SOCIAL PREFERENCES, BELIEFS, AND THE DYNAMICS OF FREE RIDING IN PUBLIC GOOD EXPERIMENTS

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One lingering puzzle is why voluntary contribu tions to public goods decline over time in experimental and real-w orld settings. We show that the decl ine of cooperation is driven by individual preferences for im perfect conditional cooperation. Many people's desire to contribute less than oth ers, rather than changing beliefs of what others will contr ibute over time or people's heterogeneity in preferences makes voluntary cooperation fragile. Universal free riding thus even tually emerges, despite the fact tha t m ost peop le a re not selfis h. (JEL C91, C72, H41, D64)

Keywords: Public goods experiments, social preferences, conditional cooperation, free riding.

In this paper we investigate the role of social preferences and beliefs for voluntary cooperation. Numerous public goods experiments have shown that many people contribute more to the public good than pure self-interest can easily explain. However, an equally important observation is that free riding increases in repeatedly played public good experiments across various parameters and participant pools.[1] The facts are clear, but their explanation is not.

An obvious candidate for explaining the decline of cooperation was learning the free rider strategy. However, Andreoni (1988) showed that cooperation resumed after a restart, which is inconsistent with a pure learning argument. In a subsequent paper he interpreted the decline in cooperation "to be due to frustrated attempts at kindness, rather than learning the free-riding incentives" (Andreoni (1995), p. 900). Several papers since argue that contributions that are not due to confusion might possibly be explained by other-regarding preferences (e.g., Thomas R. Palfrey and Jeffrey E. Prisbrey (1997); Jordi Brandts and Schram (2001); Jacob K. Goeree, Charles A. Holt and Susan K. Laury (2002); Daniel Houser and Robert Kurzban (2002); Paul J. Ferraro and Christian A. Vossler (2005); Ralph C. Bayer,

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[1] See, for instance, R. Mark Isaac, James M. Walker and Susan H. Thomas (1984); James Andreoni (1988, 1995); Joachim Weimann (1994); Laury, Walker and Arlington Williams (1995); Rachel Croson (1996); Roberto Burlando and John Hey (1997); Gächter and Ernst Fehr (1999); Axel Ockenfels and Weimann (1999); Joep Sonnemans, Arthur Schram and Theo Offerman (1999); Claudia Keser and Frans van Winden (2000); Fehr and Gächter (2000); Eun-Soo Park (2000); David Masclet et al. (2003); Croson, Enrique Fatas and Tibor Neugebauer (2005); Jeffrey P. Carpenter (2007); Martin Sefton, Robert Shupp and Walker (2007); Martijn Egas and Arno Riedl (2008); Gächter, Elke Renner and Sefton (2008); Benedikt Herrmann, Christian Thöni and Gächter (2008); Nikos Nikiforakis and Hans Normann (2008); and Neugebauer et al. (2009). The decline of cooperation has also been observed in prisoner's dilemma experiments. See, e.g., Reinhard Selten and Rolf Stoecker (1986); Andreoni and John H. Miller (1993) and Russell Cooper et al. (1996). The breakdown of cooperation is also a frequent outcome in naturally occurring situations, like in the overdepletion of common resources and in environmental degradation.

Renner and Rupert Sausgruber (2009)). One type of social preference – long argued by social psychologists (e.g., Harold Kelley and Anthony Stahelski (1970)) – is many people's propensity to cooperate (in lab and field environments) provided others cooperate as well (e.g., Sugden (1984); Joel Guttman (1986); Keser and van Winden (2000); Fischbacher, Gächter and Fehr (2001); Bruno S. Frey and Stephan Meier (2004); Croson, Fatas and Neugebauer (2005); Croson (2007); Richard Ashley, Cheryl Ball and Catherine Eckel (2008); Croson and Jen Shang (2008); see Gächter (2007) for an overview). Such "conditional cooperation" is an interesting candidate for explaining the fragility of cooperation because this motivation depends directly on how others behave or are believed to behave. Conditional cooperators who observe (or believe) that others free ride, will reduce their contributions and thus contribute to the decline of cooperation. It is unknown, however, to what extent conditional cooperation, and inter-individual differences in this regard, can explain (the decline of) cooperation. Our paper aims to shed empirical light on this question. For a related theoretical approach see Attila Ambrus and Parag A. Pathak (2007).

The novelty of our paper is to combine two observations from previous research: beliefs about other people's contributions matter and people differ in their cooperative preferences – some are free rider types, whereas others are conditional cooperators.[2] In our approach we measure people's cooperation preferences in a specially-designed public good game played in the strategy method (called the "P-experiment") and then observe the same people in a sequence of ten one-shot games (labeled the "C-experiment"), in which we also elicit their beliefs about others' contributions. This allows us to quantify how preference heterogeneity and beliefs interact in voluntary cooperation. Specifically, we can disentangle whether

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[2] See, e.g., Fischbacher, Gächter and Fehr (2001); Burlando and Francesco Guala (2005); Kurzban and Houser (2005); Nicholas Bardsley and Peter Moffatt (2007); Martin G. Kocher et al. (2008); Laurent Muller et al. (2008); John Duffy and Jack Ochs (forthcoming); and Herrmann and Thöni (forthcoming).

contributions decline because of cooperation preferences and/or because of the way people form (and change) their beliefs about how others will behave.

Our data from the P-experiment show that people differ strongly in their contribution preferences. This is consistent with previous evidence (see footnote 2). Using the classification proposed by Fischbacher, Gächter and Fehr (2001) we have (i) 55 percent conditional cooperators who cooperate if others cooperate, and (ii) 23 percent free riders who never contribute anything, irrespective of how much others contribute, (iii) 12 percent are "triangle contributors" who increase their contributions with the contribution of others up to a point and then decrease their own contributions the more others contribute, and (iv) 10 percent are unclassifiable. We push beyond this observation of preference heterogeneity by investigating how measured preferences and beliefs are related to observed contribution behavior. We have therefore designed our experiments such that we can use the P-experiment to make a point prediction for each participant about his or her contribution in the C-experiment, given his or her beliefs. Our approach allows us to answer our main research question – how do beliefs and preference heterogeneity impact on the decline of cooperation?

Our main result, which we detail in Section II, is that contributions decline because on average people are "imperfect conditional cooperators" who only partly match others' contributions. The presence of free rider types is not necessary for this result; contributions also decline if everyone is an imperfect conditional cooperator. We also show that belief formation can be described as a partial adjustment of one's belief into the direction of the observed contribution of others in the previous period. More specifically, beliefs in a given period are a weighted average of what others contributed in the previous period and one's own belief in the previous period. As we will show with the help of simulation methods, our estimated belief formation process implies that beliefs decline only if contributions decline, but not vice versa. Furthermore, we find that contributions are significantly positively

correlated with predicted contributions, that is, the elicited preferences. In addition to their preferences, people's contributions also depend directly on their beliefs about others' contributions. This implies that the P-experiment understates the extent of conditional cooperation that occurs in the C-experiment.

I. Design and procedures

Our basic decision situation is a standard linear public good game. The participants are randomly assigned to groups of four people. Each participant is endowed with 20 tokens, which he or she can either keep or contribute to a "project", the public good. The payoff function is given as

$$\pi_i = 20 - g_i + 0.4 \sum_{j=1}^{4} g_j , \qquad (1)$$

where the public good is equal to the sum of the contributions of all group members. Contributing a token to the public good yields a private marginal return of 0.4 and the social marginal benefit is 1.6. Standard assumptions therefore predict that all group members free ride completely, that is, $g_j = 0$ for all j. This leads to a socially inefficient outcome.

The instructions (see Webappendix) explained the public good problem to the participants. Since we want to measure subjects' preferences as accurately as possible, we also took great care to ensure that the participants understood both the rules of the game and the incentives. Therefore, after participants had read the instructions, they had to answer ten control questions. The questions tested the subjects' understanding of the comparative statics properties of (1), to ensure that participants are aware of their money-maximizing incentives and the dilemma situation. We did not proceed until all participants had answered all questions correctly. We can thus safely assume that the participants understood the game.

Within this basic setup we conducted two types of experiments. The first type of experiment (the "P-experiment") elicits people's contribution *preferences* in a linear one-shot public goods game. In the second type of experiment participants make *contribution choices* in a repeatedly played linear public goods environment (labeled "C-experiment"). The C-experiment consists of ten rounds in the random matching mode. We chose a random matching protocol to minimize strategic effects from repeated play. All participants play both types of experiments. For example, participants first go through the preference elicitation experiment in the P-C sessions before making their contribution choices in the C-experiment. Our C-P sessions counterbalance the order of experiments to control for possible sequence effects. The C-P sequence allows for a particularly strong test of measured preferences because people experience ten rounds of decisions in the C-experiment before their cooperation preferences are elicited in the P-experiment.

The rationale of the P-experiment is to elicit people's cooperation preferences: to what degree are people willing to cooperate given other people's degrees of cooperation?[3] Being able to observe contributions as a function of other group members' contributions without using deception requires the observation of contributions that can be contingent on others' contributions. Fischbacher, Gächter and Fehr (2001) (henceforth FGF) introduced an experimental design that accomplishes this task.[4] Since we use exactly the same method as FGF we refer the reader to FGF for all details.

The central idea of the P-experiment is to apply a variant of the so-called "strategy method" (Selten (1967)). The participants' main task in the experiment is to make two decisions, an "unconditional contribution" and a "conditional contribution". In the

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[3] Our approach does not require eliciting a utility function since we do not need a complete preference order for our purposes. It is sufficient to know subjects' best replies conditional on others' contributions.

[4] Ockenfels (1999) developed a similar design independently of FGF.

conditional contribution a subject has to indicate – in an incentive compatible way – how much he or she wants to contribute to the public good for each rounded average contribution level of other group members. Specifically, participants were shown a "contribution table" of the 21 possible values of the average contribution of the other group members (from 0 to 20) and were asked to state their corresponding contribution for *each* of the 21 possibilities. Since the FGF method elicits the contribution schedules in an incentive compatible way, free rider types have an incentive to enter a zero contribution for each of the 21 possible average contributions of other group members; conditional cooperators have an incentive to enter increasing contributions, and unconditional cooperators have an incentive to enter their preferred contribution level.[5] The experiment was only played once, and the participants knew this. We wanted to elicit subjects' preferences, without intermingling preferences with strategic considerations.

Participants in the P-C sessions (C-P sessions) were only informed after finishing the P-experiment (C-experiment) that they would play another experiment. When we explained the C-experiment we emphasized that the groups of four would be randomly reshuffled in each period.[6] After each period, participants were informed about the sum of contributions in their group in that period. In addition to their contribution decisions, subjects also had to indicate their *beliefs* about the average contribution of the other three group members in the current

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[5] The P-experiment is incentive compatible because a random draw selects three group members for whom the unconditional contribution is payoff relevant and one group member for whom the conditional contribution, given the average unconditional contributions of the other three members, is payoff relevant. The payoffs are equal to (1). See FGF or Fischbacher and Gächter (2006) for further details.

[6] The likelihood in period 1 that a player would meet another player again once during the remaining nine periods was 72 percent. The likelihood that the *same* group of four players would meet was 2.58 percent. However, since the experiment was conducted anonymously, subjects were unable to recognize whether they were matched with a particular player in the past.

period. In addition to their earnings from the public good experiment, we also paid participants based on the accuracy of their estimates.[7]

We elicited beliefs for two reasons. First, we can assess the correlation between beliefs and contributions, which we expect to differ between types of players and which helps us to check on the player type as elicited in the P-experiment. Second, by evaluating an elicited schedule at the elicited belief in a given period we can make a point prediction about an individual's contribution in the C-experiment: if an individual in the P-experiment indicates that he or she will contribute y tokens if the other group members contribute x tokens on average, then the prediction for this individual in the C-experiment is to contribute y tokens if he or she believes that others contribute x tokens on average. We will later refer to this as the "predicted contribution".

The sequence of experiments was reversed in the C-P sessions. The comparison of results from the P-experiments in the C-P sequence with those of the P-C sequence allows us to assess the relevance of experience with the public goods game for elicited cooperation preferences.

All experiments were computerized, using the software z-Tree (Fischbacher (2007)). The experiments were conducted in the computer lab of the University of Zurich. Our participants were undergraduates from various disciplines (except economics) from the University of Zurich and the Swiss Federal Institute of Technology (ETH) in Zurich. We conducted six sessions (three in the P-C sequence and three in the C-P sequence). In each of five sessions we had 24 participants and in one 20 participants. A post-experimental questionnaire

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[7] Participants had a financial incentive for correct beliefs, but it was small to avoid hedging. If their estimation was exactly right, subjects received three experimental money units ($\approx$ \$0.8) in addition to their other experimental earnings. They received two additional money units if their estimation deviated by only one point from the other group members' actual average contribution, one money unit if they deviated by two points and no additional money if their estimation was off the actual contribution by more than three points.

confirmed that participants were largely unacquainted with one another. Our 140 participants were randomly allocated to the cubicles in each session, where they took their decisions in complete anonymity from the other subjects. On average, participants earned 35 Swiss Francs (roughly $30, including a show-up fee of 10 Swiss Francs).[8] Each session lasted roughly 90 minutes.

II. Results

We organize the discussion of our results as follows: In section A, we document the decline of cooperation. In section B, we present the extent of heterogeneity in people's cooperation preferences and actual contribution patterns. In the remaining sections, we analyze behavior in the C-experiment. We show how subjects form their beliefs (section C) and how their contribution decisions are related to the elicited preferences in the P-experiment (section D). We conclude in section E with a simulation study in which we assess how the belief process and subjects' preferences affect the decline of cooperation.

A. *The Decline of Cooperation*

Figure 1 sets the stage for our analysis, which aims to explain the decline of cooperation. The figure shows the temporal patterns of cooperation and beliefs for each of our six sessions separately.

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[8] During the experiment subjects earned their payoffs in "points" (according to (1) and the earnings from correct belief estimates). At the end of the experiment, we exchanged the accumulated sum of points at an exchange rate of 1 point = CHF 0.35 for the points earned in the P-experiment and at a rate of 1 point = CHF 0.07 for the points earned in the C-experiment.
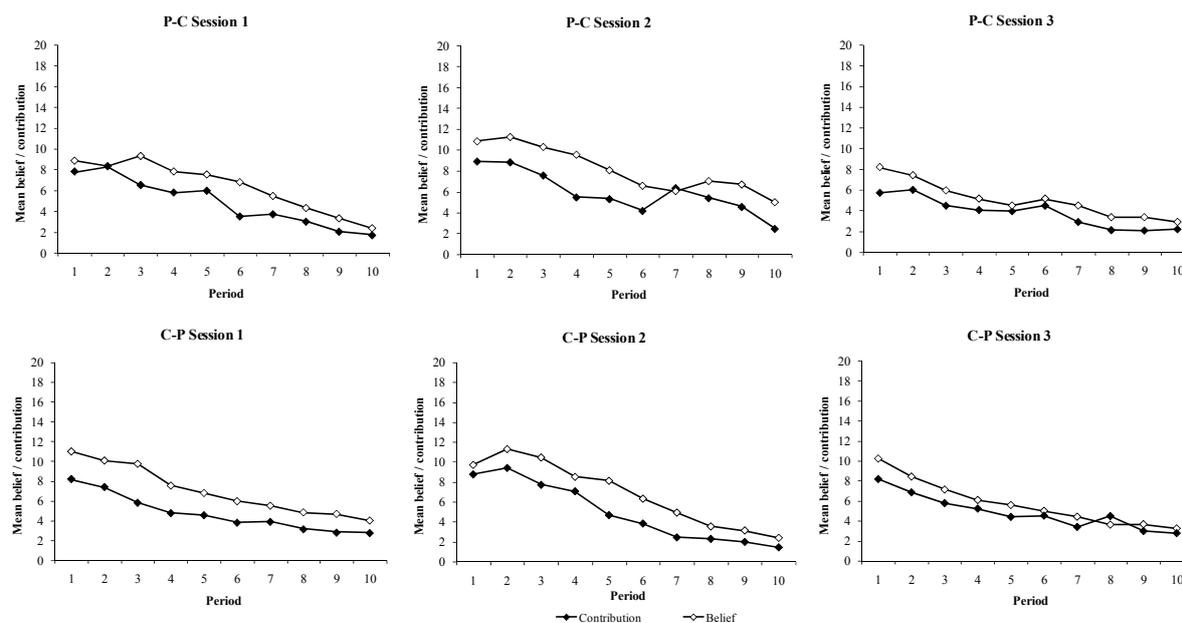
FIGURE 1. MEAN BELIEFS AND CONTRIBUTIONS OVER TIME.

Figure 1 conveys four unambiguous messages. First, contributions and beliefs decline in six out of six sessions. Second, behavior in the six sessions is very similar. Third, contributions are lower than beliefs in almost all instances. Finally, mean period contributions and beliefs are highly significantly positively correlated in all six sessions (Spearman rank correlation tests, $p < 0.007$). This finding is consistent with previous observations in public goods games where beliefs were elicited (e.g., Weimann (1994); Croson (2007); Neugebauer, et al. (forthcoming)).

B. *Heterogeneous Preferences and Contributions*

Recall that we have a complete contribution schedule from each participant that indicates how much he or she is prepared to contribute as a function of others' contribution. A simple way of characterizing heterogeneity is to look at the slope (of a linear regression) of the schedule and the mean contribution in the schedule. For instance, a free rider's schedule consists of zero contributions for all contribution levels of other group members. Therefore,

his slope and mean contribution are zero. An unconditional cooperator, who contributes 20 tokens for all others' contribution levels, has a mean contribution of 20 and a slope of zero. A perfect conditional cooperator, who contributes exactly the amount others contribute, has a slope of one and a mean contribution of 10 tokens. Figure 2A depicts the results separately for the C-P and the P-C experiments. The x-axis shows the slope of the schedules and the y-axis the average contribution in the schedule. The dots in Figure 2A correspond to individual observations, and the size of a dot to the number of observations it represents.

Figure 2A shows two things. First, there is a large degree of heterogeneity.[9] Free riders (located at 0-0) and perfect conditional cooperators (at 1-10) are relatively the largest group of subjects. We also find a few participants who contribute an unconditional positive amount (along the y-axis, at x=0). Many participants have a positive mean contribution and a positive slope; a few participants have a negatively-sloped schedule (that is, they contribute more the less others contribute). Second, the distribution between the C-P and the P-C sessions is very similar. Mann-Whitney tests do not allow the rejection of the null hypotheses that both means and slopes are equally distributed between the treatments ($p>0.87$).[10] Thus, elicitation of preferences before subjects actually experienced contributions to the public good (in the P-C sessions) or after (in the C-P sessions) did not affect the elicited preferences. This is an important finding for our interpretation that the P-experiment elicits cooperation preferences. It shows that participants in the C-P sessions who have experienced actual contribution

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[9] This evidence is consistent with other studies using different methods. See footnote 2.

[10] In Figure 2A we looked at the slope and mean contribution of a subject's schedule. However, qualitatively, we get very similar results if we look at Spearman rank order correlation coefficients, linear correlation coefficients, and slopes and intercepts of linear regressions. In all cases p-values of Mann-Whitney tests that compare the C-P and the P-C experiments yield $p>0.275$. The absolute number of [0-0]-combinations in the P-experiments was as follows: 18 in the C-P sessions and 14 in the P-C sessions. Six (seven) people are located at [1-10] in the C-P (P-C) sessions.

behavior do not express different cooperation preferences than do participants in the P-C sessions who are inexperienced in actual game playing when they express their preferences.[11]

Figure 2B shows a scatter plot of individual slopes of linear regressions (estimated without intercepts) of contributions on beliefs on the *x*-axis, and average contributions in the C-experiment on the *y*-axis. The construction of Figure 2B is similar to Figure 2A. As in Figure 2A, we distinguish between the C-P and the P-C sessions. We find no sequence effect, neither with respect to average contributions nor with respect to slopes (Mann-Whitney tests, $p > 0.21$).[12]
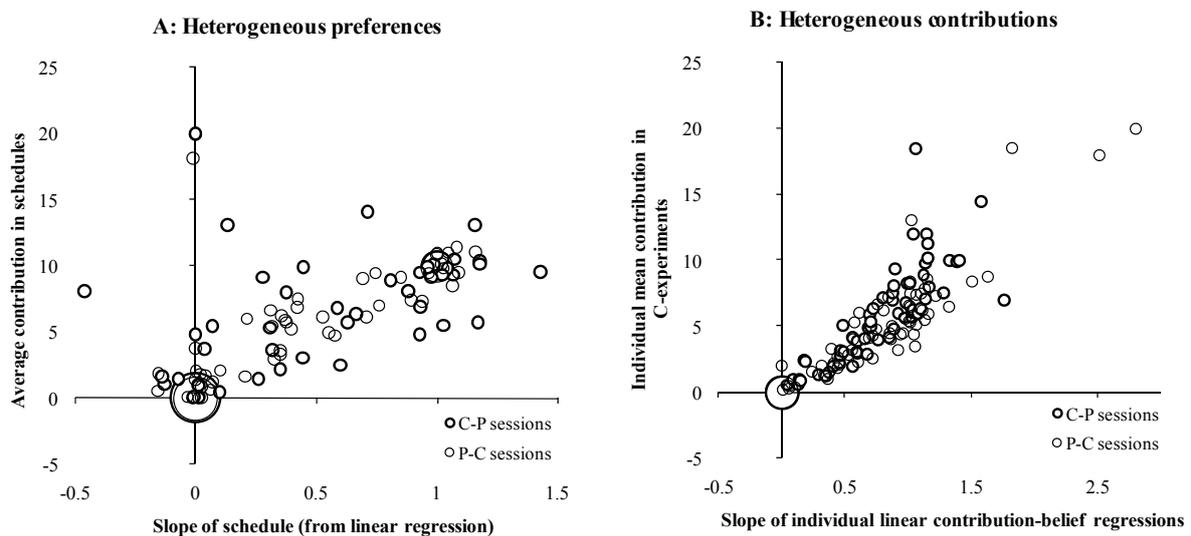
FIGURE 2. HETEROGENEOUS CONTRIBUTION PREFERENCES (PANEL A) AND

ACTUAL CONTRIBUTIONS AS A FUNCTION OF BELIEFS (PANEL B).

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[11] The elicited contribution schedules in our study are also not significantly different from FGF (χ2-test, p=0.729). See an earlier version (Fischbacher and Gächter (2006)) for further details.

[12] In the C-experiments depicted in Figure 2B nine people are located at [0-0] in each of the C-P and the P-C sessions.

Figure 2B reveals considerable heterogeneity in contribution behavior. Individual average contributions (depicted on the *y*-axis) vary between 0 and 20 tokens, although most participants contribute fewer than ten tokens on average. Fourteen percent of all participants contribute exactly zero in all ten periods. We find that the individual estimated slopes of the schedules from the P-experiment (Figure 2A) and the slopes of individual linear contribution-belief regressions in the C-experiments (Figure 2B) are highly significantly positively correlated (Spearman's $\rho=0.39$, p=0.0000). Average cooperation levels in the P-experiment and in the C-experiment are highly correlated as well (Spearman's $\rho=0.40$, p=0.0000). We interpret this as a first piece of evidence that expressed cooperation preferences and actual cooperation behavior are correlated at the individual level.

Before we investigate the link between beliefs, preferences, and contributions, we look at how people form beliefs in the C-experiment. Understanding belief formation is important because previous evidence, and our own, suggests that beliefs have an influence on contributions (see section II.D). It is therefore possible that belief formation contributes to the decay of cooperation if people reduce their beliefs *per se* , that is, independently of contributions. In section E we will address this possibility and a competing hypothesis suggested by our findings on contribution preferences (Fig. 2A) – contributions decline because people are imperfect conditional cooperators.

C. *The Formation of Beliefs*

With the help of three econometric models, we investigate the question of how people form their beliefs about their group members' contribution in a given period. The estimation

method is OLS with robust standard errors clustered on sessions as the independent units of observation.[13]

Model 1 in Table 1, which only includes "Period", simply confirms the impression from Figure 1 that beliefs decline significantly over time. However, this model cannot explain *why* there is a downward trend. Models 2 and 3 present our models of belief formation. We argue that people form their beliefs in period t on the basis of their beliefs in period t-1 and the observation of others' contributions in period t-1. To see this, take periods 1 and 2. In period 1 a subject can only rely on his or her intuitive ("home-grown") beliefs about others' contributions. In period 2, he or she also makes an observation about others' actual contribution in period 1. A subject may therefore update his or her period 2 belief on the basis of his or her period 1 belief and the observed period 1 contributions by others. A similar logic might hold in all remaining periods.

Model 2 presents the estimates of this belief formation model. We find that both "Belief (t-1)" and "Others' contribution (t-1)" are highly significantly positive; "Period" is insignificant, an order of magnitude smaller than in Model 1, and not significantly different from zero. We also estimated Model 2 separately for periods 1 to 5 and periods 6 to 10. The estimated coefficients are very similar in both halves of the experiment (Chow-test, p>0.1).[14] In other words, the way people form beliefs does not change over time.

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[13] We estimated all models with random and fixed effects specifications, as well as with Tobit, with very similar results. For instance, the correlation coefficient of predicted values of the Tobit estimation and the OLS is 0.9995. Since the estimation results are very similar, we only report the OLS results for ease of interpretation.

[14] We also applied an Arellano-Bond linear, dynamic panel-data estimation method (Manuel Arellano and Stephen R. Bond (1991)). However, there is still significant second order correlation (p<0.05, Arellano-Bond test) in the residuals implying that its estimates are inconsistent (Arellano and Bond (1991), pp. 281-282). Moreover, in simulations similar to those which we discuss in Section II.E it turned out that the Arellano-Bond estimates cannot explain the data patterns at all, whereas Model 3 can. As a further robustness check of Model 2

Model 3 is the same as Model 2 except that we drop the insignificant variable "Period". The sum of coefficients of "Belief (t-1)" and "Others' contribution (t-1)" is insignificantly different from 1 ($F(1,5) = 0.41$, p=0.549).[15] We will use this model in our simulations below.

TABLE 1—FORMING BELIEFS

	Model	Dependent variable: Belief about other group members' contribution		
		1	2	3
Period		-0.761***	-0.079	
		(0.090)	(0.042)	
Others' contrib. (t-1)			0.394***	0.415***
			(0.023)	(0.020)
Belief (t-1)			0.549***	0.569***
			(0.037)	(0.036)
Constant		10.711***	0.835*	0.118
		(0.864)	(0.398)	(0.148)
Observations		1260	1260	1260
R-squared		0.26	0.64	0.64

Notes: OLS regressions with data from period 2 to 10. Robust standard errors (clustered on sessions) in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Given these results, we can summarize the belief formation process as follows: a subject's belief in a given period is a weighted average of what he or she *believed* about others in the previous period and his or her *observation* of the others' contribution in the previous period. We will use this result when we investigate the role of belief formation for explaining the dynamics of voluntary cooperation in section II.E.

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we also included up to three lags for the variable "Others' contributions". Only the first lag is significant; the higher lags are very small and insignificant.

[15] The period coefficient in Model 2 is insignificantly different from zero but highly significantly different from the period coefficient in Model 1 (seemingly unrelated regressions, p<0.001). For reasons of comparability with Model 2 we estimated Model 1 for periods 2-10 only. The period coefficient in Model 1 for all periods equals -0.753.

D. *Explaining Contributions*

In this section we investigate determinants of people's contributions econometrically. We have three explanatory variables – "Period", "Predicted Contribution", and "Belief". We estimated three basic models which we document in Table 2. The estimation method is OLS with robust standard errors clustered on sessions as the independent units of observation.[16]

TABLE 2—EXPLAINING CONTRIBUTIONS

	Dependent variable: Contribution					
Model	1	2	3	4a	4b	4c
Periods used	1-10	1-10	1-10	1-10	1-5	6-10
Subjects excluded[+]	no	no	no	yes	yes	yes
Period	-0.639	-0.060				
	(0.071)***	(0.056)				
Predicted		0.242	0.242	0.443	0.385	0.614
Contribution		(0.069)**	(0.069)**	(0.073)***	(0.074)***	(0.082)***
Belief		0.644	0.666	0.545	0.582	0.376
		(0.071)***	(0.059)***	(0.065)***	(0.065)***	(0.116)**
Constant	8.343	0.005	-0.473	-0.318	-0.204	-0.116
	(0.545)***	(0.569)	(0.244)	(0.312)	(0.541)	(0.378)
Observations	1400	1400	1400	1260	630	630
R-squared	0.10	0.34	0.34	0.38	0.33	0.33

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%.

[+] Models 4a to 4c exclude (confused) subjects who, on the basis of the P-experiment could not be classified according to the FGF classification as either a "free rider", "conditional cooperator", or a "triangle contributor".

Model 1, which only includes "Period", confirms the impression from Figure 1 that contributions decline significantly over time. Model 2 adds the variables "Predicted Contribution" and "Belief". We find that both variables matter significantly. In other words, because "Belief" is significant there is conditional cooperation on top of contribution

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[16] As with belief formation, we estimated all models with random and fixed effects specifications, as well as with Tobit. Since the estimation results are very similar, we only report the OLS results.

preferences in the C-experiments. However, because "Period" is an order of magnitude smaller than in Model 1 and not significantly different from zero, the decline of cooperation must be due to "Predicted Contribution" and "Belief". Model 3 is the same as Model 2 but drops the insignificant variable "Period".[17]

The observations from Models 2 and 3 raise two related questions: (i) Why is the coefficient on "Predicted Contribution" surprisingly low (it should be one if the elicited preferences would predict perfectly)? (ii) Why do people condition their contribution decision based not only on their preferences according to their predicted contribution but also on their beliefs? Regression models 4a to 4c shed light on the first question. These models are the same as Model 3 but exclude "confused" subjects (10 percent) who, according to the classification proposed by FGF, could not be classified as either a free rider, a conditional cooperator, or as a triangle contributor. Model 4 shows that the coefficient on "Predicted Contributions" increases substantially (and significantly, seemingly unrelated regression, p=0.012) once the confused subjects are excluded (the coefficient is still less than one, though, and beliefs still matter on top of preferences). Regression models 4b and 4c reveal that there is also a time trend in the relative importance of "Predicted Contributions" and "Beliefs". "Beliefs" seem to be more important in the first half than in the second half of the experiment. In the second half the coefficient on "Predicted Contributions" is substantially and significantly higher than in the first half (p<0.001) and vice versa for the coefficient on "Beliefs" (p=0.039).[18]

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[17] One might worry about multi-collinearity in models 2 and 3 because beliefs enter the calculation of Predicted Contributions. Although Belief and Predicted Contribution are correlated (Spearman rho = 0.395), the variance inflation factor as an indicator of multi-collinearity is 1.22, which is below the critical value of 10 (Gujarati (2003)).

[18] However, the coefficients of "Predicted Contributions" and "Beliefs" do not significantly differ fom each other in the two regressions $(F(1, 5) = 2.42$, p= 0.181 and $F(1, 5) = 1.60$, p= 0.262)

Why do beliefs matter on top of contribution preferences? First, note that in Models 4a to 4c, the constant is not significantly different from 0, and the sum of the coefficients for "Predicted Contribution" and "Belief" add up to a number not significantly different from 1 (e.g., in regression 4a the sum equals 0.998; $F(1,5) = 0.08$, p=0.7863). Hence, according to these regressions, subjects contribute a weighted average of "Predicted Contribution" and "Belief". A contribution that matches the belief is by definition perfectly conditionally cooperative. Thus, subjects behave according to a contribution pattern that is in between their elicited contribution schedule and perfect conditional cooperation. Since most people's elicited contribution preferences lie below the diagonal, that is, below the schedule of perfect conditional cooperators, this intermediate contribution pattern lies above the predicted cooperation. This means that subjects are more conditionally cooperative in the C-experiment than predicted from their decisions in the P-experiment. Models 4b and 4c show that this is in particular the case in earlier periods; in later periods "Predicted Contribution" becomes more important than "Beliefs". One potential explanation for why beliefs matter on top of "Predicted Contribution" is subjects' willingness to invest in cooperation in order to induce high beliefs and contributions in the population even in our random matching design (for some evidence in this direction see Anabela Botelho et al. (forthcoming)).

E. *Why Do Contributions Decline?*

Because both beliefs and contribution preferences matter for determining contributions, the question arises as to how they each contribute to explaining the decline of cooperation. In this section we use simulation methods to understand why contributions decline. We distinguish between three fundamental possible causes: what individual preferences are, how beliefs change over the course of the game, and heterogeneity (in preferences or beliefs). We

use simulation methods because they allow us to use counter-factual assumptions which are helpful in disentangling the role of preferences and beliefs.

The simulations are based on a two-stage process. In the first stage, the simulated players form a belief about the other players' contributions. Then, players decide on a contribution, which they (partially) base on their beliefs. Before we address our two main questions, we make the following basic observations on the conditions under which such a two-stage process can explain the decline of cooperation. Contributions will not decline if contributions or beliefs are independent of experience and time, that is, if people are *unconditionally cooperative* or if they have *unconditional beliefs*. Thus, to explain the decline of cooperation both beliefs and contributions need to be *conditional* on the behavior of others. Of course, this is only a necessary condition. Suppose, for instance, that belief updating is naïve (that is, beliefs are equal to the average contribution in the previous period) and contributions match beliefs. In this case cooperation will be stable. Thus, cooperation will only decline if either beliefs are lower than naïve beliefs or if people are imperfect conditional cooperators. Our simulations will shed light on the relative importance of these two possibilities.

To be able to disentangle in our simulations the roles of beliefs and contributions for the decay of cooperation we make (counterfactual) assumptions about cooperation behavior and belief formation. With regard to cooperation behavior we will assume that the simulated players (i) contribute according to preferences we have observed in the P-experiment or (ii) they (counterfactually) are all perfect conditional cooperators. The second dimension concerns belief updating. Here we assume that players either (i) update according to the weighted-average model outlined above (Model 3 of Table 1) or (ii) they (counterfactually) form their beliefs naïvely. Thus, we have 2×2 combinations of assumptions about cooperation behavior and belief formation. Starting from the benchmark of perfect conditional cooperation and naïve beliefs we can hold one dimension constant and change the

other one to see whether belief formation or contributions are responsible for the decay of cooperation.

The simulations use the exact matching structure that was in place in each period of a given session.[19] As starting values we use the actual contributions and beliefs in period 1. The details of our 2×2-methodology are as follows:

1. In our benchmark model, the *pCC$_N$-model*, we assume that all players are perfect conditional cooperators, that is, players match their beliefs exactly: *Contribution*(t) = *Belief*(t). Beliefs are formed naïvely (denoted by sub-index N), that is, *Belief*(t) = *Others' Contribution*(t-1). Under these assumptions contributions are obviously stable at the initial level of contributions.

2. The *pCC$_A$-model* keeps the assumption of perfect conditional cooperation but assumes that beliefs are formed according to the actual beliefs estimated in Model 3 in Table 1 (denoted by sub-index A). In this model, contributions will only drop if beliefs *per se* become inherently pessimistic.[20] Thus, this model reveals the extent to which the belief formation process can be responsible for the decay of cooperation.

3. The *aCC$_A$-model* keeps the actual beliefs assumption but replaces perfect conditional cooperation by actual conditional cooperation as elicited in the P-experiment (denoted aCC). The weights on contribution preferences and beliefs correspond to the estimated parameters of Model 3 in Table 2. This simulation model shows the combined predicted effects of actual belief updating and actual contribution preferences for the decline of cooperation.

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[19] That is, in simulation models 3 and 4 described below we replace each human participant by his or her contribution schedule and observe how contributions evolve given our assumptions about belief updating.

[20] "Virtual learning" (Roberto Weber (2003)), that is learning with no feedback by just thinking about the problem for several periods is a possible reason for this "pessimism".

4. Finally, in the *aCC$_N$-model* the simulated players determine their contributions according to the actual conditional contribution schedules but beliefs are formed naïvely. By assuming naïve beliefs, this model reveals the extent to which the cooperation preferences themselves contribute to the decline of cooperation.

We address the role of heterogeneity for the decline of cooperation with two counter-factual models in which we remove heterogeneity from the contribution process, thus, ending up with 3×2 combinations of assumptions. By comparing these models with the actual contributions we can assess the role of heterogeneity. The models differ only in their assumptions of the belief formation process. One model assumes naïve beliefs and is thus comparable to the aCC$_N$-model; the other model uses the estimated belief formation and is thus comparable to aCC$_A$:

5. In the *iCC$_N$-model* players are assumed to be identical conditional cooperators (iCC). As a schedule, we use an *average* linear one: *Contribution* = α + *k*Contribution of others*. The estimates from the data of our P-experiment return α=0.956 and *k*=0.425. Therefore, in this model *Contribution = 0.956 + 0.425*Contribution of others* . The iCC$_N$-model assumes that belief formation is naïve. Thus, in comparison to the aCC-models, the iCC$_N$-model informs us about the role of preference heterogeneity of players under naïve belief formation.

6. Finally, the *iCC$_A$-model* is the same as the iCC$_N$-model but assumes actual belief formation.

Figure 3 depicts the simulation results. We compare the simulation results to the actual average contributions ("data"). Panel A illustrates the implications of our simulation models. For this purpose we use the average over all six sessions. Panel B depicts the predictive success of the aCC$_A$-model at the session level. We illustrate the results of the aCC$_A$-model because it is the only simulation model that does not use counter-factual assumptions.

Since the average initial contribution is 8 tokens, the pCC$_N$-benchmark implies that contributions are stable at the initial level. The pCC$_A$-model predicts that contributions will decline to the extent beliefs decline. The simulation results return stable contributions. To understand this finding recall that according to our model of actual belief formation (Model 3 of Table 1) *Belief*(t) = 0.415**Others' con tribution*(t-1) + 0.569*Belief(t-1) + 0.118. By assumption of perfect conditional cooperation *Contribution*(t-1) = *Belief*(t-1) for all players and therefore *Belief*(t) = (0.415 + 0.569)*Belief(t-1). The sum of the two coefficients (0.415 and 0.569) equals 0.984, which is insignificantly different from 1 (F-test, p=0.549). This observation implies that, under perfect conditional cooperation, beliefs remain constant. Hence, we conclude that the belief formation process *per se* does not contribute to the decline of cooperation. [21] Put differently, beliefs decline because contributions decline and not because people become inherently more pessimistic over time, irrespective of contribution behavior.

The aCC$_A$-model and the aCC$_N$-models replace the assumption of perfect conditional cooperation with people's actual contribution preferences as elicited in the P-experiment. Both simulation models predict a decline of cooperation. Since beliefs *per se* are not responsible for the unraveling of cooperation we conclude that the decline is triggered by people's contribution preferences. The aCC$_N$-model predicts a much faster decline than we actually observe in the data. By contrast, the aCC$_A$-model tracks the actual data quite well. To evaluate this model statistically, we regress the actual contributions on the predicted contributions (using OLS). We find that the model coefficient (robust s.e.)) equals 1.002 (0.030), which is not significantly different from 1. The model constant (robust s.e.) equals

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[21] If we disregard the constant and take the coefficient of 0.984 literally, the belief formation process *per se* can account for a decline of cooperation of at most 14 percent (i.e., $1-(1-0.984)^9 = 0.135$) over the nine remaining periods after period 1.

–0.036 (0.188), which is not significantly different from 0. Thus, on average, the aCC$_A$-model predicts the data very well. This is also apparent from Figure 3B, which compares the session averages with the predictions from the aCC$_A$-model applied to the respective session.[22]

Finally, we can assess the importance of preference heterogeneity by comparing the aCC-models with the iCC-models (under both naïve and actual belief updating). By construction, the iCC-models eliminate preference heterogeneity by replacing the individual preference schedules by the average preference schedule, whereas the aCC-models use the individual preference schedules. The comparison shows that preference heterogeneity is surprisingly unimportant in explaining the decay of cooperation because the aCC-models and the iCC-models match each other closely under both naïve and actual belief updating. Heterogeneity matters only towards the end of the experiment. In the iCC-models contributions stop declining towards the end while the models with heterogeneous preferences correctly predict the decline also in the last periods. Due to more realistic belief updating, the iCC$_A$-model matches the data better than the iCC$_N$-model.

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[22] All other models perform worse. In the iCC$_A$-model as the second best model, the regression of actual contributions on the predicted contributions has a slope of 1.06, which is insignificantly different from 1, and the constant equals -0.432, which is weakly significantly different from 0 (p=0.061). In all all other models the model constant is highly significantly different from 0 or the slope is highly significantly different from 1 (p<0.01). Furthermore, the correlation between actual and predicted contribution is highest for the aCC$_A$-model (Spearman correlation = 0.46). It is lower in all other models (all Spearman correlations p<0.40).
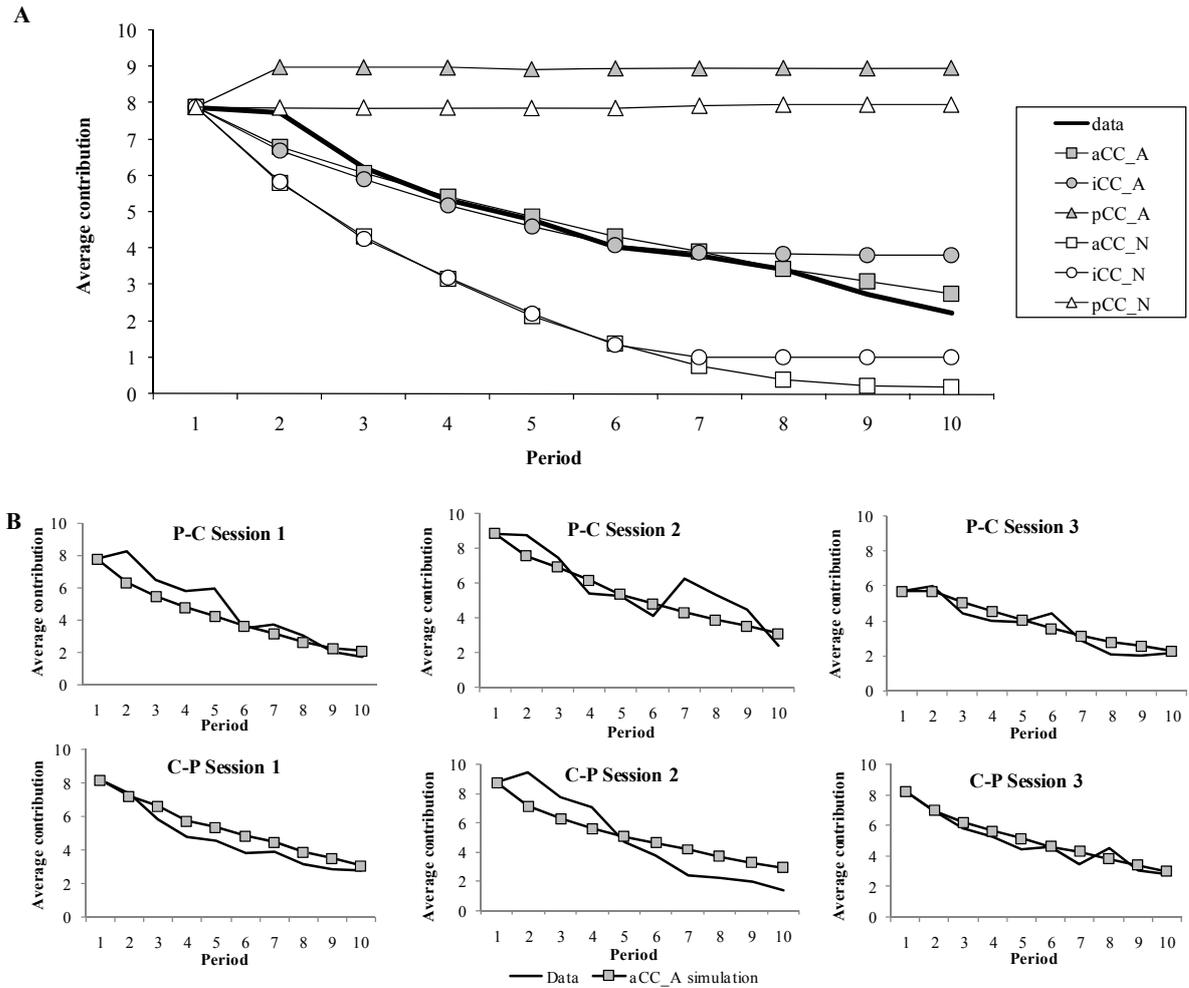
FIGURE 3. EXPLAINING THE DECLINE OF COOPERATION – SIMULATION RESULTS. PANEL A: DISENTANGLING THE SOURCES OF DECLINE. PANEL B: PREDICTING THE DECLINE FOR EACH OF THE SIX SESSIONS, USING THE aCC$_A$-MODEL.

III. Summary and Concluding Remarks

Our goal in this study was to investigate the role of social preferences and beliefs about others' contributions for the dynamics of free riding in public goods experiments. We achieved this by eliciting preferences in one specially-designed game (the "P-experiment") and observing contributions and beliefs in ten one-shot standard public goods games with random matching (the "C-experiment").

Our findings show that contributions decline (in randomly composed groups) because on average people are imperfect conditional cooperators. After some time all types *behave* like income-maximizing free riders, even though only a minority is *motivated* by pure income-maximization alone.

Scholars across the social sciences (Paul Samuelson (1954); Mancur Olson (1965);. Garrett Hardin (1968)) have long noted the inherent fragility of voluntary cooperation due to free rider incentives in the voluntary provision of public goods, collective actions, and common pool resource management. Our study showed that voluntary cooperation is inherently fragile even if most people are not free riders but conditional cooperators. However, because most of them are only imperfectly conditionally cooperative, cooperation is bound to unravel nevertheless; the presence of free riders just speeds up the decline. Other mechanisms, like punishment or rewards (Elinor Ostrom, Walker and Roy Gardner (1992); Fehr and Gächter (2000); Sefton, Shupp and Walker (2007)), communication (Isaac and Walker (1988); Ostrom, Walker and Gardner (1992); Jeannette Brosig, Ockenfels and Weimann (2003)), tax-subsidy mechanisms (Josef Falkinger et al. (2000); Jürgen Bracht, Charles Figuieres and Marisa Ratto (2008)), or, in general, good institutional designs (Ostrom (1990)) are necessary to sustain cooperation.

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