“Do you trust me or not?” - Trust games in agent societies

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Abstract. Multi-agent simulation provides a way to explore results from social studies and provide hints on how these results scale. One particular class of studies that is interesting to explore are economic-related studies. We developed a multi-agent system that simulates an investment game and incorporates the results from economic-related social studies into the design of the agents. We analyzed how several factors, such as trust and reputation influence the outcome of the agents in terms of distribution of wealth and total generated money.
Keywords: Agent Societies, Trust, Reputation, Autonomous Agents

1 Introduction

Several social studies have been performed to assess how people behave in group situations. These studies are hard to organize and often can only involve a small number of participants. One particular type of studies that is hard to orchestrate is related to economics (especially because of cost issues). Generally, in these studies, the participants are handed money upon which they have to make decisions that will, depending on several factors that are not controlled by the individual holding the money, affect the nature of their outcome as participants.

One particular area of interest in economics is how markets can be made efficient. The mechanisms that allow individuals and corporations to perform efficient transactions lie at the basis for that efficiency [9]. Low-cost transactions or transactions with no associated costs can be achieved in reputation-based markets, where reputation ensures trust from the individuals investing. Reputation itself becomes an asset that is in the interest of the holder to maintain [9]. Using multi-agent simulations with data provided by social studies it is possible to analyze the effects reputation and trust have on how the market evolves, and furthermore it allows us to provide hints on how the results from studies involving small numbers of participants scale when applied to large populations.

In order to explore these results from economics and also results from social studies that describe how people act in economic-related games, we developed a multi-agent system that simulates several interactions of the investment game [2]. The agents in the simulation were built using results from social studies [2] [12] [5] [9] concerning the dictator and investment game [2] [12], and taking into account economic-inspired definitions [9] of trust and reputation in their behavior.

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2 Related Work

Several work has been developed that explores the use of trust as a regulatory mechanism in multi-agent systems. In [8] a trust assessment process is described where an agent (*truster*) computes trust based on the quality of direct interactions with another agent (*trustee*) and by the information provided from a group of consulting agents (comprised of a selected group of trustworthy agents by the truster, and a group of advocating agents selected by the trustee). The temporal and frequency characteristics of the interactions are also taken into account, as discounting factors, when computing trust.

In [1] a belief revision process based on trust and reputation is explored and applied to agents' information sources (which can be sensory information or information provided by other agents) in non-deterministic settings.

In [13] a formal model of trust that focuses on a statistical measure of trust is described. Trust is defined over a probability distribution of the probability of positive outcomes together with an explicit measure of certainty. This particular work has the advantage of providing measures of trust that are independent of the agents' rationale and the particular object of trust.

Also, multi-agent system design based on information about human societies has been explored in several studies as a way to provide insight on several social phenomenons. It has been used as an alternative to more traditional approaches where mass amounts of social data are analyzed in order to find patterns which are then theorized in terms of underlying individual behaviors [3] [7].

Using this approach a multi-agent system was built to study social mobility [4]. The agents in the simulation were modeled using several attributes (Class, Education, Status, etc.) which influence their outcome in the simulations (directly and indirectly through interactions with other agents). The results provide insights on the population evolves in terms of its constituents and their particular characteristics (demographics, distribution of education, average education and class levels, etc).

In [6] Doran describes a simulation where possible benefits of collective misbelief are explored in an agent society. A multi-agent system is used to verify that there are situations where collective agent misbelief might be beneficial to the agent society as it is sometimes the case in human societies.

In [11] a multi-agent simulation was developed to provide insight as how people might fair in mixed human-agent societies. The multi-agent system runs a dictator game where human-like agents (based on a social study of how human act in a dictator game [12]) interact between themselves and a set of rational agents.

3 Trust Games

A game that is commonly used in experimental economics is the dictator game which is comprised of two players, the first (”the proposer") determines how much of an initial endowment to split between himself and the other player (the second player's role is entirely passive). The purpose of this game is to rebut the homo economicus model of individual behavior, where each individual is only concerned with his/her own economical well-being.

The trust game extends the dictator game in that the allocation provided by the first player is increased by some factor before given to the second player, who then has the choice of giving part of that factored allocation back or keeping it all as profit. This game's subgame perfect Nash equilibrium states that both players should give nothing, but several studies show that is rarely the case [2] [12]. The fact that people give something even when there is no guarantee of getting anything back indicates that trust must exist a priori to any transaction [2].

Following on that are theories that define reputation as how an individual/organization is expected to fulfill an implicit contract, and as an asset that is in the interest of its holder to maintain [9]. Using reputation as a way of facilitating transactions provides a way of performing exchanges of values that do not involve the costs of elaborating and enforcing contracts that describe how to deal with all the possible contingencies that can occur during the transaction, and thus making the market itself more efficient and free of transaction costs related to enforcing the agreed upon terms of how contingencies should be dealt with [9].

In [2] an experiment is devised to explore in a one time interaction the role of trust in a two-person (that never meet) exchange. This study not only shows that people have a natural tendency to trust, but also provides insight on how much they are willing to give. The game described in [2] is similar to the trust game, it is played only once between two players, where each is given an equal amount of money. The first player has the choice to give part of his/her amount to the second player. If he/she chooses to do this, that amount is multiplied by three, and the second player can then decide how much of that factored amount to keep to himself and how much to return to the first player.

In [12] a distinction is made on the population, people are classified a priori as Altruists or Egoists based on a "social value orientation" questionnaire [10]. Two studies were performed, where on the first a dictator game was played and as expected, altruists had a natural tendency to give more than egoists. A second study followed where indirect reciprocity was taken into account by having a third player reward the dictator of the first game based on his/her offering to the second player. In the second study, the amount given back by the altruists was essentially the same, but in contrast the egoists gave more.

3.1 Simulation

The simulation (Figure 1) runs a trust game that is repeated several times. In each iteration several steps take place. We have named the first step role-setting, in which half of the agents are given the role of investor, and the remaining half the role of idealists. An investor represents an agent who wants to invest some of its money in an idealist. An idealist is an agent that has an idea the can generate profit. For the sake of simplicity, all idealists make, as profit, the money invested on them multiplied by a factor of three.

After the role-setting step comes the coupling phase, where each investor is paired with an idealist. Following that, the transaction starts. Each player is handed an equal amount (c.f. trust game [2]), then the investment phase takes place where the investor decides how much of the handed money to invest in the idealist. The idealist then,

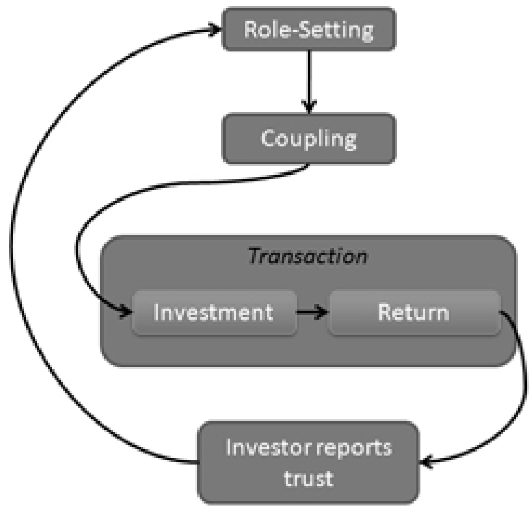

Figure 1. Simulation Cycle

in the return phase, decides how much of the generated money to return to the investor. Finally, the investor informs all agents in the simulation of how good of an investment the idealist was. And the cycle repeats.

Each agent's decisions are driven by one of two profiles, Egoist or Altruist, inspired by [12]. Although [12] describes a dictator game, where there is no return phase, we decided to look at the investment game as a two-time dictator game (where the return phase can be seen as another dictator game), we based our decision on the fact that there is some evidence that the return in an investment game is unrelated to the amount invested [2]. We are also aware that this is a weak assumption given that if past interaction history exists, the amount invested seems to influence the amount that is returned [2].

4 The Agents

The agent's role is to make decisions in each of the phases of the simulation cycle based on the role they are assigned at each iteration. The role each agent has is assigned randomly at the beginning of each cycle (the simulation ensures that half the agents are idealists and the other half investors).

As an investor, the first decision to be made is in whom to invest. The investor is aware of all the available idealists and can choose one based on previous interaction history and on the information made available by other agents.

As an idealist, if there are several interested investors, a choice is made on whom to accept investment from.

As there are always an even number of agents, the coupling phase is repeated for the uncoupled agents until all investors have an idealist to invest in.

Following the coupling phase, the investors must decide how much to invest in their idealist, the decision is made based on how much money they have available, and also from previous interaction history information provided by other investors regarding the idealist.

The idealist decides how much of the received money to return based on how much money was invested in him.

In the last step of the simulation the investor updates his trust regarding the idealists based on the payback received from its investment, and reports the updated trust to the other agents.

Each investor stores past information history regarding an idealist as a value that represents trust. As defined by [9], trust is maintained if the party that was trusted acts in a way that is expected by the trustee. In our case, we have defined trust as a positive integer that is computed by:

$$TransactionTrust = \min\left(\frac{Ar}{Ai} \times \frac{MaxTrust}{2}, MaxTrust\right) \quad (1)$$

Where Ai is the amount invested, Ar the amount returned and $MaxTrust$ the maximum trust value that an investor can assign to an idealist.

As it is defined, $\frac{MaxTrust}{2}$ represents the neutral value for trust (the investor neither wins nor loses any money). Values below that indicate negative and values over represent positive trust. Maximum trust is achieved when the amount returned is twice the amount invested, which represents the best possible outcome for both agents where they end up profiting the same amount (for example, if both are handed 10 at the beginning of the transaction, if the investor invests 5, the idealist gets 15 and returns 10, both end up with 15).

After each transaction the investor updates his trust over the idealist by averaging his previous trust with the trust computed from the current transaction:

$$Trust = \frac{Trust + TransactionTrust}{2} \quad (2)$$

4.1 Egoist

As an investor, an egoist agent will choose an idealist randomly. Conversely, as an idealist in the situation where several investors are competing for investment, the idealist chooses one investor randomly.

The egoist agents represent an agent type that has the tendency to keep most of the profit for itself. People classified as Egoists [12] have a tendency to give less in the dictator game and reciprocate less in the indirect reciprocity game (the indirect reciprocity game consists in having a third player observe the dictator behavior and then deciding how much to "reciprocate" to the dictator [12]).

In [12], the experiment where the dictator game is played without the possibility of reciprocation is called *private*, and where reciprocation is possible is named *public*. In the private experiment egoists gave an average of 22% of the money they had available. In the public experiment they gave on average 46% of the available money.

At the transaction phase, an egoist agent invests a percentage that is given by a normal probability distribution with mean 0.22 (22%) and variance 0.1. These values were inspired by the private experiment described in [12] since the investment is not covered by any form of indirect reciprocation.

As the simulation progresses and the agent interacts repeatedly with other agents, it as an investor will adjust the mean of the probability distribution accordingly to the trust it has on the investor. With neutral trust the agent invest on average 22% (private experiment results described in [12]), but as it loses or gains trust in the idealist its probability distribution changes accordingly. The investment is computed by the following equation:

$$I_{Ag_k}(Ag_j) = Mi \times P_{prv} \times 2 \times \frac{Trust_{Ag_k \to Ag_j}}{MaxTrust} \quad (3)$$

Where $I_{Ag_k}(Ag_j)$ represents the investment agent Ag_k will perform in agent Ag_j, Mi is the available money to invest, P_{prv} is the private random variable with normal distribution, $\mu = 0.22$ and $\sigma^2 = 0.1$, $Trust_{Ag_k \to Ag_j}$ is the value that represents the investor's (Ag_k) trust in the idealist (Ag_j) and $MaxTrust$ is the maximum value for trust. In neutral trust ($\frac{MaxTrust}{2}$) situations the agent behaves as in [12], however as the trust evolves favorably the average investment increases until twice the value of the neutral situation. As the trust decreases, so does the average investment until the extreme (no trust) of an average of 0% investment (Fig. 2).

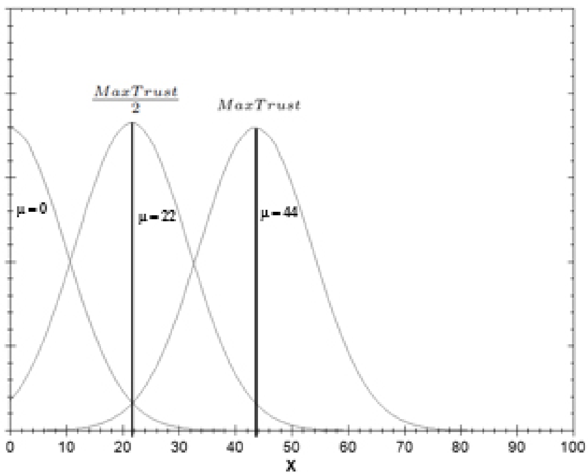

Figure 2. Egoist investment distribution

When the egoist has the role of idealist, it returns an average of 22% of the value that the idealist invested in it. This value is inspired by the donations made in private conditions in the dictator game described in [12], since in these conditions the returned money is not subjected to indirect reciprocation. The equation for the returned money is given by:

$$R_{Ag_j}(Ag_k) = M_r \times P_{prv} \quad (4)$$

Where $R_{Ag_j}(Ag_k)$ is the amount returned by agent Ag_j to agent Ag_k, M_r is the amount agent Ag_j received from agent Ag_k's investment (in our simulation it is $I_{Ag_k}(Ag_j) \times 3$), and P_{prv} is a normal probability distribution with $\mu = 0.22$ and $\sigma^2 = 0.1$.

4.2 Altruist

Regarding the coupling phase, the altruist agent behaves as the egoist. It will choose a random idealist when assigned the role of investor, and will choose a random investor if several are interested in investing in it when it has the role of idealist.

Altruist represent agents that act prosocially in all situations, meaning they will tend to give more (regardless of the existence or not of future benefits) [12]. An altruist agent in our simulation is an agent that will on average, invest more and return more than an egoist agent. In [12] people classified as altruists, gave on average 40% in the private experiment and 51% in the public experiment (where future benefits are possible via indirect reciprocity).

At the transaction phase, an altruist agent invests a percentage that is given by a normal probability distribution that ensures it invests 40% on average. As with the egoist agent, these values were inspired by the private experiment described in [12]. The equation used to compute the value to invest is equivalent to the egoist agent (Eq. 3), the diference being in that P_{prv} is a normal probability distribution with $\mu = 0.4$ and $\sigma^2 = 0.1$. The same applies to the return equation (Eq. 4).

4.3 Reputation

Reputation can be seen as a mechanism that allows future trading partners to observe the fulfillment (or lack of) of an (implicit) agreement [9]. Each time the trusted entity honors the trust ascribed in it its reputation grows, and every time it dishonors it, its reputation diminishes. From this perspective reputation can be looked upon as an asset, that is in the interest of the holder to maintain [9].

At the end of each transaction, the agent that has the role of investor tells all other agents its updated trust regarding the idealist (Eq.1 and Eq.2). The agents who receive this information store it as a triplet containing the investor, the idealist and the trust value. As the simulation progresses each agent will build up information regarding what is the level of trust each agent, as an investor, has in other agents, as idealists (Table 1).

Table 1. Example of agent Ag_1's reputation table. $Ag_{i(ide)}$ represents Ag_i as an idealist and $Ag_{i(inv)}$ represents agent Ag_i as an investor. $(-)$ means that the agents in question have not interacted previously.

	$Ag_{1(ide)}$	$Ag_{2(ide)}$	$Ag_{3(ide)}$	$Ag_{4(ide)}$
$Ag_{2(inv)}$	6	×	2	8
$Ag_{3(inv)}$	5	–	×	10
$Ag_{4(inv)}$	5	–	4	×

We compute reputation as the average of the reported trust values(Eq. 5), for example, imagine Table 1 represents the information agent Ag_1 has about the other agents present in the simulation. Agent Ag_1 will assign agent Ag_3's a reputation value of 3 ($\frac{Trust_{Ag_2 \to Ag_3} + Trust_{Ag_4 \to Ag_3}}{2}$), and for agent Ag_4 a reputation value of 9.

$$Reputation_{Ag_k}(Ag_j) = \frac{\sum_{Ag_i \in (A \setminus \{Ag_k\})} Trust_{Ag_i \to Ag_j}}{|A \setminus \{Ag_k\}|} \quad (5)$$

Where $Reputation_{Ag_k}(Ag_j)$ is the reputation agent Ag_k computes for agent Ag_j, A is the set of agents that have reported a trust value in Ag_j and $Trust_{Ag_i \to Ag_j}$ is the trust agent Ag_i reported concerning agent Ag_j.

4.3.1 Egoist

The way the egoist agent performs investments now takes into account the reputation together with trust (both are given equal weights). The investment is given by:

$$I_{Ag_k}(Ag_j) = Mi \times P_{prv} \times 2 \times \left(\frac{\frac{Trust_{Ag_i \to Ag_j}}{MaxTrust} + Reputation_{Ag_k}(Ag_j)}{2} \right) \quad (6)$$

Where $I_{Ag_k}(Ag_j)$ represents the amount Ag_k invests in Ag_j, Mi is Ag_k's available money to invest and P_{prv} is a random variable with normal distribution ($\mu = 0.22$ and $\sigma^2 = 0.1$).

Note that when investing the egoist does not take into account its reputation, since the amount invested has no effect on it. Hence, we used the same probability distribution as in Eq. 3.

Introducing reputation in the simulation is a way of making the transactions public in the way that the reported outcome (via the trust reported by the investor) will have an influence on all future investments. Because of this and because egoists are defined by the influence that (possible) future benefits have on their behavior [12], when reputation is introduced the egoists change their return behavior (so as to ensure a positive reputation). In [12], in the public setting experiment (where there was indirect reciprocity) people classified as egoists invested on average 46% (in contrast with the 22% invested in private settings).

Regarding the return, the egoist will tend to return more in order to protect its reputation:

$$R_{Ag_j}(Ag_k) = M_r \times P_{pub} \quad (7)$$

Where again $R_{Ag_j}(Ag_k)$ is the amount returned by Ag_j to Ag_k, M_r the amount Ag_j received from Ag_k's investment and P_{pub} is a random variable governed by a normal probability distribution with $\mu = 0.46$ and $\sigma^2 = 0.1$ (in contrast with P_{prv} where μ was 0.22).

4.3.2 Altruist

Altruists do not respond as markedly to the presence of possible future benefits as egoists, however in [12] there were subtle differences - altruists gave on average 51% when faced with possible future benefits (in contrast with 40% when no future benefits were accounted for).

Since there is no effect on reputation when investing, an altruist uses Eq. 6, the difference being that P_{prv} is now a normal random variable with $\mu = 0.4$ and $\sigma^2 = 0.1$.

Also, when performing the return on an investment, the altruist agent uses the same equation as the egoist (Eq. 7), where P_{pub} is a normal random variable with $\mu = 0.51$ and $\sigma^2 = 0.1$.

4.4 Weighted Reputation

In an exploratory effort to provide an alternative calculation for reputation we took into account that agents represent explicitly what level of trust each agent as an investor has on the idealists they invested in, and we incorporated those explicit representations in the computation of reputation. The agents can weigh the information provided by the level of trust they have in the provider. Defining reputation this way makes it a subjective view from the agent who is assigning it to the idealist. The reputation is now given by:

$$Reputation_{Ag_k}(Ag_j) = \frac{\sum_{Ag_i \in A_T} \left(\frac{Trust_{Ag_k \to Ag_i}}{MaxTrust} \times Trust_{Ag_i \to Ag_j} \right)}{|A \setminus \{Ag_k\}|} + \frac{\sum_{Ag_i \in (A \setminus A_T) \setminus \{Ag_k\}} Trust_{Ag_i \to Ag_j}}{|A \setminus \{Ag_k\}|} \quad (8)$$

Where the first term of the sum represents the average of the weighted trust reports from the agents the agent already has invested in, and the second term the average of the trust reports from the agents it has not interacted with as investor yet.

$Reputation_{Ag_k}(Ag_j)$ is the reputation agent Ag_k ascribes to agent Ag_j, $\frac{Trust_{Ag_k \to Ag_i}}{MaxTrust}$ is the weight (in the form of percentage) agent Ag_k devotes to the trust reported by agent Ag_i regarding agent Ag_j ($Trust_{Ag_i \to Ag_j}$). A_T is the set of agents with whom agent Ag_k has invested in (therefore having a trust value for them) and A is the set of agents that have have interacted with Ag_j as investors.

4.4.1 Egoist

By computing an agents' reputations using Eq. 8, more credit is given to agents that the calculating agent trusts. Therefore, agents that are globally more trusted have a bigger influence "in their saying" in another agent's reputation. Egoist agents can take advantage of this by using a more egoistic strategy when faced with an investor that has bad reputation (less than $\frac{MaxTrust}{2}$) and a less egoistic strategy otherwise (by deceiving an agent with a low reputation, the egoist reputation should be less affected than when deceiving an investor with high reputation).

When investing, an egoist agent behaves the same way as in Eq. 6, the difference being that reputation is now computed using Eq. 8.

When returning in a transaction the egoist now takes into account the reputation of the investor. If the investor has a good reputation, that is seen by the egoist as a sign that the investor has many trustees, on the other hand if it has a bad reputation its disclosure regarding the egoist performance in the transaction is less likely to affect significantly its reputation. The return is computed by:

$$R_{Ag_j}(Ag_k) = \begin{cases} M_r \times P_{pub} & \text{if } Reputation_{Ag_j}(Ag_k) \geq \phi; \\ M_r \times P_{prv} & \text{if } Reputation_{Ag_j}(Ag_k) < \phi. \end{cases} \tag{9}$$

Where $R_{Ag_j}(Ag_k)$ is the amount returned by Ag_j to Ag_k, M_r the amount Ag_k received from Ag_j's investment, P_{pub} is a random variable governed by a normal probability distribution with $\mu = 0.46$ and $\sigma^2 = 0.1$, P_{prv} is also a random variable with normal distribution, $\mu = 0.22$ and $\sigma^2 = 0.1$, $Reputation_{Ag_j}(Ag_k)$ the reputation computed by agent Ag_j relative to agent Ag_k and ϕ is $\frac{MaxTrust}{2}$ which represents neutral trust.

4.4.2 Altruist

As altruists have the characteristic of being less influenced by the prospect of future benefits they do not take advantage of the investor when it has a low reputation.

As like egoists, altruists use weighted reputation (Eq. 8) to decide how much to invest (Eq. 7) when having the role of investor.

However, when returning an altruist does not take into account any of the investor's characteristics, it behaves the same was as before (using Eq. 7).

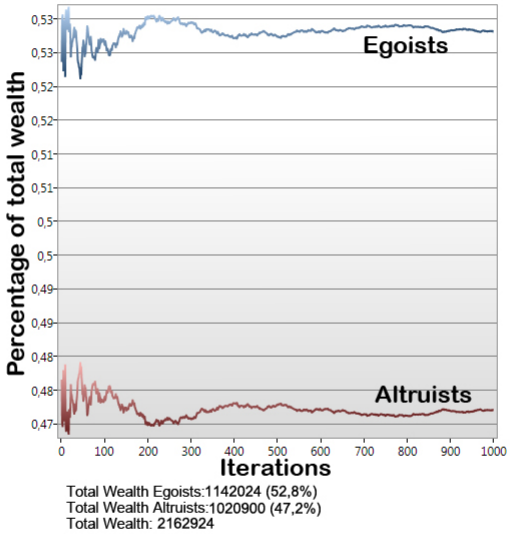

Figure 3. Agents using only results from social studies

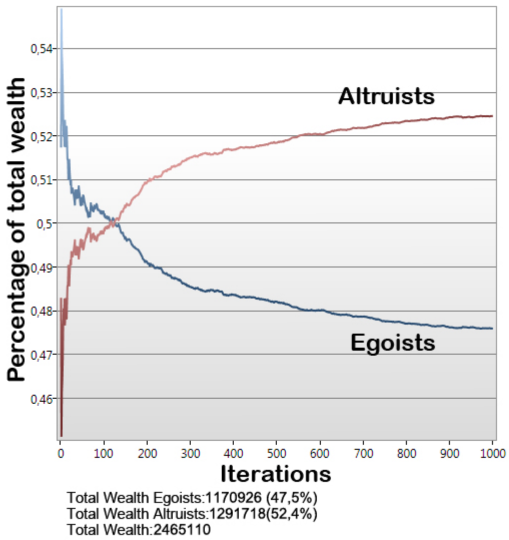

Figure 4. Agents using trust

5 Simulation Results

To assess the effect of introducing trust and reputation in a population of agents performing the trust game we have run 1000 iterations of the game (where each of the agents is handed 100 units of money per round) using several configurations. The first configuration was composed of an equal amount of egoist and altruist agents (10 each) using only the results from the social studies [2] [12]. The simulation (Figure 3) shows that, as expected, this is a favorable setting for the egoist agents.

Upon introducing trust (Figure 4) there is an inversion of the situation. The altruists now thrive since egoists are rapidly identified as bad investments.

With the inclusion of reputation (Figure 5) a balance is achieved. This is the situation where wealth is better distributed and where the whole agent population generates more money. This is an interesting result since it mirrors the benefits of reputation, described as a tool for generating efficient markets [9].

Using weighted reputation (Figure 6) proved to yield a big difference in the distribution of wealth between egoist and altruist agents, similar to the one observed when we use only trust (cf. Figure 4). In this setting the egoist agents although using a more elaborate return strategy still end up with bad reputation after a sufficient number of iterations.

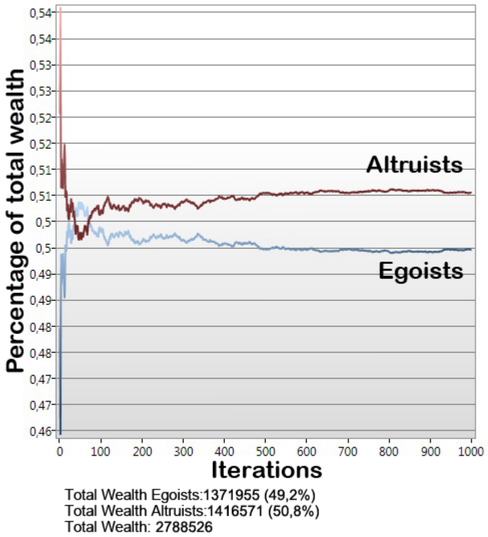

Figure 5. Agents using reputation

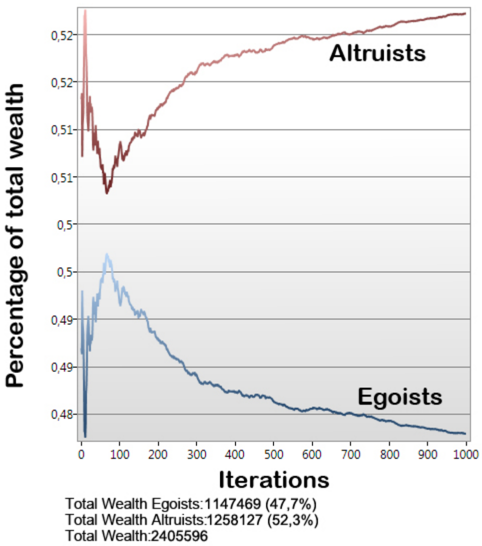

Figure 6. Agents using weighted reputation

6 Conclusions and Future Work

We have developed a multi-agent system that simulates the trust game based on results from social studies [12] [2]. Based on interpretations of trust and reputation taken from an economics market perspective [9] we simulated several runs of the trust game and were able to show the effect trust and reputation had on the way that the wealth was distributed. The introduction of reputation confirmed the expected result of being a good mechanism to regulate markets [9].

We also included an alternative computation for reputation that takes into account a subjective view of the agent that is computing it. We believe this can become useful if we include dishonesty in the simulation. We are presently modeling trust as a measure of the quality of the agent as an idealist, and not as a measure of its honesty when reporting its trust on transactions. We would like to explore this issue more, including dishonesty in the simulation and using results like [13] to handle it.

There were other aspects that we would like to address as future work in order to achieve a richer simulation environment. Issues such as the ability for the agents to choose who to invest in and who to accept investment from and other measures of trust [8] [13].

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