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Does Sharing Values Lead to Cooperation?

A Similarity-based Investigation

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Abstract

Understanding what motivates and fosters collective actions has major implications in the regulation and design of public policies, in the governance and management of organizations and has long attracted the interests of scholars and practitioners in economics and business. If trust and reciprocity certainly qualify as possible drivers of collective actions in some specific environments, as the uncertainty regarding the interaction structure increases, they are not likely to be able to explain the emergence of stable interacting groups. This paper deals with how groups of agents emerge in a dynamic contest characterized by lack of formal structure and uncertainty regarding the possible individual outcomes. Through the development of a stylized agent-based model we aim to show how similarity in values can be a successful driver for cooperation. A second-version of the model, where memory of past interactions has a role, introduces further dynamics and is able to create successful and relatively stable groups. The model nicely fits some stylized facts and sheds some light on potential avenues for the resolution of social dilemmas, such as contribution to public goods, addressing the role of perceived similarity in nurturing the cooperative process.

Keywords: Similarity, Social trust, Cooperation, Groups.

JEL Classification Numbers: B41; D74; D85.

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1 Introduction

The emergence of cooperation among utility-maximizing individuals is a long-standing puzzle for scholars, who have provided different explanations, often based on the possibility for reciprocation either directly towards the cooperator - direct reciprocity Axelrod (1984) - or towards other agents in the environment - indirect reciprocity [Nowak and Sigmund 1998, 2005]. Nevertheless, in real life, reciprocation is not always possible or sufficient to motivate the choice to commit individual resources towards a common pool that might even benefit perfect strangers.

In this paper we offer an alternative explanation for the emergence of cooperation among unrelated individuals based on the preference for similarity. The model we present fits a series of interesting real-life situations. For instance, consider joining a non-profit association contributing voluntary work to specific groups or projects. Individuals commit a fraction of their time independently from the amount of hours actually expended by other members. Moreover, there is no possibility to disentangle the effect of individual effort on the overall project.

In this case, the decision to cooperate is based on considerations such as the desire to do something good for the society that enters as an immaterial component in individuals' utility function. Nevertheless, choosing whom to cooperate with is often shaped by the possibility to join a group of people with whom one feels affinity or respect - for the pleasure of being with people one *likes*. Homophily is the tendency of social actors to form ties with other actors similar to themselves and can be widely observed. People are influenced by the choices of their peers in the selection of voluntary-work institution to join, due to the fact that it is easier to know and trust the choices of the people near us, especially when one shares values or views with them McPherson *et al.* (2001).

Another useful example to explore the dynamics of the emergence of cooperation is represented by group projects in university: when a project is graded on a group basis, there is no possibility to disentangle individual effort, but if everyone slacks, the whole group will suffer. Moreover, in the choice of group members, especially in large groups when people do not know each other well, perceived affinity or similarity in views (maybe inferred from participation to group discussions) may play an important role. Differently from the above example, group projects force individuals to commit individual resources (material or cognitive). Thus, the matter discussed in this paper includes also cases in which cooperation is voluntary only in the degree of effort expended.

Another crucial aspects of these examples that will be modeled in this paper is the positive effect of similarity on the emergence of synergies among agents. For instance, two hard-working individuals will support and encourage each other in a group, leading to a final outcome even higher than the sum of the two effort levels combined. Similarly, sharing goals and ideals is crucial to perform well also in the voluntary associations example.

In this paper we describe an agent-based model for the emergence of cooperation in which agents may join or abandon one of two possible groups. This set up generalizes for instance the choice of a non-profit institution or membership to a group project for a university course. The bounds among agents are informal (i.e., the cost of joining is null

or negligible) and are solely binding for the current period. Simply calling on the mutual recognition of similar attitudes across agents and on the role of homophily in shaping individuals' utility, it is shown that cooperation can arise without resorting to reciprocity motives.

The paper is organized as follows. After an introductory section aimed at contextualizing this work within existing literature, Section 3 introduces the main concepts and the features of the model. Results are presented in Section 4, where we discuss both representative examples and aggregate data obtained running a large number of simulations. Section 5 concludes discussing specific examples of potential application of the model and suggesting directions for further extensions.

2 Literature review

Collective action is a very important driver in economics and has rightfully attracted a lot of interests from both economic theory and empirical analysis. The emergence of stable groups of like-minded agents is at the basis of the creation of institutions, of the provision of specific goods and services and in general of the progress of human society. If a strand of literature has focused more on understanding how to incentivize players to cooperate and form stable cooperative groups, there is still uncertainty regarding what fosters informal bonds that are common in everyday life in a setting of informal, unstructured interactions. When agents are not forced to join forces, which are the drivers that make them want to?

This paper is naturally framed in the context of cooperation theory and represents an attempt to move forward in the investigation regarding the motivations for cooperative actions in informal contexts, not characterized by explicit incentive mechanisms. In such environments it is not even possible to call upon direct or indirect reciprocity when interactions are sufficiently random and the probability of meeting the same person again is very low (or there is no possibility to precisely store information about previous encounters), thus making this setting a challenging and somewhat unexplored territory for both a theoretical and an empirical investigation.

As the following section will show, the formalization of the utility function used in this model features both a material and a non-material component. The latter is based on similarity and summarizes the idea of homophily as a driver of utility for the agents. This idea fits naturally in the examples provided in the introduction; for instance, being in a group with another hard-working individual is a driver of both material utility (helping out towards the completion of the group project) and non-material utility (for the pleasure of sharing the burden of working hard for the group).

A lot of empirical evidence on the role of homophily has been provided by sociological and economic literature, showing how people prefer to connect, work, build relationships and play with similar individuals. Homophily has been explored in the literature across several dimensions like race, ethnicity, sex, age, religion, education, occupation (which refer to *status homophily*) and attitudes, abilities, beliefs and aspirations (which instead describe the *value homophily*) McPherson *et al.* (2001).

Empirical evidence supports the existence and role of homophily considerations. For instance, the study of Shrum *et al.* (1988), looking at race and gender differences shows how students of US high schools build friendships mostly among their similars.

In Lincoln & Miller (1979), it is shown also how work relations are affected by a selection bias due to homophily, leading to the significant exclusion of women and non-white members within organizations. The explanation given by the authors to the homophily bias in organizational processes is that: “Social homogeneity increases ease of communication and improves predictability of behavior, values which are central to organizational culture. Thus, [homophily] is nonetheless an expression of a rationalizing process - the need to eliminate uncertainty from organizational arrangements” Lincoln & Miller (1979). In this sense, the homophily considerations enter as an immaterial component in the utility function of organizations.

Studies focused on value homophily have shown also that attitudes, deep beliefs, and values similarity lead to attraction and interaction Huston & Levinger (1978), as for example, in the tendency of adults to associate with those with similar political orientations Verbrugge (1977).

The idea on which this paper is built draws from the possibility that group formation may be motivated by the mutual recognition of some shared individual features, a process of *similarity identification* able to overcome the individual tendency to refuse cooperation when the individual return to cooperative behavior is uncertain, perhaps because of different (or unknown) initial capabilities to contribute materially to the joint project.

The idea that similarity may in some ways foster cooperation is not new, either in experimental economics or in agent-based literature. In the former, it stems from an evolution of the experimentally founded fact that group identity or other forms of shared identity do support cooperative behavior among members (see Akerlof & Kranton (2000) for a seminal introduction to the role of identity in decision making) and increased uncooperative behavior among non-members (referred to as the in-group-out-group bias in Chen & Li (2009) and Sosis & Ruffle (2006)).

Similarity has been studied in the context of another important game used to model interactions in which both defection and cooperation motives may exist: the prisoner’s dilemma (PD), which represents a classic game in which individual and social motives diverge. The PD game was the first testing ground for the similarity argument Rapoport (1960) according to which “rational players should acknowledge the symmetry in their situation and the similarity of their goals, [...] hence considering only similar choices” Fischer (2009). This version of the symmetry argument has been later extended to its continuous version, allowing for different degrees of dependence between subjects, making players’ choices conditional upon the extent of similarity. In a context like the one defined in this work, in which there is no room for reputation, little or imperfect memory of past behavior and where in general the probability of interacting with the same partners is low, the recognition of similarity and group identity may be more difficult. Thus, it is not possible to extend the results referred to above to a context of more informal interactions. In this context of trust without possibility for reciprocation another form of similarity can play a role in fostering cooperation, namely, *salient value similarity*. This concept has been

developed in the risk management literature, where it is used in a slightly different way, but its main message is carried over to the present work: salient value similarity has been consistently found as a precursor of *social trust* - trust regarding the institutions we live in.

[Poortinga and Pidgeon, 2006] describes salient value similarity as based on the idea that people use heuristics based on perceived similarities while making choices in complex environments, basing their judgments on the feeling that other persons or organizations have the same understanding of a specific situation. According to Siegrist *et al.* (2000) “salient values consist of the individual’s sense of what the important goals (ends) and or processes (means) are that should be followed in a particular situation” and are “an aspect of the individuals understanding of the meaning of a specific situation”.

The idea of salient values will be introduced in this work as the carrier of individual characteristics on which cooperation can be built, alongside another parameter, called *general values* representing less stringent individual features that also affect, although to a minor degree, the perceived similarity across subjects.

As previously mentioned, the possibility of using similarity as a driver for cooperation is part of a relevant strand of literature devoted to agent-based models Edmonds (2006); Kim (2010). The evolutionary appeal of similarity has been established in the work of Riolo *et al.* (2001) and subsequent works by the same authors, which have shown in an evolutionary model with inheritable tags, that similarity can indeed breed cooperation.

The introduction of a parameter summarizing general values, which typically cannot overcome the importance of extreme differences in salient values, is consistent with previous formalization of similarity found for instance in the mentioned Riolo *et al.* (2001), thus reinforcing the link between this modeling exercise and the agent-based literature.

Moreover, differently from their evolving tags, general values do not simply take the value of the parameter of the person they are interacting with, but are used to smooth out partial differences in values in the basic model, and as means to evolve further similarity within the group in the extended version.

The examination of the conflict between bearing the risk of a cooperative action (joining a group) and pursuing individual goals (refusing to join any group and keeping one’s individual payoff) offers a testing ground for different theories and interaction mechanisms in an unstructured setting covered for instance in *The Tribute Game* of Axelrod (in “The Complexity of Cooperation”, Axelrod (1997)), which grasps an important feature of multi-person interactions in unstructured settings, namely, the conflict between the risk of being exploited and the higher benefit accruing from joining a coalition despite this risk. Consistently with the above-mentioned work, this paper also shows that the dominant group is not always stable, as it can be invaded and ultimately destroyed by invading “mutants”.

Lastly, it is important to mention that the features of the groups that the model reproduces can be reconciled with the description of a very important concept in social science - *the political coalition*.

In particular, the definition given by the organizational literature is especially relevant to this work. Here, the term *coalition* has been used increasingly since the late 1960’s with the seminal work in March (1962), [Cyert and March, 1963], who were the first to

introduce the idea of coalition formation within organization as a response to the existence of possible conflicts over purposes.

The term coalition appears in a variety of different literatures from political science to management, passing by more standard game theoretic approaches and social psychology.

The groups that emerge in our model can be described as resulting from voluntary interaction, deliberately formed without a formal structure -as there are no entry or exit costs- and based on mutual recognition of membership -given by the similarity perception. Interestingly, this resembles very closely the definition of political coalition, as in Stevenson *et al.* (1985).

Political coalitions in organization theory are also defined as having a clear shared purpose, normally aimed at influencing some external factor and require concerted action on the part of the members of the coalitions. This represents an interesting direction for future extensions of the model presented in this paper.

3 The model

In a nutshell, the model can be described as follows. A fixed number of heterogeneous agents are characterized by salient and general values. Agents consider the former as essential principles that are not subject to modifications or adaptation. General values, instead, are considered as less relevant issues. Both values considered, salient and general, are only those strictly related to the specific goal agents have in joining or not the group. Groups are formed by agents that share their endowment and give members a utility that increases with the size (the sum of endowments) and the overall similarity of the group.

In the presentation of the model, capital letters are assumed to denote quantities that stay constant, whereas small letters are assumed to denote variables that change with time.

Assume K agents have N salient values $S_{ij}, i = 1, \dots, K, j = 1, \dots, N$ and are given a non-perishable endowment $E_i, i = 1, \dots, K$. The stable, on-off nature of the salient values is stressed by supposing that they are drawn from the binary set $\{0, 1\}$ and denote with $\bar{S}_i = (S_{i1}, S_{i2}, \dots, S_{iN})$ the vector of salient values of the i th subject. Agents are also equipped with general values that are represented by a real variable $0 \leq V_i \leq \epsilon, i = 1, \dots, K$ and ϵ is a scale parameter.

At any stage, agents can decide to stay alone or join one of the two groups, which can be thought of as interacting associations, deliberately formed outside a formal structure, with mutual recognition of membership.

Each agent at time t can be a member of the first or second group or be on his own. Let $\mathcal{G}_t^1, \mathcal{G}_t^2, \mathcal{G}_t^0$ be a partition of $\{1, \dots, K\}$ that keeps track of the choice of the agents at any given time t . In other words, $i \in \mathcal{G}_t^w$ if and only if the i th agent is in the w th group at time t (being the "zero-group" the set of people that decided to stay out of either group).

The participation to one group yields members utility through two components. The first one comes from the equal redistribution of the total endowment of the members of the group; the second is a non-material component that depends on the synergic interaction of the members that, in turn, is a function of the overall similarity of the characteristics of

the agents (it can be thought as the benefit coming from homophily preferences).

Define a similarity function between agents i_1 and i_2 as

$$sim(i_1, i_2) = \sum_{j=1}^N \mathbf{1}(S_{i_1,j} = S_{i_2,j}) - \frac{N}{2} - (V_{i_1} - V_{i_2})^2.$$

The first term in the similarity counts the number of equal salient values; the second term subtracts $N/2$, so that the sum of the first two terms is nonnegative when at least 50% of the salient values are concordant; finally, the third term is the squared difference of the general values of the agents.

It is worth noting that the two parameters N and ϵ are related to each other: for a fixed N , a larger ϵ increases the importance of general values with respect to the salient ones. This formulation of similarity allows to model the idea that people have homophily preferences and like being in a group with like-minded individuals, where this like-mindedness is measured along the two given dimensions of values -general and salient.

In our formulation, similarity increases with common salient values but (exclusively) decreases with more different general values. Hence, the higher ϵ with respect to N , the less our agents will be willing to collaborate with other individuals, even in the presence of some consensus on salient matters.

As we will see later on, for our purpose, we set the parameters in such a way that even the complete disagreement on general values between two agents is more than compensated by the agreement on all salient values. This choice has been made to stress the relevance of salient values in the computation of similarity and, consequently, in terms of utility.

The utility of agent $i \in \mathcal{G}_t^w$, $w = 1, 2$ is then:

$$p_{it}^w = \frac{1}{|\mathcal{G}_t^w|} \sum_{i \in \mathcal{G}_t^w} E_i + \sum_{k \in \mathcal{G}_t^w, k \neq i} sim(k, i).$$

The two terms of the payoff incorporate on the one side, the fact that in a group “the more, the merrier”; on the other hand, it is of concern not only how many members there are, but who they are. The first term, $\frac{1}{|\mathcal{G}_t^w|} \sum_{i \in \mathcal{G}_t^w} E_i$, redistributes equal shares of the total amount of resources that all agents bring to a group: the decision to take part in a project implies an effort on the part of individuals and the risk of sharing one’s own endowment to build the common pie that will be equally divided among all the participants. The second term, $\sum_{k \in \mathcal{G}_t^w, k \neq i} sim(k, i)$, adds to each agent’s utility the total sum of the pairwise similarities. For each agent, this total sum can be considered as a measure of the overall coherence of the group, that results in a higher return in terms of synergies for all the members.

If $i \in \mathcal{G}_t^0$, the agent prefers to stay alone and his payoff for the current period is simply his own endowment E_i , i.e., $p_{it}^0 = E_i$.

The option to stay out, to join or leave one of the two groups is available, at no cost, at any time t . This setting represents the needed informality to model groups, defined without a formal structure (possibly acting within a more regulated environment). Agents’ decisions

will be based on partial information that is gathered at each time by randomly matching some members of groups (including agents “out” of any group). Hence, groups are dynamic structures that evolve and are shaped by in-group similarity and by the actions driven by the randomness of the matching process.

Being aware that utilities are stochastic and dependent on the fluctuating composition of the groups, at each time, every agent randomly and independently meets P other agents, exchanging information about the size of groups, the endowment and the similarity of the matches. This data is used to compute a myopic estimate of the utility of being in a given group.

Agents are myopic in the sense that they assume that the P agents they met are representative, in terms of values and endowment, of their whole group (i.e., they believe the sample has the same average value of similarity and the same average endowment of their group).

In particular, fix i and assume that $\mathcal{A}_t$ is the set of P agents that meet i . Let

$$\begin{aligned}\mathcal{A}_t^1 &= \mathcal{A}_t \cap \mathcal{G}_t^1, \\ \mathcal{A}_t^2 &= \mathcal{A}_t \cap \mathcal{G}_t^2, \\ \mathcal{A}_t^0 &= \mathcal{A}_t \cap \mathcal{G}_t^0,\end{aligned}$$

be the subsets of matched agents that are in three $\mathcal{G}_t$, where we drop the reference to i to simplify notation. The agent works out the average endowment of the members of each set and the average similarity with them. The aforementioned quantities $\hat{e}_t^w$ and $\hat{m}_t^w$ for $w = 1, 2$ are given by

$$\begin{aligned}\hat{e}_t^w &= \frac{1}{|\mathcal{A}_t^w|} \sum_{j \in \mathcal{A}_t^w} E_j; \\ \hat{m}_t^w &= \frac{1}{|\mathcal{A}_t^w|} \sum_{j \in \mathcal{A}_t^w} sim(i, j).\end{aligned}$$

Using this information, the i th agent can myopically estimate the utility that would result if he switches to one group, assuming the sample averages are representative of the whole group. Hence, estimated utilities in the three possible situations are

$$\pi_t^w = \hat{e}_t^w + |\mathcal{G}_t^w| \hat{m}_t^w, w = 1, 2$$

and

$$\pi_t^0 = E_i.$$

The utility of choosing to stay out is set equal to E_i , thus the always available exit option from an informal group corresponds to the sure alternative of keeping one’s initial endowment. The reason why individual endowment is not affected positively or negatively by the participation (or lack thereof) in a group lies in the informality of the environment.

In fact, participating in a group has no direct nor indirect costs, which can deteriorate initial endowments.

Nevertheless, agents exiting from a group are not able to keep the gains of the previous period, returning exactly to their initial state. This modeling choice wants to emphasize the fact that the benefits of being in a group come from the synergies among members and their pooling of resources. An agent who decides to stay on his own, exiting the group, can only count on its own resources.

At the end of period t , agent i chooses to move to another group or to abandon altogether any group based on the highest estimated utility. In more detail, agent i th will move to group w at $t + 1$ if

$$\pi_t^w = \max\{\pi_t^1, \pi_t^2, \pi_t^0\}.$$

This simple setup, called *basic* in what follows, can be used to computationally study how groups emerge and evolve on the basis of the similarity in values, and test for the presence of several stylized facts in the synthetic data that can be produced.

As more refined forms of reciprocal influence among agents can be conjectured, an *extended* model can take into account memory effects. The remaining part of this section outlines this enhancement.

Agents are likely to realize that better utility estimates can be obtained by blending past measures with the novel information derived from sampling. Hence, they update a running measure of the benefits arising from participating to each group and the i th agents takes the decision to switch at time $t + 1$ based on the highest among

$$\begin{aligned} q_t^1 &= \alpha q_{t-1}^1 + (1 - \alpha)\pi_t^1 \\ q_t^2 &= \alpha q_{t-1}^2 + (1 - \alpha)\pi_t^2 \\ q_t^0 &= E_i, \end{aligned}$$

where $0 \leq \alpha \leq 1$ is a memory-related coefficient. The basic setup can immediately be recovered by setting $\alpha = 0$ and the parameter α represents agents' memory, or stickiness: when $\alpha \cong 1$, agents will compute their estimates mainly using their previous results whereas for values of α close to zero, agents will rely more on their novel information.

4 Results

This Section presents the simulation results for the basic and extended versions of the model, as described in Section 3.

It is difficult to give full account of a dynamic process like the one modeled in this paper using only static pictures and tables. Thus, selected movies and animations are available at <http://multimedia.dma.unive.it/groups/abmc/>. In this paper, results are presented in a specific instance in order to give the flavor of the main dynamics. The results of multiple simulations are then summarized in table form to provide a more comprehensive look at the average properties typically present in a large sample of groups that are generated for a given constellation of parameters' values.

Table 1 shows the reference, or benchmark, values for the parameters that define a reasonable starting point for our investigation. These values were determined by trial-and-error and then modified, one at a time, to assess the incremental effects of single parametric variations.

Name	Value	Description
K	50	Number of agents
N	2	Number of salient values
ϵ	1.0	Amplitude of general value
P	2	Number of agents sampled (in computing expected utility)
α	0.0	Memory (in estimating utility)
T	200	Periods
$\bar{E}$	10	Average initial endowment

Table 1: Parameters of the benchmark environment.

A number of 50 agents is considered, with 2 salient values and a real variable uniformly sampled in $[0, 1]$ summarizing their general values. Each run of the model lasts 200 periods and, unless stated otherwise, endowments of agents are uniformly sampled in the interval $[0.5\bar{E}, 1.5\bar{E}]$, where $\bar{E} = 10$.

4.1 The Basic Model

This Section reports results of simulations with the Basic formulation of the model. In particular, no memory is used by agents (i.e., $\alpha = 0$).

The left panel of Figure 1 depicts the time series of the number of participants belonging to each group (labeled with different colors, with green indicating individuals staying out of either group). The right panel shows the average utilities of the members at each given time.

The sizes of groups fluctuate widely: out of the 50 agents populating the model, the number of members of one group frequently goes from over 20 to well below 10.

The reason of such marked fluctuation of groups' dimension is rooted in the volatile process of gathering information and in the resulting decision to join or abandon the groups they were in. The explorative nature of the group formation process is such that, interestingly, around period 90 most agents desert groups to stay on their own, as the green line clearly shows.

The average utility of group members is not strictly related to the size of the groups, as the right panel of Figure 1 shows but, again, varies widely. While staying outside of any group yields roughly 12 on average, joining the second group around periods 50 or 150, say, produces a hefty utility close or even bigger than 20.

The left graph of Figure 2 depicts the average similarity of the members of the two groups. This quantity will be referred as *coherence* of the group in the following. Although

Figure 1: Time series of the number of members (left) and average utility (right) for each group. Black, red and green lines denote the first, second group and the number of those who stay out, respectively.

there are significant variations in the average similarity over time, there are periods, like $t = 50$ or $t = 150$, where agents are grouped into fairly homogeneous groups.

The right panel of the figure represents the salient values of the members of the first group at time 154, when its coherence peaks around 0.55. The bits are color-coded, with yellow and red denoting “1” and “0”, respectively. The picture shows that every member, at that time, shares at least one salient value (out of two) with every other peer, thus explaining the large average similarity.

A plot of the similarity matrix is a useful tool to shed further light on the dynamics of the groups, in terms of size and internal coherence. Figure 3 shows two color-coded similarity matrices, relative to periods 50 (left) and 87 (right). In the matrices, members of the first, second and stay-out group are sequentially appended, and the (i, j) entry of the matrix represents the similarity of agents i and j , with yellow (red) denoting large (small) values. The first group is then shown on the bottom-left corner of the matrix whereas the second group is usually visible in the central part of the matrix, along the main diagonal. The upper-right corner represents the agents that do not belong to any group.

The left panel shows the situation in period 50, where a homogenous second group can clearly be seen in the bright block of entries $\{(i, j) : 13 \leq i, j \leq 29\}$. The first group appears to be made of less uniform agents in the bottom-left corner, where $1 \leq i, j \leq 12$. The previous figures show that sizes at time 50 are 12 and 17, with average similarities of 0.42 and 0.65 and average utilities of 12.92 and 20.37.

Figure 2: Average similarity of the first (black) and second (red) groups (left). Salient values for group 1 members, yellow and red denoting “1” and “0”, respectively (right)

The right panel of Figure 3 displays the similarity structure at time 87 when, basically, groups are dismantled and agents are still in the way to form uniform groups. The first and second groups are barely visible despite their 14 and 11 members, the average similarities are -0.08 within both groups and, hence, the utilities are (only) 7.03 and 7.29, respectively. The difference in the two plots of Figure 3 visually confirms the general outcome that there is a remarkable time-variability in the groups that emerge in a single simulation.

Figure 4 shows the time series of average endowments of the members of the groups. Typically, the endowments of agents that join in groups are smaller than the ones belonging to agents that opt to stay out. This result, depicted in a specific instance in Figure 4, is a very robust feature of the model (also with different configurations of parameters) and nicely matches a common stylized property of groups.

4.1.1 Multiple Simulations

This section is dedicated to the description of more general features of the groups generated by the model as we change the level of some key parameters.

We run 100 independent simulations and measure the average size of both groups, labeled generically “small” and “large”, together with the average size of the set of agents that decided to stay out. Moreover, we compute the *coherence* of the groups, the fraction of times in which the largest group changes (Sw), the average endowment of members (E) and their average utility (π). The last two values are normalized with the average endowment

Figure 3: Similarity matrices at times 50 (left) and 87 (right). The hue of entry (i, j) smoothly blends from bright yellow to dark red as the similarity decreases.

of the population $\bar{E}$. When computing any time-average, we discard the first 50 periods that are possibly affected by transient initial effects.

The first parameter analyzed is P , the number of individuals each agent randomly and independently meets when computing the expected utility of joining a different group.

P		Size	Cohe	Sw	E	π
1	Small	14.65	0.12	0.26	0.93	1.00
	Large	16.74	0.18	-	0.94	1.14
	Out	18.60	-	-	1.11	1.11
2	Small	15.58	0.29	0.34	0.94	1.29
	Large	18.79	0.38	-	0.95	1.56
	Out	15.63	-	-	1.12	1.12
4	Small	16.90	0.43	0.22	0.94	1.57
	Large	21.65	0.43	-	0.96	1.79
	Out	11.45	-	-	1.14	1.14

Table 2: Time-averaged quantities for different values of P .

The first panel of Table 2 shows, for example, that when agents sample $P = 1$ peer in each period, the smallest (largest) group has an average of 14.65 (16.74) members. The group of agents that stay out is normally larger (18.60 elements) and the large group changes on average every 4 periods (26%). Moreover, members of both groups are relatively poor, as shown by their endowments which is 93 or 94% of the average endowment of the

Figure 4: Average endowment of groups members: black, red and green lines refer to the first and second group and to those who stay out.

population. The payoffs of agents belonging to either group is, however, substantially larger as they get a utility that is 100 and 114% of the average endowment of the population. Subjects that do not participate to groups are richer on average (1.11) and, by definition, get exactly the very same payoff.

The other panels show that the sizes of the groups are increasing in P . This result is likely to be related to better decisions taken by agents when a larger sample size is allowed for. This interpretation is corroborated by the higher utility for members of both the small and the large group, that is due in turn to the increased coherence of both groups.

The second parameter studied is ϵ (Table 3), the upper bound of the real variable representing general values of the population. Notice that the second panel, relative to the benchmark case where $\epsilon = 1.0$, is exactly the same as in Table 2.

The Table shows that there are values of ϵ for which the coherence and size of both groups drops dramatically. When $\epsilon = 2.0$, the disruptive diversity in the general values is such that joining a group is actually harmful in terms of utilities (as the beneficial similarity in salient values is too weak and few reasons are left to call them “salient” in such a situation.)

Once again, we find that richer individuals tend to remain out of the groups, looking at the average endowment of the stay-out group. Not surprisingly, the number of people choosing not to join either group increases with ϵ , for the reasons we have just discussed.

The last parameter studied is N , the number of salient values of agents (Table 4). As N grows, it is more difficult for agents to join the “right” group, given that in the current

ϵ		Size	Cohe	Sw	E	π
0.5	Small	16.37	0.23	0.33	0.93	1.20
	Large	18.51	0.27	-	0.94	1.35
	Out	15.13	-	-	1.14	1.14
1.0	Small	15.58	0.29	0.34	0.94	1.29
	Large	18.79	0.38	-	0.95	1.56
	Out	15.63	-	-	1.12	1.12
2.0	Small	10.02	-0.03	0.26	0.88	0.72
	Large	12.78	-0.01	-	0.92	0.81
	Out	27.20	-	-	1.08	1.08

Table 3: Time-averaged quantities for different values of ϵ .

N		Size	Cohe	Sw	E	π
1	Small	19.06	0.36	0.16	0.95	1.57
	Large	25.32	0.36	-	0.99	1.84
	Out	5.61	-	-	1.17	1.17
2	Small	15.58	0.29	0.34	0.94	1.29
	Large	18.79	0.38	-	0.95	1.56
	Out	15.63	-	-	1.12	1.12
3	Small	16.49	0.10	0.29	0.96	0.96
	Large	18.34	0.12	-	0.97	1.04
	Out	15.18	-	-	1.06	1.06

Table 4: Time-averaged quantities for different values of N .

version they can choose between two groups only. Thus, the size, coherence and the average utility decrease as the number of salient values increases.

It is interesting to further explore the joint effect of the two components of the utility. Recall that one part is merely the equal share of the sum of the initial endowments of the members, whereas the second (social) component is related to similarity. Figure 5 shows how the average size and the endowment of groups depend on the average endowment $\bar{E}$ of the population. Keeping fixed the other parameters, a larger (smaller) $\bar{E}$ makes joining a group less (more) convenient on a relative basis, as the profit from interaction is a little (substantial) part of agents' wealth.

The left panel of the Figure 5 shows that, as expected, an increase in the endowment pushes more agents to choose to stay out. The size of the two groups declines and, at the same time, the average endowment of the members of the groups shrinks, as can be seen on the right panel. In other words, a larger average endowment in the population reduces the size of the groups, which end up in attracting fewer and poorer agents.

Synergies here defined can be thought both in terms of benefits coming from homophily preferences (liking to be in a group with like-minded individuals) and, borrowing from a recent survey by Mesterton-Gibbons *et al.* (2011), in terms of the ability of a group to

Figure 5: Size of groups (left) and average endowment of members (right) as a function of the average endowment of the population $\bar{E}$. Black, red and green lines refer to the small and large groups and to those who stay out, respectively. The figure is based on 1000 simulations with a randomly sampled $\bar{E} \in \{0, 1, \dots, 50\}$.

expand the pie of payoffs accessible to agents. The previous results show that N , ϵ , as well as $\bar{E}$, all have an impact on the synergy of the groups generated by the model. This outcome appears to be sensible as the number of salient values is likely to shape the willingness of agents to join together with the (possibly adverse) effect of significant general values. At the same time, wealthy populations with large $\bar{E}$ reap relatively little benefits from grouping and ultimately stay out, whereas smaller average endowments push agents to join in order to increase their utilities.

4.2 The Extended Model

This Section describes the case in which agents have some memory, characterized by a coefficient $\alpha > 0$, and estimate utility using a weighted average of past utilities and inferred information based on P samples.

As for the previous model, we first present a specific run and then aggregate many simulations to provide large-sample evidence of typical behavior.

Let the parameters be given as in Table 1, with the exception that $\alpha = 0.4$. Figure 6 shows the size and average utilities of the three groups. The presence of memory produces a large and stable group (red line) that is always dominant in size and quite often yields the highest average utility. The smallest group (black line) includes roughly 10 members,

leaving on average 15 agents on their own (green line). The right panel shows, if the initial transient is discarded, approximately steady utility for all groups.

Figure 6: Time series of the number of members (left) and average utility (right) for the three groups when the memory coefficient is $\alpha = 0.4$. Black, red and green lines denote the Small, Large and Stay-out group, respectively.

In particular, the performance of the small group in terms of utility is relatively good, taking into account the difference in size with the dominant one. This is due to the internal large coherence of the smallest group that counterbalances its small size. Consistently with this result, we report that the average coherence of the two groups are 0.78 and 0.40 in this specific simulation.

The left panel of Figure 7 shows the similarity matrix of agents in period 160. There is a small but extremely coherent first group on the bottom-left corner and a larger second group characterized by less similar agents, as shown by several darker hues. The relative stability of the groups that are formed with such a level of memory translates into a higher degree of similarity that lasts over a number of periods.

The right panel of Figure 7 displays several statistics for a specific agent whose endowment, equal to 12.53, is shown as a dashed line. In particular, the upper (lower) black line shows the estimated utilities of joining the second (first) groups. The red line, often superimposed on one of the previous estimates, depicts the utility actually cashed by the agent.

This individual mostly joins the second group, occasionally staying alone for brief periods. Clearly, the estimated utility to be in the first group (lower black line) never exceeds his endowment or the perceived benefit to join the second group (upper black line). Hence,

Figure 7: Similarity matrix in period 160 when $\alpha = 0.4$ (left panel). Time series of the estimated utilities q_t^1, q_t^2 for a given agent (right panel). Actual utility and endowment of the agent are shown with red and dashed lines respectively.

the agent frequently stays in the second group, inflating his utilities that would have been much lower if alone or in the other group.

As this example shows, introducing some memory allows agents to act correctly even if their decisions are based on a myopic estimate. In fact, the estimated utility for joining the second group is a reasonable guess of the actual payoff, given the fact that only $P = 2$ agents are sampled in each period. Notice, in particular, that local estimation errors are most often irrelevant, as they do not force the agent to abandon the group.

4.2.1 Multiple simulations

This section describes the more general features of the groups generated by the model once a memory parameter has been introduced. The structure of the presentation of the results mirrors the one of the previous Section, in which no memory was present, and, when computing any time-average, we discard the first 50 periods to avoid transient initial effects.

Table 5 shows the changes in some key variables for three levels of the memory parameter α . As α grows to 0.5, the size, coherence and average utilities increase significantly for both groups. When α grows to 0.8, it is in particular the large group that benefits from this change, attracting a much larger number of individuals. In both cases the number of agents deciding to stay out, instead, decreases markedly, but they remain the wealthiest

α		Size	Cohe	Sw	E	π
0.1	Small	15.00	0.31	0.27	0.92	1.28
	Large	18.63	0.37	-	0.95	1.54
	Out	16.37	-	-	1.12	1.12
0.4	Small	16.27	0.47	0.19	0.92	1.56
	Large	20.81	0.45	-	0.96	1.79
	Out	12.92	-	-	1.15	1.15
0.8	Small	13.73	0.57	0.05	0.85	1.45
	Large	24.56	0.43	-	0.96	1.88
	Out	11.70	-	-	1.18	1.18

Table 5: Average dynamics for different values of α .

group in the population. Coherently with the results of the basic model, the members of the large group always achieve a larger utility on average. Moreover, being in a group is always better than remaining out even in this extended model.

Some memory appears to have long-lasting effects in that more stable groups are formed. This is confirmed by a dramatic drop in the switching rate pointing out that a dominant group quickly builds and persists for most periods.

5 Discussion and conclusion

We presented an agent-based model of groups in informal settings, in which cooperation is constructed through the flexible concept of perceived similarity. In our model, agents decide whether to join or abandon one of two possible groups, without any cost - due to the informality of the setting. At the end of each period, utilities are computed on the bases of the size of the group (“the more, the merrier”) and the overall similarity of the group (“the more coherent, the better”).

An innovative aspect of our model is the characterization of agents with some personal features, called *salient* and *general* values: the former represent the standpoints agents take on matters related to a goal important for the group, whereas the latter describe agents’ position about more negotiable issues. Together with agents’ endowment (heterogeneously distributed), similarity in values drives successful or unsuccessful cooperation. Individuals will cooperate, joining forces and sharing resources, if they perceive the group can increase their utility, which has two components: the average endowment of the group, and the sum of all pairwise similarities. The latter component represents the immaterial utility of being in a group with people one likes -reflecting homophily preferences- as they share a combination of common values.

The model reproduces some known stylized facts, like the higher likelihood of poorer agents to join, and can be used to describe and interpret empirical examples of stable cooperative groups without direct or indirect reciprocity among members.

The basic formulation of our model aims at contributing to the strand of literature deal-

ing with the evolution of cooperation and, in particular, to the research on collaboration without reciprocity. The evolution of cooperation based on agents' common features has recently received some attention in agent-based research, mainly because it seems to better represent real situations. Specifically, much attention has been devoted to the research on homophily, which explores how perception of similarities between individuals can foster cooperation sustaining trust-building processes (without the introduction of incentive schemes or reciprocity concepts).

The work of Riolo *et al.* (2001), for example, has shown in an evolutionary model with inheritable tags that similarity can indeed breed cooperation. Our model is consistent with their formalization of similarity and it is able to enrich their intuition. Indeed, the distinction between general and salient values, where salient are unchangeable binary values whose importance can never be overcome by the parameter summarizing general values, leads to a sophistication of the concept of similarity towards a better representation of "real" economic agents.

The introduction of a memory parameter, in the extended version of the model, shows that the fewer agents deciding to stay out are still characterized by higher endowments than the rest of the population. More interestingly, some memory leads to the formation of more stable groups, with very low rates of switching and the presence of a dominant and persistent group for most of the periods.

There are a number of limitations in our work that point to potential avenues for future developments. Focusing on what we perceive are the most interesting issues, we plan to work on adaptation of general values and endogenization of the number of possible groups and of the memory coefficient α .

Assuming a fixed number of groups and a predetermined memory coefficient has clear shortcomings and may be inappropriate in certain circumstances. Some of the results suggest that the endogenization of α could be obtained letting agents choose which is the optimal level of memory they should have (with respect to their own characteristics) in order to maximize expected profits.

Moreover, standard clustering algorithms could be used to establish benchmark groups of agents that can be compared with the groups produced by our model of social interactions. Preliminary results (not shown here) point to subtle but persistent differences in the clusters/groups obtained with the two methods and suggest that this fact may be due to potential synergies among agents that are only captured when the similarity perception is used by agents in a dynamic way. This could have interesting potential applications in interpreting empirical facts, or even suggesting new solutions in a wide range of environments, such as business organizations or socio-economic institutions.

One last point deserves mention. Although our setting does not currently allow for the emergence of trust in its most standard way, the introduction of salient values as a medium to facilitate cooperation certainly goes in the direction of investigating what ultimately motivates trust-building processes. In the model described in this paper, there is no possibility for trust to emerge, as agents do not recall specific characteristics of other agents, but simply sample and make inferences on the average similarity of the group. Nevertheless, the perception of similarity even with respect to a group of indistinguishable

individuals is enough to foster more cooperative behavior, facilitating the emergence of profitable groups. This points to the need of further understanding what is the exact relationship between similarity and trust building, which could become a potential avenue for further development of the current model.

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