries at least as strong a signal of trust as X' if the opportunity set determined by X is at least as generous as the opportunity set generated by X'.

Thus, to say that one action carries a stronger signal of trust than another is to say that the first generates an opportunity set G that is more generous than the opportunity set F generated by the second. To say that G is more generous than F is

[9] The main point of departure is that our concerns are different: we want a framework for characterizing a set of hypotheses about networked exchange, they want to account for well-known experimental data from the standard dyadic environment. Thus, they have no need for the ability to express the comparative trust measures we need. On the other hand, we have no special need for their assumptions and constraints about the changing preferences of Receivers: given our purposes, we are happy to take on board, as a general empirical result, that return behavior increases as investments go up. That is all any of our arguments require.

just to say that a maximizing Receiver can do no worse in G than in F and that *how much better* R can do in G as compared to F isn't trumped by how much better Sender can do in G as compared to F. This second clause, notice, would not be satisfied if Sender faced no opportunity cost to investing.

Since opportunity sets are determined by Sender's action, it is sometimes useful to write them as a function of that action. In the investment game, Sender's choice is an investment bundle. In the 2-node case, it is a value for X; in the [1S-2R] case, it is a pair (X_A, X_B); and in the [2S-1R] case, each Sender makes an investment choice, X_α and X_β, and each thereby determines an opportunity set for the Receiver. Where c is an investment choice by a Sender, let $\Omega(c)$ be the opportunity set this choice determines.

Example. Consider two possible actions, or investment choices, by Sender in the 2-node investment game with endowment $M = 10$ for each player and a growth rate $r = 3$ (standard parameter values used in the investment game): $X = 2$ and $X' = 8$. Intuitively, the second action represents a stronger signal of trust than the first. This is confirmed by the model since $\Omega(X' = 8) \rhd \Omega(X = 2)$. To see this, let $F = \Omega(X = 2)$ and $G = \Omega(X' = 8)$. Then note that, for any chosen value for X, $\pi^*(R|\Omega(X)) = 3X + M$. Thus, $\pi^*(R|G) = 34 > \pi^*(R|F) = 16$. Hence a maximizing Receiver does better in G than in F. Second, note that $\pi^*(S|\Omega(X)) = M - X + 3X$ — that is, the highest profit for Sender, given some initial choice for X, is to get all of the gains from exchange back. Now, $\pi^*(S|G) - \pi^*(S|F) = 26 - 14 = 12$, which is smaller than $\pi^*(R|G) - \pi^*(R|F) = 18$. Hence the size of the potential windfall to Receiver for being in G is greater than the potential windfall to Sender. Therefore, $G \rhd F$.

We now turn to 3-node networks in which the distinction between absolute and comparative models does not collapse.

3.2. Comparative trust with two receivers

First, consider the case of [1S-2R]. Sender chooses an investment bundle (X_A, X_B) such that each X is between 0 and M and such that $X_A + X_B \leqslant M$. The question is how the bundle of investments is viewed by Receiver A and how that same bundle is viewed by Receiver B. Since a single bundle could be quite trusting to one receiver and not to another, we have to measure trust-in-A (trust$_A$) and trust-in-B (trust$_B$).

An absolute model of trust says that Receiver i views X_i as a signal of trust, full-stop. Thus trust$_i$ depends on comparing R_i's opportunities to S's, but only those of S's that are "local" to the interaction with R_i. If this is the case, then X_{-i} does not matter to Receiver i in determining a return to Sender and trust$_i = X_i$.

On the other hand, a comparative model of trust says that Receiver i compares X_i and X_{-i} in determining how trusting Sender has been. Thus, trust$_i$ depends on comparing R_i's opportunities to S's "global" opportunities. Since S's global opportunities depend in part on the link shared with R_{-i}, X_{-i} matters to the level of trust$_i$ signaled by the investment bundle. And since trust levels are tied to opportunity sets, there is no fact of the matter as to whether one opportunity set is "more generous than another" *simpliciter* in a 3-node network. So we generalize Definition 1, relativizing to a particular Receiver. We do this in a way that links R_A's opportunities and X_B (and vice versa), thus generating a comparative model of trust.

Definition 2.

1. Opportunity set G is at least as generous to Receiver i as F, $G \unrhd_i F$, iff:
   (a) $\pi^*(R_i|G) \geqslant \pi^*(R_i|F)$; and
   (b) $\pi^*(R_i|G) - \pi^*(R_i|F) \geqslant \pi^*(S|G) - \pi^*(S|F)$
2. G is more generous than F, $G \rhd_i F$, iff $G \unrhd_i F$ and $F \ntrianglerighteq_i G$

Let G_i be R_i's opportunity set determined by investment bundle $X = (X_A, X_B)$ and F_i be R_i's opportunity set determined by $X' = (X'_A, X'_B)$. X carries at least as strong a signal of trust$_i$ as X' if the opportunity set determined by X is at least as generous as the opportunity set generated by X'.

So far, this looks like a mere notational variant of the earlier definition: we have swapped R_i for R. But, as we will see below, this is not really true. That is because the term involving Sender in Condition (b) depends on Receiver $-i$'s behavior when faced with opportunity sets G_{-i} and F_{-i}. Thus while it is true that payoffs to the Receivers are independent (neither a function of the other), whether an opportunity set is more generous than another to R_i depends on the behavior (and so on the payoffs) of R_{-i}.

The following observation characterizes how differentially a bundle has to favor a Receiver in [1S-2R] — say, Receiver A — for that bundle to constitute a signal of trust$_A$. For the straightforward proof see Appendix A.

Observation 1. Consider two (potential) investment choices by Sender, and let $G = \Omega(X_A, X_B)$ and $F = \Omega(X'_A, X'_B)$. Then $G \rhd_A F$ only if the difference in investments in A are at least $(r - 1)$-fold greater than those in B.

Somewhat surprisingly, the comparative level of trust$_A$ between two investment bundles X and X' requires a corresponding difference in investment level to B across those bundles. Notice that this states a necessary, and not a sufficient, condition on comparative trust. Thus, the strength of signal of trust in A carried by a bundle X is in part a function of $X_A - X_B$. This yields an instance of our first empirical hypothesis:

Hypothesis 1 *(Comparative Trust in* [1S-2R]*).* The level of perceived trust in [1S-2R] is in part a function of $X_A - X_B$.

We can test this hypothesis by examining Receiver behavior under two different information conditions to see whether that behavior is sensitive to comparisons between X_A and X_B. If so, then this is evidence in favor of our hypothesis.

3.2.1. Information flow with two receivers

In [1S-2R] for Receivers to be able to make comparative judgments regarding trust by Sender, there must be *full information flow* within the network. The following two conditions define full information: (i) every agent in the network knows every move made by every other agent at points higher in the game tree; and (ii) after the terminal nodes are reached, there is full-disclosure about all moves. In [1S-2R] this implies that each Receiver knows how much is invested in the other Receiver before deciding on a return and both Receivers learn how the other responds through full disclosure of all moves.[10] That is:

- R_A knows the value of X_B before choosing Y_A; R_A learns Y_B through full-disclosure
- R_B knows the value of X_A before choosing Y_B; R_B learns Y_A through full-disclosure

On the other hand, a network allows for *partial information flow* if each agent *only knows* about (i.e., has full information about) the interactions in which that agent is a trader. Note that it follows immediately that agents on the short-side of the market know about all the interactions in that market. In a [1S-2R] network with partial information Receivers do *not* know the amount Sender invests in the other Receiver when making a return decision and do *not* learn how the other Receiver responds since there is not full disclosure:

- R_A does not know X_B; R_A does not learn Y_B
- R_B does not know X_A; R_B does not learn Y_A

We can vary the amount of information available to test whether or not Receivers' return behavior is sensitive to comparisons between X_A and X_B; that is, under full information, does the amount returned to Sender depend in part on what was sent to the other Receiver. We can ask a further question: if Receivers utilize a comparative measure of trust, what effect will this have on the level of cooperation? In particular, if trust signals are comparative, can this fact be leveraged to crowd-in cooperation within the network?

3.2.2. Leveraging comparative trust with two receivers

Our second general hypothesis is that comparative trust is leveraged in networks. In the [1S-2R] network, the hypothesis is that this will generate an increase in trustworthiness (i.e., an increase in cooperation by those on the long-side of the exchange):

Hypothesis 2 *(CCH in* [1S-2R]*).* Full information flow increases trustworthiness by Receivers in [1S-2R].

This hypothesis is based on the fact that with full information each Receiver knows the level of trust_A and trust_B and, therefore, can compare them before making their choice about returns. In the same network with only partial information flow, the signal of trust is masked: neither Receiver A nor Receiver B has enough information to determine trust_A and trust_B.[11] Given the broad empirical generalization about return behavior in the investment game, we would expect less cooperative return behavior by each Receiver in an environment where the Receivers cannot compute how generous an investment is by the Sender.

Our framework, however, does not give any direct prediction for a comparison between the [1S-2R] case and the dyad. In [1S-2R] Sender faces an allocation decision of dividing the initial M among two Receivers (not just one as in the dyad). A Sender matched with two Receivers may expect a lower risk from his investments for two reasons. It is well known that investment across say two projects (represented here by Receivers) lowers the overall riskiness of the enterprise with respect to allocating the same amount to only one. Hence, a Sender may experience lower risk in the [1S-2R] case than in the dyad and, therefore, invest an overall higher amount (Schechter, 2007, finds that play in a risk game is predictive of play by the Sender in a trust game). Therefore, we expect trust to be higher in the [1S-2R] case than in the dyad, independent of the information flow.

[10] In the introduction we mentioned two examples of this kind of information flow. The homeowner who may hire two contractors for two remodeling jobs or hire one for both — by voluntarily revealing discussion about terms of trade with one contractor to the other contractor is an effort to get them to compete. Another case is when deciding on a tip amount for a server in a crowded restaurant, you are most likely able to observe the service at all tables, and can make a decision on tip in part based on this information.

[11] Note that knowing only X_A, Receiver A cannot infer that $X_B = M - X_A$. S is under no obligation to invest all of M, and that is common knowledge.

Hypothesis 3 *(Efficiency in* [1S-2R]*).* Regardless of information, the [1S-2R] network generates higher trust, and hence higher efficiency, than the dyad.

Summarizing the [1S-2R] predictions, we expect to find evidence for a comparative model of trust under the full information case. We hypothesize more trustworthiness under full than under partial information and, as a consequence, a higher return ratio as well. With respect to the dyad, we predict [1S-2R] to display a higher amount of trust (i.e. overall level of investment) from the Sender.

3.3. Comparative trust with two senders

Consider the case of [2S-1R]. Here an investment bundle (X_α, X_β) in Receiver is determined by the joint actions of Sender α and Sender β. The question is how the bundle of investments is viewed by Receiver. Since there are two independent parts of that bundle (one from Sender α and one from Sender β), part of that bundle could be quite trusting and the other part not trusting. So we have to measure trust-from-α (trust$^\alpha$) and trust-from-β (trust$^\beta$).

An absolute model of trust says that Receiver views X_i as a signal of trust^i. Thus trust^i depends on comparing S_i's opportunities to R's, but only those of R's that are "local" to interaction with S_i. If this is the case, then X_{-i} does not matter. We again develop a comparative model: trust^i depends on comparing S_i's opportunities to R's "global" opportunities. Thus, since R's global opportunities depend in part on the link shared with S_{-i}, X_{-i} matters to the level of trust^i signaled by the investment bundle.

It is sufficient to say when investment bundles signal trust$^\alpha$ and trust$^\beta$. In the [1S-2R] network, what is relevant is how *different* investment bundles are viewed by Receivers, each from their own point of view. In [2S-1R], however, what is relevant is how a *single* investment bundle affects what the Receiver thinks about the two independent Senders: given the generosity of the space of opportunities R faces, we want to model α's contribution to that and β's contribution to that.

Given an investment bundle $X = (X_\alpha, X_\beta)$ that determines an opportunity set G (note that this is a set of triples, as in the [1S-2R] network) we will give a comparative assessment of when G's comparative generosity is due to S_α as opposed to S_β. There are different ways of modeling this; we focus on a particularly simple version. What we will do is find a comparative measure of how much of the generosity of G is due to S_α as opposed to S_β by abstracting away the contributions of the other Sender.[12]

Notice that we can restrict G by eliminating one of its coordinates — say the coordinate for Sender α's profits; such a restriction is the *α-free slice of G*. Thus the α-free slice of G is the set of possible distributions in G to Receiver and Sender β. This allows us to evaluate relative generosity of G, an opportunity set that is a function in part of α's investment, while ignoring α's potential profits in G. Similarly, we can also take the *β-free slice of G*: the possible distributions in G involving Receiver and Sender α. Since G is a set of ordered triples, these slices are planes (sets of pairs) and are like opportunity sets from the 2-node investment game, except that Receiver's profits reflect that he is linked with two Senders. But they are (2-person) opportunity sets, and so can be compared for relative generosity. Receiver's range of profits are the same in these two slices, and so his maximum profit is the same. Thus if the slices differ in their generosity, it must be because one of the Sender's has a higher maximum profit in his slice than the other has in his; the former is less generous.

Definition 3. Let G be the opportunity set determined by investment bundle $X = (X_\alpha, X_\beta)$.

1. Restricted opportunity sets:
   (a) α-free slice of G: $G_{\setminus\alpha} = \{(w_\beta, z)\colon\ (v, w_\beta, z) \in G \text{ for some } v\}$
   (b) β-free slice of G: $G_{\setminus\beta} = \{(w_\alpha, z)\colon\ (w_\alpha, v, z) \in G \text{ for some } v\}$
2. Sender i is at least as generous in G as Sender j is iff $G_{\setminus i} \trianglerighteq G_{\setminus j}$

The level of trust^i signaled by investment bundle X is at least as great as trust^j iff Sender i is at least as generous in G as Sender j is.

Observation 2. Sender i is at least as generous in G as j iff $X_i - X_j \geqslant 0$.

See Appendix B for the straightforward proof of this observation. Observation 2 yields the following empirical hypothesis:

Hypothesis 4 *(Comparative Trust in* [2S-1R]*).* The level of perceived trust is in part a function of $X_\alpha - X_\beta$.

As in [1S-2R] we can test this hypothesis by examining Receiver behavior under two different information conditions to see whether that behavior is sensitive to comparisons between X_α and X_β. If so, then this is evidence in favor of our hypothesis.

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[12] Since Receiver's potential windfall is a function of both investments, if we didn't abstract away S_{-i}'s contribution it would be hard to say in a clear way whether S_i's contribution to that windfall is at least as much as S_{-i}'s.

3.3.1. Information flow with two senders

In the [2S-1R] network with full information flow, full-disclosure implies that Senders each learn about what the other invests following own investment choice and also learn how Receiver responds to the other Sender's investment:

- S_α learns the value of X_β and Y_β
- S_β learns the value of X_α and Y_α

In the [2S-1R] network with partial information flow, Senders do not learn the amount the other invests or how the Receiver responds to that:

- S_α does not know X_β or Y_β
- S_β does not know X_α or Y_α

Notice that since Receiver is on the short-side of the network, the type of information flow within the network does not change what she knows when she makes her return decisions; the only difference is that under partial information she knows that the Senders never learn what the other sent to her or how she responded to the other.

Again, we can vary the type of information to test whether or not Receiver's return behavior is sensitive to comparisons between X_α and X_β; that is, under full information, does the amount returned to Sender i depend in part on what was sent by the other Sender. As in [1S-2R], we can ask a further question: if Receiver utilizes a comparative measure of trust, what effect will this have on the level of cooperation? In particular, if trust signals are comparative, can this fact be leveraged to crowd-in cooperation within the network?

3.3.2. Leveraging comparative trust with two senders

Again, our second general hypothesis is that comparative trust is leveraged in networks. In the [2S-1R] network, the hypothesis is that this will generate an increase in trust (i.e., an increase in cooperation by those on the long-side of the exchange):

Hypothesis 5 *(CCH in* [2S-1R]*).* Full information flow increases trust by Senders in [2S-1R].

CCH implies that in [2S-1R], with full information flow, there will be competition on the long-side of the exchange between Senders α and β for the Receiver's attention. That is because, at the end of each stage, each Sender knows the level of trust$^\alpha$ and trust$^\beta$. Each also learns the Receiver's reaction to those levels. So, if Receiver responds differentially to differences between trust$^\alpha$ and trust$^\beta$ (and given the broad empirical generalization about return behavior in investment games, this is to be expected), then we would expect an arms race in transfers between the Senders. However, in the same network with only partial information flow, Receiver's differential responses to Sender α and Sender β cannot be traced to differences in trust$^\alpha$ and trust$^\beta$. Thus, the Receiver cannot reveal his response-type to the Senders and we would therefore expect less cooperative behavior by Senders since comparative trust cannot be leveraged.

Now that we have put forward our main hypotheses about the relationship between information flow, comparative trust measures, and rates of trust and trustworthiness in the 3-node networks, we turn to our experimental design and procedures.

4. Experimental design and procedures

The first condition is the standard 2-node investment game. We then cross type of 3-node network {[1S-2R], [2S-1R]} with kind of information flow {Full Info, Partial Info} to obtain our $1 + (2 \times 2)$ conditions.[13] We use standard parameter values for initial endowments, $M = \$10$, and for the growth rate, $r = 3$. The sessions were run at the Learning and Experimental Economics Projects of Santa Cruz (UC-Santa Cruz) and the Robert Zajonc's Laboratory (Institute for Social Research, University of Michigan).[14] The sessions were run May 2005 through July 2006. Three sessions of each treatment were conducted.

An experimental session ran as follows. Subjects earned \$5 for showing up on time and were immediately seated in the lab. Instructions were read aloud and subjects were given an opportunity to ask questions. The only difference in the instructions for the treatment conditions was the description of either the network structure or the information available (see Appendices C and D for the [1S-2R] treatment).[15] Prior to beginning the experiment, subjects were required to complete a quiz regarding the interaction, including payoff calculations for both roles, which the experimenter checked for accuracy. Subjects were randomly assigned a role as either a Sender or Receiver and kept this role throughout the session. Subjects participated in forty periods of one of the treatments, and this was common information. At the start of each period, they

[13] The complete design for the overall project on networked exchange has 3 matching treatments $\times$ 2 3-node network structures $\times$ 2 information conditions; in addition to the 2-node investment game.

[14] Subjects who had previously participated in similar experiments were excluded from recruitment.

[15] Computer interface screen shots for the [1S-2R] INFO treatment are available at http://www.umich.edu/~mrigdon/1s2rinfo.pdf.

Table 1
Dyad — Random-effects regressions.

	Amt. Returned†		Amt. Sent
Intercept	−1.088	−1.060	1.804***
	(1.651)	(1.565)	(0.360)
Amt. Sent	0.451***	0.449***	
	(0.029)	(0.030)	
Lag Amt. Sent		−0.148***	0.229***
		(0.035)	(0.012)
Lag Amt. Ret.		0.315***	0.064***
		(0.048)	(0.014)
Period Number		0.162**	−0.040
		(0.072)	(0.033)
Period Number^2		−0.005***	0.001
		(0.002)	(0.001)
n obs.	646	581	633
n groups	18	18	18
Wald χ^2	236.70	282.92	672.42
Prob. > χ^2	0.00	0.00	0.00
R-squared			0.5171

† Censored lower limit = 0; upper limit = Amt. Sent.
* 90% significance; ** 95% significance; *** 99% significance.

were randomly re-matched. Once the session was finished, subjects were paid their accumulated earnings in private. Each session had 12 subjects and took less than 1 hour to complete. Average earnings in the dyad were $11.61 for Senders and $21.29 for Receivers; in the [1S-2R] $11.49 for Senders and $17.83 for Receivers; in the [2S-1R] $12.19 for Senders and $32.64 for Receivers.

All treatments reported here used a “one-shot” random matching treatment (i.e. “strangers”).[16] This design choice aims to further explore the scope and the limits of the absolute model of trust by adding a dynamic component. Cox et al. (2008) test the theory's prediction that the amount returned is increasing in the amount sent using observations from pairs of subjects involved in two-person one-shot games. They report that the data confirm the theory's prediction *across* subjects.[17] We repeat the game forty times with random matching to be able to test our theory — not just across subjects (subjects that are given more in the first stage return more than subjects that are given less) — but *within* subjects. This will allow us to understand whether Receivers possess a stable and absolute judgement of what is considered a more or less generous offer or whether such judgment is itself relative to current circumstances, like what others have sent in previous periods.

5. Results

Our experimental data support the Comparative Trust Hypothesis and the Competition for Cooperation Hypothesis under both 3-node network structures. In particular, return decisions by Receivers depend in part on the investment behavior along the other link in the network. Moreover, this comparative trust can be leveraged, generating an increase in cooperation on the long-side of the exchange: under full information, trustworthiness is higher in the [1S-2R] network and trust is higher in the [2S-1R] network.

Tables 1–4 contain the results of panel Random-effects regressions that provide direct tests of the theoretical predictions to be discussed in detail below. Tables 5–7 report detailed descriptive statistics for the dyad, [1S-2R], and [2S-1R], respectively. To the *right* of the average, subscripts and superscripts indicate significant differences across the two information treatments. To the *left* of the average, subscripts and underlining indicate significant differences with respect to the corresponding measure in the dyad. Note that superscripts report significant differences using a non-parametric Mann–Whitney two-sided test; subscripts and superscripts report significant differences using the more conservative panel estimation.[18] In the majority of cases, a result reporting a significant difference with the Mann–Whitney test is confirmed by the respective panel estimation (although the panel results often yield a larger p-value). The discussion below is mostly based on the regression results in Tables 1–4 and partially based on the less conservative non-parametric results.

[16] Results with fixed pairings, finitely repeated networked investment games are available in Cassar and Rigdon (2010).
[17] They estimate a censored regression ($Y \in [0, 3X]$ with the constant restricted to 0) finding a coefficient value of 0.58.
[18] The panel estimation involves individual level Random-effects panel regressions, where the only independent variable is either the information treatment dummy or the network dummy.

Table 2
[1S-2R] — Random-effects regressions.

	Amt. Returned to $S^{\dagger}$				Diff. Returned‡	Amt. Sent	
	PARTIAL	FULL	PARTIAL	FULL		PARTIAL	FULL
Intercept	−1.915**	−0.315	−1.223	−0.240	0.597	2.768***	1.950***
	(0.858)	(0.713)	(0.996)	(0.903)	(0.786)	(0.376)	(0.354)
Amt. Sent to R_i	0.469***	0.442***	0.450***	0.492***			
	(0.020)	(0.022)	(0.021)	(0.025)			
Amt. Sent to R_{-i}	−0.011	−0.043*	−0.026	−0.042*			
	(0.020)	(0.024)	(0.021)	(0.026)			
Lag Amt. Sent to R_i			−0.102***	−0.106***		0.059	0.283***
			(0.029)	(0.032)		(0.051)	(0.054)
Lag Amt. Sent to R_{-i}			0.004	0.006			
			(0.020)	(0.025)			
Lag Amt. Ret. by R_i			0.224***	0.208***		0.165***	0.115***
			(0.045)	(0.048)		(0.025)	(0.027)
Period Number			0.077**	0.050	0.075	0.079	0.050
			(0.037)	(0.048)	(0.062)	(0.031)	(0.034)
Period Number^2			−0.003***	−0.003***	0.002	−0.002***	−0.001
			(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Diff. Sent					0.421***		
					(0.024)		
Info					0.252		
					(0.854)		
Info × Diff. Sent					0.083**		
					(0.038)		
Lag Diff. Ret.					0.130***		
					(0.047)		
Lag Diff. Sent					−0.057**		
					(0.028)		
n obs.	829	774	710	630	489	813	763
n groups	24	24	24	24	24	12	12
Wald χ^2	985.33	726.84	1118.11	809.95	631.99	110.49	172.03
Prob. > χ^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R-squared						0.1387	0.2101

† Censored lower limit = 0; upper limit = Amt. Sent.
‡ Lower limit = 0 – Amt. Sent to R_B; upper limit = Amt. Sent to R_A.
* 90% significance; ** 95% significance; *** 99% significance.

5.1. Results with one receiver and one sender

The results in the 2-node treatment serve both as baseline for comparison with the [1S-2R] and [2S-1R] networks and as a replication of earlier investment game experiments with random matching (Bohnet and Huck, 2004; Cochard et al., 2004; Ben-Ner and Putterman, 2009). The main empirical finding is that return behavior by Receivers confirms expectations: higher trust (i.e., higher amount sent) is met with greater trustworthiness (i.e., higher amount returned). See Table 5, reporting that Senders on average invest $6.45 out of their $10 endowment, Receivers return an average of $9 (or 39% of the gains from exchange), and the return ratio is 1.18.[19]

We also find that in the repeat random matching protocol, the level of trust perceived by a Receiver is also comparative in a dynamic sense. Table 1 reports results from two panel Random-effects Tobit regressions, where the dependent variable is the amount returned by Receiver.[20] The first regression has the amount sent by the Sender as the only independent variable and we find that the Receiver returns approximately 45% of an extra dollar received. This result is robust once we add other variables to capture a possible reaction to a different Sender's offer (*Lag Amt. Sent*); a Receiver's homegrown trustworthiness (*Lag Amt. Ret.*); and a time effect (*Period Number* and *Period Number*^{2} allowing for a nonlinear time trend).

[19] The return ratio is calculated as the amount returned by Receiver divided by the amount sent by Sender ($\frac{Y}{X}$).
[20] The censoring is between 0 and the amount X sent by the Sender.

Table 3
[2S-1R] — Random-effects Tobit regressions for trustworthiness.

	Amt. Returned to S_i†				Diff. Returned‡
	PARTIAL	FULL	PARTIAL	FULL	
Intercept	−3.994**	2.897**	−4.238**	0.873	0.296
	(1.769)	(1.431)	(1.700)	(1.368)	(0.579)
Amt. Sent by S_i	0.522***	0.413***	0.549***	0.403***	
	(0.017)	(0.031)	(0.020)	(0.030)	
Amt. Sent by S_{-i}	0.034**	−0.101***	0.026	−0.117***	
	(0.014)	(0.022)	(0.016)	(0.022)	
Lag Total Amt. Sent			−0.060***	−0.029	
			(0.019)	(0.022)	
Lag Total Amt. Ret.			−0.093***	0.203***	
			(0.025)	(0.024)	
Period Number			0.093*	0.111	−0.022
			(0.054)	(0.074)	(0.061)
Period Number ^{2}			−0.002	−0.005***	0.001
			(0.001)	(0.002)	(0.001)
Diff. Sent					0.369***
					(0.017)
Info					−0.053
					(0.332)
Info × Diff. Sent					0.136***
					(0.024)
Lag Diff. Sent					−0.036*
					(0.020)
Lag Diff. Ret.					−0.046
					(0.037)
n obs.	793	854	632	683	936
n groups	12	12	12	12	12
Wald χ^2	1014.38	198.94	884.97	348.20	1393.35
Prob. > χ^2	0.00	0.00	0.00	0.00	0.00

† Censored lower limit = 0; upper limit = Amt. Sent by S.
‡ Lower limit = 0 – Amt. Sent to R_B; upper limit = Amt. Sent to R_A.
* 90% significance; ** 95% significance; *** 99% significance.

The results show that these additional regressors are all highly significant. Receivers re-adjust what is considered a generous offer depending on the offer previously sent by a different Sender: if the previous offer was — *ceteris paribus* — higher, the Receiver sends less to the current Sender. Such behavior indicates that in the repeated game Receivers in dyadic relationships use a comparative model of trust in that they base return decisions this period in part on what was sent the previous period. We find evidence that some Receivers are consistently more trustworthy than others; and that trustworthiness first increases with time and declines only slightly toward the end of the game. Table 1 also reports the results from a Random-effects regression, where the dependent variable is the amount sent by the Sender (*Amt. Sent*). The independent variables that are positive and significant are the amount sent by the Sender in the previous period (*Lag Amt. Sent*) and what was returned to the Sender by another Receiver in the previous period (*Lag Amt. Ret.*). The first result indicates a significant amount of homegrown trusting preferences, and the second results indicates that Senders who get burned trust less in the following period while Senders that were rewarded increase their trust in the following period.

5.2. Results with two receivers

First, we test whether Receiver i's choice behavior depends in part on what the Sender invested in the other Receiver. In particular, we examine the extent to which Receivers' return behavior depends on trust$_A$ and trust$_B$. Such comparative trust should be visible in FULL INFO when the Receivers possess the information necessary to make a comparison in the amounts sent before deciding on a return. If, on the other hand, Receivers utilize an absolute measure of trust, then we would expect that in both information treatments the only variable mattering to a Receiver i's return is the amount sent to i.

Table 4
[2S-1R] — Random-effects regressions for trust.

	Amt. Sent by S_i, S_j	
Intercept	3.073***	3.440***
	(0.376)	(0.426)
Lag Amt. Sent	0.506***	0.495***
	(0.045)	(0.045)
Lag Amt. Sent by S_j	−0.013	−0.075
	(0.039)	(0.052)
Lag Amt. Ret. to S_i	0.039**	0.041**
	(0.019)	(0.019)
Lag Amt. Ret. to S_j	0.017	0.031
	(0.019)	(0.024)
Info	0.453*	−0.198
	(0.242)	(0.488)
Info × Lag Amt. Sent by S_j		0.120*
		(0.064)
Info × Lag Amt. Ret. to S_j		−0.026
		(0.024)
Period Number	−0.002	0.000
	(0.023)	(0.27)
Period Number^2	0.000	0.000
	(0.000)	(0.000)
n obs.	715	715
n groups	24	24
Wald χ^2	310.44	303.06
Prob. > χ^2	0.00	0.00
R-squared	0.4920	0.4953

* 90% significance; ** 95% significance; *** 99% significance.

Table 5
Dyad — Descriptive statistics.

	Sent (X)	Return (Y)	Share ($\frac{Y}{3X}$)	Return ratio ($\frac{Y}{X}$)
When $X \geqslant 0$	6.45	8.06	–	–
	(3.44)	(7.61)		
When $X > 0$	7.19	8.98	39.43	1.18
	(2.81)	(7.50)	(27.35)	(0.82)
N	720	646	646	646

Note: Std. dev. in parentheses.

In Table 2, we report the results from several Random-effects Tobit regressions on the amount returned.[21] The first two regressions estimate the effects separately by information condition, where the dependent variable is the amount returned by Receiver$_i$ to the Sender.[22] The two independent variables are amount sent to Receiver$_i$ and amount sent to the other Receiver. Under PARTIAL INFO, as predicted, the amount returned depends only on the amount sent to Receiver$_i$ and not on the amount sent to Receiver$_{-i}$ ($p = 0.000$ and 0.599, respectively). Approximately 47% of each unit received is returned to the Sender. Under FULL INFO, 44% of each unit received is returned to Sender ($p = 0.000$). The important thing to notice is that under FULL INFO the coefficient on the amount sent to Receiver$_{-i}$ is also significant and negative ($p = 0.067$). This indicates that Receiver$_i$ discounts the level of generosity of the Sender if she observes increasing generosity toward Receiver$_{-i}$. The result confirms the prediction that Receivers use a comparative version of trust to determine the level of trustworthiness when the information is available to do so.

The evidence of comparative trust is robust. The third and fourth model specifications add a series of independent variables to test for a dependency of the amount returned on the amount sent to the Receiver by another Sender in the previous period (*Lag Amt. Sent to* R_i), for a Receiver's homegrown altruism (*Lag Amt. Ret. by* R_i), and time trends. There is strong evidence that all three have significant effects in both information conditions: Receivers adjust to the amount previously sent

[21] Our primary focus in the [1S-2R] network is on trustworthiness — Hypothesis 2 states that comparative trust will be leveraged, generating an increase in trustworthiness. For consistency we have also provided Random-effects regressions on the amount sent.

[22] The censoring is between 0 and the amount X sent by the Sender.

Table 6
[1S-2R] — Descriptive statistics.

	Trust (X) — Panel & Mann–Whitney tests							
	Tot. from S^{a}	Tot. from S^{b}	Tot. from S^{c}	Tot. from S^{d}	To high R_i	To low R_{-i}	To Eq. R^{b}	To Eq. R^{e}
Full	${}^{***}_{**}8.43$ (2.96)	${}^{***}_{**}8.88$ (2.30)	${}^{***}_{***}9.16$ (2.04)	${}^{***}_{*}8.23$ (2.71)	7.54 (2.27)	${}^{***}_{***}2.66$ (1.02)	${}^{***}_{***}4.43^{**}$ (1.20)	${}^{***}_{***}3.90$ (1.83)
Partial	${}^{***}_{***}8.72$ (2.46)	${}^{***}_{***}8.96$ (2.01)	${}^{***}_{***}9.10$ (1.84)	${}^{***}8.46$ (2.44)	7.54 (2.00)	${}^{***}_{***}2.69$ (0.98)	${}^{***}_{***}4.34^{**}$ (1.08)	${}^{***}_{***}4.08$ (1.47)
Overall	${}^{***}_{***}8.58$ (2.72)	${}^{***}_{***}8.92$ (2.16)	${}^{***}_{***}9.13$ (1.94)	${}^{***}_{**}8.33$ (2.59)	7.54 (2.14)	${}^{***}_{***}2.68$ (1.00)	${}^{***}_{***}4.38$ (1.14)	${}^{***}_{***}3.99$ (1.66)
	Trustworthiness (Y) — Mann–Whitney tests							
	Tot. to S^{a}	Tot. to S^{b}	Tot. to S^{c}	Tot. to S^{d}	From high R_i	From low R_{-i}	From Eq. R^{b}	From Eq. R^{e}
Full	${}^{***}10.38$ (5.80)	${}^{***}10.92^{**}$ (5.42)	${}^{***}11.19^{***}$ (5.24)	${}^{***}10.30$ (5.78)	${}^{***}9.49$ (5.22)	${}^{***}2.58$ (2.29)	${}^{***}5.56^{**}$ (2.72)	${}^{***}4.89$ (3.13)
Partial	${}^{***}9.76$ (5.43)	${}^{***}10.03^{**}$ (5.25)	${}^{***}9.82^{***}$ (4.87)	${}^{***}10.77$ (6.33)	8.90 (5.72)	${}^{***}2.31$ (2.02)	${}^{***}4.84^{***}$ (2.36)	${}^{***}4.55$ (2.56)
Overall	${}^{***}10.07$ (5.62)	${}^{***}10.47$ (5.35)	${}^{***}10.46$ (5.09)	${}^{***}10.51$ (6.02)	${}^{**}9.20$ (5.47)	${}^{***}2.44$ (2.15)	${}^{***}5.18$ (2.56)	${}^{***}4.71$ (2.85)
		Trustworthiness (% Returned) — Mann–Whitney tests						
		% Tot. to S^{b}	% Tot. to S^{c}	% Tot. to S^{d}	% High R_i	% Low R_{-i}	% Eq. R^{b}	
Full		40.51^{**} (17.45)	40.46^{***} (17.08)	40.64 (18.34)	41.30 (19.15)	${}^{***}32.00$ (26.69)	41.20^{***} (16.81)	
Partial		36.86^{**} (17.48)	${}^{**}35.47^{***}$ (15.65)	41.66 (22.14)	38.56 (21.77)	${}^{***}28.14$ (22.52)	36.17^{***} (14.66)	
Overall		38.67 (17.56)	37.81 (16.51)	41.08 (20.03)	39.97 (20.49)	${}^{***}29.95$ (24.60)	38.52 (15.88)	
		Return ratio ($\frac{Y}{X}$) — Panel & Mann–Whitney tests						
		Total[b]	Total[c]	Total[d]	From high R_i	From low R_{-i}	From Eq. R^{b}	
Full		1.22^{**}_{*} (0.52)	1.21^{***}_{**} (0.51)	1.21 (0.55)	1.24 (0.57)	${}^{***}0.96$ (0.80)	1.24^{***}_{**} (0.50)	
Partial		1.11^{**}_{*} (0.52)	${}^{**}1.06^{***}_{**}$ (0.47)	1.25 (0.66)	1.16 (0.65)	${}^{***}_{***}0.84$ (0.68)	1.08^{***}_{**} (0.44)	
Overall		1.16 (0.53)	1.13 (0.50)	1.23 (0.60)	1.20 (0.61)	${}^{***}_{***}0.90$ (0.74)	1.16 (0.48)	
N_{full}	480	456	318	138	280	142	176	200
$N_{partial}$	480	467	362	105	266	161	201	214
$N_{overall}$	960	923	680	243	546	303	377	414

Notes: Superscripts report Mann–Whitney results; subscripts report panel results; to the right of the mean indicates significant differences within network across information treatment; to the left indicates significant differences across network treatment with respect to the dyad; std. dev. in parentheses.

[a] Incl. $X_A \geqslant 0$, $X_B \geqslant 0$.
[b] Excl. $X_A = X_B = 0$.
[c] Incl. $X_A > 0$, $X_B > 0$.
[d] Incl. $X_i > 0$, $X_j > 0$.
[e] Incl. $X_A = X_B = 0$.
[*] 90% significance; [**] 95% significance; [***] 99% significance.

by returning more this period if they received a smaller amount the previous period (showing that also in the [1S-2R] case the comparative model of trust has a dynamic component), the Receivers exhibit homegrown trustworthiness by returning more this period if they had returned more the previous period, and the time trend shows a non-linear effect. After controlling for these variables, under FULL INFO, the negative reaction to the amount sent by Sender to Receiver$_{-i}$ is still negative and weakly significant ($p = 0.10$).

The final regression on trustworthiness has as the dependent variable the difference in amounts returned between Receivers A and B to the same Sender (*Diff. Ret.* $= Y_A - Y_B$). The independent variables are the difference in the amounts sent to R_A and R_B (*Diff. Sent*), a dummy for the information treatment which equals 1 for FULL INFO (*Info*), an interaction term between information and the difference in the amounts sent (*Info* $\times$ *Diff. Sent*), lags on the differences (*Lag Diff. Ret.* and *Lag Diff. Sent*), and time trends. The results show that the difference between the amounts sent is a highly significant factor: 42% more is returned to the Sender for each unit sent to Receiver$_i$ in excess of what was sent to Receiver$_{-i}$ ($p = 0.000$).

Table 7
[2S-1R] — Descriptive statistics.

	Trust (X) — Mann–Whitney tests							
	Avg. from Ss^a	Avg. from Ss^b	Avg. from Ss^c	Avg. from Ss^d	From high S_i	From low S_{-i}	From Eq. R^b	From Eq. R^e
Full	***7.28*** (2.54)	7.35*** (2.44)	***8.18*** (1.92)	***8.16*** (2.46)	***8.73** (1.99)	***5.61 (2.27)	***9.54 (1.33)	***9.23*** (2.14)
Partial	***6.23*** (3.10)	***6.74*** (2.64)	7.64*** (2.08)	6.86*** (3.34)	***8.29** (2.46)	***5.63 (2.52)	***9.23 (1.08)	6.21*** (4.61)
Overall	6.75 (2.88)	**7.05 (2.56)	**7.92 (2.01)	*7.51 (2.99)	***8.5 (2.26)	***5.62 (2.41)	***9.44 (1.53)	***7.98 (3.70)

	Trustworthiness (Y) — Panel & Mann–Whitney tests							
	Avg. to each S^a	Avg. to each S^b	Avg. to each S^c	Avg. to each S^d	To high S	To low S	To Eq. Ss^b	To Eq. Ss^e
Full	***9.84*** (6.34)	***9.94*** (6.29)	***10.93 (6.36)	${}^{***}12.09^{***}_{**}$ (5.78)	${}^{***}_{**}12.23^{***}$ (7.26)	**7.32 (5.32)	***12.65 (7.28)	***12.24*** (3.13)
Partial	8.05*** (6.91)	8.70*** (6.29)	***10.23 (6.68)	${}^{***}6.17^{***}_{**}$ (6.58)	***10.22*** (7.38)	***6.77 (5.48)	***14.05 (7.88)	${}_{*}9.45^{***}$ (9.24)
Overall	***8.94 (6.69)	**9.34 (6.56)	***10.59 (6.52)	9.15 (8.08)	***11.16 (7.39)	***7.02 (5.41)	***13.11 (7.50)	***11.08 (8.37)

	Trustworthiness (% Returned) — Panel & Mann–Whitney tests					
	% Tot. to Ss^b	% Tot. to Ss^c	% Tot. to Ss^d	% to high S	% to low S	% to Eq. Ss^b
Full	***45.52** (24.72)	***44.69 (17.08)	${}^{***}48.83^{***}_{**}$ (29.38)	***46.54** (25.80)	42.28 (24.76)	**44.68 (25.38)
Partial	***39.40** (23.67)	***42.68 (22.87)	27.32^{***}_{**} (22.71)	38.99** (24.33)	37.29 (21.88)	***49.09 (24.98)
Overall	***42.56 (24.40)	***43.73 (23.13)	38.13 (28.33)	***42.52 (25.29)	39.56 (23.34)	***46.14 (25.27)

	Return ratio ($\frac{Y}{X}$) — Panel & Mann–Whitney tests					
	Total[b]	Total[c]	Total[d]	High S	Low S	Eq. Ss^b
Full	***1.37** (0.74)	***1.34 (0.70)	***1.46*** (0.88)	***1.40** (0.77)	1.27 (0.74)	**1.34 (0.76)
Partial	1.18** (0.71)	***1.28 (0.69)	***0.82*** (0.68)	1.17** (0.73)	1.12 (0.66)	***1.47 (0.75)
Overall	***1.28 (0.73)	***1.31 (0.69)	1.14 (0.85)	***1.28 (0.76)	1.19 (0.70)	***1.38 (0.76)

N_{full}	480	475	379	96	325	229	150	155
$N_{partial}$	480	444	349	95	370	275	74	110
$N_{overall}$	960	919	728	191	695	504	224	265

Notes: Superscripts report Mann–Whitney results; subscripts report panel results; to the right of the mean indicates significant differences within network across information treatment; to the left indicates significant differences across network treatment with respect to the dyad; std. dev. in parentheses.
[a] Incl. $X_\alpha \geqslant 0,\ X_\beta \geqslant 0$.
[b] Excl. $X_\alpha = X_\beta = 0$.
[c] Incl. $X_\alpha > 0,\ X_\beta > 0$.
[d] Incl. $X_i > 0,\ X_j = 0$.
[e] Incl. $X_\alpha = X_\beta = 0$.
[*] 90% significance; [**] 95% significance; [***] 99% significance.

Moreover, the interaction term of information treatment with the difference in amounts sent is highly significant, indicating that — when Receivers have information about what was sent to the other at the time they make their return decision — they strictly compare to determine how much to return ($p = 0.027$). These regression results provide clear evidence that Receivers utilize a notion of comparative trust in [1S-2R], providing confirmation of Hypothesis 1.

Result 1 *(Comparative Trust in* [1S-2R]*).* Receiver i directly compares the amount sent to Receiver $-i$, discounting the level of generosity of the Sender if i observes increasing generosity toward Receiver $-i$.

Given that Receiver behavior depends on a comparative measure of trust, we can test whether this can be leveraged to increase returns under FULL INFO over the returns under PARTIAL INFO. Table 6 reports descriptive statistics for [1S-2R].

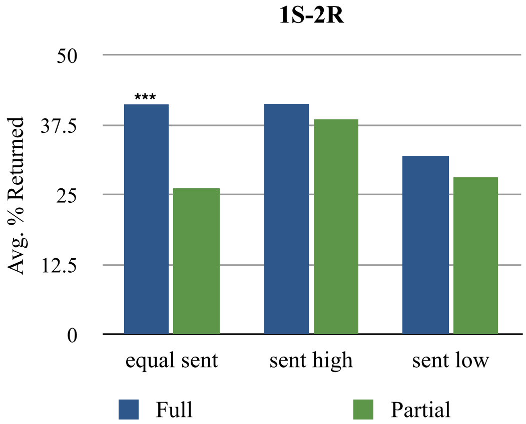


Fig. 2. Average percent returned conditional on amounts sent.

Both trustworthiness (measured by the percent of the gains from exchange the Receiver returned) and the return ratio (measured as a ratio between the amount returned and the amount sent) are higher. There is virtually no difference in the total amount sent by Senders across information treatments (see first panel); yet the total amount returned is almost always higher (second panel) under FULL INFO. This is even more pronounced if we look at the cases where the Sender sent a positive amount to both Receivers (third column); a significant difference of about a dollar in return yields a 5% higher percentage return to the Sender in FULL INFO. Return ratios (fourth panel) confirm this result with significantly higher ratio of 1.21 under FULL INFO versus 1.06 under PARTIAL INFO.

Using the [1S-2R] framework, we would expect that the strongest signal of trust — which should then induce the highest trustworthiness — is when the Sender sends significantly more to one Receiver than to the other, and this information is common knowledge between the two Receivers. Table 6 shows that under FULL INFO the Sender sends a positive amount to one Receiver and zero to the other in 29% of the cases, sending on average about $8.23 (which is even greater than the amount sent in the dyad); under PARTIAL INFO the percentage of cases is significantly lower at 22%. Quite interestingly, contrary to what we expected, under FULL INFO the return ratio is the same regardless of whether or not the Sender treated the Receivers equally or unequally (1.24). Yet, the difference in return behavior shows up across information conditions in cases where Receivers are treated equally by the Sender with Receivers on average returning significantly more under FULL INFO than PARTIAL INFO ($5.56 versus $4.84; p-value < 0.001). This also shows up in a higher return ratio under FULL INFO: 1.24 versus 1.08 (p-value < 0.001). These results suggest that an investment strategy by the Sender of spreading risk across the two Receivers works to his advantage under particular information conditions; namely, only when Receivers can directly observe this strategy via full information flow. See Fig. 2 for a graphical representation of this result. Taken together, these results confirm the CCH, giving us our second main result:

Result 2 *(CCH in* [1S-2R]*).* Full information increases trustworthiness by Receivers; this is amplified in cases where the Sender invests positive amounts in both Receivers with the highest return ratio occurring when the Sender invests exactly equal amounts.

To test Hypothesis 3 — that the [1S-2R] network generates higher efficiency over the dyad because a Sender can spread his investment risk over the two Receivers — see Table 8.[23] In the dyad, overall efficiency is only 82.2%.[24] The [1S-2R] network is the *most efficient* with a rate of 94%, independent of flow of information as trust rates are high in both.[25] The efficiency gains are directly due to the fact that trust is much higher in [1S-2R] regardless of information condition with $2 more sent compared to that sent in the dyad. This is evidence in support of Hypothesis 3:

Result 3 *(Efficiency in* [1S-2R]*).* Efficiency is significantly higher in [1S-2R] than in the dyad, with the highest efficiency rates of any of the networks.

[23] Efficiency is calculated for each dyad or triad as the ratio of the sum of profits of all the parties at the end of each interaction to the maximum potential surplus available — which is always at its maximum when Sender(s) sends the entire endowment — plus the endowment of the Receiver(s).

[24] The maximum surplus would occur if Sender sent the entire endowment to the Receiver, which would be tripled, yielding 30; additionally, the Receiver begins with an endowment of 10. For the dyad, efficiency $= \frac{x+y}{40} \times 100$, where $x =$ Sender's profit, and $y =$ Receiver's profit.

[25] The maximum surplus would occur if Sender sent the entire endowment to the Receivers, which would be tripled, yielding 30; additionally, each of the Receivers begins with an endowment of 10. For the [1S-2R], efficiency$= \frac{x+y_A+y_B}{50} \times 100$, where $x =$ Sender's profit, $y_A =$ Receiver A's profit, and $y_B =$ Receiver B's profit.

Table 8
Efficiency (%) — Realized percentage of theoretical maximum gains.

	Dyad	[1S-2R]	[2S-1R]
Full	82.24	***93.73	84.43***
	(17.22)	(11.85)	(14.52)
Partial	–	***94.87	***78.47***
		(9.83)	(17.71)
Overall	82.24	***94.3	*81.45
	(17.22)	(10.90)	(16.45)
N	720	960	960

Notes: Superscripts report Mann–Whitney results; subscripts report panel results; to the right of the mean indicates significant differences within network across information treatment; to the left indicates significant differences across network treatment with respect to the dyad; std. dev. in parentheses.

* 90% significance; ** 95% significance; *** 99% significance.

In conclusion, in [1S-2R] we find evidence for: a comparative model of trust when Receivers can directly make these comparisons prior to making return decisions; trustworthiness is higher under full information flow and most amplified when the Sender chooses to invest positive amounts in both with the highest return ratio occurring when the Sender invests exactly equal amounts; and the highest overall efficiency due to higher rates of trust.

5.3. Results with two senders

First, we test whether the Receiver's return behavior to Sender i depends in part on what was sent by Sender$_{-i}$. That is, we test whether Y_α (Y_β) depends on both X_α and X_β instead of just X_α (X_β). We find evidence for this hypothesis under FULL INFO, but not under PARTIAL INFO. This is particularly interesting given that the information the Receiver has is the same from her point view in both treatments, except that under FULL INFO she knows the Senders learn through full disclosure what each Sender sent and how she responded to each investment decision.

In Table 3, we report the results from several Random-effects Tobit regressions. The first two regressions estimate the effects separately by information condition, where the dependent variable is the amount returned by the Receiver to Sender$_i$, and the two independent variables are amount sent by Sender$_i$ and the amount sent by Sender$_{-i}$.[26] Our results show that in both information conditions, as the amount sent by Sender$_i$ increases, the amount returned to Sender$_i$ by the Receiver increases: for one additional dollar received by the Receiver, she returns \$0.52 in PARTIAL INFO and returns \$0.41 in FULL INFO to the relevant Sender (note that the means are different under the two information treatments, see Table 7). This is consistent with the body of evidence from investment game experiments.

The more important result is that, under FULL INFO, the Receiver's return behavior depends on comparing investment levels across the two Senders. A Receiver sends \$0.10 less to Sender$_i$ for one additional dollar sent by Sender$_{-i}$, suggesting the Receiver is punishing Sender$_i$ for being stingier than the other Sender. Another way to look at the result is that a Receiver sends \$0.10 more to Sender$_i$ for one dollar less sent by Sender$_{-i}$, suggesting the Receiver is rewarding Sender$_i$ for his relative generosity. We will see below that the data indicate evidence of intention to reward, but only under FULL INFO, when the Senders learn through full disclosure of the differential treatment. This is not the case under PARTIAL INFO; rather Receivers reward Sender$_i$ slightly more — about \$0.03 — the more she gets from the other Sender ($p = 0.014$). This suggests that when Senders have no information about what is occurring on the other side of the exchange, the Receiver, who could still punish a stingier Sender or reward the Sender who is relatively more generous as she has the relevant information to make the comparison in both cases, the Receiver does not do so. Instead, she tries to induce more cooperation by marginally increasing the reward to Sender$_i$ the more Sender$_{-i}$ sends.

The third and fourth model specifications in Table 3 add a series of independent variables. The first controls for the effects of total amount sent to the Receiver in the previous period to test for dynamics in the comparative model of trust (*Lag Tot. Amt. Sent*). The second controls for the Receiver's homegrown trustworthiness (*Lag Tot. Amt. Ret.*). The last two control for time trends. Under PARTIAL INFO, Receivers return about 55% of the gains from exchange; under FULL INFO they return a smaller percentage, about 40%. Importantly, after controlling for these variables, under FULL INFO, the reaction to the amount sent by the other Sender is still highly significant with the Receiver rewarding (penalizing) Sender$_i$ by returning almost \$0.12 more (less) for each fewer (additional) dollars sent by Sender$_{-i}$. Under PARTIAL INFO, however, the coefficient for the amount sent by the other Sender is not significantly different from zero, indicating no intention by the Receiver to reward or punish. Again, we find evidence for a dynamic interpretation of trust, shown by the negative coefficients for the lag of the total amount sent (significant only under PARTIAL INFO). Under FULL INFO, the positive and significant coefficient found for the lag of the total amount returned confirms homegrown preferences toward trustworthiness; this is not robust though, as under partial information it is significantly negative.

[26] The censoring is between 0 and the amount X sent by Sender$_i$.

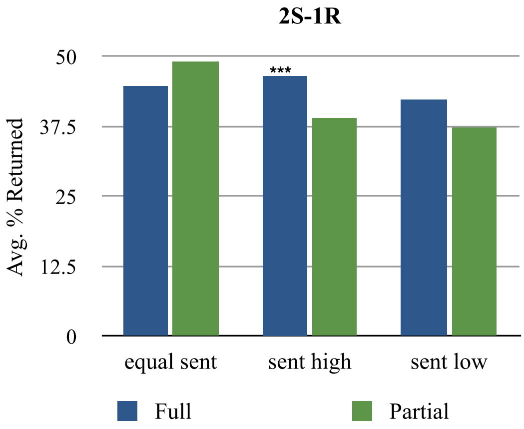


Fig. 3. Average percent returned conditional on amounts sent.

The final regression we report on trustworthiness has as the dependent variable the difference in amounts returned by the Receiver to Sender α and Sender β (*Diff. Returned* $= Y_\alpha - Y_\beta$). The difference between the amounts sent by the two Senders has a significant effect of $0.37 extra returned to Sender$_\alpha$ for every one dollar difference in the amounts sent. Most notably, the interaction effect of the information condition with the difference in the amount sent is highly significant ($p = 0.000$), indicating that Receivers use this ex-post information, signaling to Senders their intention to reward (punish) more generous (stingier) Sender. These regression results provide evidence that Receivers utilize a notion of comparative trust in [2S-1R], providing confirmation of Hypothesis 4.

Result 4 *(Comparative Trust in* [2S-1R]*).* The Receiver directly compares the amounts sent by both Senders, and under FULL INFO, bases return decisions on this difference.

So does the Receiver reward generosity for generosity sake or does she reward generosity to show the less trusting Sender that he could have earned more were he to trust more? Does the Receiver punish the least generous Sender for punishment sake or to send a message to the other that the stingier has been punished? Let's start with rewarding behavior. See Table 7. The number of cases in which one Sender sends nothing and the other Sender sends a strictly positive amount is remarkably similar under both information conditions, but the resulting behavior by the Receiver is very different (see fourth column). The average amount returned to each Sender is almost twice as much under FULL INFO ($12.09 or 48.83%) than under PARTIAL INFO ($6.17 or 27.32%). One complication is that under FULL INFO the Sender sending the positive amount sends more on average than under PARTIAL INFO ($8.16 versus $6.86); however, that the return is 20% higher under FULL INFO provides evidence that the Receiver rewards the high Sender who sent a positive amount to signal to the other Sender what he could have received had he been more trusting, not to reward generosity per se. After all, if it were the latter, the Receiver would have also done so under PARTIAL INFO! Similarly, under FULL INFO, if we consider the 67% of cases for which one Sender sends an amount strictly greater than the other Sender, 47% of the gains from exchange are returned to the high Sender whereas only 39% of the gains are returned under PARTIAL INFO (see fifth column). Fig. 3 displays a graphical representation of this information. So again punishment does not seem to play a large role.

Given that Receiver behavior depends on a comparative measure of trust and Receivers, under FULL INFO, reward the most trusting Sender by returning a larger share of the gains to this Sender than the other, we can test whether such behavior increases trust under FULL INFO relative to under PARTIAL INFO. Table 4 reports the results from Random-effects regressions on the amount sent. In the first specification, notice that the independent variable *Info* is positive and significant, indicating that the amount sent critically depends on the treatment. In the second specification, the interaction term *Info* $\times$ *Lag Amt. Sent by* S_j is positive and significant, indicating that under FULL INFO the amount sent by Sender i in the current period is significantly influenced by the amount sent by the other Sender in the previous period. So a Sender's trusting behavior is directly impacted by other Sender's trusting behavior. And on average, these rates are higher under FULL INFO than under PARTIAL INFO (all four averages in Table 7). Additional evidence that differential treatment by the Receiver under FULL INFO increases trust can be seen by comparing the rates at which Senders coordinate on the exact same amount sent with $X_\alpha = X_\beta$ and the average amount sent in these cases. Even though trust decisions are being made simultaneously by the Senders, they end up coordinating at a much higher rate under FULL INFO: 65% of the triads compared to only 45% of the triads under PARTIAL INFO. The average amount sent in these cases is $9.13 — nearly the entire endowment — under FULL INFO, whereas under PARTIAL INFO the average amount sent in these cases is significantly lower at $6.21.

Result 5 *(CCH in* [2S-1R]*).* Full information increases trust in [2S-1R], and also increases trustworthiness, especially in cases where one Sender sends a higher amount than the other Sender.

Table 9
Profit.

	Dyad			[1S-2R]		[2S-1R]		
	S	*R*	*R* net	*S*	Avg. *R*	Avg. *S*	*R*	*R* net by *S*
Full	11.61 (6.06)	21.29 (8.09)	11.29 (8.09)	$^{***}11.94^{**}$ (4.41)	$^{***}_{***}17.46^{***}$ (6.00)	$^{***}12.56^{*}$ (6.13)	$^{***}_{***}33.98^{***}$ (14.16)	$^{*}11.99^{***}$ (8.29)
Partial	–	–	–	11.05^{**} (4.59)	$^{***}_{***}18.19^{***}$ (5.77)	$^{**}11.81^{*}$ (5.51)	$^{***}_{***}31.30^{***}$ (12.79)	$^{*}10.65^{***}$ (7.89)
Overall	11.61 (6.06)	21.29 (8.09)	11.29 (8.09)	$^{*}11.49$ (4.52)	$^{***}_{***}17.83$ (5.90)	$^{***}12.19$ (5.84)	$^{***}_{***}32.64^{***}$ (13.55)	11.32 (8.12)
N	720	720	720	960	1920	1920	960	1920

Notes: Superscripts report Mann–Whitney results; subscripts report panel results; to the right of the mean indicates significant differences within network across information treatment; to the left indicates significant differences across network treatment with respect to the dyad; std. dev. in parentheses.

* 90% significance; ** 95% significance; *** 99% significance.

With respect to the dyad, adding one additional Sender does not make much difference under PARTIAL INFO: the average amount of trust is the same ($6.45 in the dyad and $6.23 in [2S-1R]), the average rate of trustworthiness is the same ($8.98 or 39.43% in the dyad and $8.70 or 39.4% in [2S-1R]), and the return ratios are identical at 1.18. However, under FULL INFO, in [2S-1R], the rate of trust increases ($7.28), trustworthiness is significantly higher ($9.94 or 45.52%) with a higher return ratio of 1.37. This is suggestive that comparative trust is leveraged and improves overall cooperation rates under FULL INFO.

Overall, then, the results in [2S-1R] confirm both of our general hypotheses. We find that Receivers are more trustworthy to the more generous Sender (preferring to reward rather than to punish), but only if the two Senders will have a complete picture of both transactions at the end of each period. Such trustworthiness under FULL INFO can explain why the average amount sent is higher in the full information condition; namely, there is an arms-race among Senders to attempt to coordinate on the amount sent. Interestingly, this arms-race among Senders is to their advantage: under FULL INFO, they receive the highest returns among all three networks (see fourth panel of Table 9).

The [2S-1R] network does not generate efficiency gains over the baseline with an overall efficiency of approximately 82%; however, FULL INFO is significantly more efficient than PARTIAL INFO due to higher rates of trust.[27] In terms of profits, the Senders and the Receiver fare better on average than under the dyadic network.

Overall, our findings in the networked investment games are significantly different from those obtained with proposer or responder competition in the ultimatum game. Roth et al. (1991) find that proposer competition — nine proposers and one responder — drives ultimatum offers to the subgame-perfect equilibrium outcome, with the responder reaping the entire endowment, within five or six periods in each of the four countries studied. Fischbacher et al. (2009) report results from an experiment varying the degree of competition among proposers and also study the effects of responder competition. Under proposer competition, their findings are similar to Roth et al. (1991); under responder competition behavior also converges to the subgame-perfect equilibrium, with the single proposer reaping the entire endowment. Competition in the ultimatum game causes people to behave more selfishly. Our results, on the other hand, suggest that when gains from exchange are possible (i.e., $r > 1$), Receivers in [1S-2R] and Senders in [2S-1R] — those on the long-side of the exchange — behave more cooperatively. This is a very different outcome.

6. Conclusions

We utilize 3-node networked versions of the investment game to explore the nature of trust in these exchange environments and analyze the network effects on crucial variables, trust and reciprocity. Once we consider networked exchange, we have to consider whether standard behavioral measures of trust in these environments are adequate. In [1S-2R], does Receiver$_i$ view the level of the Sender's trust as the amount sent to i or does Receiver$_i$ compare the amount sent to the other Receiver to determine the degree of the Sender's trust? Similarly, in [2S-1R], does the Receiver view Sender$_i$'s level of trust as the amount sent by i or does the Receiver compare the amount sent by the other Sender to make the determination? By developing a simple comparative model, we generated our two primary hypotheses: (1) in the networked games, comparative trust would be operative, and (2) this type of trust could be leveraged to increase cooperation by those players on the long-side of the exchange. Our findings are supportive of both of our main hypotheses. First, we find evidence that in both of the 3-node networked exchange environments, Receivers utilize a comparative rather than an absolute measure of trust. Second, we find that when information flows fully, cooperation is enhanced. In the [1S-2R] network, this manifests itself in increasing returns; in the [2S-1R] network, Receivers reward the more generous Sender, triggering an arms race on investments by Senders, i.e. higher levels of trust by those on the long-side of the exchange.

[27] The maximum surplus would occur if the two Senders sent their entire endowments to the Receiver, which would both be tripled, yielding 60; additionally, the Receiver begins with an endowment of 10. For the [2S-1R], efficiency $= \frac{x_\alpha + x_\beta + y}{70} \times 100$, where x_α = Sender α's profit, x_β = Sender β's profit, and y = Receiver's profit.

Appendix A. Proof for Observation 1 – [1S-2R] network

Proof. By definition, $G \trianglerighteq_A F$ only if:

Condition (b) $\pi^*(A|G) - \pi^*(A|F) \geqslant \pi^*(S|G) - \pi^*(S|F)$

The structure of the investment game gives us the following identities for R_A's payoffs (where r is the rate of growth):

$$\pi^*(A|G) = M + rX_A$$
$$\pi^*(A|F) = M + rX'_A \tag{1}$$

Similarly for Sender's payoffs:

$$\pi^*(S|G) = M - X_A - X_B + rX_A + rX_B$$
$$\pi^*(S|F) = M - X'_A - X'_B + rX'_A + rX'_B \tag{2}$$

So the requirement imposed by Condition (b) is that:

$$r\left(X_A - X'_A\right) \geqslant (r-1)\left(X_A - X'_A\right) + (r-1)\left(X_B - X'_B\right) \tag{3}$$

Which yields:

$$X_A - (r-1)X_B \geqslant X'_A - (r-1)X'_B \quad \square \tag{4}$$

Appendix B. Proof for Observation 2 – [2S-1R] network

Proof. Suppose Sender i is at least as generous in G as j is. Then $G_{\setminus i} \trianglerighteq G_{\setminus j}$. But this is so iff

(a) $\pi^*(R|G_{\setminus i}) \geqslant \pi^*(R|G_{\setminus j})$; and
(b) $\pi^*(R|G_{\setminus i}) - \pi^*(R|G_{\setminus j}) \geqslant \pi^*(j|G_{\setminus i}) - \pi^*(i|G_{\setminus j})$

But

$$\pi^*(R|G_{\setminus i}) = \pi^*(R|G_{\setminus j}) \tag{5}$$

so $G_{\setminus i} \trianglerighteq G_{\setminus j}$ iff (b) holds. That is, iff

$$0 \geqslant \pi^*(j|G_{\setminus i}) - \pi^*(i|G_{\setminus j}) \tag{6}$$

That is, iff $0 \geqslant 3X_j - 3X_i$ iff $X_i - X_j \geqslant 0$. $\square$

Appendix C. Instructions for [1S-2R] full info

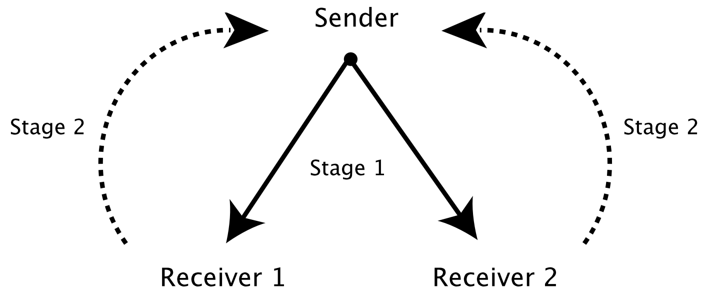
You have been asked to participate in an economics experiment. Now that the experiment has started, we ask that you do not talk during the experiment. Please raise your hand if you have a question.

You will be randomly selected to either be a SENDER or a RECEIVER. If you are a SENDER you will be paired with two RECEIVERS, RECEIVER 1 and RECEIVER 2. If you are a RECEIVER you will be paired with one SENDER. You will not be told who these people are either during or after the experiment.

A round consists of two stages. At the beginning of the round, the SENDER begins with 10 points, and each RECEIVER begins with 10 points. In the first stage, the SENDER will have the opportunity to send any part of his/her 10 points (from 0, 1, …, 10) to RECEIVER 1 and RECEIVER 2. Each point sent will be tripled. Note: The total amount sent to RECEIVER 1 *and* RECEIVER 2 should be less than or equal to 10 points prior to being tripled, or less than or equal to 30 points after being tripled. Each RECEIVER will see the number of points the SENDER sent to him/her as well as to the other RECEIVER.

In the second stage, both RECEIVER 1 and RECEIVER 2 have a decision to make: how many of the tripled points to send back to the SENDER and how many to keep. Once both of the RECEIVERS decide, the SENDER and the other RECEIVER will learn of the decisions.

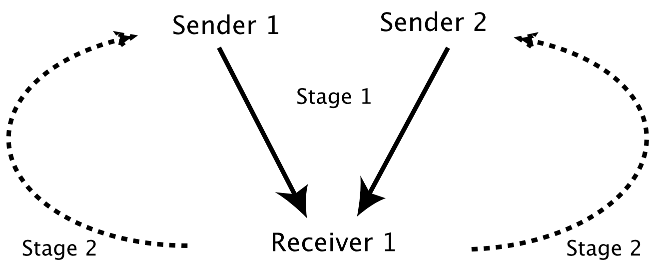
See a diagram representing the two stages:



You will participate in a total of 40 rounds. You will keep your same role throughout the experiment.
You will be randomly re-matched with counterparts at the beginning of each round.
Your earnings are the total number of points accumulated up to the final round; points will be converted to U.S. dollars at the rate of 2.5 cents for 1 point.
Since your decisions are private, we ask that you do not tell anyone your decision either during, or after, the experiment.
Are there any questions before we begin?
Note: Please pay attention to your computer screen. Following the completion of each round, on the results page, there will be a “Finished" button. Be sure to click the button once you have viewed the results. The next round will not begin until *everyone* has clicked.

Appendix D. Instructions for [1S-2R] partial info

You have been asked to participate in an economics experiment. Now that the experiment has started, we ask that you do not talk during the experiment. Please raise your hand if you have a question.
You will be randomly selected to either be a SENDER or a RECEIVER. If you are a SENDER you will be paired with two RECEIVERS, RECEIVER 1 and RECEIVER 2. If you are a RECEIVER you will be paired with one SENDER. You will not be told who these people are either during or after the experiment.
A round consists of two stages. At the beginning of the round, the SENDER begins with 10 points, and each RECEIVER begins with 10 points. In the first stage, the SENDER will have the opportunity to send any part of his/her 10 points (from 0, 1, ..., 10) to RECEIVER 1 and RECEIVER 2. Each point sent will be tripled. Note: The total amount sent to RECEIVER 1 *and* RECEIVER 2 should be less than or equal to 10 points or less than or equal to 30 points after being tripled.
In the second stage, both RECEIVER 1 and RECEIVER 2 have a decision to make: how many of the tripled points to send back to the SENDER and how many to keep. Once both of the RECEIVERS decide, the SENDER will learn of the decisions.
See a diagram representing the two stages:



You will participate in a total of 40 rounds. You will keep your same role throughout the experiment.
You will be randomly re-matched with counterparts at the beginning of each round.
Your earnings are the total number of points accumulated up to the final round; points will be converted to U.S. dollars at the rate of 2.5 cents for 1 point.
Since your decisions are private, we ask that you do not tell anyone your decision either during, or after, the experiment.
Are there any questions before we begin?
Note: Please pay attention to your computer screen. Following the completion of each round, on the results page, there will be a “Finished" button. Be sure to click the button once you have viewed the results. The next round will not begin until *everyone* has clicked.

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