

Endogenous Preferences and Relational Dynamics: A Co-evolutionary Model

Michele Biavati[♦]

ABSTRACT

Following the common references to the behavioural hypothesis, cooperative actions take place in interactive environments within which not only monetary incentives are at work and strategically sophisticated courses of action can play a role. In this paper I develop an evolutionary approach in which individual preferences are endogenous and endeavour to explain whether evolution favours altruistic or selfish attitudes. In particular, within a social network involving different types of players, I assume that a co-evolutionary relationship develops, at the individual level, between motivational structure and social interaction.

A crucial point of my analysis is that I do not assume a priori fixed levels of social openness, which will mechanically drive to a cooperative Nash Equilibrium. I start from a scenario in which all agents are potentially characterized by some sort of altruism, but in order for these forces to emerge, a certain level of interaction is required. Through iterations, the parameters of inequity aversion dynamically evolve till the point where, for some agents, adopting a cooperative behaviour gives more utility than keep using the “defect” strategy among well-known opponents.

The model, focusing on the dynamic interplay of motivational, behavioural and relational dimensions, sheds light on the capacity of motivational forces to make emerge the Pareto-efficient cooperative configurations as interactions go on over time. In a further extension of the model, I adopt an evolutionary scenario, in which agents that obtain relatively better results are able to replicate themselves quicker than others. These results clearly show how, after a certain period of time, any initial

[♦] Universidad Carlos III de Madrid, Department of Economics, c/Madrid 126, 28903 Getafe, Madrid, Spain. Email: mbiavati@eco.uc3m.es Tel: (+34) 916249781

network of agents that start with the “defect” strategy evolves in an environment where cooperation is the unique evolutionary stable strategy.

The possible applications for this model can be related to the design of principal-agents contracts, theory of teams, theory of unions, and more in general to all those situations when the interaction among agents involves relational levels different from the monetary ones. Also, particular interesting is the application to the study of networks where, clearly, the strength and intensity of the relations play a key role.

Altruism as “complication” of an agent’s motivational spectrum

Tullok (1976) and Stigler (1981) sustain that the rational choice paradigm provides a satisfying explanation of human behaviour, assigning a very marginal role to individual choices that do not satisfy the *only* principle that drives human behaviour: the pursuit of personal benefit. The leading version of this principle can be found in the Edgeworth’s (1981) proposition. It states that the most important principle in economics is that what drives economic agents is only the maximisation of the personal profit. The concept of rationality in economics is also based on this idea. Collard (1978) goes even further, picturing the economic agent as envious and malevolent, incapable of benevolence towards neighbours. In other words, the idea of self-interest is methodologically considered as a “neutral” assumption. In our opinion, this assumption is far from being neutral, because it emphasizes the atomistic nature of the economic agent, excluding, *a priori*, any *relational* dimension. In this thematic wishing, Kirzner (1990) offers an extension of the meaning of self-interest. In his contribution, he underlines the fact that, although the subjects are necessarily the ones that make choices, the final aim of these subjects is not necessarily the pursuit their own *personal interests*. A conceptual distinction is established between choices and interests. This is very similar to the distinction proposed by Sen (1985) that assigns a relative autonomy, but non-fictitious to the category of self-goal choice and self-welfare goal¹. Both Tully and Stigler focus on the fact that it is not possible to adduce theoretical argumentations that will link the concept of individual rationality with that of personal interest. On the other hand, with a pure individualistic view how could we possibly justify the notion of gift? “(...) why do people donate if they are fundamentally and exclusively egoist?” (Godbout 1998). Such questions are, more and more, supported by convincing empirical and experimental results, showing that the methodological decision to adopt a pure selfish motivational category, in

¹ Sen (1995) shows how the requirement imposed by traditional economics models (implicitly or explicitly) to the individual rationality are totally independent and distinct by another fundamental requirement: he define this the self-centred goal, which impose to the individual the adoption of atomistic behaviours, totally independent by any social influence in the decisional process finalized to reach the individual welfare.

complete disregard of the extra-individualistic categories, dramatically reduces the explicative capacity of economics models.

In the light of these considerations, the analysis of the altruistic dimension is one of the most promising in trying to “complicate” the motivational spectrum of the traditional economic theory. Following this direction it is possible to relax the atomistic assumption and allow a more complex and vast behavioural set inside these social-economics interactions.

Because of the complexity of the problem, we must get over the common but superficial simplification that reduces the altruistic dimension to a more or less sophisticated version of egoism. Eisenberg (1982) qualifies altruism as an intentional and voluntary behaviour that has as its goal the welfare of the other without any personal interests or prospective reward. On the same theme, Zamagni (1995) proposes that individuals behave altruistically when they consider the welfare of others as a goal *pro se*, that results as a consequence of their actions and that is relevant regardless of the subjective welfare. The crucial point is the lack of any expected personal benefits. The presence of an expectation of reward will lead to a characterization of the altruism as an “enlightened egoism”²

It is also important to notice that the number of studies that point out the inadequacy of a paradigm based only on self-interested motivations or on a conceptualization of altruism based on individualistic reasons is increasing. In other words, it is relevant that in various social-economics contexts, choices that are not self-interested are performed on a different base of the pure self-interest.

A serious attempt to characterize the altruistic dimension of behaviours involves the distinction between the “psychological benefit” as the “motive” of the individual behaviour and the “psychological benefit” as a simple “positive externality” as a choice implemented on the base of different reasons. It is not possible to exclude *a priori* that the altruistic behaviour is adopted without the

² About this Zamagni (1995) is very explicit: "a defence of altruism in terms of self-interest, albeit broadly conceived, is unlikely to be successful, the reason being that whereas the concept of utility expresses a certain relationship of the individual with the 'object' of his desires or preferences, the very idea of altruism expresses a relationship between persons. (...) If my concern with the welfare of others is merely an instrument for promoting my longer-term ends and ceases once these ends can be more easily pursued in some other way, I am an enlightened self-interested person, not an altruist"

consideration of the possible psychological benefits³. Therefore, the error of characterizing the economic agent as individual driven only by pro-social motivations should be avoided.

Altruism failures: a “relational” concept of social openness

In light of previous arguments, our model tries to incorporate a non-monistic vision of the individual motivations, therefore different from a vision that assumes altruism as a homogenous motivation that differs only in level among agents. The fact is that there exists different types of altruism, capable of generating different behaviours. On the other hand, it is important to define altruism as a motivational strength, not only anthropologically motivated, but also economically rational; it is important to avoid the idea that altruism leads to easily exploitable choices from agents of pure self-interest. The economic literature has already pointed out the limitations and failures of altruism, as shown in the altruist dilemma (Delbono and Zamagni 1996) and in the example of a football team composed only by pure altruists (Hollis 1998). These failures came from the unilateral dimension of pro-social behaviours. An alternative and more appealing approach to the study of hetero-directed behaviours is the “relational” approach: in this perspective the network of social relations in which an agent takes her actions is considered as the “interpretative set,” capable of sustaining altruistic decisions. Altruism results then as rational in a social context where subjects are characterized by a non-instrumental attention with respect to the interpersonal dimension. It is obvious then, that in an evolutionary game between two agents that adopt the same vision, they both play the roles of altruist and beneficiary. The dynamic of the game will evolutionarily establish the different roles of every period in the game.

In our model, the coexistence of the two roles in a single subject is possible because altruist behaviour is not *a priori* assumed, but is strongly related to the relational dimensions that decisively characterize the objective

³ This is a delicate distinction because it is not observable. In a behavioural approach this distinction is irrelevant. *Vice versa*, in a motivational analysis, this is crucial in order to distinguish equivalent behaviours on the basis of different motivations.

functions that agents maximize. More specifically, in our model, altruism is related to a specific form of interpersonal relation that dynamically evolves during the game.

We have labelled the kind of altruism we are considering as “empathic altruist”, in the sense that a subject identifies himself, up to a certain level, with the people around him. We are following Hoffman (1995), who underlines the empirical existence of a correlation between individual empathy and altruistic behaviour. He also notices how altruism could derive from the perception of a degree of similarity among people. Other studies, such as the work of Akerlof and Kranton (2000) clarify this theme: several experiments emphasise the emergence of selective and discriminant behaviours, correlated with the degree of interpersonal identification.

In our model, the beneficiary of an altruistic act is not anonymous nor is it linked to the altruist from a previous relation, but it is a subject that gradually establishes a relation on the base of the opponent behaviours. The altruism is not assumed *a priori*, but it is based on the direct observations of agents’ decisions.

The Model

In order to explain how our model works, we start with a simple case in which two homogeneous agents are involved. The structure of the game is the usual prisoner dilemma game with perfect information about the payoff matrix. It is a well established result that, considering the selfish utility functions of the agents, cooperation is a dominated strategy and the Pareto-efficient solution does not endogenously emerge. The peculiar characteristic of our model is represented by the hypothesis that in a social network there coexist different types of agents that, without knowing each other at the beginning of the game, play the game repeatedly. The result is the emergence of a co-evolutionary relation between motivations and behaviour. More precisely, the utility function of the agents leads to a certain strategic choice that indirectly (but in a decisive way) influences the results of the interaction; interaction itself, in the course of the game, leads to a retroactive effect on the agents’ utility functions causing a co-evolutionary dynamic. We

assume that, potentially, each agent is characterized by a certain degree of altruism. The evolution of preferences is driven by a mechanism that modifies a parameter called relational-intensity (R) from which depends the level of altruism (w) present in the agents.

At the beginning we focus on a two-agent case, agents A and B that play repeatedly (for a finite number of periods) the usual prisoner dilemma game with the following payoff matrix.

| | C | D |
|---|-------|-------|
| C | 2 , 2 | 0 , 3 |
| D | 3 , 0 | 1 , 1 |

The agents are characterized by the utility functions:

$$(1) U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot \Pi_{ji}$$

where Π_{ij} denotes the monetary payoff of agent i when playing against j .

The relation that links the altruism parameter with R is given by

$$(2) w_{ij} = [R_{ij} / (R_{ij} + b)] , \text{ (where } b \in \mathfrak{R}_+ , \text{ with } w_b' < 0, w_R' > 0 \text{ and } w_R'' < 0)$$

The level of altruism is therefore an increasing function of R passing through the origin.

During the game, the relations among the two agents evolve, in the sense that they learn the characteristics of the opponent by her strategic choices. We assume that the agents are homogeneous, characterized by a utility function that assigns a potentially non-null weight to the monetary payoff of the other. The “strength” of the relation is quantified through the relational-intensity indicator $R \in \mathbb{Z}$. We assume that R , starting from a value of zero (the two agents do not know each other at the beginning of the game), during the game increases by one unit if the players adopt the same strategy and

decreases by one unit otherwise. The motivation arises because playing the same strategy reveals a degree of similarity in behaviour. Obviously, the relational intensities of the two agents are symmetric ($R_{AB} = R_{BA}$).

The hypothesis that the agents are to a certain extent altruistic, it is summarized by the fact that in the utility function of an agent, besides her payoff, the payoff of the opponent is weighted by the parameter w that captures the altruism's degree. It is important to notice that, in our model, the altruism empathic is based on a form of adaptive rationality⁴

The empathic altruism represents, therefore, a particular form of partial altruism⁵, in the sense that w assumes values between zero and one ($0 \leq w < 1$)⁶. Naturally the higher the value of w is, the more altruistic an agent will be. With w close to one we will have the case of a quasi-perfect altruist and a quasi-egoist when w is very close to zero. We assume that the agent is driven by "pro-social" motivation, combined with respect to his own individuality, which does not disappear with an altruistic behaviour. We can therefore consider the partial altruist as a different agent positioned in between the pure selfishness and the unconditional altruism⁷.

In our model, we do not assume that the agents are *a priori* altruistic. Indeed, the degree of "openness" with respect to the other systematically depends on the particular relation that is established during the interactions. What happens is that altruism increases with the increasing of the relational-intensity, but after a certain number of periods this takes place in a less than proportional way, due to the fact that the opportunity cost of an increase of the opponent payoff's weight is counterbalanced by the decrease of the weight of one's payoff in the utility function.

⁴ In our context the agent's altruism is not based on any deterministic basis. In other words, in order to emerge, it needs proper dynamics of the agents' behaviours.

⁵ "(...) I would identify as 'partially' altruistic a beneficial behaviour x actuated by a mixture of altruistic and non-altruistic reasons when neither the former in the absence of the latter, nor the latter in absence of the former would have been sufficient to generate x " (Zamagni, 1995).

⁶ Our model excludes the possibility of having $w=1$ (perfect altruism) where the agents do not assign any importance to her payoff and her utility coincides with the opponent payoff. Such an extreme is ruled out mainly for two reasons: first of all with $w=1$ the subject will lack a minimum level of self consideration with respect to her individual identity. Second, this will be the case where the agent is subject to a very high risk of exploitation and not very interesting from a social interaction point of view.

⁷ "(...) between the frozen pole of egoism and the tropical expanse of utilitarianism (there is)... the position of one for whom in a calm moment his neighbour's utility compared with his own neither counts for nothing, nor 'counts for one', but counts for a fraction" Edgeworth, 1981).

A numerical example helps us to understand this dynamic and the relation among the parameters b , R and w , assuming the agents adopt the same strategy in each period.

| Time | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|---|------|------|------|------|------|------|------|------|------|------|
| R | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| W(b=3) | 0 | 0.25 | 0.4 | 0.5 | 0.57 | 0.62 | 0.67 | 0.7 | 0.72 | 0.75 | 0.77 |
| W(b=9) | 0 | 0.1 | 0.18 | 0.25 | 0.3 | 0.35 | 0.4 | 0.44 | 0.47 | 0.5 | 0.52 |

Looking at the above values, it is worth noticing that with a low level of b ($=3$), just after three periods an agent weights the opponent's payoff as much as hers. Vice versa, with a high b ($=9$) this happens much later, when they are characterized by a stronger relationship. Due to the hypothesis that the two agents do not know each other when they start to play, at the beginning of the game ($T=0$) R is equal to zero; by construction also $w=0$, therefore, when the game starts the utility of the agents coincides with their monetary payoffs and the agents can be considered as purely selfish.

To conclude the model, we considered the agents characterized by limited rationality: they decided the strategy to adopt in each period assuming that the opponent will play the same strategy adopted in the previous period (adaptive expectations).

The Dynamic of the Game

At the beginning of the game ($T=0$) $R_{AB}=R_{BA}=w_{AB}=w_{BA}=0$. Consequently, the utilities are:

$$(3) U_A = \Pi_{AB}$$

$$(4) U_B = \Pi_{BA}$$

Each agent then acts as the selfish model has predicted and will defect (strategy D). In the next period we will have $R_{AB}=R_{BA}=1$ because in $T=0$ the

agents adopted the same strategy. From now on players will start to assign a positive weight to the opponent's payoff but this is not enough to modify the strategy. On the basis of our hypothesis, we are able to anticipate that this kind of relation will lead to a point in which R is sufficiently high to endogenously induce a simultaneous change in the behaviour. Given the structure of the payoffs they will arrive at one period where the utility obtained from the fact that the opponent will get the highest monetary payoff more than compensates for the utility lost from being exploited. Therefore they will collaborate (C) believing that the opponent will continue to defect (we assume that in the case of indifference the agent will continue to defect). Based on this, we can calculate the period and the values of w and R for which an agent will change strategy. For agent A, from (1) we can calculate the expected payoffs given that the opponent keep defect:

$$U_A(A_C | B_D) = (1 - w_{AB}) \cdot 0 + w_{AB} \cdot 3$$

$$U_A(A_D | B_D) = (1 - w_{AB}) \cdot 1 + w_{AB} \cdot 1$$

Agent A will change strategy when $U_A(A_C | B_D) > U_A(A_D | B_D)$, then

$$3 \cdot w_{AB} > 1 \Rightarrow w_{AB} > 1/3$$

Substituting w in the formula that links w with R (3) we obtain that for the agent it is more convenient to collaborate than defect when $R > b/2$. Because of the hypothesis that R grows of one unity each period in correspondence of the same behaviour we obtain that the strategy's change will happen in $T > b/2$. Due to the fact that the agents are symmetric, they will change the strategy simultaneously and both will obtain a higher utility than the expected one. From $T > b/2$ the two agents will stably continue to collaborate.

Before analyzing the general case with more than two heterogynous agents interacting in a complex network, we will study another simple case in which the two agents are characterized by a slightly different utility function. In this context the altruistic propensity does not refer only to the opponent's payoff, but rather on the collective results of the society ("benthamian

altruism”) to show how, also in this case, the strategies of the agents converge to a stable cooperation between themselves.

In this case the utilities of the agents assume the following form:

$$(5) U_i = (1 - w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot (\Pi_{ij} + \Pi_{ji})$$

In this case the utility is not a weighted average anymore, but is given by a weighted average of one’s payoff and the total payoff that, in a benthamian perspective represents the society’s welfare.

(5) can be rewritten in another way that better captures the difference with respect to the previous case:

$$(5 \text{ bis}) U_i = \Pi_{ij} + w_{ij} \cdot \Pi_{ji}$$

With this formulation, it is easy to notice how the fact that the altruism refers to the “society” and not to the single opponent lowers the weight associated with the opponent’s payoff. This still increases with the increase of the relational-intensity, but it is always less than the weight associated with the agent’s own payoff.

Following the same steps of the previous case we have the change in strategies for agent A when

$$U_A(A_C | B_D) = w_{AB} \cdot 3 > U_A(A_D | B_D) = 1 + w_{AB} \cdot 1 \quad \Leftrightarrow \\ w_{AB} > 1/2 \Rightarrow R_{AB} > b$$

In this case a mutual collaboration emerges in a period of time that is two times longer than in the previous case. This difference is due to the fact that, if before an increase in the weight of the opponent payoff was associated with a decrease in one’s own payoff, in this case the agent’s own weight does not decrease as the game goes on. In both cases, anyway, the period necessary for collaboration to emerge increases with respect to the parameter b.

Interactions in a Network Society with Heterogeneous Agents

From the previous analyses, cooperation in a social network emerges because as the relational-intensities strengthen, the degree of altruism rises among agents. This crucially depends on the particular utilities functions that we considered. Supported by this assumption we observed how after a certain number of periods general defection makes R (and consequently w) rise until the point in which cooperation is individually more preferable than defection. What we aim to analyze next is what happens if we consider different types (in term of utility functions) of agents, a case that better represents the complexity present in real societies. We allow the presence of different types of altruists and egoists and we simulated the interactions among agents. In particular we considered six different types of agents. For $i \neq j$ we have:

| | |
|----------------------------|--|
| <i>Partial Altruist:</i> | (6) $U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot \Pi_{ji}$ |
| <i>Benthamian Altruist</i> | (7) $U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot (\Pi_{ij} + \Pi_{ji})$ |
| <i>Rowlsian Altruist</i> | (8) $U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot F_i$ |
| | where $F_i = \Pi_{ji}$ if $\Pi_{ji} < \Pi_{ij}$ |
| | $= \Pi_{ij}$ if $\Pi_{ji} \geq \Pi_{ij}$ |

| | |
|---------------------------|---|
| <i>Pure Egoist</i> | (9) $U_i = \Pi_{ij}$ |
| <i>Nietzschian Egoist</i> | (10) $U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot (\Pi_{ij} - \Pi_{ji})$ |
| <i>Positional Egoist</i> | (11) $U_i = (1-w_{ij}) \cdot \Pi_{ij} + w_{ij} \cdot P_i$ |
| | where $P_i = \Pi_{ij}$ if $\Pi_{ij} > \Pi_{ji}$ |
| | $= \Pi_{ij} - \Pi_{ji}$ if $\Pi_{ij} \leq \Pi_{ji}$ |

Besides the pure egoist (who maximizes her monetary payoff) and the partial and benthamian altruist, we considered the rawlsian altruist (who weights her opponents payoff only when this is less than hers), the nietzschian egoist (interested in the “social inequality’s degree” here formalized with the absolute value of payoffs’ difference) and the positional

egoist (who, beside her payoff weight only a positive difference in the opponent's result and hers).

It is easy to notice that in such a society cooperation cannot become the only dominant strategy because of the presence of agents that will constantly defect independently from the levels of the relational-intensity and w ⁸. In the previous case, another factor that favoured cooperation was the assumption that R increases one unit even when the two players both defected, the same as if they both collaborated. Here, we wanted to avoid an overly mechanic evolution of the relational-intensities and of the agents' motivations and therefore we relax this assumption assuming that in the presence of a strategy profile (D,D) the relational-intensity increases by one unit with probability h and remains constant with probability $1-h$. In fact it is reasonable thinking the real motivations of agents are not fully revealed by their strategic choices and therefore it is not possible to distinguish between the motivations when defection is adopted in order to exploit the (possible) cooperative behaviour of the opponent or when this behaviour is just a consequence of a weak relationship among the two agents.

The simulations (over 300.000 periods) take into consideration a thirty agents' population where the type of the agents is randomly chosen with equal probability. In each period there is only one interaction between two agents that are casually matched. The parameters $b=3.2$ ⁹ and $h=0.5$ are constant among the agents. We also assume that at a negative value of R there corresponds a value of $w=0$.

The simulations permit us to observe the dynamics of strategies, the relational-intensity and the values of w of the agents.

⁸ Here w assume a meaning that cannot be considered as altruism, due to the fact that we consider egoistic agents. In this context w has to be interpreted as a "degree of social influence", as to say the weight that each agent in the network assigns to the opponent's payoff or to the difference in payoffs.

⁹ We choose such a value to avoid indeterminacy problems that may arise with $b \in \mathbb{N}$ when $R=-b$

Results within the homogenous types

We ran many iterations (more than one hundred) to avoid the bias that could have occurred in a single case (the type of agent is randomly chosen by the computer, therefore there were cases where not all of the types were present in the population). Here we report just the results of one simulation that captures the main results observable in any simulation where the population was composed by all of the six types. In appendix A all the tables of relational-intensity, “social openness” and strategies of a single case are reported. Here we show only the ones that refer to the interactions among partial altruists as an example. The values indicate the relational-intensity, the “social openness” and the strategies (1 corresponds to cooperation and 0 to defection) of the subjects “row” with respect to agents “column”.

We have decided to analyze the behaviour among the agents of the same types and the performances among these types.

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 1 | 0 | 667 | 0 | 690 | 0 | .995 | 0 | .995 | 0 | 1 | 0 | 1 |
| 2 | 667 | 0 | 704 | 618 | .995 | 0 | .995 | .994 | 1 | 0 | 1 | 1 |
| 3 | 1 | 704 | 0 | 571 | .238 | .995 | 0 | .994 | 0 | 1 | 0 | 1 |
| 4 | 690 | 618 | 571 | 0 | .995 | .994 | .994 | 0 | 1 | 1 | 1 | 0 |

a) Partial Altruists: among agents of this type, collaboration always emerges endogenously, given that the agents could meet a sufficient number of times. Moreover, these subjects are characterized by very high values of R and consequently of w, meaning that the relationships are very solid and that the social openness (for this type of agent we can call this the degree of altruism) are significantly high.

b) Benthamian Altruists: among these agents the cooperative strategy is the most widespread behaviour. Most of the relations are strong and the social openness is high. Among these agents, collaboration is more difficult to emerge and thus become a stable strategy. This is due to the fact that the

benthamian altruist always weights their monetary payoff more than that of their opponent.

c) Nietzschean Egoists: although the relations among those agents are very solid and the social openness is extremely high, the nietzschian egoists are characterized by a very unstable behaviour, in the sense that among themselves, they alternate between defection and cooperation.

d) Positional Egoists: cooperation does not emerge among these agents because of their particular characteristics. In fact, they will never start to collaborate even if their opponent initiates the collaboration. With respect to our hypothesis that at the beginning of the game everybody will defect, the positional egoist will always defect within this homogenous sub-network.

e) Pure Egoists: these agents will always defect by definition, even in the case that they “build” a substantially strong relationship amongst themselves.

f) Rawlsian Altruists: paradoxically, these agents behave exactly like the pure egoists; also, the values of R and w are very similar in these two categories. The reason is that even if the rawlsian altruists are very sensitive with respect to those who are in a lesser position than them, in our model, where at the beginning everyone will defect, they see themselves as the subject in the worst situation. Therefore, the best strategy with respect to a defecting opponent is defection. In addition, this strategy played among them remains constant throughout the game.

By looking more closely at the values, we can see how the values of R differ among subjects. In particular, the pure egoists and the rawlsian altruists are characterized by values of R that are, more or less, half of the values associated with the other two types of altruists. This happens because, whereas among the latest the relations strengthen through cooperation (this leads to an increase of R of one unit for every period), pure egoists and rawlsian altruists consolidate the relation on the basis of defection, that, on average, lets R increase by one unit for every two periods.

Results among different types

Based on the simulations, the cooperative strategy between partial and benthamian altruists is the most widespread. In addition, it is possible to observe very strong relations and high levels of w between the two groups; the strategies are always symmetric (cooperation is played only against cooperation). Defection results as a transitory behaviour that disappears during the game as the agents strengthen their relationships. The time necessary for cooperation to emerge is longer than the time observed among homogenous sub-groups, due to the difference in the utility functions.

The behaviour of neitzschian egoists pit against these two types of altruists is very unstable. We observed that cooperative strategies are alternated with defection quite regularly. This is due to the fact that altruists, when their R is sufficiently high, decide to cooperate, but this strategy never successfully becomes stable because neitzschians react to cooperation with defection. Defection, however, likewise never becomes stable, because it happens that neitzschians will sometimes cooperate in reaction to the strategies (defection) of the altruists. These instable behaviours are summarized in the matrix of relational-intensity where the greater majority of the values are negative (remember R decrease in the case that the two agents play opposite strategies).

More extreme is the behaviour of positional egoists when they play against partial and benthamian altruists. They will always react with defection against any strategy of their opponent and this leads to a cyclical behaviour: every certain number of periods the altruists try to play with cooperation but with no success in changing the strategy of the positional. Moreover, whereas all the relational-intensities of the altruists – with respect to the positionals – are low but always positive, the majority of the values of R of the positionals – with respect to altruists – are negative.

More interesting is the case of the interactions among neitzschian and positional egoists: due to the fact that the positional egoist will always defect, we observe a high level of cooperation from neitzschians that, as we know, prefer to play the opposite strategy than that of their opponent. This leads to a very low level of relational-intensity between the two groups.

A cyclical behaviour also emerges when we consider the relations between pure egoists and partial and benthamian altruists. It should come as no surprise that even if altruists find it convenient to try cooperation this will not succeed in changing the strategy of the opponent egoists. Therefore, the relation-intensity levels of egoists with respect to altruists are mostly negative, whereas in the other way, the relationship is always characterized by a positive but very low level of R , not sufficient enough to induce a stable cooperation. Also, the neitzschians, with less frequency, sometimes cooperate against the pure egoists but without any appreciable result. The relations are very weak among these two groups.

The last three categories of agents (positional egoists, rowlsian altruists and pure egoists) can be analyzed together because there is a high level of homogeneity in both strategies and levels of R when they play amongst themselves. In fact, they always play defection and their relationships consolidate through this strategy, leading to a significantly high level of R (more or less half of the level observed between partial and benthamian altruists). In other words, positional egoists and rowlsian altruists behave exactly “as if” they were pure egoists and their behaviour is indistinguishable.

Rowlsian altruists deserve a special consideration. These agents strongly privilege the results of those who obtain a worse result than them and therefore, in theory, they should be the agents that get the more satisfaction in cooperating. However, given our assumption that at the beginning of the game everyone will defect, they will always consider themselves in the worst situation given a defection of the opponent; therefore they will systematically defect against defection. The only cooperative strategies of these subjects we have observed are when they play against partial and benthamian altruists. Crucially, this depends on the behaviour of the opponent, who necessarily has to be the first to cooperate in order to induce the rowlsian to cooperate in the next period. However, the fact that there is a discrepancy in timing when the agents collaborate makes the relations remain at a very low level; cooperation does not flourish as a stable strategy. What we have observed is a sort of random cooperation between rowlsian altruists and partial and benthamian altruist.

Dynamics in Population's Agents

After having analyzed the results of the interaction among groups and within the groups, we wanted to take into consideration two other possible consequences of the presence of agents that, in taking their decision, are driven by more than just selfish motivation.

The first aim was to study which agents will perform better during the game from an evolutionary game theory point of view. The basic idea, arising from the natural sciences, is that the agents that obtain the best results are able to replicate themselves more quickly than the others and, as a result, can increase their presence within the population. It seems natural, in our case, assuming that people will become familiar with one another during the game, that the agent will also observe the performances of the agents with whom they have to interact with. As a result, we assume that an agent could decide to mimic the behaviour of the agents that outperformed her in order to obtain better results in the future.

The second aspect of our analysis was to consider the possibility that the relational-intensity built during the game represents, in addition to the channel with which the opponent result is weighted, also a sort physical relation existing amongst the agents. The idea, following a network analysis approach, is that the stronger a relationship, the higher and more efficiently the agents can interact amongst themselves. This assumption gives us the chance to observe the presence of clusters in the population. We are able to analyse which agents will remain isolated due to the fact that with their behaviour they are unable to consolidate the relationships with the others.

We introduce these aspects into our model assuming that, every certain number of periods, agents can observe the average monetary payoff of the entire population (because everyone will interact with all of the agents) and compare this value with their own expected payoff. If an agent's expected result is worse than this value, she will change type with probability proportional to the average payoffs obtained by all the types (this allows for the possibility that an agent could remain of the same type). It is important to notice that an agent does not compare utilities (the range of the utilities differs among types), but simply monetary payoff. Moreover, in the case that an

agent will change type, she will still be characterized by her previous relational-intensities, meaning that once the typology of another type is mimed, she will need to gain a reputation among the population and strengthen her relationship with appropriate behaviour.

In addition, in order to capture the dynamics of the relations and the formation of cluster, we assume that the probability with which the agents are matched is proportional to the relational-intensities that an agent has with her opponents, according to the following formula:

$$(12) \ p_{ij} = R_{ij} / \sum_j R_{ij}$$

This seems a reasonable assumption that captures the idea that agents prefer to interact with opponent that showed similarity in behaviour, fact that increase the relational-intensity that links two agents.

The rest of the models work exactly as the previous one, but in the simulations we increased the number of agents up to 60 in an attempt to better avoid the possibility that some types do not appear in the starting population and, in order to allow more periods for cooperation to emerge we also increased the value of b (now $b=6.2$). Moreover we fix the numbers of revision of the agents' typology during a 10000 periods' game at 60. The edit of the program is reported in Appendix C.

Results

As before we ran many simulations and found a very strong consistency in the results both for the evolution of the types and in the formation of very strong links among agents.

Cooperation is the strategy that in the long run obtains the best results, and this leads to the vast majority of populations being composed of only altruists (more than 95% of the cases). Contrary to the previous case, rowlsian altruists are now also able to stably adopt their preferred strategy (cooperation) and they are able to generate very strong relationships both amongst themselves and with the other two kinds of altruists (see Figure 1.

Here we reported the results of a single simulation that captured the majority of the general results)

In the remaining cases (5%), the final population consists, with equal probability, of the three kinds of egoists and the only strategy played in the population is defection. However, this result is mainly due to the fact that, in the starting population, very few altruists (of all the kinds) were present and, at the beginning of the game, they obtained very low results because there were not enough agents with whom they could cooperate. Thus, all of their altruistic behaviours were exploited by their opponents.

Types' Evolution

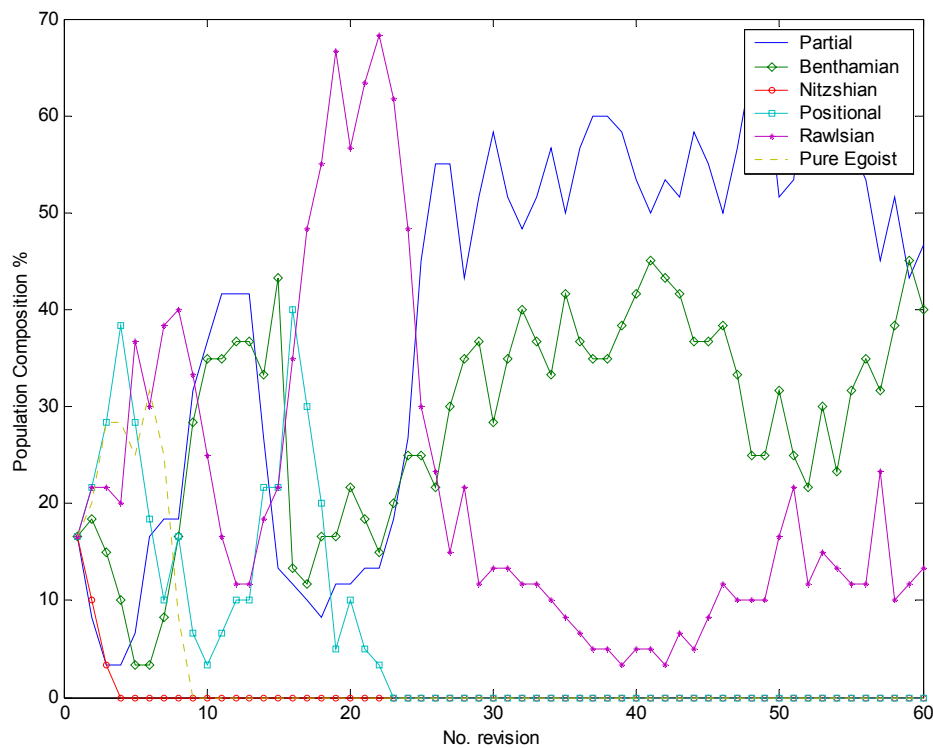


Figure 1

Looking in closer detail at the final composition of the populations, we notice that, although benthamian altruists and rowlsian egoists are always present in the cases where cooperation spreads within the entire population, partial altruists are not always present. In fact, there is, more or less, one case out of three where only the benthamian altruists and rowlsian egoists will remain in

the game. This happens because partial altruists are the ones who will first cooperate amongst all of the agents and, at the beginning of the game, they will never gain in adopting this strategy. If there are not enough partial altruists among whom cooperation can flourish, they will obtain worse results than all of the other opponents that play defection against them.

Nonetheless, independently of the presence of two or three kinds of altruists, cooperation is the only strategy played, leading to an equal average payoff (corresponding to the (C,C) equilibrium) among altruists (see figure 2).

Payoffs Evolution

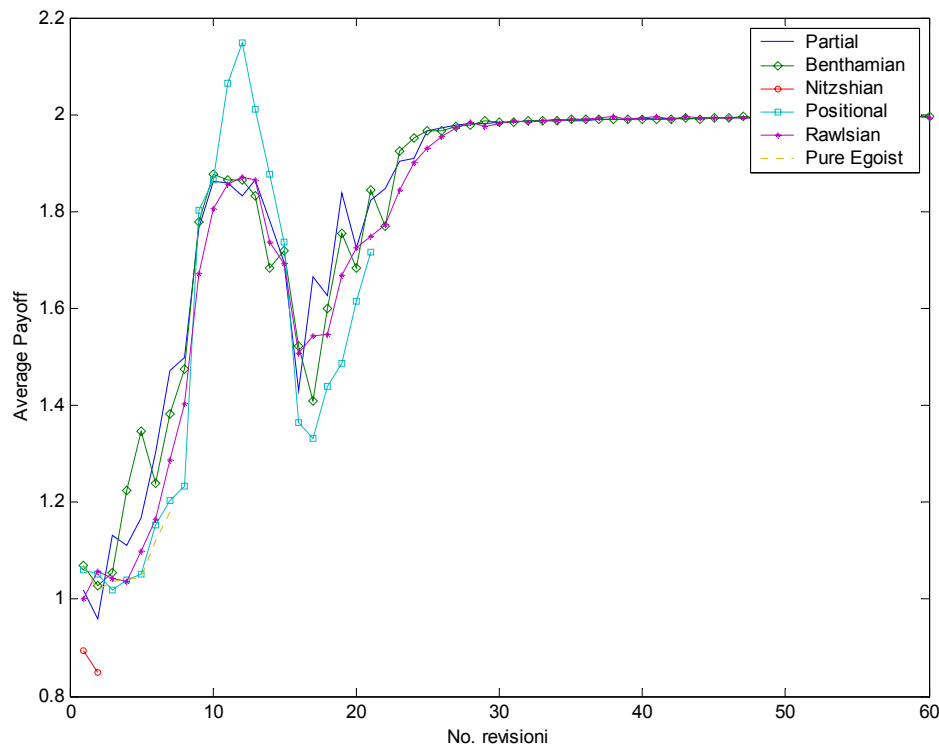


Figure 2

With very strong regularity, a sequence occurs in which the three types of egoists will disappear within the population: the neitzchians are always the first to change typology, because of their behaviour: as a result of their decision to always play the opposite strategy than that of their opponents, at the beginning when everyone defects, they will get an expected payoff of always less than one. This does not happen to altruists, because they can gain from collaborating among themselves. The second type to disappear is

the pure egoist. Even if they gain from exploiting the behaviour of the altruists, the assumption on the dynamic of the matching probability leads them to be very much “disconnected” with those subjects and they will end up always defecting against the other types of egoists. Later this happens also to the positional egoist, but they can survive longer because they tend to play cooperatively more often than the other egoists do.

Dynamics of averages R among types

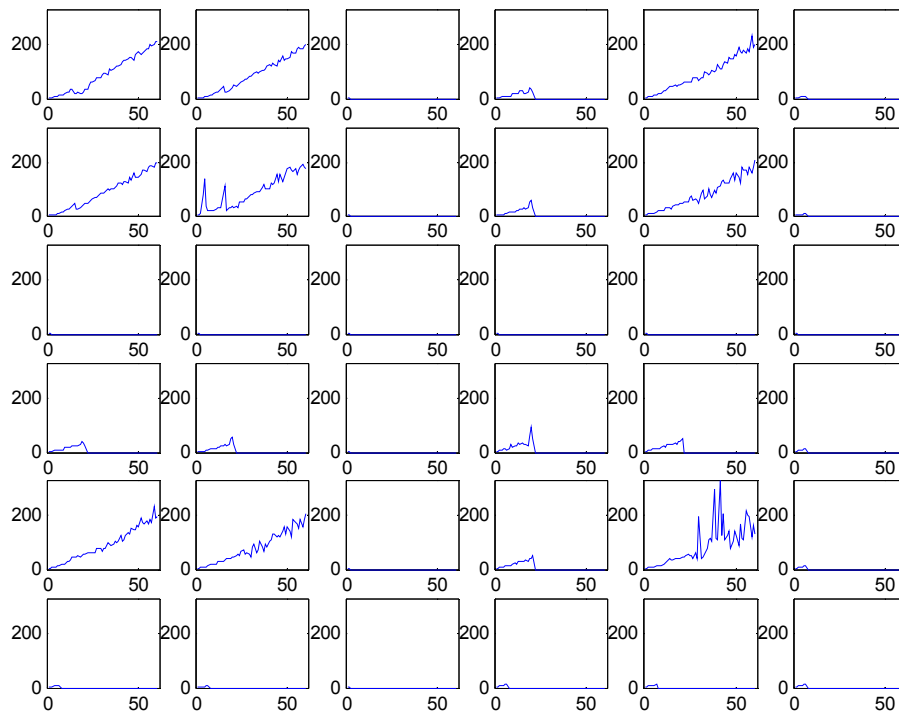


Figure 3

Analyzing how the dynamics of the relations evolve, the results are very robust. It happens that altruists build very strong relationships among themselves through cooperation. This results in more or less double values of relational-intensities than those of egoists who strengthen their relationship on the basis of defection.

Looking at Figure 3, those dynamics are very clear. Here we reported the average relational-intensity among groups, where the types are ordered in the same way as the results within the homogeneous types are. For example, the

first row of graphs summarizes the evolution of the average level of R of the partial altruist with respect to themselves, benthamian, neitzchian, positionals, pure egoist and rowlsian altruist.¹⁰

Finally, in Figure 4 we report the spread of cooperation among the agents. Here, a dot represents the cooperative strategy of the agent “row” with respect to agents “column”. As we point out before, cooperation is the only “active” strategy in the final population (as it is evident from observing the average payoff that is equal to two). The empty spaces (that in theory indicate defection), here can be interpreted here as the agent’s relationships that are “inactive” in the sense that defection is still the best strategy against agents with whom there is a probability to be matched close to zero. The lines separate the three types of altruists that remained in the final population

Frequency of Cooperation

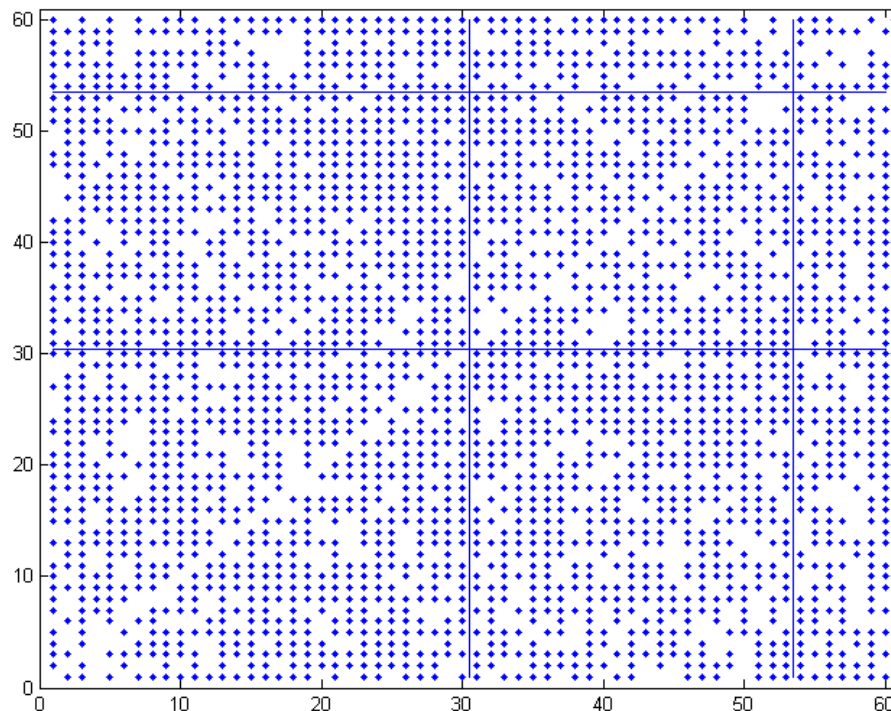


Figure 4

¹⁰ In appendix B is reported a similar figure, where the dynamics of w are summarized. Notice that the average is substantially lower than the average's of the previous analysis. This is because in appendix B a non weighted average is reported which includes also very low w corresponding to low values of R that indicate that a relation is “inactive”, meaning that the interaction among the two agents is very unlikely to take place

Conclusions

We analyzed a model where different types of individual are connected in a circular way: maximization of utility functions drives the behaviour of agents that has, not only (direct) consequences in terms of payoff, but also (indirect) consequences on the relational-intensity that links the agents. This has effects of the motivational dimension of the subjects through the degree of social openness. The model takes a co-evolutionary approach based on three levels: the motivational, the behavioural and the relational. As the analysis emphasises the role played by the relational dimension, it is crucial both on the utility function and on the relational link itself (when we allowed correlation between R and matching probabilities) that, retroactively, modify the relation through the strategic behaviours

Moreover we observed that the emergence of cooperation as an endogenous effect of behaviour is not imposed by any external intervention. We can think of the relationship between matching probabilities and relational-intensity as a sort of mechanism that punishes differences in behaviours (notice that this does not punish defection, because in the presence of simultaneous defections R increases and so does the matching probability). Through this relationship we obtain that cooperation stably emerges and altruists are the subjects that achieve the best results and are able to stably “dominate” social communities.

APENDIX A

The populations consist of four partial altruists, seven benthamian altruists, three nietzschian egoists, four positional egoists, eight rowlsian altruist and four pure egoists. The values indicate the relational-intensity, the “social openness” and the strategies (1 corresponds to cooperation and 0 to defection) of the subjects “row” with respect to agents “column”.

Partial Altruists

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 1 | 0 | 667 | 0 | 690 | 0 | .995 | 0 | .995 | 0 | 1 | 0 | 1 |
| 2 | 667 | 0 | 704 | 618 | .995 | 0 | .995 | .994 | 1 | 0 | 1 | 1 |
| 3 | 1 | 704 | 0 | 571 | .238 | .995 | 0 | .994 | 0 | 1 | 0 | 1 |
| 4 | 690 | 618 | 571 | 0 | .995 | .994 | .994 | 0 | 1 | 1 | 1 | 0 |

Benthamian Altruists

| Agent | R | | | | | | | w | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|
| 5 | 0 | 631 | -14 | 635 | 3 | 4 | 669 | 0 | .994 | 0 | .994 | .483 | .555 | .995 |
| 6 | 631 | 0 | 645 | 690 | -5 | 378 | 691 | .994 | 0 | .995 | .995 | 0 | .991 | .995 |
| 7 | 3 | 645 | 0 | 601 | 3 | 678 | 4 | .483 | .995 | 0 | .994 | .483 | .995 | .555 |
| 8 | 635 | 690 | 601 | 0 | 97 | 593 | 670 | .994 | .995 | .994 | 0 | .968 | .994 | .995 |
| 9 | -1 | 3 | -11 | 97 | 0 | 745 | 672 | 0 | .483 | 0 | .968 | 0 | .995 | .995 |
| 10 | -15 | 387 | 678 | 593 | 745 | 0 | 682 | 0 | .991 | .995 | .994 | .995 | 0 | .995 |
| 11 | 669 | 691 | -17 | 670 | 672 | 682 | 0 | .995 | .995 | 0 | .995 | .995 | .995 | 0 |

| S | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 |

Nietzschian Egoists

| Agent | R | | | w | | | S | | |
|-------|-----|-----|-----|------|------|------|---|---|---|
| 12 | 0 | 499 | 431 | 0 | .993 | .992 | 0 | 0 | 0 |
| 13 | 496 | 0 | 378 | .993 | 0 | .991 | 0 | 0 | 1 |
| 14 | 442 | 401 | 0 | .992 | .992 | 0 | 0 | 1 | 0 |

Positional Egoists

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 15 | 0 | 345 | 309 | 329 | 0 | .991 | 0 | .990 | 0 | 0 | 0 | 0 |
| 16 | 363 | 0 | 320 | 309 | .991 | 0 | .990 | .990 | 0 | 0 | 0 | 0 |
| 17 | 319 | 323 | 0 | 362 | .990 | .990 | 0 | .991 | 0 | 0 | 0 | 0 |
| 18 | 369 | 326 | 378 | 0 | .991 | .990 | .991 | 0 | 0 | 0 | 0 | 0 |

Rawlsian Altruists

| Agent | R | | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
| 19 | 0 | 346 | 365 | 345 | 348 | 309 | 346 | 340 |
| 20 | 334 | 0 | 322 | 346 | 331 | 326 | 323 | 362 |
| 21 | 350 | 345 | 0 | 352 | 369 | 377 | 330 | 374 |
| 22 | 363 | 355 | 353 | 0 | 339 | 355 | 317 | 336 |
| 23 | 361 | 329 | 331 | 352 | 0 | 358 | 328 | 330 |
| 24 | 337 | 343 | 370 | 343 | 339 | 0 | 359 | 310 |
| 25 | 342 | 322 | 313 | 327 | 348 | 353 | 0 | 368 |
| 26 | 363 | 360 | 339 | 374 | 347 | 346 | 374 | 0 |

| w | | | | | | | |
|------|------|------|------|------|-------|------|------|
| 0 | .990 | .991 | .990 | .990 | 0.989 | .990 | .990 |
| .990 | 0 | .990 | .990 | .990 | .990 | .990 | .991 |
| .990 | .990 | 0 | .991 | .991 | .991 | .990 | .991 |
| .991 | .991 | .991 | 0 | .990 | .991 | .990 | .991 |
| .991 | .990 | .990 | .990 | 0 | .991 | .990 | .990 |
| .990 | .990 | .990 | .990 | .990 | 0 | .990 | .989 |
| .990 | .990 | .989 | .990 | .990 | .990 | 0 | .991 |
| .991 | .991 | .991 | .991 | .990 | .990 | .991 | 0 |

| S | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Pure Egoists

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 27 | 0 | 356 | 345 | 392 | 0 | .991 | .990 | .992 | 0 | 0 | 0 | 0 |
| 28 | 336 | 0 | 353 | 347 | .990 | 0 | .991 | .990 | 0 | 0 | 0 | 0 |
| 29 | 350 | 361 | 0 | 347 | .990 | .990 | 0 | .990 | 0 | 0 | 0 | 0 |
| 30 | 359 | 302 | 357 | 0 | .991 | .989 | .991 | 0 | 0 | 0 | 0 | 0 |

Altruisti parziali vs Altruisti benthamiani

| Agent | R | | | | | | | w | | | | | | | S | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|---|---|---|---|---|---|---|
| 1 | 670 | 627 | -37 | -19 | 642 | 522 | 663 | .995 | 994 | 0 | 0 | .995 | .993 | .995 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 2 | 628 | 178 | 545 | 193 | 601 | 148 | 705 | .994 | .982 | .994 | .983 | .994 | .978 | .995 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 679 | 1 | 523 | 654 | 655 | 690 | 419 | .995 | .238 | .993 | .995 | .995 | .995 | .992 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 4 | 630 | 580 | 1 | 254 | 619 | 82 | 55 | .994 | .994 | .238 | .987 | .994 | .962 | .945 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |

Altruisti benthamiani vs Altruisti parziali

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 5 | 672 | 630 | 681 | 632 | .995 | .994 | .995 | .994 | 1 | 1 | 1 | 1 |
| 6 | 629 | 180 | 0 | 582 | .994 | .982 | 0 | .994 | 1 | 1 | 0 | 1 |
| 7 | 4 | 547 | 525 | -12 | .555 | .994 | .993 | 0 | 0 | 1 | 1 | 0 |
| 8 | 3 | 195 | 656 | 256 | .483 | .983 | .995 | .987 | 0 | 1 | 1 | 1 |
| 9 | 644 | 603 | 657 | 621 | .995 | .994 | .995 | .994 | 1 | 1 | 1 | 1 |
| 10 | 524 | 150 | 692 | 84 | .993 | .979 | .995 | .963 | 1 | 1 | 1 | 1 |
| 11 | 665 | 707 | 421 | 57 | .995 | .995 | .992 | .946 | 1 | 1 | 1 | 1 |

Altruisti parziali vs Egoisti nietzschiani

| Agent | R | | | w | | | S | | |
|-------|-----|----|-----|------|------|------|---|---|---|
| 1 | 1 | 1 | -29 | .238 | .238 | 0 | 0 | 1 | 0 |
| 2 | 1 | 1 | 1 | .238 | .238 | .238 | 1 | 0 | 1 |
| 3 | 2 | -1 | 1 | .384 | 0 | .238 | 0 | 0 | 1 |
| 4 | -20 | 1 | -6 | 0 | .238 | 0 | 0 | 0 | 0 |

Egoisti nietzschiani vs Altruisti parziali

| Agent | R | | | | W | | | | S | | | |
|-------|-----|----|-----|-----|------|------|------|------|---|---|---|---|
| 12 | -13 | -3 | -23 | 1 | 0 | 0 | 0 | .238 | 0 | 0 | 0 | 1 |
| 13 | -8 | 2 | 2 | -19 | 0 | .384 | .384 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | -4 | -1 | 1 | .238 | 0 | 0 | .238 | 1 | 0 | 0 | 0 |

Altruisti benthamiani vs Egoisti nietzschiani

| Agent | R | | | w | | | S | | |
|-------|-----|-----|-----|------|------|------|---|---|---|
| 5 | -9 | -6 | 3 | 0 | 0 | .483 | 0 | 0 | 1 |
| 6 | 3 | 3 | -11 | .483 | .483 | 0 | 1 | 0 | 0 |
| 7 | 1 | -11 | 3 | .238 | 0 | .483 | 0 | 0 | 1 |
| 8 | -15 | 3 | 3 | 0 | .483 | .483 | 0 | 1 | 1 |
| 9 | 3 | 3 | 3 | .483 | .483 | .483 | 1 | 1 | 1 |
| 10 | -1 | 3 | -8 | 0 | .483 | 0 | 0 | 1 | 0 |
| 11 | 3 | 2 | -8 | .483 | .384 | 0 | 0 | 0 | 0 |

Egoisti nietzschiani vs Altruisti benthamiani

| Agent | R | | | | | | | W | | | | | | |
|-------|-----|-----|-----|----|-----|---|-----|------|------|------|------|---|------|------|
| 12 | 1 | -15 | 1 | 2 | -18 | 1 | -21 | .238 | 0 | .238 | .384 | 0 | .238 | 0 |
| 13 | 1 | -7 | 1 | -2 | -13 | 1 | 2 | .238 | 0 | .238 | 0 | 0 | .238 | .384 |
| 14 | -13 | 2 | -26 | 0 | -3 | 1 | 1 | 0 | .384 | 0 | 0 | 0 | .238 | .238 |

| S | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |

Altruisti parziali vs Egoisti posizionalisti

| Agents | R | | | | w | | | | S | | | |
|--------|---|---|---|---|------|------|------|------|---|---|---|---|
| 1 | 1 | 2 | 1 | 2 | .238 | .384 | .238 | .384 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 1 | 1 | .238 | .238 | .238 | .238 | 1 | 0 | 1 | 1 |
| 3 | 1 | 1 | 2 | 1 | .238 | .238 | .384 | .238 | 1 | 0 | 0 | 1 |
| 4 | 1 | 1 | 1 | 2 | .238 | .238 | .238 | .384 | 0 | 1 | 1 | 0 |

Egoisti posizionalisti vs Altruisti parziali

| Agent | R | | | | w | | | | S | | | |
|-------|---|----|-----|-----|------|------|------|------|---|---|---|---|
| 15 | 8 | 18 | -18 | -12 | .714 | .849 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 3 | 20 | 0 | 10 | .483 | .862 | 0 | .757 | 0 | 0 | 0 | 0 |
| 17 | 6 | -7 | -31 | -20 | .652 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 6 | 11 | 32 | -12 | .652 | .774 | .909 | 0 | 0 | 0 | 0 | 0 |

Altruisti benthamiani vs Egoisti posizionalisti

| Agents | R | | | | w | | | | S | | | |
|--------|---|---|---|---|------|------|------|------|---|---|---|---|
| 5 | 3 | 3 | 3 | 3 | .483 | .483 | .483 | .483 | 0 | 0 | 0 | 1 |
| 6 | 3 | 3 | 3 | 3 | .483 | .483 | .483 | .483 | 1 | 0 | 0 | 1 |
| 7 | 3 | 3 | 3 | 3 | .483 | .483 | .483 | .483 | 0 | 0 | 0 | 1 |
| 8 | 4 | 4 | 3 | 3 | .555 | .555 | .483 | .483 | 0 | 0 | 1 | 0 |
| 9 | 3 | 3 | 4 | 4 | .483 | .483 | .555 | .555 | 0 | 1 | 0 | 0 |
| 10 | 3 | 3 | 4 | 3 | .483 | .483 | .555 | .483 | 1 | 0 | 0 | 0 |
| 11 | 4 | 4 | 3 | 4 | .555 | .555 | .483 | .555 | 0 | 0 | 1 | 0 |

Egoisti posizionalisti vs Altruisti benthamiani

| Agent | R | | | | | | | w | | | | | | |
|-------|-----|-----|-----|---|-----|-----|-----|---|------|------|------|------|------|------|
| 15 | 0 | -21 | 48 | 3 | -16 | -4 | -12 | 0 | 0 | .937 | .483 | 0 | 0 | 0 |
| 16 | -15 | -20 | -3 | 9 | 23 | 16 | -29 | 0 | 0 | 0 | .737 | .877 | .833 | 0 |
| 17 | -6 | 6 | 1 | 3 | -9 | -23 | -16 | 0 | .652 | .238 | .483 | 0 | 0 | 0 |
| 18 | -19 | 0 | -21 | 2 | -1 | -8 | 19 | 0 | 0 | 0 | .384 | 0 | 0 | .855 |

| S | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Egoisti nietzschiani vs Egoisti posizionalisti

| Agent | R | | | | w | | | | S | | | |
|-------|---|---|---|---|------|------|------|------|---|---|---|---|
| 12 | 1 | 1 | 2 | 2 | .238 | .238 | .384 | .384 | 0 | 1 | 0 | 0 |
| 13 | 1 | 1 | 2 | 1 | .238 | .238 | .384 | .238 | 1 | 1 | 0 | 1 |
| 14 | 1 | 1 | 1 | 2 | .238 | .238 | .238 | .384 | 0 | 1 | 0 | 0 |

Egoisti posizionalisti vs Egoisti nietzschiani

| Agents | R | | | w | | | S | | |
|--------|-----|----|----|------|------|------|---|---|---|
| 15 | -18 | 22 | 26 | 0 | .873 | .890 | 0 | 0 | 0 |
| 16 | 24 | 13 | 2 | .882 | .802 | .384 | 0 | 0 | 0 |
| 17 | 20 | 4 | -6 | .862 | .555 | 0 | 0 | 0 | 0 |
| 18 | 6 | 4 | 10 | .652 | .555 | .757 | 0 | 0 | 0 |

Egoisti puri vs Altruisti rawlsiani

| Agent | R | | | | | | | | w | | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 27 | 324 | 371 | 334 | 328 | 348 | 342 | 356 | 344 | 990 | 991 | 990 | 990 | 990 | 990 | 991 | 990 |
| 28 | 349 | 323 | 357 | 339 | 357 | 353 | 353 | 359 | 990 | 990 | 991 | 990 | 991 | 991 | 991 | 991 |
| 29 | 366 | 380 | 339 | 380 | 363 | 354 | 294 | 317 | 991 | 991 | 990 | 991 | 991 | 991 | 989 | 990 |
| 30 | 331 | 323 | 368 | 342 | 356 | 329 | 318 | 343 | 990 | 990 | 991 | 990 | 991 | 990 | 990 | 990 |

| S | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Altruisti rawlsiani vs Egoisti puri

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 19 | 363 | 330 | 326 | 342 | .991 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 20 | 365 | 332 | 394 | 336 | .991 | .990 | .991 | .990 | 0 | 0 | 0 | 0 |
| 21 | 355 | 352 | 337 | 361 | .991 | .990 | .990 | .991 | 0 | 0 | 0 | 0 |
| 22 | 318 | 358 | 389 | 322 | .990 | .991 | .991 | .990 | 0 | 0 | 0 | 0 |
| 23 | 369 | 373 | 340 | 324 | .991 | .991 | .990 | .990 | 0 | 0 | 0 | 0 |
| 24 | 372 | 347 | 351 | 330 | .991 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 25 | 349 | 333 | 349 | 338 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 26 | 336 | 346 | 314 | 356 | .990 | .990 | .989 | .991 | 0 | 0 | 0 | 0 |

Egoisti posizionalisti vs Altruisti rawlsiani

| Agent | R | | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
| 15 | 333 | 340 | 343 | 346 | 336 | 320 | 326 | 320 |
| 16 | 340 | 368 | 346 | 357 | 330 | 321 | 320 | 354 |
| 17 | 339 | 377 | 344 | 350 | 342 | 353 | 361 | 357 |
| 18 | 344 | 318 | 343 | 332 | 328 | 367 | 327 | 362 |

| w | | | | | | | |
|------|------|------|------|------|------|------|------|
| .990 | .990 | .990 | .990 | .990 | .990 | .990 | .990 |
| .990 | .991 | .990 | .991 | .990 | .990 | .990 | .991 |
| .990 | .991 | .990 | .990 | .990 | .991 | .991 | .991 |
| .990 | .990 | .990 | .990 | .990 | .991 | .990 | .991 |

| S | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Altruisti rawlsiani vs Egoisti posizionalisti

| Agent | IR | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 19 | 321 | 326 | 331 | 328 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 20 | 335 | 346 | 350 | 337 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 21 | 341 | 346 | 350 | 334 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 22 | 349 | 391 | 347 | 343 | .990 | .991 | .990 | .990 | 0 | 0 | 0 | 0 |
| 23 | 339 | 325 | 331 | 328 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 24 | 344 | 327 | 382 | 358 | .990 | .990 | .991 | .991 | 0 | 0 | 0 | 0 |
| 25 | 326 | 317 | 337 | 342 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 26 | 335 | 350 | 354 | 352 | .990 | .990 | .991 | .990 | 0 | 0 | 0 | 0 |

Egoisti posizionalisti vs Egoisti puri

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 15 | 348 | 362 | 339 | 336 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 16 | 330 | 351 | 363 | 382 | .990 | .990 | .990 | .990 | 0 | 0 | 0 | 0 |
| 17 | 305 | 379 | 346 | 319 | .989 | .991 | .990 | .990 | 0 | 0 | 0 | 0 |
| 18 | 354 | 350 | 361 | 389 | .991 | .990 | .991 | .990 | 0 | 0 | 0 | 0 |

Egoisti puri vs Egoisti posizionalisti

| Agent | R | | | | w | | | | S | | | |
|-------|-----|-----|-----|-----|------|------|------|------|---|---|---|---|
| 27 | 358 | 357 | 329 | 375 | .991 | .991 | .990 | .991 | 0 | 0 | 0 | 0 |
| 28 | 337 | 358 | 359 | 326 | .990 | .991 | .991 | .990 | 0 | 0 | 0 | 0 |
| 29 | 332 | 357 | 341 | 325 | .990 | .991 | .990 | .990 | 0 | 0 | 0 | 0 |
| 30 | 345 | 385 | 335 | 372 | .990 | .991 | .990 | .990 | 0 | 0 | 0 | 0 |

Altruisti parziali vs Egoisti puri

| Agent | R | | | | w | | | | S | | | |
|-------|---|---|---|---|------|------|------|------|---|---|---|---|
| 1 | 1 | 1 | 1 | 2 | .238 | .238 | .238 | .384 | 1 | 1 | 1 | 0 |
| 2 | 1 | 2 | 1 | 1 | .238 | .384 | .238 | .238 | 1 | 0 | 0 | 0 |
| 3 | 2 | 1 | 1 | 1 | .384 | .238 | .238 | .238 | 0 | 1 | 1 | 0 |
| 4 | 1 | 2 | 2 | 1 | .238 | .384 | .384 | .238 | 0 | 0 | 0 | 1 |

Egoisti puri vs Altruisti parziali

| Agent | R | | | | w | | | | S | | | |
|-------|-----|----|-----|-----|------|------|------|------|---|---|---|---|
| 27 | -13 | 16 | 0 | -14 | 0 | .833 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 6 | 11 | 1 | 8 | .652 | .774 | .238 | .714 | 0 | 0 | 0 | 0 |
| 29 | -30 | -3 | 17 | 26 | 0 | 0 | .841 | .890 | 0 | 0 | 0 | 0 |
| 30 | -21 | 9 | -16 | 11 | 0 | .737 | 0 | .774 | 0 | 0 | 0 | 0 |

Altruisti benthamiani vs Egoisti puri

| Agent | R | | | | w | | | | S | | | |
|-------|---|---|---|---|------|------|------|------|---|---|---|---|
| 5 | 4 | 3 | 3 | 4 | .555 | .483 | .483 | .555 | 0 | 1 | 1 | 0 |
| 6 | 3 | 3 | 3 | 4 | .483 | .483 | .483 | .555 | 0 | 1 | 1 | 0 |
| 7 | 4 | 4 | 4 | 4 | .555 | .555 | .555 | .555 | 0 | 0 | 0 | 0 |
| 8 | 4 | 3 | 3 | 4 | .555 | .483 | .483 | .555 | 0 | 0 | 1 | 0 |
| 9 | 3 | 4 | 3 | 4 | .483 | .555 | .483 | .555 | 1 | 0 | 0 | 0 |
| 10 | 3 | 3 | 3 | 4 | .483 | .483 | .483 | .555 | 1 | 1 | 1 | 0 |
| 11 | 3 | 4 | 3 | 3 | .483 | .555 | .483 | .483 | 0 | 0 | 1 | 0 |

Egoisti puri vs Altruisti benthamiani

| Agent | R | | | | | | |
|-------|----|----|----|-----|-----|----|----|
| 27 | 25 | 4 | 5 | 0 | -11 | -4 | -6 |
| 28 | 29 | 6 | 24 | -19 | 9 | 4 | 22 |
| 29 | 6 | 12 | 11 | 22 | 16 | 13 | -5 |
| 30 | -8 | 21 | 13 | 21 | 2 | 21 | -4 |

| w | | | | | | |
|------|------|------|------|------|------|------|
| .886 | .555 | .609 | 0 | 0 | 0 | 0 |
| 9 | .652 | .882 | 0 | .737 | .555 | .873 |
| .652 | .789 | .774 | .873 | .833 | .802 | 0 |
| 0 | .867 | .802 | .867 | .384 | .867 | 0 |

| S | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Egoisti nietzschiani vs Egoisti puri

| Agent | R | | | | w | | | | S | | | |
|-------|---|---|---|---|------|------|------|------|---|---|---|---|
| 12 | 1 | 2 | 1 | 2 | .238 | .384 | .238 | .384 | 1 | 0 | 1 | 0 |
| 13 | 2 | 1 | 2 | 1 | .384 | .238 | .384 | .238 | 0 | 0 | 0 | 1 |
| 14 | 1 | 1 | 2 | 1 | .238 | .238 | .384 | .238 | 1 | 1 | 0 | 0 |

Egoisti puri vs Egoisti nietzschiani

| Agents | R | | | w | | | S | | |
|--------|-----|----|-----|------|------|------|---|---|---|
| 15 | -1 | 1 | 3 | 0 | .238 | .483 | 0 | 0 | 0 |
| 16 | 10 | 4 | 9 | .757 | .555 | .737 | 0 | 0 | 0 |
| 17 | -3 | 3 | 26 | 0 | .483 | .890 | 0 | 0 | 0 |
| 18 | -43 | 20 | -14 | 0 | .862 | 0 | 0 | 0 | 0 |

Egoisti nietzschiani vs Altruisti Rawlsiani

| Agent | R | | | | | | | |
|-------|---|---|---|---|---|---|---|---|
| 12 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 |
| 13 | 1 | 1 | 1 | 0 | 0 | 2 | 0 | 1 |
| 14 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 1 |

| w | | | | | | | |
|------|------|------|------|------|------|------|------|
| .238 | .238 | .384 | .238 | .238 | .238 | .238 | .384 |
| .238 | .238 | .238 | 0 | 0 | .384 | 0 | .238 |
| .238 | .238 | .384 | .384 | .238 | .384 | .384 | .238 |

| S | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |

Altruisti rawlsiani vs Egoisti nietzschiani

| Agent | R | | | w | | | S | | |
|-------|-----|-----|-----|------|------|------|---|---|---|
| 19 | 1 | -25 | 7 | .238 | 0 | .686 | 0 | 0 | 0 |
| 20 | -11 | -3 | 6 | 0 | 0 | .652 | 0 | 0 | 0 |
| 21 | -7 | -12 | -26 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | -25 | 5 | 3 | 0 | .609 | .483 | 0 | 1 | 0 |
| 23 | 7 | 15 | -2 | .686 | .824 | 0 | 0 | 0 | 0 |
| 24 | -14 | -26 | 19 | 0 | 0 | .855 | 0 | 0 | 0 |
| 25 | 2 | 41 | -24 | .384 | .927 | 0 | 0 | 0 | 0 |
| 26 | -4 | 20 | 1 | 0 | .862 | .238 | 0 | 0 | 0 |

Altruisti parziali vs Altruisti rawlsiani

| Agent | | R | | | | | | | |
|-------|--|---|---|---|---|---|---|---|---|
| 1 | | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| 2 | | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| 3 | | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 0 |
| 4 | | 1 | 0 | 2 | 2 | 1 | 1 | 2 | 0 |

| w | | | | | | | |
|------|------|------|------|------|------|------|------|
| 0 | 0 | 0 | 0 | 0 | .384 | 0 | .238 |
| .238 | .238 | .384 | .384 | .238 | .238 | .238 | .238 |
| .238 | .238 | .238 | 0 | .384 | .384 | .238 | 0 |
| .238 | 0 | .384 | .384 | .238 | .238 | .384 | 0 |

| S | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Altruisti rawlsiani vs Altruisti parziali

| Agent | IR | | | | w | | | | S | | | |
|-------|-----|----|----|-----|------|------|------|------|---|---|---|---|
| 19 | 4 | 23 | 13 | -20 | .555 | .877 | .802 | 0 | 0 | 0 | 0 | 0 |
| 20 | 15 | 6 | 3 | 26 | .824 | .652 | .483 | .890 | 1 | 0 | 0 | 1 |
| 21 | 13 | 23 | 9 | 13 | .802 | .877 | .737 | .802 | 1 | 0 | 0 | 0 |
| 22 | 9 | -9 | 7 | -17 | .737 | 0 | .686 | 0 | 1 | 0 | 1 | 0 |
| 23 | 19 | 7 | 23 | 13 | .855 | .686 | .877 | .802 | 1 | 0 | 0 | 0 |
| 24 | -3 | 2 | 22 | -15 | 0 | .384 | .873 | 0 | 0 | 0 | 0 | 0 |
| 25 | 14 | 28 | 0 | 1 | .813 | .897 | 0 | .238 | 1 | 0 | 0 | 0 |
| 26 | -17 | -9 | 3 | 30 | 0 | 0 | .483 | .903 | 0 | 0 | 0 | 0 |

Altruisti benthamiani vs Altruisti rawlsiani

| Agents | R | | | | | | | |
|--------|---|---|---|---|---|---|---|---|
| 5 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 |
| 6 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 7 | 4 | 3 | 3 | 2 | 3 | 3 | 4 | 3 |
| 8 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 |
| 9 | 3 | 4 | 4 | 3 | 3 | 2 | 4 | 2 |
| 10 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 |
| 11 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 |

| w | | | | | | | |
|------|------|------|------|------|------|------|------|
| .483 | .483 | .483 | .555 | .555 | .483 | .483 | .483 |
| .483 | .384 | .483 | .483 | .483 | .483 | .483 | .483 |
| .555 | .483 | .483 | .384 | .480 | .483 | .555 | .483 |
| .483 | .483 | .483 | .555 | .483 | .483 | .483 | .483 |
| .483 | .555 | .555 | .483 | .483 | .384 | .555 | .384 |
| .483 | .483 | .483 | .555 | .555 | .483 | .483 | .483 |
| .483 | .384 | .483 | .384 | .483 | .384 | .483 | .384 |

| s | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Altruisti rawlsiani vs Altruisti benthamiani

| Agent | R | | | | | | |
|-------|-----|-----|-----|-----|-----|-----|-----|
| 19 | -19 | 21 | 4 | 9 | -3 | 29 | 0 |
| 20 | 1 | 4 | 13 | -10 | -7 | -5 | 9 |
| 21 | -4 | 2 | -24 | 0 | 14 | -19 | -6 |
| 22 | -22 | 2 | 6 | -4 | -14 | -9 | 34 |
| 23 | 9 | 0 | 1 | 16 | -8 | -31 | -17 |
| 24 | -2 | -12 | 10 | -3 | 18 | -7 | 5 |
| 25 | -7 | 2 | -1 | -5 | -10 | -19 | 29 |
| 26 | 13 | 23 | 4 | -28 | 16 | 21 | 5 |

| w | | | | | | | | s | | | | | | |
|------|------|------|------|------|------|------|--|---|---|---|---|---|---|---|
| 0 | .867 | .555 | .737 | 0 | .9 | 0 | | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| .238 | .555 | .802 | 0 | 0 | 0 | .737 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | .384 | 0 | 0 | .813 | 0 | 0 | | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | .384 | .652 | 0 | 0 | 0 | .913 | | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| .737 | 0 | .238 | .833 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | .757 | 0 | .849 | 0 | .609 | | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | .384 | 0 | 0 | 0 | 0 | .9 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| .802 | .877 | .555 | 0 | .833 | .867 | .609 | | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

APPENDIX B

Dynamics of averages w among different types

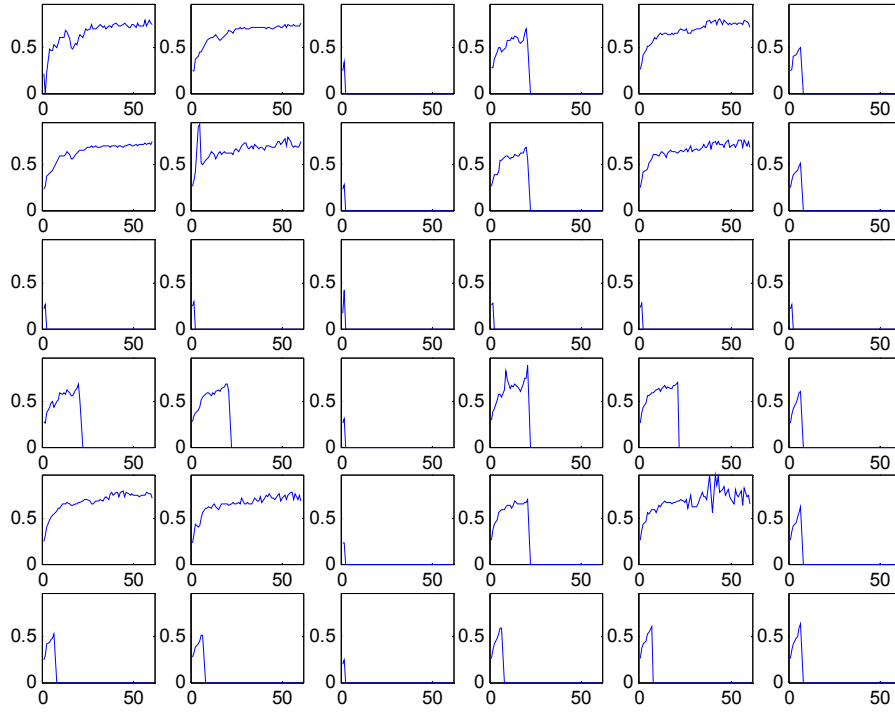


Figure 5

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