A Few Can Do – Ethical Behavior And The Provision Of Public Goods

by

Michael Pickhardt*

January 2009

Abstract: In this paper I examine the influence which a population of different behavioral types may have on the provision of public goods. In particular, the population or subject pool consists of three behavioral types: myopic selfish agents, enlightened selfish agents and ethically motivated agents. I use a simple agent-based simulation approach that incorporates type interaction based on conditional cooperation within a standard linear public goods model. Among other things, I show that under the given circumstances non-provision of public goods is a negligible issue, if the share of ethically motivated types in the population is 33.33% or higher. Maple codes are provided.

JEL Classifications: A13, C15, C90, H41

Keywords: ethical behavior, public goods, agent-based modeling, conditional cooperation,

Contact:

PD Dr Michael Pickhardt
University of Münster
Institute of Public Finance
Wilmergasse 6-8

48143 Münster/Germany

Phone: +49-251-83-21939
Fax: +49-251-83-22826
Email: michael@pickhardt.com
michael.pickhardt@wirtschaft.tu-chemnitz.de

* I am grateful to two anonymous referees, Ingo Barens, Klaus Beckmann, Daniel Eckert, Manfred Holler, Frederic B. Jennings jr., Vesa Kanniainen, Thomas Kuhn, Aloys Prinz and Hannu Tanninen for helpful comments and suggestions. However, I bear full responsibility for any errors or shortcomings.

A Few Can Do – Ethical Behavior And The Provision Of Public Goods

by

Michael Pickhardt

1 Introduction

One of Paul A. Samuelson's (1954) motivations to write out his seminal model of public goods was his dissatisfaction with the fundamental meaning of the Lindahl (1919) model (see Pickhardt 2006a, p. 450). Samuelson maintained that agents would not voluntarily contribute to public goods because that would be against their own self-interest (1954, p. 388-389). In modern terms, this is shown with the prisoner's dilemma where the dominant strategy of rational, payoff maximizing agents is not to contribute to public goods. Therefore, mainstream neoclassical public goods theory argues that the government should step in and use its power to tax so that the necessary means for providing public goods could be raised. In contrast, Lindahl's (1919) model is based on the implicit assumption that for one reason or another all agents are truth-tellers. Under these circumstances a voluntary bargaining process may lead to a Pareto-optimal provision of public goods (see Musgrave 1939, p. 216).

From a behavioral perspective, however, both models represent extreme cases because they are based on the assumption that all agents are of just one behavioral type. Yet, ample experimental evidence from public goods games in the laboratory and from field experiments suggests that there are several behavioral patterns and types, including those that fit the Samuelson and Lindahl models (e.g. see Herrmann and Thöni 2008; Fischbacher et. al. 2001; Ledyard 1995). Experimental researchers are spending a great deal of effort on identifying possible motivations for such behavior patterns. Another question of interest concerns the conditions under which different behavioral types may interact in a way that leads to a Pareto-optimal provision of public goods. Reciprocal action, conditional cooperation, etc. are topics of interest here (e.g. see Croson 2007; Frey and Meier 2004; Fischbacher et al. 2001). But in experimental settings identification of the behavioral type of a subject before the actual experiment, say via questionnaires or pre-testing, is associated with various problems, in particular, when the entire subject pool is of interest. For this reason, I take a somewhat different approach by using an agent-based simulation where the impact and the interaction of different, a priori defined, behavioral types can be analyzed (for an overview and introduction to agent-based modeling see Tesfatsion and Judd 2006; for the link between agent-based models and human subject experiments see Duffy 2006).

In particular, the purpose of this paper is to examine the influence which a population of different behavioral types, which explicitly includes a certain fraction of types that show ethically motivated behavior patterns, may have on the provision of public goods. The paper proceeds as follows. In section two I first describe the set of behavioral types I consider. Next, I briefly discuss a simple linear public goods game which is frequently used in experimental settings and which I use here as a framework to identify Pareto-optimal allocations. I then introduce a model of behavioral type interaction that may lead to a Pareto-optimal provision level of public goods. I use this model to simulate the impact of group composition and type interaction on the provision level of public goods, when the distribution of ethically motivated types in the population differs. Finally, I discuss a number of possible extensions of the model. Maple codes of the model are provided in an appendix. The last section summarizes and concludes.

2 Behavioral Types and Public Goods Provision

Over the last three decades experimental researchers have accumulated a considerable amount of empirical evidence on the behavior of real human beings from laboratory experiments with public goods. According to Ledyard (1995, p. 173), casual observation suggests that many subject pools consist of three different types: (a) those who are always prepared to lie and, therefore, free ride if that promises higher benefits than truth-telling or contributing, (b) those who sometimes free ride and sometimes contribute to the public good, and (c) those who always contribute to the public good. Often the relative shares of these subgroups are in the range of 50, 40 and 10 percent, respectively (Ledyard 1995, p. 173). As these three behavioral types and their relative shares continue to show up in more recent work on public goods games (e.g. see Herrmann and Thöni 2008; Pickhardt 2005a; Fischbacher et al. 2001), I use these behavioral types in the following.

Accordingly, the behavior patterns of a-type agents are characterized by pure or myopic selfish behavior, that is, in a linear public goods game they always free ride and never contribute to the public good. Agents that show a b-type behavior pattern may either contribute to the public good or may decide not to contribute to the public good. A number of different motivations have been put forward to explain such behavior patterns. In this paper, however, I assume that b-types contribute to the public good subject to certain conditions. In the short-run they contribute if and only if others are contributing as well and they continue to contribute in the long-run if and only if they are better off by contributing. To this extent their behavior pattern could be characterized as enlightened selfish behavior. Finally, agents that show a c-type behavior pattern will always contribute to the public good, irrespective of the consequences that may have for their own individual payoff in either the short-run or long-run. The behavior of c-type agents may be explained with ethical motivations. For example, c-types may regard truth-telling (i.e. contributing) as their duty in a Kantian sense. Although they may incur an individual loss in terms of their own payoffs, they continue to contribute to the public good in all rounds irrespectively of the consequences (e.g. see Croson 2007, pp. 201–202; Bordignon 1990; Laffont 1975, for modeling Kantian behavior). Altruistic motivations may serve as an alternative explanation of the c-type behavior pattern (e.g. see Croson 2007, pp. 202–203; Fender 1998; Andreoni 1989, 1990). I shall come back to these alternative ethical motivations later on.

Regarding the provision of public goods, two conclusions can be immediately drawn from this frequently observed group composition.

(i) *Any group of individuals that contains a non-empty set of c-type agents will provide itself with a positive provision level (PPL) of public goods.*

(ii) *Interaction between b-type and c-type agents may allow a group of individuals to provide itself with a Pareto-optimal provision level of public goods.*

To be sure, 'itself' here means that no external force such as the government with its power to tax is needed and that the provision is, therefore, 'voluntarily' subject to the ethical motivation (or internal force), 'public goods' refers to goods consumed in a nonrival manner and public good provision may be suboptimal, unless type interaction or a sufficient number of c-types within the group leads to a Pareto-optimal provision level for the group.

To proceed, I now introduce a simple linear public goods game that is frequently used in experimental economics (e.g. see Batina and Ihori 2005; Pickhardt 2005a; Zelmer 2003). Within this framework, I then analyze the effects of group composition and type interaction. I assume a group of n agents with each agent facing the following linear payoff function:

$$U_i = 5y_i + 2X \,, \tag{1}$$

where U_i denotes the payoff of the i-th agent in terms of tokens, y_i represents the quantity of the private good and X is the quantity of the public good. Each agent has a given endowment or budget B_i of two resource units per round. Hence, in principle, each agent may contribute 0, 1, or 2 resource units to either the private or public good. But for simplicity alone, I now assume that agents contribute both units either exclusively to the private good y_i or to the public good x_i in order to maximize payoff:

$$\overline{B}_i = 2 = y_i + x_i, \qquad y_i, x_i \in \{0, 2\}, y_i \neq x_i. \tag{2}$$

The public good *X* is defined as the sum of individual contributions to the public good:

$$X = \sum_{i=1}^{n} x_i, \quad i = 1, ..., n. \tag{3}$$

Also, the public good *X* can be consumed in a non-rival manner by all *n* agents and from now on I consider a group of five agents, with $n = 5$.

$$X = X_i, \qquad \forall i. \tag{4}$$

Inspection of the payoff function (1) shows that it gives each agent an incentive to free ride completely, that is, to invest its entire endowment into the private good and nothing into the public good. Hence, it is the dominant strategy not to contribute to the public good, but the resulting non-cooperative equilibrium is not Pareto-optimal. In fact, such a prisoner's dilemma situation arises whenever the following condition holds:

$$1/n < \text{MPCR} < 1 \tag{5}$$

where MPCR is the marginal per capita return of a contribution to the public good (e.g. see Croson 2007, p. 200). In general, the MPCR is the product of the marginal rate of substitution and the marginal rate of transformation and, therefore, the marginal incentive to contribute to the public good (see Ledyard 1995, p. 149). Based on this definition it follows from (1) and

(2) that the MPCR amounts to: (2/5) · 1 = 0.4. Hence, because of n = 5 condition (5) holds with: 0.2 < 0.4 < 1.

Moreover, for a group of n agents, it follows from (1) and (4) that the social payoff for a unit increase in X is $2n$ tokens, whereas the private cost is five tokens. Hence, with n = 5 the group gains (2·5 – 5 =) 5 tokens for every resource unit that is invested into the public instead of the private good. Put differently, with n = 5 each unit of resources contributed to the public good generates a social net gain of (10 – 2 =) 8 tokens and an individual net loss of (5 – 2 =) 3 tokens, which amounts to an overall net gain of five tokens per resource unit for the group. In this context it is worth noting that altruists would always be better off, if they contribute their two resource units to the public good, which gives an overall net gain for society of (8·2–3·2 =) 10 tokens per contributor. To this extent, as noted above, the behavior of the c-types may comply with altruistic behavior patterns as well as Kantian behavior patterns (see also Croson 2007, pp. 201–203).

Following Pickhardt (2005, p. 147), Table 1 shows the set of feasible allocations, if there are five agents in a group and each agent can either choose not to contribute (i.e., y_i = 2, x_i = 0) or choose to contribute to the public good (i.e., y_i = 0, x_i =2). In addition, Table 1 shows the payoff each agent receives and the aggregate payoff for the group of five, subject to the linear public goods model described in equations (1) to (4). For example, consider allocation *II* in Table 1. Here four agents choose not to contribute to the public good and keep their resources instead for the private good (y_i = 2, x_i = 0; i = 1, ..., 4), whereas the fifth agent contributes its resources to the public good (y_5 = 0, x_5 = 2). According to (3) this yields X = 2, and according to (1) and (4) each of the four non-contributing agents has a payoff of (5·2 + 2·2 =) 14, whereas the contributing agent has a payoff of (5·0 + 2·2 =) 4, so that the overall payoff or welfare level is (4·14 + 1·4 =) 60. Furthermore, once allocation *VI* prevails, an agent would maximize its own payoff by deviating from contributing because this yields (5·2 + 2·8 =) 26 tokens for the deviating agent according to allocation *V*, which is higher than the (5·0 + 2·10

=) 20 tokens the agent would get according to allocation *VI*. Thus, Table 1 visualizes the prevailing prisoner's dilemma where the dominant strategy is not to contribute to the public good.

Table 1: Set of Feasible Allocations and Payoffs (in tokens)

	Individual and Aggregate Payoff		**Overall Payoff**
Allocation	**Non-Contributors**	**Contributors**	**(Welfare)**
	$(n_k \cdot U_{ik})$	$(n_p \cdot U_{ip})$	$(n_k \cdot U_{ik} + n_p \cdot U_{ip})$
I	5 · 10	---	50
II	4 · 14	1 · 4	60
III	3 · 18	2 · 8	70
IV	*2 · 22*	*3 · 12*	*80*
V	*1 · 26*	*4 · 16*	*90*
VI	---	*5 · 20*	*100*

Notes: Allocation denotes the numbers of the six conceivable allocations. Individual and Aggregate Payoff denotes the individual and aggregate payoffs for Non-Contributors and Contributors. In particular, column 2 denotes the individual and aggregate payoff received by non-contributors in terms of tokens, where n_k denotes the number of agents who keep their endowment and do not contribute to the public good and U_{ik} denotes the individual payoff which each non-contributing agent receives and the product ($n_k \cdot U_{ik}$) denotes the aggregate payoff (result not displayed). Likewise, column 3 denotes the individual and aggregate payoff received by contributors in terms of tokens, with n_p denoting the number of agents who play their endowment and contribute to the public good and U_{ip} is the individual payoff which each contributing agent receives. Overall payoff, which can be interpreted as the welfare level, denotes the sum of aggregate payoffs received by non-contributors and contributors.

Inspection of Table 1 also reveals that if any of the allocations *I*, *II* or *III* prevails, at least one other allocation can be offered that makes one or more agents better off without making any other agent worse off. For example, if allocation *II* prevails, allocations *V* and *VI* could be offered which would both make the four non-contributors, who get 14 in *II*, and the contributor, who gets 4 in *II*, better off. Yet, if any of the allocations *IV*, *V* or *VI* prevails, no such offer can be made because at least one agent will be worse off. Hence, allocations *IV*, *V* and *VI* are Pareto-optimal (shaded area in Table 1). In contrast, allocations *I*, *II* and *III* are not Pareto-optimal, with allocation *I* representing the unique non-cooperative equilibrium. This makes it clear that contrary to other tools, Table 1 allows for identifying all existing Pareto-optimal allocations and the associated welfare levels.

Finally, because every resource unit invested into the public good increases welfare by five tokens, column 4 of Table 1 (overall payoff or welfare) shows that every additional agent who contributes its entire endowment to the public good increases welfare by (2·5 =) 10 tokens and that welfare is increased by 50 tokens in total, if all 10 resource units are invested into the public good (allocation *VI* versus *I*).

3 Type Interaction and Pareto-optimal Provision

I now assume an agent population of size s that consists of the three behavioral types a, b, and c, as defined above. This population could be interpreted as the subject pool of an experimental laboratory or the inhabitants of a village, etc. Next, and in line with the linear public goods model introduced in the previous section, I assume that groups of five agents are drawn from this population. In this case, 21 different group compositions are conceivable. Table 2 shows these 21 group compositions in descending order with respect to the maximum number of identical types per group (see Table 2, columns 1 and 2). Note, however, that actual occurrence of all 21 groups implies that the number of each agent type in the population s_a, s_b, s_c, with $s = s_a + s_b + s_c$, is sufficiently large with respect to the group size n. This minimal population size $\breve{s}$ can be calculated from:

$$\breve{s} = n \cdot \frac{1}{\rho} \tag{6}$$

where ρ is the percentage share of the smallest type fraction. For example, consider the case where the types *a*, *b*, and *c* are distributed in the population with shares of 50%, 40% and 10%, respectively. In this case, the smallest type fraction is the c-type fraction with 10% and, thus, $\breve{s}$ is (5 · 1/0.1 =) 50 and the type shares are: s_a = 25, s_b = 20, s_c = 5. This ensures that all 21 group constellations shown in Table 2 may actually be drawn from the population, including group 3, where all five agents are of type *c*. In contrast, if a population size below $\breve{s}$ is chosen, say *s* = 30, type shares are: s_a = 15, s_b = 12, s_c = 3, and group 3 could never be drawn because there are only 3 c-types in the population. Therefore, the population size *s* must be equal to or larger than the minimal population size $\breve{s}$ and, in addition, it must be ensured that each type fraction can be represented by an integer. Hence, for the two relevant type distributions shown in Table 2, that is, 50/40/10 percent and equal distribution, the minimal population sizes are $\breve{s}$ = 50 and $\breve{s}$ = 15, respectively. But to keep the two simulations shown in Table 2 comparable, I have used *s* = 60 for both simulations. This population size ensures that the minimal population size is respected in both cases and gives integers for all type fractions, i.e. (30/24/6) and (20/20/20), with ($s_a/s_b/s_c$).

The next step consists of identifying the allocation that emerges for each group composition in the long-run. To do so, the contribution to the public good must be predicted for each type of agent. Given the above definitions and assumptions, a-type agents will always contribute 0, that is, $x_{i_a} = 0, \forall\, i_a$. Likewise, c-type agents will always contribute 2, that is, $x_{i_c} = 2, \forall\, i_c$. Regarding the b-types, however, predicting their contribution is a bit more complex. Due to the first condition mentioned above, they will never contribute in the first round, because in a simultaneous move game they cannot figure out whether or not others contribute as well. To this extent, the first round serves to reveal the number of c-types within the group of five agents. For simplicity, I now specify that each b-type will contribute in round two if at least one other agent has contributed in round one (*first condition*). In other words, if there is at least one c-type in the group of five. However, b-types will continue to contribute in round 3 if and only if the second condition is fulfilled. In the present context, b-types will contribute if their payoff in the previous round (here round 2, with contributing) was higher than in round 1 (without contributing) (*second condition*). Inspection of Table 1 shows that this condition may hold only in cases where the group of five contains one or two c-types. The reasoning is as follows: (a) if there is no c-type in the group, b-types will not contribute in round 2 and in all further rounds because of the first condition, (b) if there are more than two c-types in the group (i.e. 3 or 4 c-types), the allocation in round 1 will already be Pareto-optimal (i.e. allocations *IV* or *V*, respectively), and although b-types will contribute in round 2 because of condition one, inspection of Table 1 shows that contributing cannot make them better off than in the first round and, therefore, the second condition is not fulfilled so that b-types do not contribute in round 3. Hence, condition two requires $n_c \in \{1, 2\}$.

Moreover, even if the group under consideration contains just one or two c-types, by inspection of Table 1 it can be shown that the second condition also requires that there are three or more b-types in the group. For example, if there are three b-types, one a-type and one c-type in the group (see group 15, Table 2), allocation *II* emerges in round 1 and allocation *V* in round 2, with the payoff of each of the b-types rising from 14 to 16 tokens. Yet, with just two b-types it would drop from 14 to 12 tokens, *ceteris paribus*. In general, condition two also requires that for each b-type the additional payoff from induced b-type contributions (here: $2 \cdot X_b$) is strictly higher than the private payoff which a b-type would get from not contributing (here: $5 \cdot y_i$):

$$2X_b > 5y_i \,, \qquad \text{with } X_b = n_b \cdot x_{i_b} \tag{7}$$

Thus, other things being equal, condition two requires that $n_c \in \{1, 2\}$ and $n_b \in \{3, 4\}$, which implies $n_a \in \{0, 1\}$, because of $n = 5 = n_a + n_b + n_c$. Inspection of Table 2 shows that only groups 7, 14 and 15 may fulfill this condition.

Finally, to establish a long-run contribution environment from round three onwards, two more conditions must hold, to which I shall refer as conditions three and four. Condition three requires that b-types assume that others will mimic their own behavior (*third condition*). Therefore, they anticipate that others may stop contributing, if they themselves stop contributing. Put differently, they know that if they deviate from contributing the allocation of the first round will soon re-emerge. As this will make them worse off, they will not deviate from contributing although deviating would make them better off, provided that all others continue to contribute (see Table 1, allocation *VI* versus allocation *V*). Of course, condition three implies that b-types show a non-Nash behavior, whereas a-type and c-type behavior patterns comply with Nash-behavior. The fourth condition states that b-types will not start contributing again, once their first attempt failed (*fourth condition*). Hence, they contribute in round 2, if condition one is fulfilled and they continue to contribute as of round three, if conditions two and three are fulfilled. Yet, if condition two is not fulfilled in round two or in any following round, they will never contribute again. Hence, condition four reinforces that b-types continue to contribute once conditions two and three prevail, as they anticipate that they may not get a re-switch once cooperation has broken down.

To summarize, b-type agents will contribute in the long-run (i.e., as of round 3), if:

#1: at least one other agent has contributed in round one,

#2: the payoff in the previous round (here round 2, with contributing) was higher than in round 1 (without contributing),

#3: they assume that others will mimic their own behavior and

#4: they are not prepared to start contributing again, once their first attempt has failed.

This simple form of conditional cooperation of b-types can be reproduced with a few loops in a computerized simulation model and Maple codes for the type interaction model are provided in appendix A. Based on the predicted contributions for each type of agent, it is now possible to predict the long-run allocation for each of the 21 groups in Table 2. The result is displayed in column 3 of Table 2. For example, in group 6 (b,b,b,b,a), allocation *I* of Table 1 emerges in the long-run because in round one none of the five agents will contribute and this situation will never change. In other words, if the group contains an empty set of c-types, the public good is not provided at all, which is denoted by SAM in column 4 of Table 2, because this result complies with the prediction of the Samuelson model. In group 19 (a,a,b,b,c), allocation *II* emerges in the long run because in round 1 the c-type agent will contribute and, therefore, the b-types will contribute in round two as well. But in round 3 the two b-type agents do not contribute because condition two was not fulfilled in round 2. Hence, because of condition four, allocation *II* prevails as of round 3. Note that allocations *II* and *III* imply a positive but suboptimal provision level (SPL) of the public good, which is denoted in column 4 of Table 2.

Eventually, in group 15 (b,b,b,a,c), type interaction will lead to allocation *V* as of round 3, because the three b-types will start contributing in round 2 and continue to do so in round 3 because condition two holds (16 tokens > 14 tokens, see Table 1 and (7)) and in all following rounds because of conditions three and four. Hence, in group 15 the Pareto-optimal allocation *V* emerges due to type interaction, which is denoted by T-Pareto in column 4 of Table 2. In cases where a Pareto-optimal allocation emerges already in round 1, because the group contains three or more c-types, this is denoted by C-Pareto in column 4 of Table 2.

Table 2: Group Compositions, Welfare Specifications and Simulation Results

No.	Group Composition	Allocation		*50/40/10* Freq.	*50/40/10* Welfare	Equal Freq.	Equal Welfare
1	a,a,a,a,a	I	SAM	34	1,700	4	200
2	b,b,b,b,b	I	SAM	10	500	4	200
3	c,c,c,c,c	VI	C-Pareto	0	0	8	800
4	a,a,a,a,b	I	SAM	150	7,500	32	1,600
5	a,a,a,a,c	II	SPL	38	2,280	31	1,860
6	b,b,b,b,a	I	SAM	57	2,850	13	650
7	b,b,b,b,c	VI	T-Pareto	10	1,000	25	2,500
8	c,c,c,c,a	V	C-Pareto	0	0	19	1,710
9	c,c,c,c,b	V	C-Pareto	0	0	24	2,160
10	a,a,a,b,b	I	SAM	251	12,550	39	1,950
11	a,a,a,c,c	III	SPL	12	840	41	2,870
12	a,a,a,b,c	II	SPL	121	7,260	96	5,760
13	b,b,b,a,a	I	SAM	193	9,650	54	2,700
14	b,b,b,c,c	VI	T-Pareto	5	500	52	5,200
15	b,b,b,a,c	V	T-Pareto	69	6,210	102	9,180
16	c,c,c,a,a	IV	C-Pareto	3	240	55	4,400
17	c,c,c,b,b	IV	C-Pareto	0	0	51	4,080
18	c,c,c,a,b	IV	C-Pareto	4	320	92	7,360
19	a,a,b,b,c	II	SPL	177	10,620	155	9,300
20	b,b,c,c,a	III	SPL	30	2,100	159	11,130
21	c,c,a,a,b	III	SPL	36	2,520	144	10,080
				1,200	*68,640*	*1,200*	*85,690*
	Layer 1			*Layer 2a*	*Layer 3a*	*Layer 2b*	*Layer3b*
	28.57%		*SAM*	*57.92%*	*50.63%*	*12.17%*	*8.52%*
	71.43%		*PPL*	*42.08%*	*49.37%*	*87.83%*	*91.48%*
	28.57%		*SPL*	*34.5%*	*37.33%*	*52.17%*	*47.85%*
	28.57%		*C-Pareto*	*0.58%*	*0.83%*	*20.75%*	*23.94%*
	14.29%		*T-Pareto*	*7%*	*11.23%*	*14.92%*	*19.7%*

Notes: No. denotes the group number; a, b, c denotes the behavioral type of the agent; Allocation (column 3) denotes allocations corresponding to those in Table 1, while column 4 indicates the associated long-run welfare specification with C-Pareto denoting a Pareto-optimal allocation due to c-type contributions, SAM denotes non-provision as predicted by the Samuelson model, SPL denotes suboptimal provision level, and T-Pareto denotes a Pareto-optimal allocation due to type interaction; 50/40/10 and Equal denote the distribution of a,b,c agents in the population, respectively; Freq. denotes the frequency with which each of the 21 groups were drawn and Welfare denotes the actual welfare level in terms of tokens, which results from multiplying the frequencies with the relevant overall payoff or welfare given in column 4 of Table 1. Percentage figures at the bottom show the relative shares with which each welfare specification occurs, with PPL denoting positive provision level. For brevity, variances and other statistics are not displayed here.

In this context it is worth noting that the result of the Lindahl model complies with either a C-Pareto or a T-Pareto allocation, although there is no real bargaining process. Also, the type interaction process effectively transforms the pure simultaneous move game into a sequential move game (e.g. see Farina and Sbriglia (2008) with respect to sequential move games).

Inspection of Table 2, columns 2 and 4, shows that non-provision of the public good, as predicted by the Samuelson model (SAM), occurs in six cases (≈ 28.57%) of the 21 groups, while the remaining 15 groups (≈ 71.43%) have a positive provision level (PPL) of the public good. Closer examination of these 15 PPL groups reveals that in six groups (≈ 28.57%) the positive provision level is suboptimal (SPL), whereas in the remaining nine groups (≈ 42.86%) a Pareto-optimal allocation emerges in the long-run. Also, regarding the nine Pareto-optimal cases, in three of these cases (≈ 14.29%) Pareto-optimality is achieved by type interaction (T-Pareto), while in the remaining six cases (≈ 28.57%) Pareto-optimality is directly achieved by c-type contributions (C-Pareto). The relative shares with which these groups occur depend on the number of agent types *m*, the group size *n* and the underlying public goods model. In the following I refer to these relative shares as layer 1 shares (see Table 2, bottom).

However, the 21 groups may not occur with the same probability. In fact, the actual probability with which these groups occur depends on the distribution of types in the population or subject pool and on the selection criterion with which agents are drawn from the population or subject pool to form groups of five. I now assume that there is no specific selection procedure or selection bias, so that agents are drawn at random from the population. In this case, *ceteris paribus* the entire outcome of the process depends solely on the distribution of agent types within the population. Table 2, column 5, shows the frequencies with which each group occurs in a simulation based on 12 sessions with 100 runs each, when agent types *a*, *b*, and *c* are distributed in proportions of 50, 40 and 10 percent, respectively (see Ledyard 1995, p. 173). Likewise, column 7 shows the same simulation when agent types are equally distributed in the population. The simulations have been carried out with the Maple 11 software package and Maple codes are provided in appendix B.

Comparison of the percentage figures at the bottom of Table 2, columns 2, 5 and 7, reveals how the initial group weights (column 2, layer 1) are changed by the prevailing distribution of agent types in the population (columns 5 and 7, layers 2a and 2b). For example, as the SAM and PPL levels depend solely on the c-type share, it follows from these figures that replication of the initial group weights (column 2, layer 1) requires a c-type share in the population somewhere between 10% and 33.33%. Moreover, column 5 (layer 2a) and column 7 (layer 2b), show that a comparatively small fraction of c-type agents (i.e. 10% and 33.33%, respectively) is sufficient to generate a substantially higher share of groups that exhibit a positive provision level (PPL), here 42.08% and 87.83%, respectively. Also, figures in Table 2 suggest that a PPL close to 100% would require a share of c-types well below 50%. Put differently, under the given circumstances non-provision of public goods is a negligible issue, if the share of c-types in the population is 33.33% or higher.

I now consider a third layer of interest, the welfare in terms of tokens that emerges for each simulation, which is shown in Table 2, columns 6 and 8, respectively. The relevant values are obtained from multiplying the frequencies with the relevant overall payoff or welfare given in Table 1, column 4. Note that this third layer changes the relative shares once again, but now the changes are due to the parameters of the underlying public goods model. Inspection of Table 2, columns 6 and 8 (layers 3a and 3b), with respect to PPL shows that the parameters of the public goods model now raise the share of welfare generated in groups with a positive provision level (PPL) to 49.37% and 91.48%, respectively. This reinforces the previous finding that under the given circumstances non-provision of public goods is a negligible issue, if the share of c-types in the population is 33.33% or higher.

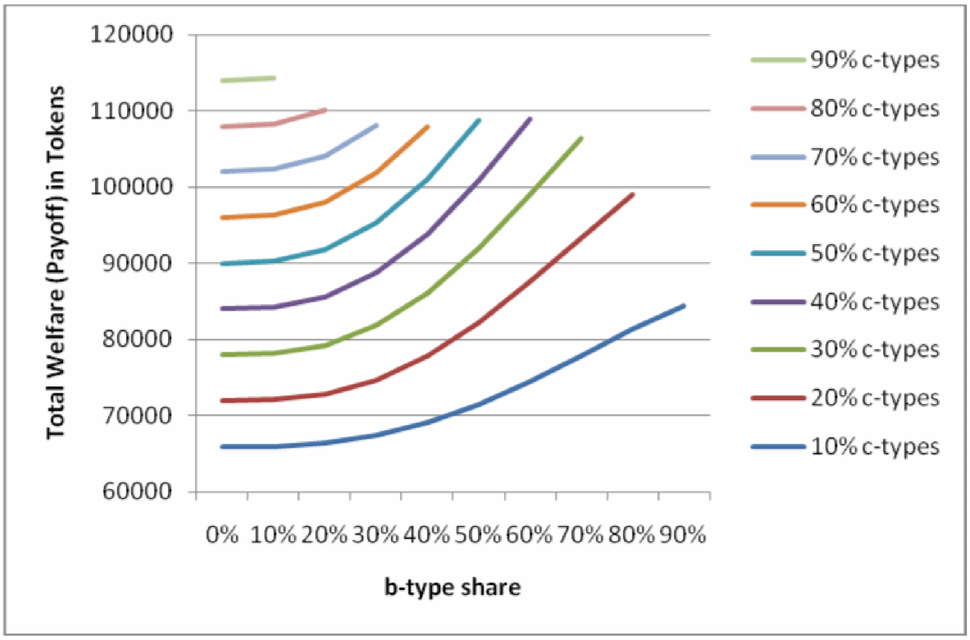
Regarding total welfare it is worth noting that the benchmark level is 60,000 tokens, which is calculated under the assumption that there are no c-types in the population. Hence, in this case only allocation *I* can emerge (SAM groups in Table 2) and total welfare amounts to: 1,200 · 50 = 60,000. Given this benchmark, Table 2, column 6 (68,640 tokens) and column 8 (85,690 tokens), reveal that the presence of c-types in the population generates additional welfare of 8,640 tokens (14.4%) and 25,690 tokens (42.82%), respectively. Moreover, both values can be separated in additional welfare generated from the pure presence of c-types and from type interaction of b-types and c-types. To do so, one has to bear in mind that if type interaction is not possible for some reason, groups 7, 14 and 15 would change to SPL specifications, representing allocations *II*, *III* and *II*, respectively. Hence, the net welfare effect of type interaction can be calculated from the net welfare difference in terms of tokens according to Table 1, (*VI*-*II* =) 40, (*VI*-*III* =) 30 and (*V*-*II* =) 30, respectively, multiplied with the relevant frequencies according to Table 2, columns 5 and 7. These procedures yield 6,020 tokens (10.03%) and 20.070 tokens (33.45%), respectively, of additional welfare from pure c-type contributions and 2,620 tokens (4.37%) and 5,620 tokens (9.37%), respectively, of additional welfare from type interaction. Note that the percentage share of additional welfare from pure c-type contribution almost coincides with the share of c-types in the population, i.e. 10% and 33.33%, respectively. Hence, under the present circumstances, type interaction ensures that additional welfare in excess of the c-type share in the population is generated.

In addition, the separation makes it clear that with respect to the third layer, the PPL welfare level does not solely depend on the c-type share, but also on the b-type share. Therefore, a correction is required to assess the pure impact of the c-type share on welfare (i.e. additional welfare from type interaction has to be deducted from both total welfare and the PPL welfare level). The correction procedure gives the percentage shares of 47.36% and 90.88% for welfare generated from pure c-type presence. Comparison with the uncorrected figures provided earlier on (i.e. 49.37% and 91.48%, respectively) shows that the difference does not change the conclusion already drawn.

The influence of type interaction on welfare, together with the massive increase of C-Pareto allocations shown in Table 2, clearly indicates that ethical education, by which c-types [b-types] may be 'produced' from either a-types or b-types [a-types] using capital and labor as inputs, may not only be beneficial for society as a whole but has also a potential for economies of scale. Notably, the reverse is also true, that is, a collapse of moral order or ethical behavior patterns may cause excessive harm to society as a whole.

Of course, these propositions can be worked out in further detail. For example, by fixing the number of c-types to a certain percentage share and raising the share of b-types *ceteris paribus* from zero to ninety percent, at the expense of the a-type share. Figure 1 shows how total welfare develops for such alternative b-type and c-type shares.

Figure 1: Total Welfare for Alternative *b*-type and *c*-type Shares (for *n* = 5)



Notes: Each line in Figure 1 represents a fixed c-type share, where the lowest line represents a ten percent c-type share and the highest line represents a ninety percent c-type share.

Reading Figure 1 vertically, and fixing the b-type share to zero percent, shows how total welfare increases from the benchmark of 60,000 tokens (c-type share of zero percent) to the maximum of 120,000 tokens (c-type share of hundred percent), if the c-type share is increased stepwise by ten percentage points, at the expense of the a-type share. Reading Figure 1 horizontally shows how total welfare increases, for each fixed c-type share, if the share of b-types is increased at the expense of the a-type share. Thus, vertically Figure 1 shows the pure c-type effect on total welfare and horizontally Figure 1 shows the type interaction effect on total welfare. Also, total welfare of the 50/40/10 percent simulation shown in Table 2, that is, 68,640 tokens would be represented by a dot near the lowest line in Figure 1, at the 40 percent b-type share. Likewise, total welfare of the equal shares simulation, that is, 85,690 tokens would be represented by another dot in Figure 1, which would be located somewhere above the line that represents the 30 percent c-type share and somewhat to the right of the 30 percent b-type share.

To give another example, ethical education could be introduced in form of a production function with a-types or b-types, capital and labor as inputs and, in fact, many other aspects of the basic model could be examined in further detail. However, I shall leave these tasks to the interested reader because the essential points have already been made clear and can be summarized as follows:

(iii) *In any population that contains a non-empty set of ethically motivated agents (c-types) in the range of 33% or higher, non-provision of public goods is a negligible issue, if the circumstances described above prevail.*

(iv) *By the same token, ethical education may be welfare enhancing and could generate economies of scale over certain ranges, if type interaction among enlightened selfish agents (b-types) and ethically motivated agents (c-types) is possible.*

4 Extensions

It follows from the deterministic nature of the basic type interaction model introduced in the previous section that percentage shares of the three layers could have been worked out by simply calculating the relevant probabilities, instead of running simulations. Yet, the basic model can be extended in many ways to capture the complexity of human behavior and relevant decision environments. In these cases, a simulation approach has clear advantages. Therefore, I shall briefly discuss some extensions of the basic type interaction model. Maple codes for the extensions are provided in appendix C.

E1 – Mistakes: Real human beings are observed to make mistakes with different frequencies. Mistakes are usually regarded as something negative, but in the type interaction model mistakes might even have a positive impact. For example, suppose that a-types are observed to make mistakes. Now consider group 6 of Table 2. If the a-type agent makes a mistake in round 1 by contributing its 2 units to the public good, all four b-types will contribute in round 2 as well, while the a-type, having realized its mistake, would not contribute anymore. Hence, in round 2 allocation *V* is reached and because each b-type has a higher payoff than in round 1, they will all continue to contribute in round 3 and in all forthcoming rounds. In other words, the mistake of the a-type has turned a SAM allocation with non-provision into a Pareto-optimal allocation in which everyone, including the a-type, is better off in the long-run due to accidental type interaction. A similar situation is conceivable for a b-type mistake in group 2. This notwithstanding, mistakes by b-types or c-types might have negative effects, for example, if they lead to the collapse of cooperation or if they prevent type interaction in the first place.

E2 – Non-binary decision environment: For simplicity, in the basic model only binary decisions, i.e. "non-contribution = 0" or "contribution = 2", are possible. As shown in section 2, this is not much of a restriction because due to the linear public goods model rational a-types would anyway keep their entire endowment for the private good, while rational c-types

(Altruists and Kantians) would always contribute their entire endowment to the public good, with rational b-types doing one of these options subject to certain conditions. Hence, one extension could be that agents are free to choose their contribution to the public good from an integer interval such as [0, 2] or [0, 20], etc., thereby allowing for non-optimal choices by some agents. Note, however, that *ceteris paribus* allowing for even a small integer interval such as [0, 2] would lead to a substantial increase in the number of conceivable allocations in Table 1. Another option could be to allow for different endowments among agents.

E3 – Type diversification: The basic model is limited to just three behavioral types. Real human behavior patterns, however, are much richer and diverse. Therefore, one could either assume additional types or differentiate the three existing types *a*, *b*, *c* into sub-types. For example, it could be interesting to change the conditional cooperation parameters of some of the b-types. In the basic model I assumed that the individual willingness to contribute, γ, was "one other agent", implying that all b-types would start contributing once they observed that at least one other agent had contributed in the preceding round. Now assume that there are some b-types, say b0-types, for which $\gamma = 0$ holds, meaning that they would contribute even if no other agent has contributed previously. Again, *ceteris paribus* this would induce various changes. In round 1, for example, b0-types and c-types would now contribute, which makes it clear that b0-types may effectively fulfill the same role for type interaction as the c-types do. Note that this has important consequences insofar as b0-types may substitute for c-types and, therefore, type interaction may take place even if there are just b-types. Hence, if a b0-type shows up in group 2 or 6 the SAM allocation would be changed to a T-Pareto allocation. Yet, in groups 4, 10 and 13 both b0-types and normal b-types would refrain from contributing as of round 3 onwards, because condition two does not hold. By the same token, b1-types, b2-types, etc. could be introduced, where the b1-type coincides with the standard b-type of the basic model. Of course, the relative shares of the sub-types could vary within the overall b-type share. Note, however, if extension *E2* has already been introduced, conditional cooperation should depend on either the absolute number of tokens contributed by others or on the average contribution of others (e.g. as in Fischbacher et al. 2001 and others), rather than on the number of contributors and the sub-type definitions should be adjusted accordingly.

Moreover, sub-type variations could be based on other implicit parameters of the basic type interaction model. For example, the individual willingness to wait until condition two is fulfilled, θ, which was set to just 1 round in the basic model, could be changed for some b-types to 2 rounds or more. Note that this change would on the one hand serve as a reaction buffer if some agents make mistakes, while on the other hand it would allow for the evolution of cooperation over various rounds, if same b-types start contributing only if the average contribution of others reaches certain levels. Other examples include the individual willingness to deviate from contributing, δ, which was set to 1 agent in the basic type interaction model due to condition three (i.e. if one agent is observed to deviate, all others deviate as well). This parameter determines the reaction of b-types who are contributing because conditions one and two hold, but who notice that the level of contribution has dropped from the penultimate round to the last round. This drop in the observed contribution level could be due to mistakes or due to deliberate action, if there is a b-type who beliefs (contrary to condition three of the basic model) that all others would tolerate one deviating agent provided that conditions one and two continue to hold. Put differently, this b-type assumes that for all other conditional contributors $\delta > 1$ holds. If the belief is true, conditional cooperation prevails and deviation is tolerated to some extent, however, if the belief is false, cooperation will inevitably collapse. Of course, b-types may differ in their beliefs about other's willingness to deviate, ϕ. Also, b-types could differ with respect to their individual willingness to re-initiate a type interaction process, λ. In the basic model this parameter was captured with condition four and was set to 0 attempts (which implies no re-switches). If for some agents this parameter is raised to positive levels, conditional cooperation patterns could be re-started once cooperation has collapsed for some reason. Note, that this would allow for incorporating learning procedures, if a break down of successful type interaction leads to adjustments with respect to other individual parameter values. Finally, new types of agents could be created, for example, some agents may draw their contribution at random from the relevant integer interval, say [0, 20].

E4 – Linear public goods game: Another alternative to extent the basic model would consist of changing the parameters of the underlying linear public goods game. Consider for example condition (5), which is: 1/n < MPCR < 1. Now assume that the MPCR drops to 0.2, because *ceteris paribus* (1) has changed to $U_i = 5y_i + X$. In this case, condition two of the type interaction model could never be fulfilled so that type interaction would never be beneficial in the long-run, because condition (5) would not hold anymore, with: 0.2 = 0.2 < 1. Similarly, if $U_i = 5y_i + 3X$ prevails *ceteris paribus*, condition (5) would still hold, with 0.2 < 0.6 < 1, but allocation *IV* would no longer be Pareto-optimal and this would again have certain consequences for the simulation results, as can be seen from Table 2. Changing the group size parameter, *n*, would have similar consequences and, in addition, the number of allocations (Table 1), the number of groups (Table 2) and the layer shares (Table 2) would change as well. For example, with *n* = 4, *ceteris paribus* only five allocations would be possible, of which the first two would not be Pareto-optimal, while the remaining three would be Pareto-optimal. Also, in Table 2 the number of groups declines to 15, of which 5 (33.33%) are SAM, 3 (20%) SPL, 6 (40%) C-Pareto and just 1 (6.66%) is T-Pareto. The impact of a higher group size, with *n* = 10, is illustrated *ceteris paribus* for layer 3 shares in Table 3. Inspection of Table 3, in particular with respect to the SAM and PPL shares, shows that the results presented in the previous section are reinforced if *n* is increased, *ceteris paribus*.

Changes to the remaining variables and parameters of the linear public goods game, i.e., x_i, y_i, and B_i, have already been discussed above under *E2*. Finally, one could think of introducing threshold public goods by changing (3) or consider a non-linear public goods game by specifying the payoff function (1) accordingly.

Table 3: Layer 3 Shares for Group Sizes of 5 and 10

Runs = 1,200	***Distribution 50/40/10***		***Distribution 'Equal'***	
Group Size	*n=5*	*n=10*	*n=5*	*n=10*
Population Size	s=60	s=120	s=60	s=120
$s_a/s_b/s_c$	30/24/6	60/48/12	20/20/20	40/40/40
Welfare				
Benchmark	60,000	120,000	60,000	120,000
Welfare Level	68,640	238,992	85,690	340,584
Increase in %	14.4%	99.16%	42.82%	183.82%
SAM	50.63%	16.75%	8.52%	0,5%
PPL	49.37%	83.25%	91.48%	99.5%
C-SPL	37.33%	9.50%	47.85%	22.67%
T-SPL	-	66.70%	-	44.81%
C-Pareto	0.83%	0%	23.94%	0.3%
T-Pareto	11.23%	7.05%	19.7%	31.72%

*Notes: The number of runs and the distribution of types are the same as in the Table 2, with respect to n= 5. The benchmark is denoted in tokens and calculated in the same way as in section 3, (i.e., 1,200*the welfare of allocation I, which is here 50 and 100, respectively. Likewise, the welfare level is denoted in tokens and obtained in the same way as in Table 2, with the values for n=5 directly taken from Table 2, bottom, layer 3. The percentage increase is directly calculated from the difference between the welfare level and the benchmark. With respect to n = 10, the SAM and PPL (C-SPL, T-SPL, C-Pareto and T-Pareto) percentage figures are calculated by first working out Table 1 for n=10 (which has 11 allocations) and then Table 2 (which has 66 groups). Otherwise, the procedure is exactly the same as in Table 2, bottom. Finally, with n ≥ 7, SPL allocations must be distinguished into those exclusively due to c-type presence (C-SPL) and those where type interaction leads to a higher level of welfare (T-SPL).*

E5 – Other forms of cooperation: In the basic model type interaction rests on a very simple form of conditional cooperation, where b-type agents react to a signal which is based on a positive provision level in the previous round. Many other forms of conditional cooperation and communication of types are conceivable. For example, one could give up the notion that the group of five takes the decision to contribute or not simultaneously in each round and assume instead that group members take the decision in a sequential manner. In this case, and in contrast to the basic model, both the permutation of types within the group and the order with which agents are called to take their decision matters. Consider group 7 (Table 2) and assume that agents are called from left to right. Then, other things being equal, with permutation [b,b,b,b,c] allocation *II* would result in the first round because none of the b-types would contribute as the c-type contributes last. Yet, with permutation [b,c,b,b,b] the last three b-types would contribute and allocation *V* would emerge already in the first round, which is again T-Pareto.

Furthermore, in line with a typical agent-based modeling feature, one could assume that agents look at the behavior of other agents in their neighborhood. For example, b-types may just consider what their immediate neighbor to the left and (or) to the right has done in the previous round. Consider again group 7, with permutation [b_1,b_2,b_3,b_4,c]. In the first round just the c-type would contribute, in the second round b_4 and b_1 would contribute as well because they observe that one of their neighbors (here the c-type) has contributed in round 1. Note that in this context, the row vector of agents has to be interpreted as a circle on which the agents are placed. In agent-based modeling such a circle is known as a 'ring world' (e.g. see Epstein and Axtell 1996, pp. 170–176). In the third round b_2 and b_3 will join in, because their neighbor's b_4 and b_1 have contributed in round 2. Then, if the individual willingness to wait until condition two is fulfilled is equal to or larger than two rounds, i.e., if $\theta \geq 2$ holds for b_4 and b_1, allocation *VI* emerges as of round 3. But if $\theta = 1$ holds for all b-types, b_4 and b_1 will not continue to contribute in round 3 and b_2 and b_3 will not continue to contribute in round 4, so that in round 4 allocation *II* re-emerges. Also, the visibility parameter could be raised to more than one neighbor, which is particularly interesting in larger groups. In this context it is worth noting that the form of conditional cooperation I have introduced in section 3 complies with a ring world where visibility is set to n-1 agents.

Of course, many more variants and other extensions are conceivable, but the suggestions discussed above are already sufficient to illustrate the potential of the basic type interaction model.

5 Summary and Concluding Remarks

In this paper I have tried to shed some light on the role ethical behavior patterns may play in providing public goods. In particular, I assumed that the population contained three behavioral types: myopic selfish agents (a-types), enlightened selfish agents (b-types) and ethically motivated agents (c-types). I then analyzed the impact which alternative distributions of these agent types in the population may have by using an agent-based simulation approach and a standard linear public goods model. Three layers of interest were identified and for each layer the relative shares of the welfare specifications SAM (non-provision of the public good) and PPL (positive provision level of the public good) were calculated, together with the relative shares of relevant PPL sub-specifications.

With respect to the first two layers (group composition and frequency) only the share of c-types in the population matters, because the PPL share does not change if type interaction is impossible so that T-Pareto allocations become SPL allocations. For both layers and for both simulations, it was shown that the PPL share was well in excess of the share of c-types in the population. Moreover, this observation holds true if the third layer (welfare) is considered and corrections are taken to assess the pure impact of the c-type share. These findings clearly indicate that non-provision of public goods, as predicted by the Samuelson model, can be substantially reduced by even a small fraction of ethical motivated agents in the population and it can be almost eliminated if that fraction is somewhat higher than one third. It must be emphasized, however, that Samuelson (1954, p. 389) himself already recognized that Kantian behavior patterns would lead to different results. Yet, it might not have been entirely clear that it may well be sufficient if just a few actually show such behavior patterns.

In addition, the increase of welfare in terms of tokens and the increase of C-Pareto allocations indicates that ethical education is not only beneficial for society as a whole, but may also generate economies of scale over certain ranges. Put differently, although ethically motivated behavior patterns may not be explained by even the broadest definition of self-interest and, therefore, may remain alien to any economics framework (see Pickhardt 2006b, 2005b; Wilber 2004), such behavior patterns can play an important role in welfare enhancing procedures. Recently, this latter point has been stressed with respect to the role moral order plays for the efficient working of market economies (e.g. see Kirchgässner 2008; Petrick and Pies 2007).

Of course, the extensions discussed in section 4 would move the analysis much closer to real world decision environments, which in turn would lead to additional layers and findings. To this extent, the analysis has also demonstrated that reality may be interpreted as an arrangement of layers, each having certain causes and consequences, as illustrated in Table 2 and that agent-based modeling is most suitable for unfolding such layers. Moreover, an extended version of the basic type interaction model may serve as a tool, for example, to replicate results obtained from experiments with human subjects, to gain new insights by comparing and contrasting results from such experiments and agent-based set-ups, and to complement findings from experiments with human subjects by investigating aspects that cannot (or just with difficulties) be done in these experiments (see also Duffy 2006). But this rather delineates a future research agenda.

Appendix: Maple Codes

The following codes refer to the Maple 11 software package, but should run on versions down to Maple 6. For brevity all steps are provided in abbreviated form only and may require some additional, but self-explaining, adjustments with respect to the extensions E1 to E5. In any case it is advisable to consult the Maple user guide. With respect to the extensions and simulations it might also be useful to consult the Maple programming guide and use procedures to link codes. For large scale applications, however, languages such as Java or Fortran may be more suitable.

(A) Type interaction model

```
> restart:                              #clears memory#
> with(combinat, randcomb);             #calls the commands of the combinat-package#
                          [randcomb]
> lst := randcomb([a, b, c, a, b, c, a, b, c, a, b, c, a, b, c], 5);
#defines a list with 5 elements which are drawn at random from the list of elements given in
square brackets; this list is the population or subject pool of size s and the output list is the
group of size n, here with n = 5#
                        [b, c, a, b, b]
> *** Round 1 ***
> x11 := lst[1];
#selects the first element or agent of the group list and defines that the contribution to the
public good of agent 1 in the first round, x11, is made by the selected agent type, which is a b-
type here#
                              b
> x12 := lst[2];
#Likewise, selects the second element or agent of the group list and, defines that the
contribution to the public good of agent 2 in the first round, x12, is made by the selected
agent type, which is a c-type here; proceed in the same way with x13, x14 and x15#
                              c
> if x11 = a then x11 := 0 elif x11 = c then x11 := 2 elif x11 = b then x11 := 0 fi;
#checks the behavioral type of agent 1 in round 1 and provides the appropriate action, which
is defined in round 1 as "not contributing = 0" for a-types and b-types and as "contributing
= 2" for c-types; here 0 for x11; proceed in the same way with x12 to x15#
                              0
> X1 := x11+x12+x13+x14+x15;
#defines X1 as the public good quantity of round 1 by adding up the individual contributions
made by each agent in round 1; see equation (3) in the main text; here X1=2#
                              2
> y11 := 2-x11;
#defines the private good contribution of agent 1 in the first round based on equation (2) of
the main text; proceed in the same way with y12 to y15#
                              2
> U11 := 5*y11+2*X1;
#calculates the payoff of agent 1 in the first round based on equation (1) of the main text;
proceed in the same way with U12 to U15#
                              14
> U1 := U11+U12+U13+U14+U15;
#calculates the overall payoff or welfare level for the first round (see Table 1)#
                              60
```

> *** Round 2 ***

#copy the code of round one and then make the necessary index change for round 2 wherever that applies, that is, x21 to x25, X2, y21 to y25, U21 to U25, U2#

> if x21 = a then x21 := 0 elif x21 = c then x21 := 2 elif x21 = b and X1 > 0 and X1 < 6 then x21 := 2 else x21 := 0 fi;

#regarding b-types it is now checked whether there was a positive provision level caused by either one or two c-types, if so, the b-type contributes and otherwise it does not contribute. Note that one may skip the second 'and' command, X1< 6#

2

> *** Round 3 ***

#copy the code of round 1 or 2 and then make the necessary index change for round 3 wherever that applies, that is, x31 to x35, X3, etc.#

> if x31 = a then x31 := 0 elif x31 = c then x31 := 2 elif x31 = b and X2 > 0 and U21 > U11 then x31 := 2 else x31 := 0 fi;

#regarding b-types it is now checked whether there was a positive provision level in the previous round and whether contributing in the previous round has generated a higher payoff than in the first round (without contributing), if so, the b-type contributes and otherwise it does not contribute#

> U3 := U31+U32+U33+U34+U35;

#payoff of round 3 is calculated, which is here the long-run payoff that prevails throughout all following rounds#

90

> *** End ***

(B) Simulations with alternative agent distributions in the population

Simulation Session 1

> r := 3;

#sets the number of runs (or group lists to be generated) to 3; for the simulations shown in Table 2 of the main text I used r=100#

3

> with(combinat, randcomb);

[randcomb]

> seq(l(i) = randcomb([a, b, c, a, b, c, a, b, c, a, b, c, a, b, c], 5), i = 1 .. r);

#generates a sequence of r group lists with 5 elements, which are selected at random from the given population or subject pool, in this example 3 group lists are generated and numbered 1 to 3; also, in this example the population consists of 15 agents and the three types a, b, and c are equally distributed, yet the order with which a,b,c show up does not matter; for the simulation in the main text I used a population of 60 agents with (20/20/20) for the equal distribution and (30/24/6) for the 50%/40%/10% distribution, respectively; you may have to use lst(i) instead of l(i) in versions lower than Maple 11#

l(1) [c, a, a, a, c], l(2) [b, a, c, b, c], l(3) [a, b, b, a, b]

#I did 12 sessions with 100 group lists per session; of course setting r := 1,200 would have been an alternative#

#At this stage one may either continue with Maple or export the result (i.e. the group lists) via plaint text and then import the result to a spreadsheet package such as MS Excel and analyse the result there; in both cases a simple syntax can be applied: copy the result three times, then replace in the first copy all a's by 1, in the second all b's by 1, etc.; by summing over each group list you get a vector that tells you the number of a,b,c, types in each group list; these three vectors allow you to identify each of the 21 groups of Table 2 with a few simple "if & and" loops and to identify the frequency with which each group has occurred, as shown in Table 2; alternatively a procedure may be used again#

(C) Extensions

#**E1**: *Here one may use the "randcomb" command again. Suppose that all a-types are observed to make a mistake with a probability of, say 10%, then the command* randcomb([0,0,0,0,0,0,0,0,0,2], 1) *could be incorporated into the if loop with*: > if x11 = a then x11 := randcomb([0,0,0,0,0,0,0,0,0,2], 1); *for an alternative syntax see E3#*

#**E2**: *To begin with, I assume that agents can choose from the integer interval [0,1,2]. Agents of type a and c continue to choose just 0 and 2, respectively. However, b-types may either choose 1 or 2, if they decide to contribute and continue to choose 0, if they decide not to contribute. This can be done by either using pre-determined sub-types, say b1-types, who choose either 0 or 1 and b2-types, who choose either 0 or 2. Alternatively, b-types may choose 0, if they do not contribute and select either 1 or 2 at random, if they decide to contribute. In this case the random command may be used with: rand(1..2)(), which selects either 1 or 2 at random.#*

#**E3**: *Again, sub-types could be defined by pre-determining their specific behaviour patterns. For example, consider* $b_{\gamma\theta}$*-types. Then, some of the 24 b-types of distribution (30/24/6) may be ordinary* b_{11}*-types, others may be* b_{03}*-types or* b_{22}*-types, etc. For example, a* b_{22}*-type requires that at least two others have contributed in the previous round in order to make a contribution in the short-run. Also, the b22-type is prepared to wait two rounds until condition two has to be fulfilled. In this case, the 'else if' loop has to be changed to: "elif x21 = b22 and X1 > 2 and X1 < 6 then x21 := 2 else x21 := 0", in rounds 2 [and 3], and to "elif x41 = b22 and X3 > 0 and X3 < 6 and U21 > U11 or U31 > U11 then x41 := 2 else x41 := 0", in round 4. Alternatively, one could create a new agent type, for example, a z-type, who selects its contribution at random from the integer interval [0,1,2], so that the if loop has to be adjusted by: if x11 = z then x11 := rand(0..2)(), for the first round and all following rounds. Alternatively, if a larger integer interval is considered, say [0, 20], some z-types may choose from just the lower part of the interval, rand(0..10)(), or from just a certain upper fraction, rand(16..20)(), etc. This same syntax can be used as an alternative to create mistakes (see E1)#*

#**E4**: *Changes with respect to the parameters* α *and* β *simply require changing U11 to U15, etc. accordingly. Likewise, changes to* B_i *simply require changing y11 to y15, etc. And changes to n require an adjustment of the randcomb command and, of course, an adjustment of all indices.*

#**E5**: *If b-type agents react to the behaviour of their neighbours, it is generally advisable to introduce a round 0, where all agent types by definition contribute 0, so that: x01 := 0, x02 := 0, etc. This is particularly helpful if procedures are used. For round 1 the if loop then is: > if x11 = a then x11 := 0 elif x11 = c then x11 := 2 elif x11 = b and x05 =2 or x02 = 2 then x11 := 2 else x11 := 0 fi; For round 2 the if loop is: > if x21 = a then x21 := 0 elif x21 = c then x21 := 2 elif x21 = b and x15 =2 or x12 = 2 then x21 := 2 else x21 := 0 fi; etc. Note, however, that for the contribution of the second agent x12 (round1) the neighbours' contributions to inspect are x01 and x03 (round 0), and so on.*

References

Andreoni, J. (1989). Giving with Impure Altruism: Application to Charity and Ricardian Equivalence, *Journal of Political Economy,* 97, pp. 1447–1458.

Andreoni, J. (1990). Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving, *Economic Journal*, 100, pp. 464–477.

Batina, R. G. and Ihori, T. (2005). *Public Goods,* Springer, Berlin.

Bordignon, M. (1990). "Was Kant right? Voluntary Provision of Public Goods under the Principle of Unconditional Commitment, *Economic Notes,* 3, pp. 342–372.

Croson, R. T. A. (2007). Theories of Commitment, Altruism and Reciprocity: Evidence from Linear Public Goods Games, *Economic Inquiry*, 45, pp. 199–216.

Duffy, J. (2006). Agent-based Models and Human Subject Experiments, in: Tesfatsion, L. and Judd, K.L. (eds), *Handbook of Computational Economics*, Elsevier: Amsterdam, Volume 2, Chapter 19, pp. 949–1011.

Epstein, J.M. and Axtell, R. (1996). *Growing Artificial Societies*, The MIT Press: Cambridge (Mass.).

Farina, F. and Sbriglia, P. (2008). Conditional cooperation in a sequential move game, *International Review of Economics,* 55, pp. 149–165.

Fender, J. (1998). Altruism and Economics, in: Chadwick, R. (ed.), *Encyclopedia of Applied Ethics,* Volume 1, Academic Press, San Diego.

Fischbacher, U., Gächter, S. and Fehr, E. (2001). Are people conditionally cooperative? Evidence from a public goods experiment, *Economics Letters*, 71, pp. 397–404.

Frey, B.S. and Meier, S. (2004). Social Comparisons and Pro-social Behavior: Testing "Conditional Cooperation" in a Field Experiment, *American Economic Review*, 94, pp. 1717–1722.

Herrmann, B. and Thöni, C. (2008). Measuring conditional cooperation: a replication study in Russia, *Experimental Economics*, forthcoming (available online).

Kirchgässner, G. (2008). *On Minimal Morals*, paper presented at the *CESifo* conference on Ethics and Economics, Munich, February 2008.

Laffont, J-J. (1975). Macroeconomic Constraints, Economic Efficiency and Ethics: an Introduction to Kantian Economics, *Economica*, 42, pp. 430–437.

Ledyard, J. O. (1995). Public Goods: A survey of experimental research, in: J. H. Kagel and A. Roth (eds.), *The Handbook of Experimental Economics,* Princeton University Press, Princeton, pp. 111–194.

Lindahl, E. (1919). Die Gerechtigkeit der Besteuerung. Eine Analyse der Steuerprinzipien auf Grundlage der Grenznutzentheorie. Translated by E. Henderson as: Just taxation – a positive solution, in R. A. Musgrave and A. T. Peacock (eds.), *Classics in the Theory of Public Finance*, London 1958, 4th Impression 1967, pp. 68–176.

Musgrave, R. A. (1939). The Voluntary Exchange Theory of Public Economy, *Quarterly Journal of Economics*, 53, pp. 213–237.

Petrick, M. and Pies, I. (2007). In search for rules that secure gains from cooperation: the heuristic value of social dilemmas for normative institutional economics, *European Journal of Law and Economics*, 23, pp. 251–271.

Pickhardt, M. (2005a). Teaching Public Goods Theory with a Classroom Game, *Journal of Economic Education*, 36, pp. 145–159.

Pickhardt, M. (2005b). Some Remarks on Self-Interest, the Historical Schools and the Evolution of the Theory of Public Goods, *Journal of Economic Studies*, 32, pp. 275–293.

Pickhardt, M. (2006a). Fifty years after Samuelson's 'The Pure Theory of Public Expenditure': What are we left with?, *Journal of the History of Economic Thought*, 28 (4), pp. 439–460.

Pickhardt, M. (2006b). Ética y la provisíon de bienes publicós, in: Miguel Angel Galindo Martín (ed.), *Ética y Economía*, Instituto de Estudios Fiscales: Madrid, pp. 229–249.

Samuelson, P.A. (1954). The Pure Theory of Public Expenditure, *Review of Economics and Statistics*, 36, pp. 387–389.

Tesfatsion, L. and Judd, K.L. (eds.) (2006). *Handbook of Computational Economics*, Volume 2, Elsevier: Amsterdam.

Wilber, Ch. K. (2004). Ethics and Social Economics, *Review of Social Economy*, 62, pp. 425–439.

Zelmer, J. (2003). Linear Public Goods Experiments: A Meta-Analysis, *Experimental Economics*, 6, pp. 299–310.