A discusión

COOPERATION IN VISCOUS POPULATIONS - EXPERIMENTAL EVIDENCE*

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ABSTRACT

We experimentally investigate the effect of population viscosity (an increased probability to interact with others of one's type or group) on cooperation in a standard prisoner's dilemma environment. Subjects can repeatedly choose between two groups that differ in the defector gain in the associated prisoner's dilemma. Choosing into the group with the smaller defector-gain can signal one's willingness to cooperate. The degree of viscosity is varied across treatments. We find that viscosity produces an endogenous sorting of cooperators and defectors and persistently high rates of cooperation. Higher viscosity leads to a sharp increase in overall cooperation rates and in addition positively affects the subjects' intrinsic willingness to cooperate.

Keywords: Experiments, Cooperation, Group Selection, Norms, Population Viscosity.

JEL classification: C70, C73, C90.

1 Introduction

Population viscosity refers to a tendency of agents in a population to interact with increased probability with other individuals of their own type. The concept is often used in evolutionary biology to explain the emergence of altruistic behavior in both animals and humans.[1] The intuition simply is that if altruists interact with (sufficiently) increased probability among themselves they benefit more often from the cooperative behavior of others and thus enjoy higher fitness than selfish types. While there is a lot of theoretical work on viscosity, to our knowledge viscosity has not been tested experimentally.[2]

In this experiment we investigate the effect of population viscosity on cooperation and the strength of cooperative norms in a standard prisoner's dilemma environment. More precisely we try to answer the following questions.

- Can population viscosity induce an endogenous sorting of cooperators and defectors?
- Can persistently high rates of cooperation be sustained in sufficiently viscous populations?
- What is the effect of viscosity on cooperative norms?

To answer these research questions we tried to choose an experimental design that is both simple and natural for these kinds of questions. Subjects in our experiment play 100 rounds of a prisoner's dilemma game. They can repeatedly choose between two groups. In one of the groups (group A) the defector payoff is lower making cooperation less costly relative to defection. Agents can choose into that group in order to signal their willingness to cooperate. The degree of population viscosity, i.e. the probability of interacting with others of one's own group, is varied across treatments.

We find that participants choose group A if and only if the degree of viscosity (or separation between groups) is high enough. Also, while most of the agents in the "cooperative" group cooperate whenever the degree of viscosity is high, agents in the other group almost never cooperate. Both, the share of agents that choose into the "cooperative" group and the share

[1]See Mitteldorf and Wilson (2000), Boyd and Richerson (2005), Richerson, Boyd and Henrich (2003), Myerson, Pollock and Swinkels (1991), Mengel (2007a) or Wilson and Sober (1994), among others. Early references are Hamilton (1964) or Price (1971).

[2]An exception is Grimm and Mengel (2007), which we discuss below. There are also several experimental works on group selection (e.g. Page, Puttermann and Unel (2005) or Bohnet and Kübler (2005)) but none of them investigate population viscosity.

of agents that cooperate, rise sharply and monotonically with the degree of population viscosity. With high viscosity 35%-60% (depending on the exact degree of viscosity) of all subjects choose group A and cooperate until the end of the experiment.

An interesting feature of our results is that we do not observe an endgame effect (i.e. cooperation does not decline towards the end of the experiment). Note also that there is no punishment mechanism whatsoever that could induce agents to cooperate. Furthermore there is no exclusion, i.e. defectors are always free to (costlessly) switch into group A. The fact that they do not do so (although it would be profitable under high viscosity as our results show), is evidence for an implicit consensus that supports an endogenous sorting of cooperative and non-cooperative types. Of course, if cooperators were motivated by purely altruistic motives, viscosity would not be necessary in our experiment to sustain cooperation. Our results (in particular the breakdown of cooperation under low viscosity) indicate that subjects rather than being altruists are conditional cooperators, i.e. are willing to cooperate only if they expect many others to do so.

To further investigate this conjecture we use a random utility model and estimate the subjects' intrinsic disposition to cooperate as a function of the expected probability of cooperation of others. We find that subjects indeed act as conditional cooperators, i.e. are more willing to cooperate if the share of cooperators is higher. This effect is more pronounced for high degrees of viscosity. Measurement of the individual cooperator types reveals that as viscosity decreases there are significantly less agents guided by cooperative norms and significantly more flat defectors. These results take into account only the intrinsic - not the extrinsic (material) - incentives to cooperate.[3]

Our experimental evidence allows us to answer the above questions as follows.

- Viscosity can induce an endogenous sorting of cooperators and defectors.
- Viscosity can sustain persistently high cooperation in the population. There is no endgame effect.
- Viscosity seems to increase the intrinsic willingness of subjects to cooperate.

[3] The pattern of cooperator types we find is roughly consistent with results by Fischbacher, Fehr and Gächter (2001), Fischbacher and Gächter (2006) or Brandts and Schram (2001).

Let us finally relate our study to the experimental literature. Only very recently experimental economics has started to focus on the relation between interaction structures and cooperation. Coricelli, Fehr and Fellner (2004), Engelmann and Grimm (2006), or Page, Putterman and Unel (2005) are examples of studies in which agents can endogenously choose interaction partners.[4] In Bohnet and Kübler (2005) subjects can choose between groups that are perfectly separated. In this study, however, cooperation cannot establish at a high level. Two studies investigate group selection in the presence of punishment institutions. Guererk, Irlenbusch and Rockenbach (2006) and Grimm and Mengel (2007) show that subjects learn to choose into a group where a punishment mechanism is at place.[5] In Grimm and Mengel (2007) we induced agents to cooperate via a sanctioning mechanism in group A. In that study we were interested in the question whether agents opt for such a mechanism or not. All the above studies (except Grimm and Mengel (2007)) deal only with the case of perfect separation of groups. To our knowledge our studies are the first to analyze population viscosity in an experiment.

The paper is organized as follows. Section 2 describes the experimental design. The results from the experiment are presented and discussed in Section 3. In Section 4 we derive a random utility model in order to estimate the norms that guide the subjects' behavior and report the results. Section 5 concludes. The appendix contains regression tables and a translation of the experimental instructions.

2 The Experiment

In our experiment 128 participants (with no, or very little, prior exposure to game theory) anonymously interacted in a social dilemma situation in 100 rounds.[6] Each round consisted of three stages. In the first stage subjects chose their group. In the second stage they had to deliver an estimate of the cooperativeness of their next round match. And at the last stage they played a prisoner's dilemma game.

We ran three treatments that differed in the matching technology. In all three treatments matching took place in a viscous population, meaning that individuals faced an increased probability to interact with others of their group. The degree of viscosity is measured by the parameter $x \in [0, 1]$. $x = 1$

[4]See also Ones and Putterman (2006) or the literature on network experiments reviewed in Falk and Kosfeld (2003).

[5]See also Goette, Huffman and Meier (2006) for a field study on these issues.

[6]We excluded economics and business students from the experiment.

corresponds to the case of (unbiased) random matching. $x = 0$ means that the population is fully viscous, implying that agents interact with probability 1 with agents of the same group and never with agents from another group. In a viscous society with parameter x, if p_A is the share of agents of type A (members of group A) the probability for any one of them to interact with a B type is $(1 - p_A)x = p_B x$ and the probability to interact with a member of group A is $(1 - (1 - p_A)x) = 1 - p_B x$. The matching probabilities are summarized in Table 1.

	A	B
A	$1 - p_B x$	$p_B x$
B	$p_A x$	$1 - p_A x$

Table 1: Matching Probabilities

In the experiment we chose the values $x \in \{0, \frac{1}{3}, \frac{2}{3}\}$ for our three treatments T0, T1 and T2. One population consisted of 8 subjects. The members of a population were initially randomly assigned to groups A and B in equal proportions. At the first stage of each round, two of the eight subjects could decide to either join the other group, or to stay in their own group. Each subject could make this decision every fourth round. At the second stage of each round subjects were asked for their expectation on the cooperation probability of their match.[7] At the third stage subjects played the prisoner's dilemma game with payoffs as given by Table 2 with an interaction partner who was assigned randomly according to the matching technology. As it can be seen from Table 2, the two groups differ only in the defector's payoff. Independently of their group membership, subjects face a prisoner's dilemma game. However, in group A the defector's payoff is lower (i.e. cooperation is less costly as compared to defection).

Group A		other	
		C	D
me	C	800	100
	D	850	150

Group B		other	
		C	D
me	C	800	100
	D	1100	400

Table 2: Payoffs in the Prisoner Dilemma Games.

Prior to playing the game subjects were informed about (a) the percentage of subjects in groups A and B, and (b) their individual probability to meet

[7] We did not pay this answer because we wanted to avoid that subjects try to trade off earnings from correct guessing and from the game's payoffs.

a group A and group B member, respectively. When choosing an action in the bilateral game at stage three, agents had incomplete information about the group membership (i.e. the type) of their match.[8] They had to estimate the type of their match from the information we gave to them.

Since in our experiment the population was necessarily finite, one-to-one matching was not feasible. Instead, we first realized a random draw with the probabilities given in Table 1 to decide whether a subject's interaction partner was from group A or B. Then the interaction partner played the actions "cooperate" or "defect" with probabilities that corresponded to the proportions with which those actions were played in the respective group (in that round). In the unlikely event that only one subject remained in a group (either A or B) and the first random draw determined that he had to play against an member of his own group, the subject's interaction partner was preprogrammed to play C or D with equal probabilities.[9] After each of the 100 rounds, subjects were informed of whether their interaction partner belonged to group A or B, his action, and their own monetary payoffs.

The experiment was conducted in four sessions in October, 2006. The four experimental sessions were computerized.[10] Written instructions were distributed at the beginning of the experiment.[11] Each session took approximately 90-120 minutes (including reading the instructions, answering a post-experimental questionnaire and receiving payments). Subjects participating in the experiment received 2.50 Euros just to show up. On average subjects earned Euro 15.16 (all included).

3 Results

Figure 1 impressively illustrates the effect population viscosity has on group choice. While under perfect separation of groups (treatment T0) a high share of subjects join group A, the share of subjects that choose into group A decreases as viscosity decreases. We find that in the treatments with a high degree of viscosity group A contains a considerable share of subjects (averages are 59.2% in treatment T0 and 36.8% in treatment T1). Interestingly, we do not observe that the share of subjects decreases in the last periods.

[8] This is not true for treatment T0 where agents were certain to interact with a member of their own group.

[9] The subjects were informed that the interaction partner would use a preprogrammed strategy in this case.

[10] The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007).

[11] The instructions for T1 ($x = \frac{1}{3}$), translated from German into English, can be found in the Appendix. Instructions for the remaining treatments are available upon request.

In treatment T2, on the contrary, group A shrinks and finally disappears (the average share of subjects in group A is 9.8%). Pairwise comparison of the three treatments shows that all differences in group choice are highly significant (Mann-Whitney Test, $p = 0.0000$). Summing up, we observe an endogenous sorting of the subjects in the two groups under high viscosity ($x = 0$ and $x = \frac{1}{3}$), whereas under low viscosity almost all subjects pool in the same group (group B).

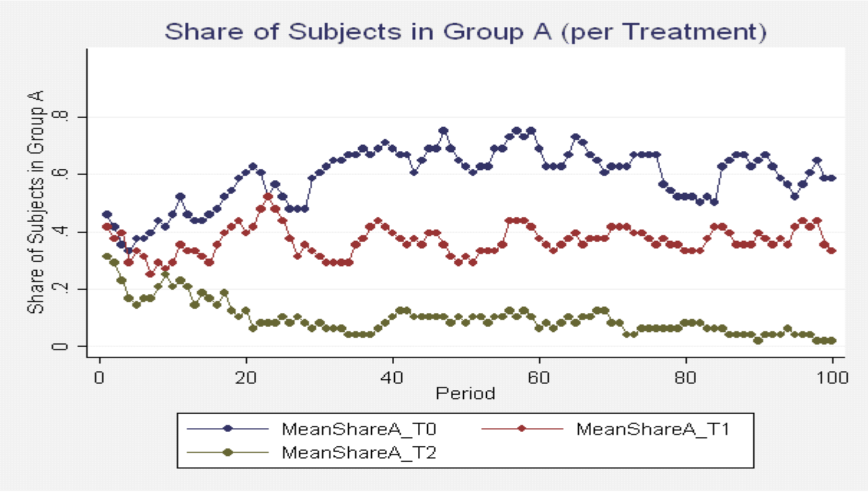

Figure 1: The Share of Subjects in Group A (per Treatment).

RESULT 1 (GROUP CHOICE) *The share of subjects in group A is the higher, the more viscous the population is. In T0 and T1 a constant share of around 60% and 35%, respectively, is in group A. In treatment T2 the share of subjects in group A decreases until it is finally zero.*

Taken by itself Result 1 only shows that some sorting took place. The really interesting question is of course whether this sorting does indeed produce cooperative behavior. Analyzing cooperation rates separately for the two different groups (A and B) reveals that in all treatments the majority of subjects in group A cooperates, while almost no group B–member does.

As Figure 2 illustrates, the shares of cooperating subjects in group A is constantly around 60% in treatments T0 and T1. In treatment T2 the cooperation rate in group A fluctuates a lot, which is mainly due to the low number of subjects in group A. Note that Figures 1 and 2 also show that - unlike in most other experimental studies of cooperation - cooperation does not break down at the end of the experiment, i.e. there is no so-called

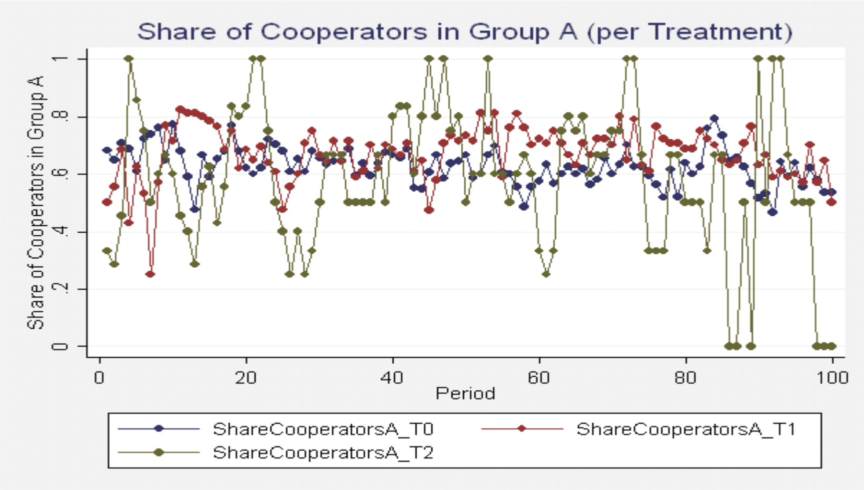

Figure 2: Shares of Cooperators in Group A (per Treatment).

"endgame effect". This illustrates a) that viscosity produces persistent cooperation and b) that the behavior observed is not driven by the use of repeated game strategies of players with limited foresight.

Figure 3 shows that in group B initial cooperation quickly breaks down and that from round 20 on almost no one cooperates in that group. Table 3 gives an overview over average cooperation rates, separately for both groups and the whole population. The table illustrates that higher viscosity leads to a sharp increase in overall cooperation rates. Pairwise comparison of overall cooperation rates between treatments shows that all differences are highly significant. (Mann-Whitney Test, $p = 0.0000$). Note that given the share of cooperation in group A any defector could obtain a higher payoff by switching from group B to group A (compare also Table 4 below). This effect is particularly strong in treatment T0. There seems to be some sort of implicit consensus sustaining sorting (and thus cooperation) that prevents defectors from doing so.

Result 2 (Cooperation)

Subjects in group A cooperate significantly more than subjects in group B. Consequently the rate of cooperation is highest in treatment T0 and lowest in treatment T2.

The observed behavior (concerning group choice and cooperation) had clear consequences on profits. Note that overall rates of cooperation in the population were the higher, the higher population viscosity was (compare

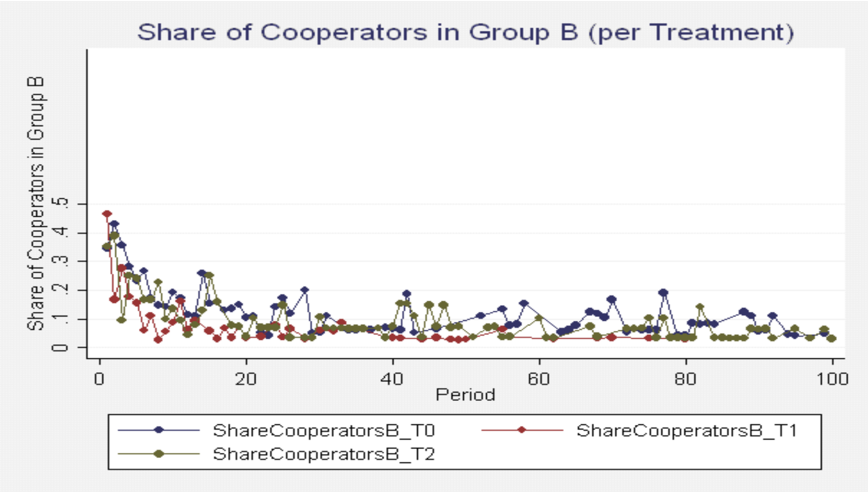

Figure 3: Shares of Cooperators in Group B (per Treatment).

Treatment	Group		Overall
	A	B	
$x = 0$	62.4	9.9	41.0
$x = \frac{1}{3}$	67.1	3.2	26.7
$x = \frac{2}{3}$	59.5	6.7	11.9

Table 3: Average Cooperation Rates

also table 3). Consequently, payoffs were highest in treatment T0, lowest (and close to the payoffs from mutual defection) for T2, and in between for the remaining treatment. Table 4 reports the profits obtained in the different treatments.

Result 3 (Profits)

(i) Average profits in the population are highest in treatment T0, followed by T1 and T2.

(ii) The profit of a group A–member is higher than the profit of a group B–member in treatments T0 and T1 and the opposite is true in T2.

The payoff differences in group A are highly significant between all treatments (Mann-Whitney Test, $p = 0.0000$). There are no significant payoff differences in group B between treatments T0 and T1 (Mann-Whitney Test, $p = 0.6732$). Differences between T0 and T2 as well as between T1 and

Treatment	Group		Overall
	A	B	
$x = 0$	560	457	518
$x = \frac{1}{3}$	494	460	472
$x = \frac{2}{3}$	350	452	436

Table 4: Profits.

T2 though are significant (Mann-Whitney Test, $p = 0.0516$ (0.0055)). The intuition simply is that since in T2 overall cooperation converges quickly to zero, there are no possibilities for exploitation. The differences, though, are small (and for T0 only weakly significant) as possibilities for exploitation are small (or even non-existent) in T0 and T1 as well because of high viscosity.

Note that Table 4 also shows that group choice is not an equilibrium (given action choice). In particular agents in treatment T0 have strong incentives to switch from group B to group A (irrespective of whether they correlate group choice with action choice).[12] Viscosity seems to induce a consensus for an endogenous sorting of different cooperator types.[13] Of course if cooperators are motivated by unconditional altruism, sorting (or viscosity) is not necessary to sustain cooperation in the experiment. If they are conditional cooperators, though, (cooperating only if they believe that their match is likely to do so as well) viscosity can become necessary to sustain cooperation. Our results indicate that this could be the case (as in T2 cooperation breaks down).[14] The aim of the next section is to investigate this conjecture and to gain a better understanding of the different intrinsic incentives of our subjects.

[12]The payoff differences persist if one omits the first rounds of the experiment, as should also become clear from inspection of Figures 1-3.

[13]One could also think that (as we do not provide information on average payoffs) subjects are simply not able to learn the payoff-differences. Inspection of the individual data though shows that (almost) all subjects switch groups often in the first 50 rounds of the experiment and do experiment with action choice (mostly in early rounds).

[14]Other studies have shown that subjects often behave as conditional cooperators. See Fischbacher, Fehr and Gächter (2001) or Fischbacher and Gächter (2006). See Mengel (2007a) for a theoretical analysis of the relation between viscosity and the emergence of conditionally cooperative behavior.

4 Feedback Effects between Interaction Structure and Norm

Our results clearly indicate that subjects display intrinsic incentives to cooperate.[15] To estimate those intrinsic incentives we use a model which assumes that the subjects attach a value w to "being cooperative" as compared to defecting. Let us call a subject's incentive w his or her *norm* in the following. We use the general term "norm" here, because the psychological incentives we model could either stem from private (moral) norms of cooperation (that possibly depend on how others behave) or from social norms (shared beliefs) of behavior.[16] We are interested in whether such norms exist and how (if at all) their shape varies with the matching structure.[17] Estimating the norm w both, at the aggregate and at the individual level we find that indeed it changes with the degree of population viscosity.

4.1 The Model

To estimate the norm w we use a random utility model. Consider the following payoff matrix (payoffs for row player, denoted player i). w_i measures

		other	
		C	D
me (player i)	C	$800 + \varepsilon_{iC}$	$100 + \varepsilon_{iC}$
	D	$850 + 250\delta_B^i - w_i + \varepsilon_{iD}$	$150 + 250\delta_B^i - w_i + \varepsilon_{iD}$

Table 5: Random Utilities.

player $i's$ intrinsic incentive to cooperate (i.e. his norm), $\delta_B^i(t) = 1$ if i is in group B at time t and zero otherwise, and ε_{iC}, ε_{iD} are error terms. We define $\varepsilon_i = \varepsilon_{iD} - \varepsilon_{iC}$. We denote by $\widehat{c}_{it}$ the probability with which an agent i believes that his match cooperates at time t (we elicit this probability in our

[15] Since a) we do not observe endgame effects and b) observe suboptimal group choice, the observed behavior seems difficult to explain through strategic behavior of agents that only consider the monetary incentives.

[16] One possibility to distinguish between the two is to elicit second-order beliefs (i.e. inquiring about the probability with which one beliefs one's partner believes that one cooperates). We chose not to do so in order to leave the experimental setting as simple as possible and leave this open question for further research.

[17] If this is indeed the case interesting effects arise as has been studied theoretically by Benabou and Tirole (2007), Lindbeck, Nyberg and Weibull (1999), Mengel (2007b) and Traxler (2005).

experiment). Say $c_{it} = 1$ if agent i cooperates at time t and $c_{it} = 0$ otherwise. Then the expected utility of an agent can be written,

$$U(c_{it}) = \underbrace{800\widehat{c}_{it} + 100(1-\widehat{c}_{it}) + \varepsilon_{iCt}}_{\text{exp. profit from coop.}} + (1-c_{it})\underbrace{(50 + 250\delta_B(t) - w_i + \varepsilon_{it})}_{\text{add. perceived profit from defection}}. \qquad (1)$$

The choice rule of an expected utility maximizing agent then predicts that whenever the additional perceived profit of defection as compared to cooperation, i.e. whenever

$$c^*_{it} = w_i - (50 + 250\delta_B(t)) + \varepsilon_{it}$$

is negative, a subject cooperates whereas if it is positive, the subject defects. The choice rule is,

$$c_{it} = \begin{cases} 1 & \text{if } c^*_{it} \geq 0 \\ 0 & \text{otherwise.} \end{cases}$$

If we assume that the ε_{it} are iid extreme value distributed with cumulative distribution function

$$F(\varepsilon_{it}) = e^{-e^{-\mu\varepsilon_{it}-\gamma}}$$

we have a logit choice model. We want to allow the intrinsic incentives of the agent (or in other words their norms) to depend on the beliefs $\widehat{c}$. In the estimation we consider the following quadratic specification for the norm w,

$$w_i = n_i + m_i\widehat{c} + l_i(\widehat{c})^2.$$

The case where w is a constant and does not depend on $\widehat{c}$ and the case where w is linear in $\widehat{c}$ will be treated as special cases of the quadratic model where the coefficients of higher order terms are zero. We estimate a logit choice model where the independent variables are the expected monetary payoff of defection as compared to cooperation ($\Delta = 50 + 250\delta_B$) as well as the agent's norm $w_i = n_i + m_i\widehat{c} + l_i(\widehat{c})^2$. The logit model for the quadratic case can be written

$$\Pr(c_{it} = 1) = \frac{e^{\mu(n_i + m_i\widehat{c}_{it} + l_i(\widehat{c}_{it})^2 - 50 - 250\delta^i_B(t))}}{1 + e^{\mu(n_i + m_i\widehat{c}_{it} + l_i(\widehat{c}_{it})^2 - 50 - 250\delta^i_B(t))}}. \qquad (2)$$

Regressing $\Pr(c_{it} = 1)$ on $\widehat{c}_{it}$, $(\widehat{c}_{it})^2$and $\delta^i_B(t)$, we have that (given our utility model) the coefficient for the constant term (of the regression) is an estimate of $\mu(m_i - 50)$, the coefficient on $\delta^i_B(t)$ is an estimate of -250μ, the coefficient on $\widehat{c}_{it}$ is an estimate of μn_i and the coefficient on $(\widehat{c}_{it})^2$ is an estimate of μl_i. Comparing these coefficients allows us to eliminate μ and thus to distinguish between the effect of noise and that of the norm.

4.2 Results

We find that on average the norm depends as follows on $\widehat{c}$ in our three treatments.[18]

$$\begin{array}{rcll} w_0 & = & -103.77 + 838.01\widehat{c} - 545.21\,(\widehat{c})^2 & \text{in T0} \\ w_1 & = & -111.3 + 812.25\widehat{c} - 543.71\,(\widehat{c})^2 & \text{in T1} \\ w_2 & = & -119.72 + 1104.0\widehat{c} - 995.91\,(\widehat{c})^2 & \text{in T2} \end{array}$$

If $\widehat{c} = 0$ the norm w is actually negative, i.e. subjects seem to have additional incentives to defect. This could indicate the presence of motives like "spite" or "anger". But then the norm-function is rapidly increasing in $\widehat{c}$ in all treatments indicating that conditional cooperation is a strong behavioral motive. All three functions are concave in $\widehat{c}$, i.e. intrinsic incentives to cooperate seem to rise faster with $\widehat{c}$ for smaller levels of cooperation.

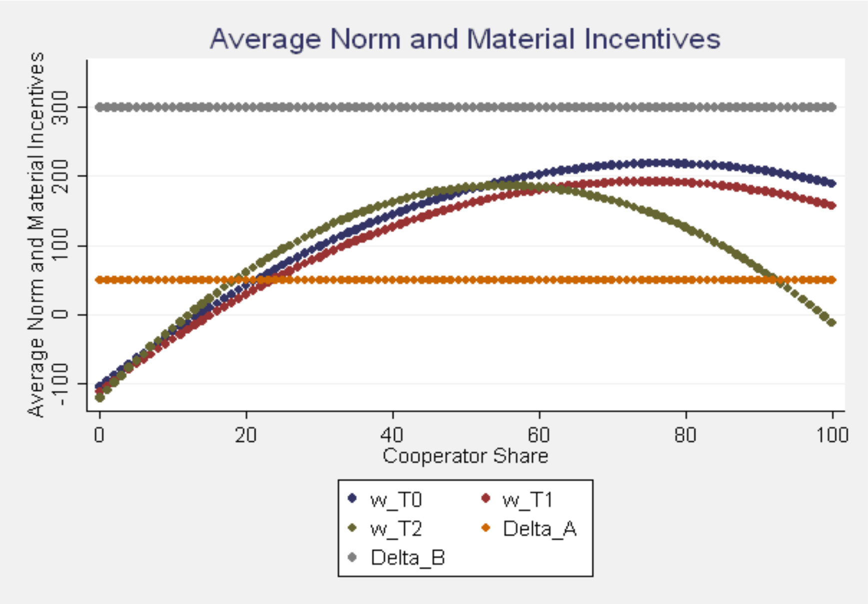

Figure 4: Average Norm and Material Incentives.

The result is illustrated in Figure 4. In the figure, the lower of the two similar lines is T1, whereas the most "U-shaped" one is T2. In all treatments subjects on average are reluctant to cooperate if they expect cooperative behavior only of a *low* fraction of other subjects (the functions $w(\widehat{c})$ are increasing). These findings are well in line with other experimental findings,

[18]The regression tables are given in the appendix.

like Fischbacher, Fehr and Gächter (2001) or Fischbacher and Gächter (2006) who observe conditionally cooperative behavior. We do not only observe conditionally cooperative behavior, but are indeed able to identify a behavioral motive for conditional cooperation.

In addition viscosity seems to have some feedback effect on cooperative norms. Under full viscosity ($x = 0$) the norm is slightly stronger than with $x = 1/3$. In treatment T2 the function $w(\widehat{c})$ is inversely U-shaped. This implies low willingness to cooperate also if subjects expect a *high* share of cooperators among the other players (whereas subjects are rather cooperative if they expect intermediate cooperation rates). If population viscosity is low, the possibility to exploit other subjects seems to yield additional psychological benefits for the agents.[19]

Treatment	$x = 0$	$x = \frac{1}{3}$	$x = \frac{2}{3}$
Constant Model	13 %	6 %	3 %
Linear Model	38 %	36 %	16 %
Quadratic Model	19 %	10 %	13 %
C in A, D in B	6 %	13 %	3 %
Always C	4 %	2 %	0 %
Always D	10 %	27 %	53 %
None	10 %	6 %	12 %

Table 6: Subject Classification in the Three Treatments.

Naturally the average norm does not reflect all the differences at the individual level. In order to investigate how individual behavior differed across treatments we ran individual regressions for each subject in each treatment. This allowed us to classify the subjects into six types that displayed different kinds of norm guided behavior. The results are given in table 6. A subject is attributed the model that fits best. To be attributed any model all, the coefficients of the regression have to be significant at 10% at least.[20] Subjects who cooperate/defect at least 91 out of 100 times are classified into always C / always D, respectively. Subjects that follow a strategy C in A and D in B at least 91 out of 100 times are classified into that category. Those who cannot be classified in any of the categories are classified into "none of the previous".

[19] Of course there are only few data points for high values of $\widehat{c}$ in the treatment T2. (In fact there are only 11 guesses exceeding 90% in this treatment). Consequently the results should be interpreted with some care. The coefficient on $(\widehat{c})^2$ is though significantly different from that in the treatments T0 and T1.

[20] Mostly the significance level is 1%.

It is remarkable that the total share of norm guided agents (constant model, linear model, quadratic model and always C) decreases and that of flat defectors (always D) increases as population viscosity decreases.

5 Conclusion

In this paper we have experimentally investigated the impact of population viscosity on cooperation in social dilemma situations. Participants in our experiment could repeatedly choose between two groups, where in one of them cooperation was less costly as compared to defection. The degree of population viscosity was varied between treatments. We found that under high population viscosity many subjects chose into the group with the lower defector payoff in order to signal their willingness to cooperate. In all treatments a significant share of subjects actually cooperated in that group, while almost no subject cooperated in the other group. The share of participants that choose into the "cooperative" group rises with the degree of population viscosity. Average profits for participants in the "cooperative" group are higher the more separated groups are. Under high population viscosity subjects realize a significant part of the possible efficiency gains of mutual cooperation.

Population viscosity seems to enable an endogenous sorting of cooperative and non-cooperative agents and to sustain persistent cooperation. Whenever they are (at least partly) protected from exploitation by others, subjects quickly learn to make use of group choice as a signal of their willingness to cooperate. We also find evidence for a positive relation between norms and population viscosity. Participants of treatments characterized by high viscosity tend to have higher intrinsic incentives to cooperate. Also the distribution of cooperator types changes with population viscosity. In short, population viscosity seems a powerful and important mechanism not only for sustaining cooperation *given* a distribution of cooperator types but it also positively *affects* this distribution towards a more cooperative society. To further understand the way population viscosity acts on economic incentives and norms gives rich potential for further research, both theoretically and experimentally.

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A Regression Results

Regression Results Cooperation, all Treatments

c_i	Coef.	Std. Err	$P > \|z\|$	[95% Conf. Interval]
constant	$-.5211202$	.1092775	0.000	$-.7353002, -.3069402$
$\widehat{c}_i$	.0291948	.0013919	0.000	$.0264667, .0319228$
δ_B^i	-2.84822	.1158171	0.000	$-3.075217, -2.621223$
Treatment1 (T1)	$-.7628143$	.1492469	0.000	$-1.055333, -.4702957$
Treatment2 (T2)	.2530817	.3071179	0.410	$-.3488583, .8550217$
T1*δ_B^i	$-.8251537$	.1797644	0.000	$-1.177485 - .4728219$
T2*δ_B^i	.3893097	.2087595	0.062	$-.0198515, .7984708$
σ_u	1.548935			
ρ	0.421721			

Table 7: Random Effects Logit Regression Cooperation, 12800 Observations.

Estimated "Average" Norm[21]

Treatment T0

c_i	Coef.	Std. Err	z	$P > \|z\|$	[95% Conf. Interval]
constant	−1.516847	.2404864	−6.31	0.000	−1.988192, −1.045503
$\widehat{c_i}$	.0826623	.0081416	10.15	0.000	.066705, .0986197
$(\widehat{c_i})^2$	−.0005378	.0000715	−7.52	0.000	−.0006779 − .0003976
δ_B^i	−2.466043	.1262566	−19.53	0.000	−2.713502, −2.218585
σ_u	1.598325				
ρ	0.4371011				

Table 8: Random Effects Logit Regression, Cooperate (4600 Observations).

Treatment T1

c_i	Coef.	Std. Err	z	$P > \|z\|$	[95% Conf. Interval]
constant	−2.098794	.2365592	−8.87	0.000	−2.562442, −1.635146
$\widehat{c_i}$	.1056852	.0108448	9.75	0.000	.0844298, .1269405
$(\widehat{c_i})^2$	−.0007066	.0001133	−6.24	0.000	−.0009286, −.0004845
δ_B^i	−3.252846	.1574204	−20.66	0.000	−3.561384, −2.944308
σ_u	1.587211				
ρ	0.4336705				

Table 9: Random Effects Logit Regression, Cooperate (4800 Observations).

Treatment T2

c_i	Coef.	Std. Err	z	$P > \|z\|$	[95% Conf. Interval]
constant	−1.453488	.2358278	−6.16	0.000	−2.562442, −1.635146
$\widehat{c_i}$	.0945457	.0087753	10.77	0.000	.0844298, .1269405
$(\widehat{c_i})^2$	−.0008529	.0001005	−8.48	0.000	−.0009286, −.0004845
δ_B^i	−2.141006	.171408	−12.49	0.000	−3.561384, −2.944308
σ_u	1.166163				
ρ	0.2924717				

Table 10: Random Effects Logit Regression, Cooperate (4800 Observations).

[21] From the regression in the $x = 0$ treatment we excluded 2 out of 48 students because their behavior did not produce enough variation.

B Instructions Treatment $x = \frac{1}{3}$

Welcome and thanks for participating at this experiment. Please read these instructions carefully. They are identical for all the participants with whom you will interact during this experiment.

If you have any questions please raise your hand. One of the experimenters will come to you and answer your questions. From now on communication with other participants is forbidden. If you do not conform to these rules we are sorry to have to exclude you from the experiment. Please do also switch off your mobile phone at this moment.

For your participation you will receive 2,50 Euro. During the experiment you can earn more. How much depends on your behavior and the behavior of the other participants. During the experiment we will use ECU (Experimental Currency Units) and at the end we will pay you in Euros according to the exchange rate 1 Euro = 2500 ECU. All your decisions will be treated confidentially.

The Experiment At the beginning of the experiment we will split you and the other participants equally into two groups — **group A and group B**. In each round of the experiment you play a game against a "representative member" either from group A or group B that we will call in the following your **interaction partner**.

Each round has three phases:

- **phase 1**: Each round some participants can decide whether to change groups or not. You can make this decision for the first time between round 1 and 4 and from then on every 4 rounds.
- **phase 2**: You are asked to give an estimate about your opponent's likely behavior.
- **phase 3**: You play the game that we will describe in the next section.

The Experiment consists of 100 rounds.

The Game and the payments Independently from which group (A or B) you are in, you play during the first 4 rounds and in the second phase of every following round the following game with a randomly selected interaction partner:

In each round you and your interaction partner can choose between two alternative, C and D. How much you **earn** in each round depends on **what**

you and your interaction partner have chosen and in **which group you are**.

Each member of group A receives the following payments:

Group A		your match chooses C	your match chooses D
you choose	C	800 ECU	100 ECU
	D	850 ECU	150 ECU

The table reads as follows:

- if both choose D, each gets 150 ECU (down right)
- if you choose D and your interaction partner C, you get 850 ECU (down left)
- if you choose C and your interaction partner D, you get 100 ECU (up right)
- if both choose C, each gets 800 ECU (up left)

Each member of group B receives the following payments:

Group B		your match chooses C	your match chooses D
you choose	C	800 ECU	100 ECU
	D	1000 ECU	490 ECU

The table reads as follows:

- if both choose D, each gets 400 ECU (down right)
- if you choose D and your interaction partner C, you get 1100 ECU (down left)
- if you choose C and your interaction partner D, you get 100 ECU (up right)
- if both choose C, each gets 800 ECU (up left)

Who do I play with and how does this depend on my group ? In each round your interaction partner is determined randomly. The probability to interact with someone of your own group differs from that of interacting with someone from the other group. The following is true:

- The more members a group has the more likely it is to meet a member of that group.
- Relatively it is more likely to meet someone from your own group.

The following tables give you an overview of the probabilities to interact with a member of group A or B respectively, depending on whether you yourself are in group A or B. If you are in group A the relevant table is table 1. If you are in group B the relevant table is table 2.

Table 1: you are in group A					
percentage of participants in group A:		25	50	75	100
percentage of participants in group B:		75	50	25	0
In which percent of all cases do	A	71	81	90	100
I meet someone from group	B	29	19	10	0

Table 2: you are in group B					
percentage of participants in group A:		0	25	50	75
percentage of participants in group B:		100	75	50	25
In which percent of all cases do	A	0	10	19	29
I meet someone from group	B	100	90	81	71

The tables are for your orientation. It can happen that the actual share of participants in group A is not listed in the table. Each time we will thus calculate the corresponding probabilities for you and inform you about them before the start of phase 2.

Your interaction partner Your interaction partner in each round is not another participant of the experiment, but a ”representative member” of the group in which you are at the moment. He chooses the actions C and D with probabilities that correspond to the shares with which the other members of your group have chosen C and D.

If you are the only member of your group, the behavior of your interaction partner will be simulated by the computer (**but only in this case**). In all other cases the behavior of your interaction partner depends **exclusively** on the **behavior of the other members** of your group.

These rules obviously are the same for all other participants of the experiment.

Example: You are in group A and consequently your interaction partner will also be from group A.

- if among the other members in group A 70% chose action C and 30% chose action D, your interaction partner will choose with probability 70% action C and with probability 30% action D.
- if all other members of group A have chosen action C, your interaction partner will choose action C with probability 100%.

Information you receive Survey of the three phases and the information you get

- Phase 1: Some participants can change their group.
- Phase 2:
  (a) We inform you about,
    * your current group,
    * which share of participants is in group A and B respectively ,
    * with which probability you meet a participant of group A or B

  (b) You give an estimate about the behavior of your match. Specifically we will ask you the following question:

    How likely do you think it is (in percent) that your match in the next round will cooperate?
- Phase 3: you play the game described above with a randomly chosen match.

  After the third phase you are informed about which action you and your match have chosen and about your payment.