A few can do –
Ethical behavior and the provision of public goods in an agent-based model

by

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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 forward-looking 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, even if the share of ethically motivated types in the population is rather small.

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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, neoclassical public goods theory of the Samuelson-Musgrave type 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 reveal their true preferences. 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 Fischbacher and Gächter 2010; Herrmann and Thöni 2009; 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 positive provision levels or even a Pareto-optimal provision of public goods. Reciprocal action, conditional cooperation, other-regarding preferences, etc. are topics of interest here (e.g. see Fischbacher and Gächter 2010; Croson 2007; Frey and Meier 2004; Brandt and Schram 2001; Fischbacher et al. 2001). Yet, in experimental settings identification of the exact behavioral type of a human 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. In contrast, an agent-based approach allows for a perfect control of the behavioral types and their shares in the subject pool, even if the subject pool is rather large. Also, running experiments with human subjects for a large set of different parameter values may be rather costly. For these reasons, I am 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 may have on the provision of public goods, if one agent type shows ethically motivated behavior patterns. 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, among other things, as a framework to distinguish Pareto-optimal allocations from Pareto-suboptimal allocations. In section three I then introduce a model of behavioral type interaction that may increase the level of public good provision and may even lead to a Pareto-optimal provision level of public goods. Simulation results are provided in section four and in the following section I discuss these results and the underlying driving forces. Finally, in section six I offer a few extensions of the basic type interaction model. 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 human subjects from laboratory experiments with public goods (e.g. see Hold and Laury 2008; Zelmer 2003; Ledyard 1995). 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 free ride if that promises higher benefits than 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 2009; Pickhardt 2005a; Burlando and Guala 2005; Kurzban and Houser 2001; Fischbacher et al. 2001), I use these behavioral types in the following.

Accordingly, the behavior patterns of a-type agents are characterized by 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 because they have recognized that they may maximize their long-run payoff by contributing, if certain conditions hold. To this extent, their behavior is forward-looking and in line with the modeling approach of Isaac et al. (1994, pp. 21–26). In particular, b-types contribute in the short-run if and only if others are contributing as well. In this sense they are conditional cooperators. However, they continue to contribute in the long-run if and only if they are better off by contributing, that is, if ‘cooperative gain seeking’ is successful. It is for this reason that I describe b-type behavior as enlightened selfish behavior. Isaac et al. (1994) and Brandts and Schram (2001) provide experimental evidence for such b-type behavior patterns in linear public goods games and Farina and Sbriglia (2008, p. 164) find experimental evidence for such behavior patterns in a sequential move game.

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 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 Figuieres et al. 2009, pp. 6-8; 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 immediately be 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 that contains non-empty sets of a-, b- and c-types 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, voluntary, 'public goods' refers to goods consumed in a nonrival manner and public goods 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 follow Brown-Kruse and Hummels (1993), McCrokle and Watts (1996) or Isaac et al. (1994, pp. 21–23) and assume a binary contribution environment in which 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:

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

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 public good model, equations (1) to (4), 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:

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

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 marginal rate of substitution and, therefore, the marginal incentive to contribute to the public good (see Ledyard 1995, p. 149). Based on this definition it follows from (1) that the MPCR amounts to: (2/5) = 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 $(2 \cdot 5 - 5 =)$ 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 $(8 \cdot 2 - 3 \cdot 2 =)$ 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 (2005a, 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.

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*

Note: 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 two 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 three denotes the individual and aggregate payoff received by contributors in terms of tokens, with n_p denoting the number of agents who provide 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.

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 tokens, whereas the contributing agent has a payoff of (5·0 + 2·2 =) 4 tokens, so that the overall payoff or welfare level is (4·14 + 1·4 =) 60 tokens. 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 illustrates the prevailing prisoner's dilemma where the dominant strategy is not to contribute to the public good.

Inspection of Table 1 also reveals that if any of the allocations *I, II* or *III* prevails, at least one other allocation exists in the set of feasible allocations 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* 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 allocation exists 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. Hokamp and Pickhardt (2010) develop a generalized method for calculating Table 1 that can be applied to any conceivable parameter constellation. Among other things, they also show that the binary decision case does not restrict the generality of the results.

Finally, because every resource unit invested into the public good increases welfare by five tokens, column four 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 one and two). 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 of the smallest type share. 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 share is the c-type share with 10% and, thus, $\breve{s}$ is (5 · 1/0.1 =) 50 and the absolute 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 three, where all five agents are of type *c*. In contrast, if a population size below $\breve{s}$ is chosen, say $s = 30$, absolute type shares are: $s_a = 15$, $s_b = 12$, $s_c = 3$, and group three could never be drawn because there are only three 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 the number of agents of each type 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 absolute type shares, 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 zero, that is, $x_{i_a} = 0$, $\forall\ i_a$. Likewise, c-type agents will always contribute two, 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 three 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 two, with contributing) was higher than in round one (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: 1) if there is no c-type in the group, b-types will not contribute in round two and in all further rounds because of the first condition, 2) if there are more than two c-types in the group (i.e. three or four c-types), the allocation in round one will already be Pareto-optimal (i.e. allocations *IV* or *V*, respectively), and although b-types will contribute in round two 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 three. 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 one and allocation *V* in round two, 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*). In other words, condition three implies that b-types assume their own behavior has an impact on the behavior of others. Therefore, they anticipate that others may stop contributing in the following round, if they themselves stop contributing. Put differently, they know that if they deviate from contributing in round three the allocation of the first round will re-emerge in round four. Hence, although unilateral deviating from contributing may lead to a higher payoff in the short-run (here in round three), they anticipate that their unilateral deviating would lead to lower payoffs in the long-run (here as of round four) and, therefore, refrain from unilateral deviating and continue to contribute.

The fourth condition states that b-types will not start contributing again, once their first attempt to establish a profitable long-run contribution environment has failed (*fourth condition*). Hence, they contribute in round two, if condition one is fulfilled and they continue to contribute as of round three, if conditions two and three are fulfilled. Yet, if this is not the case in round two or in any following round, they will stop contributing and never start contributing again in any following round. Thus, 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.

Essentially, the four conditions represent implicit additional constraints which b-types take into account in maximizing their long-run payoff. In the following section I demonstrate this with a few numerical examples. To summarize, b-type agents will contribute in the long-run (i.e., as of round three), if:

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

#2: the payoff in round two (with contributing) was higher than in round one (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 to establish a profitable long-run contribution environment has failed.

Thus, the type interaction model works as follows: In round zero nature gives the type distribution in the population of size *s*. In the first round a group of size *n* is drawn from the population of size *s* and the number of c-types in this group is revealed because only c-types contribute in the first round. In the second round the number of b-types in the group of size *n* is revealed, provided that there is at least one c-type in the group, because in this case all b-types contribute in the second round. In the third round, depending on whether type interaction is stable or not, either the allocation of the second or the first round, respectively, re-emerges. This re-emerged allocation then prevails in all following rounds.

Finally, it should be emphasized that the type interaction model I have introduced above may be viewed as a binary, multi-period extension of the forward-looking approach of Isaac et al. (1994, pp. 21-26) and also complies with the approach of Brandts and Schram (2001). Holt and Laury (2008) provide an overview.

4. Simulation results

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 three 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 four 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 one the c-type agent will contribute and, therefore, the b-types will contribute in round two as well. But in round three the two b-type agents do not contribute because condition two was not fulfilled in round two and because of condition four, allocation *II* prevails as of round three.

Table 2: Group compositions, welfare specifications and simulation results

	Group	Allocation		*50/40/10*		Equal	
No.	**Composition**			**Freq.**	**Welfare**	**Freq.**	**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%*	*0.82%*	*20.75%*	*23.94%*
	14.29%		*T-Pareto*	*7%*	*11.23%*	*14.92%*	*19.7%*

Note: No. denotes the group number; a, b, c denotes the behavioral type of the agent; Allocation (column three) denotes allocations corresponding to those in Table 1, while column four 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 four of Table 1. Percentage figures at the bottom show the relative shares with which each welfare specification occurs, with PPL denoting positive provision level (so that SPL, C-Pareto and T-Pareto are PPL sublevels). For brevity, variances and other statistics are not displayed here.

Note that allocations *II* and *III* imply a positive but suboptimal provision level (SPL) of the public good, which is denoted in column four of Table 2. Moreover, according to Table 1 the payoff stream in tokens for each of the two b-types is: 14, 12, 14, 14, …, in rounds one to four, respectively. The payoff stream makes it clear that b-types are risking a possible lower payoff in round two (here 12 instead of 14 tokens, thus, two tokens forgone payoff) in exchange for a possible higher payoff in the long-run. However, in this example it turns out that the b-types are not rewarded by a higher long-run payoff and, therefore, the two b-types do not continue to contribute to the public good as of round three.

In contrast, in group 15 (b,b,b,a,c), type interaction will lead to allocation *V* as of round three, because the three b-types will start contributing in round two and continue to do so in round three and all following rounds because condition two holds (16 tokens > 14 tokens, see Table 1 and (7)) and because conditions three and four hold as well. Therefore, according to Table 1 the payoff stream in tokens for each of the three b-types is: 14, 16, 16, 16, 16, 16, …, in rounds one to six, respectively. This payoff stream is also useful for demonstrating that b-types maximize their long-run payoff by contributing, if the four conditions hold. For example, if one of the b-types had instead opted for unilateral deviating in round three, the resulting payoff stream in tokens for the deviating b-type would have been: 14, 16, 22, 14, 14, 14, …, in rounds one to six, respectively. Adding up the payoffs of the first six rounds shows that both payoff streams amount to 94 tokens. Thus, in this example, from round seven onwards the long-run payoff from contributing exceeds the payoff from unilateral free-riding.[1]

[1] Discounting is disregarded here because typically in linear public goods games about 10 to 30 rounds are played and games take just about 60 to 90 minutes. This notwithstanding, discounting would not alter the main conclusions. Also, to give another example, consider group 7 (b,b,b,b,c), Table 2. Other things being equal, the payoff stream in tokens for a b-type that deviates in round three is now: 14, 20, 26, 14, 14, 14, …, in rounds one to six, respectively. But if all four conditions hold it is: 14, 20, 20, 20, 20, 20, …, in rounds one to six, respectively. In this case the payoff streams are equal after just four rounds (74 tokens) and as of round five the long-run payoff from contributing exceeds the payoff from unilateral free-riding.

Hence, in group 15 the Pareto-optimal allocation *V* emerges due to type interaction, which is denoted by T-Pareto in column four of Table 2. In cases where a Pareto-optimal allocation emerges already in round one, because the group contains three or more c-types, this is denoted by C-Pareto in column four of Table 2. 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 Masclet et al. 2009; Farina and Sbriglia 2008; with respect to sequential move games).

Further inspection of Table 2, columns two and four, 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 one 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, the entire outcome of the process c*eteris paribus* depends solely on the distribution of agent types within the population. Table 2, column five, shows the frequencies with which each group occurs in a simulation based on 1,200 runs, 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 seven 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 by the author upon request.

Comparison of the percentage figures at the bottom of Table 2, columns two, five and seven, reveals how the initial group weights (column two, layer one) are changed by the prevailing distribution of agent types in the population (columns five and seven, layers 2a and 2b). Moreover, column five (layer 2a) and column seven (layer 2b), show that a comparatively small fraction of c-type agents (i.e., 10% and 33.33%, respectively) is sufficient to ensure that a substantially higher share of groups exhibits 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 about 33.33% or higher, but below 50%.

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 six and eight, respectively. The relevant values are obtained from multiplying the frequencies with the relevant overall payoff or welfare given in Table 1, column four. 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 six and eight (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 in the range of 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 six (68,640 tokens) and column eight (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 five and seven. 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.

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 in groups with a positive provision level due to pure c-type presence. Comparison with the uncorrected figures provided earlier on (i.e. 49.37% and

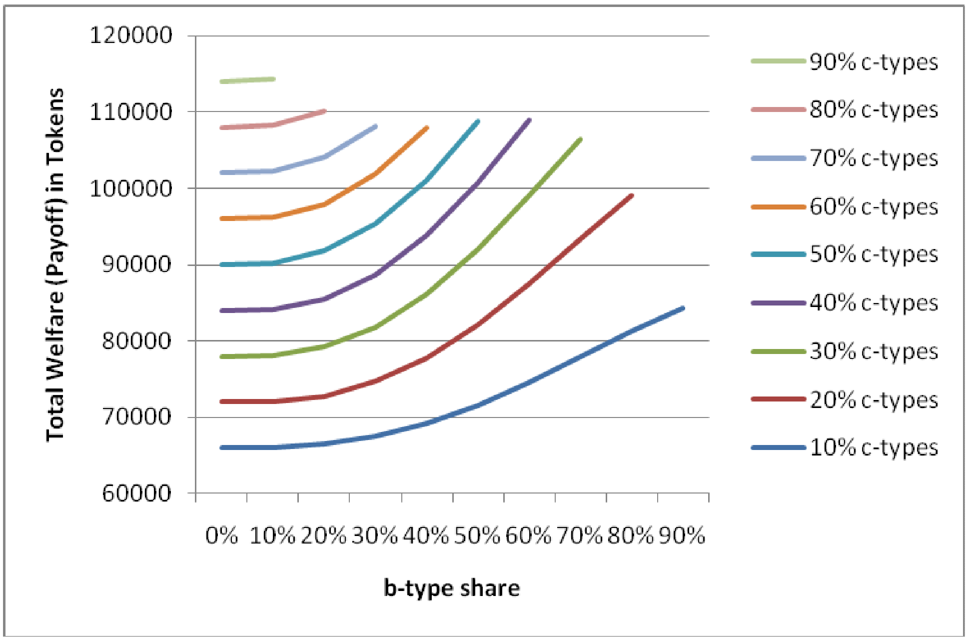
91.48%, respectively) shows that the difference does not change the conclusion already drawn.

5. Discussion

The simulation results obtained from the basic type interaction model raise three questions of particular interest: 1) What happens if alternative agent type distributions are considered? 2) Will the results be influenced by an increase of the group size *n*?, and 3) What drives the results?

To address the first question, I fix the number of c-types to a certain percentage share and then raise the share of b-types *ceteris paribus* from zero to ninety percent, at the expense of the a-type share. This procedure allows for considering any conceivable type distribution and Figure 1 shows how total welfare develops for alternative type distributions in the population, if the group size *n* is set to five.

Figure 1: Total welfare for alternative *b*-type and *c*-type shares (for *n* = 5)



Note: 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; a-type share of 100 percent) to the maximum of 120,000 tokens (c-type share of 100 percent; a-type share of zero 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 c-type effect on total welfare and horizontally Figure 1 shows the type interaction effect on total welfare. For example, 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 somewhat above the line that represents the 30 percent c-type share and somewhat to the right of the 30 percent b-type share.

To address the second question, I raise the group size *ceteris paribus* in steps of five from n=5 to n=50 and consider the effect on the layer 3 percentage shares of the welfare specifications (see Table 2, bottom). Results are shown in Figure 2. For example, in Figure 2a where the distribution of a-types, b-types and c-types in the population is 50/40/10 percent, respectively, the PPL share approaches 100 percent when n is about 35. Essentially the same is true for the equal type distribution shown in Figure 2b, but here a group size, n, of about 10 is already sufficient. If the a-type share is rather high, as in Figure 2c with a type distribution of 95/4/1 percent, the PPL share approaches 100 percent only when n is raised to about 500 (not displayed in Figure 2c).

With respect to the first three values of the group size, n, that is, 5, 10 and 15, more detailed results are also presented in Table 3.

Figure 2: Layer 3 shares for alternative group sizes and type distributions

Figure 2a: 50/40/10 percent distribution

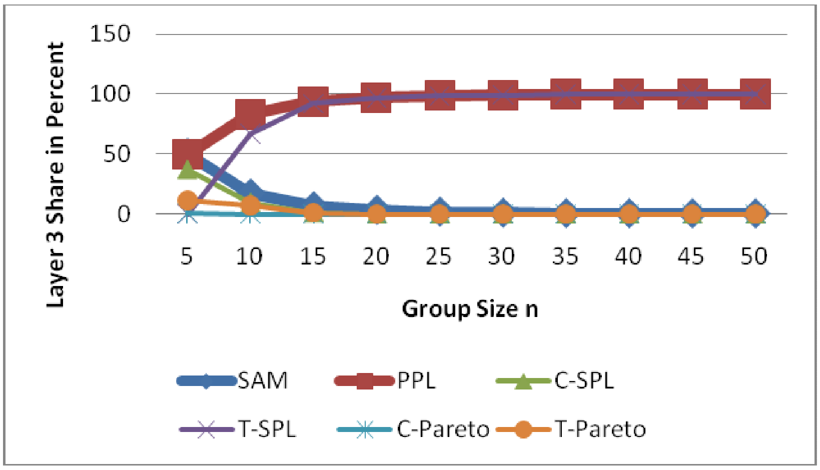


Figure 2b: Equal distribution

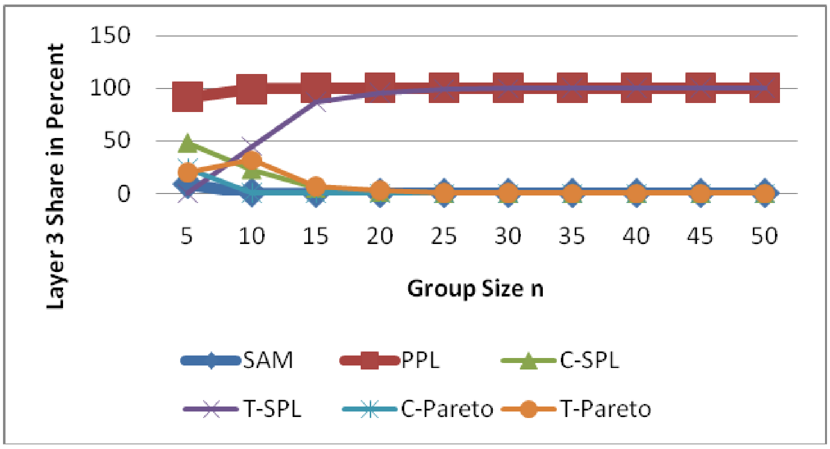


Figure 2c: 95/4/1 percent distribution

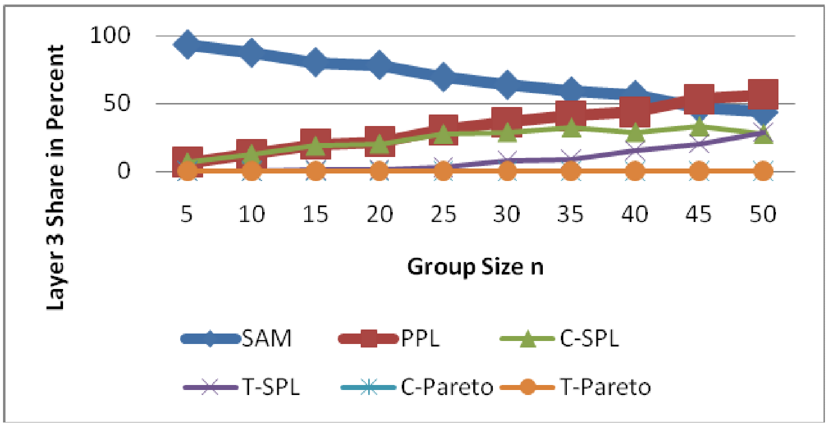


Figure 2d: 1/4/95 percent distribution

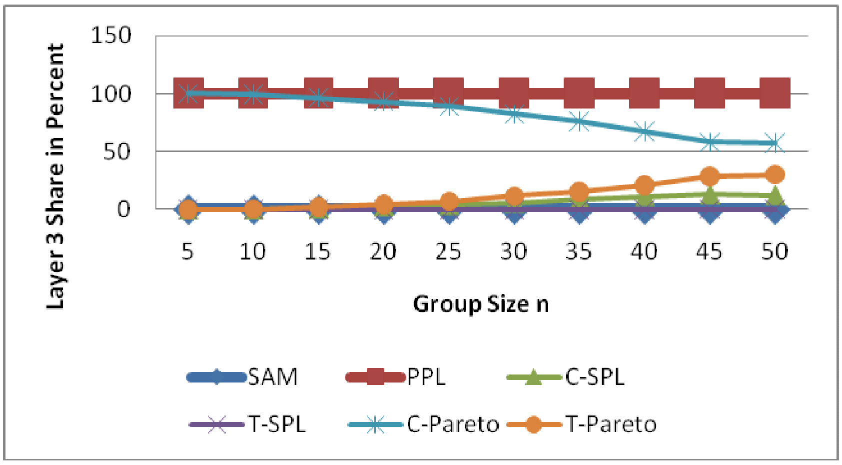
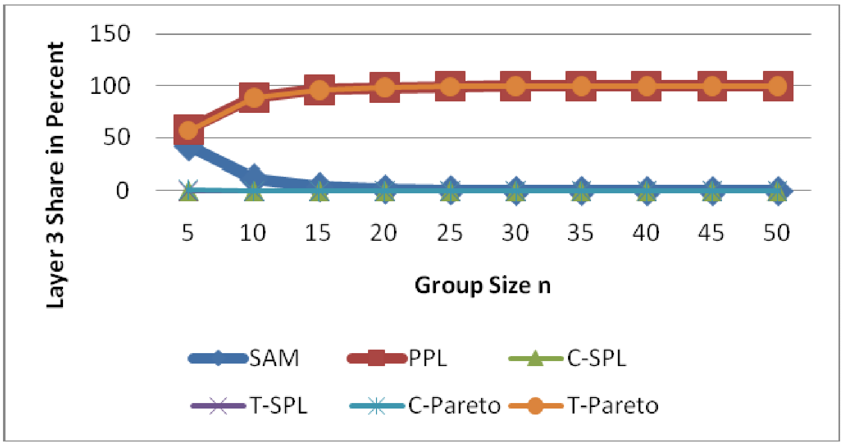


Figure 2e: 0/90/10 percent distribution



Note: Each distribution refers to the percentage shares of agent types in the population, using the format (a-types / b-types / c-types). Values of the welfare specifications SAM and PPL are provided in bold lines and values of the PPL sub-specifications C-SPL, T-SPL, C-Pareto and T-Pareto are displayed by thin lines. The percentage shares refer to the layer 3 (welfare) shares provided in Table 2, bottom (just for the first two distributions, Figures 2a and 2b).

Moreover, it is important to note that with $n \geq 7$, SPL (suboptimal provision level) specifications 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).

Inspection of Figure 2 and Table 3, in particular with respect to the SAM and PPL shares (see bold lines in Figure 2), shows that the results presented in the previous section are reinforced if n is increased, *ceteris paribus*. In particular, Figure 2 and Table 3 indicate that for any type distribution where the a-type share does not approach 100 percent and the c-type share does not approach zero percent, all welfare will eventually be generated in groups with a positive provision level of the public good (PPL), if a sufficiently high *n* is selected. With type distributions 1/4/95 percent and 0/90/10 percent, a low *n* of 5 and 30, respectively, already yields a 100 percent PPL share.

Also, with respect to the first four type distributions, Figures 2a to 2d, the positive provision level (PPL) eventually consists entirely of T-SPL specifications, with C-SPL, C-Pareto and T-Pareto specification shares all approaching zero percent. In Figures 2a and 2b, this process is already visualized, whereas in Figures 2c and 2d a higher group size, *n*, of about 500 and 1,000, respectively, would be required (not displayed in Figure 2).

Table 3: Layer 3 shares for group sizes of 5, 10 and 15

Runs=1,200	***Distr. 50/40/10 Percent***			***Distr. Equal***		
	n=5	*n=10*	*n=15*	*n=5*	*n=10*	*n=15*
	s=60	s=120	s=180	s=60	s=120	s=180
$s_a/s_b/s_c$	30/24/6	60/48/12	90/72/18	20/20/20	40/40/40	60/60/60
Welfare						
Benchmark	60,000	120,000	180,000	60,000	120,000	180,000
Welfare Level	68,640	238,992	550,860	85,690	340,584	771,828
Increase in %	14.4%	99.16%	206.03%	42.82%	183.82%	328.79%
SAM	50.63%	16.75%	6.28%	8.52%	0,5%	0.04%
PPL	49.37%	83.25%	93.72%	91.48%	99.5%	99.96%
C-SPL	37.33%	9.50%	1.21%	47.85%	22.67%	5.28%
T-SPL	-	66.70%	92.07%	-	44.81%	85.83%
C-Pareto	0.83%	0%	0%	23.94%	0.3%	0%
T-Pareto	11.23%	7.05%	0.44%	19.7%	31.72%	8.85%

*Note: 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 4, (i.e., 1,200*the welfare of allocation I, which is here 50, 100 and 150, for n=5, 10 and 15, 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 [n=15], the SAM and PPL (C-SPL, T-SPL, C-Pareto and T-Pareto) percentage figures are calculated by first working out Table 1 (which has 11 [16] allocations) and then Table 2 (which has 66 [136] groups). Otherwise, the procedure is exactly the same as in Table 2, bottom. Finally, with $n \geq 7$, SPL (suboptimal provision level) specifications 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).*

It must be emphasized, however, that although in each of these four cases the PPL is eventually dominated by T-SPL specifications, the layer 3 total welfare levels in terms of tokens would differ in each case, depending on the exact type distribution. To some extent, this is already illustrated in Table 3 for the n = 15 values of the total welfare level (550,860 tokens versus 770,826 tokens). Furthermore, in contrast to the first four distributions shown in Figure 2, the PPL is entirely dominated by T-Pareto specifications for $n \geq 5$ in Figure 2e, with type distribution 0/90/10 percent.

Finally, Table 3 shows that increasing returns are clearly present. For example, multiplying n, s_a, s_b, and s_c with factor 2 raises total welfare by factor 3.48 in case of the 50/40/10 percent distribution (i.e., from 68,640 to 238,992 tokens) and by factor 3.97 in case of the equal shares distribution (i.e., from 85,690 to 340,584 tokens).

To summarize, if the group size n is sufficiently large, then, for any type distribution where all three agent types a, b, c have a positive percentage share in the population, the percentage share of SAM specifications will approach zero and all welfare will be generated in groups that show a PPL specification. In addition, the PPL will be eventually dominated by T-SPL specifications. These two critical group sizes, n_{PPL} and $n_{T\text{-}SPL}$, may or may not coincide (see Figure 2). Likewise, if the a-type share is zero and the b-type and c-type shares are both positive, all welfare will again be generated in groups that show a PPL specification. However, the PPL will now be dominated by T-Pareto specifications rather than by T-SPL specifications. Again, these two critical group sizes, n_{PPL} and $n_{T\text{-}Pareto}$, may or may not coincide (see Figure 2). Put differently, all welfare will be generated in groups where no public good is provided (SAM specifications), only if either the a-type share in the population is 100 percent or the b-type share is 100 percent or if the a-type and b-type shares add up to 100 percent.

To address the third question of what drives the results, I now consider the conditions for the occurrence of each welfare specification, subject to the prevailing public goods model of section 2. These conditions are summarized in Table 4, for SAM and for the PPL sublevels C-SPL, T-SPL, C-Pareto and T-Pareto. Moreover, they are provided for group sizes of 5, 10 and 15 and in generalized form for the relevant cases of *n* > 2. Inspection of Table 4 shows that these conditions address the group composition, that is, how many b-types and/or c-types are required or allowed in a group of size *n*, so that a certain welfare specification may actually occur. For example, with respect to *n* = 5, the conditions yield the group composition requirements discussed above in section 3 and comply with the group compositions shown for each welfare specification in Table 2, column two (with SPL in Table 2 referring to C-SPL in Table 4).

Table 4: Group composition conditions for each welfare specification

Group Size	n = 5	n = 10	n = 15	n > 2
SAM	$n_c = 0$	$n_c = 0$	$n_c = 0$	$n_c = 0$
PPL				
C-SPL	$0 < n_c \leq 2$ $n_b \leq 2$	$0 < n_c \leq 7$ $n_b \leq 2$	$0 < n_c \leq 12$ $n_b \leq 2$	$0 < n_c \leq (n-3)$ $n_b \leq 2$
T-SPL	---	$0 < n_c \leq 4$ $n_b \geq 3$ $n_c + n_b \leq 7$	$0 < n_c \leq 9$ $n_b \geq 3$ $n_c + n_b \leq 12$	$0 < n_c \leq (n-6)$ $n_b \geq 3$ $n_c + n_b \leq (n-3)$
C-Pareto	$n_c \geq 3$	$n_c \geq 8$	$n_c \geq 13$	$n_c \geq (n-2)$
T-Pareto	$0< n_c \leq 2$ $n_b \geq 3$ ---	$0 < n_c \leq 7$ $n_b \geq 3$ $n_c + n_b \geq 8$	$0 < n_c \leq 12$ $n_b \geq 3$ $n_c + n_b \geq 13$	$0 < n_c \leq (n-3)$ $n_b \geq 3$ $n_c + n_b \geq (n-2)$

Note: SAM denotes non-provision of the public good, PPL denotes a positive provision level of the public good, C-SPL denotes supoptimal provision level due to c-type presence, T-SPL denotes supoptimal provision level due to type interaction, C-Pareto denotes Pareto-optimal provision level due to c-type presence and T-Pareto denotes Pareto-optimal provision level due to type interaction, and n_b*,* n_c *denote the number of b-types and c-types, respectively, in a group of n agents.*

Table 4 also shows that for the SAM and C-Pareto specifications only one condition applies, whereas two conditions must be fulfilled simultaneously for C-SPL specifications and even three conditions must hold simultaneously for stable type interaction (i.e., T-SPL and T-Pareto specifications). Further, some conditions depend on the group size *n*, but others do not and for some welfare specifications just the c-type share matters, whereas for other specifications both the c-type and the b-type share matters. The group composition conditions provided in Table 4 fully explain the results shown in Figures 1 and 2 and Tables 2 and 3 and they can be used to assess *ceteris paribus* the expected results of any other conceivable type distribution and/or group size.

For example, consider Figure 2d with an agent type distribution of 1/4/95 percent. With a low group size, the probability that the C-Pareto condition, $n_c \geq (n\text{-}2)$, is fulfilled is virtually one (see Figure 2d, $n \leq 10$). Yet, as the group size increases *ceteris paribus* the occurrence of either a-types or b-types in a group becomes more likely and, thus, it is less likely that the C-Pareto condition can be fulfilled. Eventually, as *n* increases further, the probability that C-Pareto specifications occur at all approaches zero. Moreover, even the probability that Pareto-optimal specifications (C-Pareto and T-Pareto) occur at all becomes zero, because the expected number of a-types in each group becomes sufficiently high to prevent both the C-Pareto condition, $n_c \geq (n\text{-}2)$, and the T-Pareto condition, $n_c + n_b \geq (n\text{-}2)$. In contrast, if the a-type share is zero and both the b-type and c-type shares are positive, as in Figure 2e with agent type distribution of 0/90/10 percent, all welfare will eventually be generated in groups that show a T-Pareto specification, if the group size is sufficiently large.

Furthermore, with respect to type interaction in general (see Table 4, T-SPL and T-Pareto), it is worth noting that the first conditions, $0 < n_c \leq (n\text{-}6)$ and $0 < n_c \leq (n\text{-}3)$, are fulfilled *ceteris paribus* for any positive share of both b-types and c-types if *n* is sufficiently large and the c-type share does not approach 100 percent. The second condition, $n_b \geq 3$, is the same for all *n* due to equation (7). Hence, with either a higher share of b-types or a higher group size *n* (or both taken together), the probability that this condition is fulfilled increases *ceteris paribus*. Also, the third condition for either a T-SPL or T-Pareto specification, $n_c + n_b \leq (n\text{-}3)$ and $n_c +$

$n_b \geq (n-2)$, respectively, are complements so that one of them always holds. Therefore, all welfare will eventually be generated in groups where type interaction (T-SPL or T-Pareto specifications) prevails, provided that the population contains non-empty sets of b-types and c-types and the group size *n* is sufficiently large.

Finally, the simulation results presented in section 4 and the discussion in this section clearly indicate 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, many other aspects of the basic type interaction 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), non-provision of public goods is a negligible issue, if the circumstances described above prevail and the group size is sufficiently large.*

(iv) *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.*

These findings have a number of policy implications. For example, the private provision of public goods by ethically motivated agents and via type interaction may to some extent replace public goods provision by government through a political process. Also, in some cases it may even turn out that a political decision to raise the level of ethical education is more efficient with respect to the desired level of public goods than a political process that aims directly at the public goods provision level. Further, rather than representing an individual agent, the three behavioral types may represent social interest groups who are interacting in a political process over public goods provision. Areas of interest could be environmental or social security insurance issues, where some interest groups may represent members with myopic selfish views, while others my hold enlightened selfish views and still others may be ethically motivated.

6. Extensions

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 and the simulation results obtained from the basic type interaction model may serve as a benchmark. Therefore, I shall briefly discuss some extensions of the basic type interaction model.

E1 – Type diversification: The basic model is limited to just three behavioral types. Real human behavior patterns, however, are much richer and diverse. Hence, 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 implicit conditional cooperation parameters of some of the b-types. In the basic model I assumed that the parameter value for 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. Thus, in round one, 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. In addition, b1-types, b2-types, etc. could be introduced, where the b1-type coincides with the standard b-type of the basic model.

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 one round in the basic model, could be changed for some b-types to two 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 some b-types start contributing only if the average contribution of others reaches certain threshold levels. Other examples include the individual willingness to deviate from contributing, δ, which was set to one 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). Furthermore, b-types may differ in their beliefs about other's willingness to deviate, ϕ, which was also set to one agent in the basic model, or 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 zero 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 breakdown of successful type interaction leads to adjustments with respect to other individual parameter values.

E2 – Other forms of cooperation: The basic type interaction model 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 type communication 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. 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. Note that in this case 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). 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 mentioning 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.

7. Summary and concluding remarks

In this paper I have 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. In contrast to the black-box approach usually employed in agent-based modeling, this procedure allowed me to identify three layers of interest and to calculate 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), 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 [T-SPL] allocations become SPL [C-SPL] allocations. For both layers and for both simulations, it was shown in Table 2 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. Further, they continue to hold and may even be reinforced if alternative type distributions and higher group sizes are considered, as demonstrated in section 5. 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 that it can be eliminated for any type distribution that contains a non-empty set of c-types, if the group size n is sufficiently large. 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 due to type interaction and the possible high share of welfare generated in groups that show a C-Pareto or T-Pareto provision level 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 Petrick and Pies 2007).

Of course, the extensions discussed in section 6 would move the analysis much closer to real world decision environments, which in turn would lead to additional layers and findings. Moreover, an extended version of the basic type interaction model may serve as a tool, for example, to test the findings from the agent-based model in an experiment with human subjects, to replicate results obtained from other 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.

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