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INEQUALITY, TRUST, AND GROWTH: AN EXPERIMENTAL STUDY

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Discussion paper

Inequality, Trust, and Growth: An Experimental Study

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Abstract

In a three player dynamic public goods experiment, social output today determines production possibilities tomorrow. In each period, players choose to sabotage, to co-operate, or to play best response. Sabotage harms social output and growth. Mutual co-operation maximises both. The property rights to social output are distributed unequally. Extent and skew of inequality are varied. Empirical studies indicate a negative impact of inequality on trust and growth. We observe equilibrium play in most cases. There is also substantial co-operation, but little sabotage. Our exogenous variations of inequality are neutral to growth, neither negatively correlated to co-operation, nor positively correlated to sabotage.

JEL codes: C91, H55

Keywords: dynamic public goods, fairness, reciprocity, growth

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1. Introduction

A long-standing contentious issue in democracies is the effect of income inequality on the growth rates of economies. In one view, inequality stimulates growth, because the rich are assumed to have a greater propensity to invest than the poor. Thus, as inequality is increased, investments are increased, leading to an increased growth. In a contrasting view, increased inequality reduces economic growth, because it enhances the negative effects of a number of socio-economic variables. Some authors, for example, argue that increased income inequality leads to decreased growth, because of an increased re-allocation of resources from production into distributive conflicts (e.g. Persson and Tabellini 1994). Other authors argue that growth is impeded by inequality, because inequality is detrimental to trust that is essential for reducing transaction costs and increasing investments (Knack and Keefer 1997; Zak and Knack 2001).

The empirical results received so far on the effects of inequality on growth are mixed (Forbes 2000). All empirical studies on the topic, however, are based on macroeconomic data, while the theories that produce the tested hypotheses are based on individuals' motives (see Aghion, Caroli, and Garcia-Peñalosa 1999 and Zweimüller 2000 for overviews). It seems to us that, as controlled variation is possible, the method of economic experimentation complements the macro data analysis, giving a better insight into the actual motives driving individual behaviour. To this end, the merits of controlled experimentation have been impressively documented by a growing number authors (e.g. Hey 1991; Roth 1995; Loomes 1999; Starmer 1999; Fehr and Gächter 2000b).

With this paper, we present the first experimental study of individual behaviour under controlled variation of inequality that is aimed at understanding the connection between inequality, trust, and growth. The hypothesised negative effect of inequality on trust and growth is based on two central assumptions. First, it is assumed that inequality negatively affects trust amongst society's members. Second, it is assumed that the lack of trust impedes growth, because it leads to an inefficient increase of transaction costs. There is a strong case for the second assumption both in the empirical and in the experimental literature. Knack and Keefer (1997) and Zak and Knack (2001) use cross-country regressions to demonstrate a positive correlation of growth (and the ratio of investments to GDP) to a measure of trust that is based on two questions from the World Values Surveys (see Inglehart 1999). They also verify that the trust measure used is highly correlated to experimental evidence on the "lost wallet game" across countries.[1] Glaeser, Laibson, Scheinkman, and Soutter (2000) compare trust measures of the type used in the macro data analyses and compare these to individual behaviour in an experiment. They find a weak positive correlation of the measures to trusting behaviour and a strong positive correlation to trustworthiness. Furthermore, the trust measure is explicitly meant to include reputation effects and formal or informal sanctions, both of which have been shown to enhance co-operation and efficiency in experiments (e.g. Keser and van Winden 2000; Fehr and Gächter 2000a).

The evidence on the first assumption, however, is far from complete, leaving the question open whether inequality actually has a negative impact on trust. Using plausible assumptions, Zak and Knack (2001) analytically derive the result that social distance reduces trust. But empirically, social distance is a vague concept that can be measured along many dimensions, income inequality being only one of the candidates. Indeed, although Zak and Knack (2001) find inequality (in terms of the Gini coefficient) to be negatively correlated to their trust measure, they caution the reader that their evidence is based on "... preliminary tests that do not fully resolve the causality issues." (p. 314) Other variables such as "ethnic homogeneity" and "economic discrimination" also have a strong impact on their trust variable. It is an open issue which of these (and other) variables independently effect trust. It might well be the case that inequality and trust are both related to the same underlying variable (perhaps to economic discrimination). In that case, "social distance" may actually be very strongly correlated to trust, but not necessarily through income inequality. This may explain why Glaeser *et al.* (2000) do not even consider income inequality as a correlate of trust, but do find a significant negative effect of social distance (measured in "national and racial heterogeneity") on trust. A similar result is documented in the experiment of Fershtman and Gneezy (2000).

So far, no clear experimental evidence has emerged establishing the hypothesised negative effect of inequality on either trust or trustworthiness. In fact, the two experiments that come closest to the core of this issue (Chan, Mestelman, Moir, and Muller 1996 and 1999) both report a contradicting result. They find a small but positive effect of inequality on voluntary contributions to public goods (especially by the "poor"), which indicates a (partially) positive correlation between inequality and trust.

[1] In these experiments, wallets containing cash and the contact address of the "owner" are deliberately "lost" on the street. The measure of "trustworthiness" of a community is the number of finders who return wallets.

In addition to the papers mentioned above, there is a large body of empirical and experimental research showing that fairness motives may govern economic decisions in the presence of income inequality. These findings have resulted in a number of new theories that propose utility functions incorporating fairness motives. There are two main types of fairness utility theories. The *distributional justice* theories (Akerlof 1982; Akerlof and Yellen 1990; Bolton 1991; Fehr and Schmidt 1999; Bolton and Ockenfels 2000) assume that people are interested in equity when comparing their own payoff to that of others. The *reciprocal behaviour* theories (Axelrod 1984; Rabin 1992; Dufwenberg and Kirchsteiger 1998) assume that people are willing to reward others in return for kind treatment and to punish others in return for unfair treatment. Both types of behaviour can have growth enhancing consequences, if it is assumed that the social production function (at least to some extent) depends on voluntary co-operation, e.g. on the voluntary (non-contractable) contribution of effort by the individuals.

The model we introduce allows us to examine the behavioural patterns predicted by the various fairness models in a dynamic setting, in which increased trust leads to economic growth. The individuals in our model may be “poor” or “rich” and the degree of inequality is varied. All payoffs are derived from the *social production function* (i.e. we concentrate on the part of the economic activity that requires the co-operation of all individuals). In this context, being poor means having a smaller share of the property rights to the social output than the rich. Since the provision of effort to the production process is voluntary, but costly, and since the production frontier depends on capital accumulation, we effectively have a dynamic public good game with voluntary contributions.

In this setting, the models of distributional justice predict that the poor, who own the rights to only a small (perhaps *unfairly* small) fraction of the total income, may choose to sabotage the social production in order to equalise payoff opportunities. At the same time, these models predict that the rich may be willing to reduce inequality by providing more voluntary effort than in the purely money maximising Nash equilibrium. Although both types of action are thought to increase with inequality, their implications are contrary: While sabotage reduces growth (implying a negative correlation between inequality and growth), co-operatively high effort increases growth (implying a positive correlation between inequality and growth).

The models of reciprocal behaviour, on the other hand, predict that co-operation will emerge based on *tit-for-tat* type strategies that reward co-operative and punish non-co-operative actions. Thus, an above equilibrium provision of effort (especially by the rich) is assumed to induce co-operation, while a below equilibrium effort choice is assumed to induce sabotage by the others. These theories, however, are silent on the question in which way inequality affects the prevalence of positive reciprocal cycles that lead to increased growth.

Using a dynamic 3-person public good game, we examine four different inequality settings. We vary the degree of inequality (*low inequality* with a Gini-coefficient of .10 and *high inequality* with a Gini-coefficient of .25) and the skew of the income distribution (*left-skewed* with 2 poor and 1 rich and *right-skewed* with 1 poor and 2 rich). In each of the five periods of the game, subjects can choose one of three actions: *sabotage*, *Nash*, or *co-operation*. The strategy combination consisting of Nash action choices by all players in all periods is the sub-game perfect equilibrium of the dynamic game (and thus, also the sub-game perfect equilibrium at any stage in the game). The sabotage action is strictly payoff dominated by the Nash action at any point of the game. Nevertheless, the sabotage action may be attractive to some subjects, because it reduces the payoffs of all players to below equilibrium levels and, thus, reduces the degree of income inequality.[2] The co-operation action is also costly, but – in contrast to sabotage – it increases the payoffs of the others. As in a prisoner's dilemma game, choosing the co-operation action may be attractive to subjects, because the highest payoffs are achieved when all players co-operate in all rounds.

We find that most choices correspond to Nash equilibrium behaviour. Those choices that are out of equilibrium are significantly more often co-operation than sabotage. This is true both for the poor and the rich players, although the poor exhibit significantly more variance in their behaviour. Overall, average behaviour is more co-operative and average growth is stronger than in equilibrium. But surprisingly, neither the degree of inequality, nor the skew of the distribution have a significant effect on co-operative behaviour or growth. Moreover, we find no evidence for reciprocal behaviour.[3] These results do not contradict the empirical findings by Keefer and Knack (1998) and Zak and Knack (2001) concerning the positive effect of trust

[2] A number of experimental studies have shown that subjects are willing to incur a substantial loss, if necessary, in order to avoid a large income inequality. In ultimatum games, for example, responders reject up to 40% of the benefits of trade, just to avoid an *unfair* 40%-60% division of the surplus. Although this type of rejection behavior may be instrumental, in the sense that rejections are used to influence future behavior of the players making unfair offers by "teaching them a lesson", Abbink, Sadrieh, and Zamir (2002) have shown that many subjects have a purely emotional motivation for rejecting unfair offers. The phenomenon that subjects are willing to pay a high price to reduce income inequality is not only observed in the ultimatum game, but also in other games (see e.g. Abbink, Irlenbusch, and Renner 2000; Bosman and van Winden 2002).

[3] There is some evidence for a "teaching" effect, however. In some cases, the choice of sabotage by poor is rewarded with co-operative responses of the rich, which make sabotage mildly profitable to the poor.

on growth. However, they do cast some serious doubts on the assumption that income inequality impairs trust (and thus growth). In this sense, our study is supports the approach of Glaeser *et al.* (2000) not to consider income inequality as a determinant of trust.

Our study is mainly related to two branches of experimental work. First, our experiment shares the feature of being a public good provision game with heterogeneous players with the work by Chan *et al.* (1996 and 1999). Those studies employ experiments with a static public good game to examine whether observed voluntary contributions to the public good are invariant to income redistribution as predicted by Warr (1983). They observe quite a bit of co-operation, but yet have to conclude that the Nash equilibrium of the game, in which the neutrality result holds, "on average" cannot be rejected as descriptive of the observed behaviour. Our game adds a dynamic aspect to their setup, but clear parallels in the observations remain. We also find quite a bit of co-operation in our experiment. Yet, most of the observed behaviour in our experiment is in line with the Nash equilibrium of the game in which contributions to the public good are invariant to any redistribution. This "neutrality" of contributions to inequality that is observed both in the static and the dynamic game seems to be the underlying reason why we find no significant effect of inequality on growth.

The second type of experimental setup that is related to our work is reported by Durham, Hirshleifer, and Smith (1998). They investigate the question whether in a heterogeneous society (consisting of a rich and a poor individual) initial inequalities are widened, if individuals can choose to invest their limited resources either in productive efforts or in fighting efforts. The productive efforts of the two subjects combined determine the available total income, while the ratio of the individual fighting efforts determines the distribution of the available income. Durham *et al.* (1998) find that if the resource endowments are initially unequal, the rich "fight harder" (i.e. invest more in redistribution) and are less co-operative than the poor. Thus, that study finds inequality having an impact on behaviour, while we find no such effect. But, there are important differences between the games that may help explain the discrepancy. Most importantly, Durham *et al.* (1998) have modelled an open rent-seeking competition of the poor and the rich that determines the distribution of income. In contrast, redistribution in our game can only be achieved through growth, i.e. the size and the distribution of income depends on the growth path that is realised given the effort level choices. Thus, the open "fighting" option that is affected by inequality in the study of Durham *et al.* (1998) simply does not exist in our game.

In the next section we present model and discuss some of theoretical implications. In section 3, we describe the experimental parameterisation and, in section 4, the experimental procedures. Section 5 contains the results and section 6 concludes.

2. The Model

We assume there are n individuals i = 1,...,n with exogenously given capital endowments, $\omega_i > 0$. All capital is productive and returns are distributed proportionally to capital endowments (i.e. the endowments are ownership rights to society's production). The social production function $f(\omega, \sigma)$ combines the capital with the efforts σ_i that are exerted by the individuals $i = 1,..., n$.

$$\mathrm{f}(\omega, \sigma) = \ln(1 + \sum_{j=1}^{n} \sigma_{\mathrm{j}}) \sum_{j=1}^{n} \omega_{\mathrm{j}} \tag{1}$$

Effort can be interpreted as the time or attention an individual contributes to the production process. The sum of all individual efforts generates a monetary return on the invested capital. All individual's efforts are perfect substitutes in generating returns on capital, i.e. the marginal productivity of effort is the same for every individual. The individual's effort involves a cost (e.g. a decrease in utility due to the loss of leisure) that is borne by the individual himself. The payoff of individual i is equal to his share $\omega_i / \sum \omega$ of the total production:

$$\pi_i = (\omega_i / \sum_{j=1}^{n} \omega_j) f(\omega, \sigma) - \beta \sigma_i^2 = \ln(1 + \sum_{j=1}^{n} \sigma_{\mathrm{j}}) \omega_i - \beta \sigma_i^2 \tag{2}$$

where $\sigma_{\mathrm{j}} \geq 0, j = 1,..., n$ are the individual effort choices. Notice that the individual effort choices have the character of voluntary contributions to a public good: All members of the society gain from effort contributions towards generating a return on the endowment, but the cost incurs only to the individual exerting the effort. Moreover, if no individual contributes to the generation of a return on investment (i.e. $\sigma_{\mathrm{j}} = 0, j = 1,..., n$) everyone's gross and net return will be zero. It can readily be calculated that for given contributions σ_{j} by the other individuals the optimal effort for individual i will be given by

$$\sigma_{\mathrm{i}}(1+\sum_{j=i}^{n}\sigma_{\mathrm{j}}) - \frac{1}{2\beta}\omega_i = 0 \tag{3}$$

The reaction function of individual *i* can be obtained from the first order condition[4] (3) as:

$$\sigma_{\mathrm{i}} = -\frac{1}{2}(1+\sum_{j\neq i}\sigma_{\mathrm{j}}) + \frac{1}{2}\sqrt{(1+\sum_{j\neq i}\sigma_{\mathrm{j}})^2 + \frac{2}{\beta}\omega_i} \tag{4}$$

Two things are worth mentioning at the outset. First, according to equation (4), it will always be optimal to contribute towards the public good, i.e. $\sigma_I > 0$, irrespective of the contributions by the others. Thus, the Nash equilibrium will not be at a corner of the action space of $\sigma_{\mathrm{j}}, j = 1,..., n$. Second, from equation (3) we find that in equilibrium $\sigma_i / \omega_i = \sigma_j / \omega_j$ always holds. Thus, the contribution to the public good will be some fixed proportion of any given endowment. In this sense, the "neutrality" result of Warr (1983) holds in our model.

Using the fact that all contributions are in the same fixed ration to the capital endowment, we can easily calculate the Nash equilibrium strategy of player *i*:

$$\sigma_i^N = -\frac{\omega_i}{2\sum_{j=i}^{n}\omega_{\mathrm{j}}} + \frac{\omega_i}{2\sum_{j=i}^{n}\omega_{\mathrm{j}}}\sqrt{1+\frac{2\sum_{j=i}^{n}\omega_{\mathrm{j}}}{\beta}} \tag{5}$$

A co-operative solution of the game can be obtained by maximising of the sum of the individual net returns, i.e. $\max(\Omega = \sum_i \omega_i)$. However, since the non-co-operative game does not allow for explicit side payments, the distribution of the payoffs must be taken into consideration. It seems sensible to assume that co-operating players will split the total payoff in fixed proportions of the Nash equilibrium payoffs – as would be the case in the Nash bargaining solution. Thus, we assume that $s = \sigma_i \omega_i$, where *s* is the policy instrument. Differentiating Ω with respect to *s* then generates the co-operative solution:

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[4] The second order condition is $-1/(1+\sum_{j=1}^{n}\sigma_j) - 2\beta \leq 0$ for all $\sigma_i \geq 0$ and $\beta \geq 0$.

$$\sigma_i^C = -\frac{\omega_i}{2\sum_{j=i}^{n}\omega_j} + \frac{\omega_i}{2\sum_{j=i}^{n}\omega_j}\sqrt{1+\frac{2(\sum_{j=i}^{n}\omega_j)^3}{\beta\sum_{j=i}^{n}\omega_j^2}} \tag{6}$$

Apparently, the only difference between the non-co-operative and the co-operative case is that in the latter case under the square root the term $\sum_j \omega_j$ is replaced by $(\sum_j \omega_j)^3 / \sum_j \omega_j^2$. It is easy to see that the latter term is always larger than the former term. This, of course, is due to the fact that the positive external effects of contributions on other individuals' net returns are accounted for. As a result, $\sigma_i^C > \sigma_i^N$ will obviously hold.

We now introduce dynamic considerations by assuming that capital for the next period equals the current capital plus the obtained net returns, defined by equation (2). Introducing a time index as superscript, the capital in period *t*+1 is $\omega_i^{t+1} = (\pi_i^t + \omega_i^t)/(1+\rho)$ where ρ is a discount rate. We examine a finite-horizon model with T periods. Each individual i maximises the sum of the instantaneous payoffs $\sum_{t=1}^{T}\omega_i^t$, where ω_i^1 is the exogenous initial capital endowment. It can easily be demonstrated that for most parameterisations the dynamic objective function is maximised, if the individual plays the stage game Nash equilibrium strategy (5) in every period.

3. Experimental Conditions

The dynamic public goods game described in the previous section was played in four experimental conditions that differed in the distribution of the players' endowments. As can be seen in table 1, there were 3 players in every treatment with a total endowment of 300. In two treatments, 2P10 and 2P25, there were two "poor" players and one "rich", while the opposite was true in the other two treatments, 1P10 and 1P25. Moreover, the Gini-coefficient of the distribution of endowments was varied across treatments, with the treatments 2P10 and 1P10 each having a Gini of .10 and the treatments 2P25 and 1P25 each having a Gini of .25. By varying across the degree of inequality and the skew of the income distribution, we have tried to span a relatively large range of social setups with our four treatments.

Table 1 – Experimental Treatments

treatment name	player 1	endowments (ω_i) player 2	player 3	Total	number of poor	Gini coefficient
1P10	80	110	110	300	1	.10
1P25	50	125	125	300	1	.25
2P10	90	90	120	300	2	.10
2P25	75	75	150	300	2	.25

In all treatments, a five period version of the dynamic public goods game was played. In each of the five periods, players first chose their effort levels and then received feedback on all choices and the capital development in their game. Then, the next period began. After the last period had been completed, subjects received their accumulated capital (including the endowment) as payoffs. The cost parameter was set to one, i.e. $\beta = 1$, and the discount factor was set to $\rho = 2.4$ in all treatments.

To make the game more easily accessible for the subjects, the set of actions was restricted to only three possible effort levels: *low* (L), *medium* (M), and *high* (H). The low effort level L is the lowest possible non-zero effort, $\sigma = 1$. Choosing L corresponds to *sabotage*, because it entails the costly destruction of the public good, harming not only one-self, but also all others. Note, that the sabotage action L is a dominated strategy. No matter what action the others choose, the monetary payoff of choosing sabotage is always smaller than that of choosing a different strategy. This is not only true for the payoffs in each stage of the game, but also for the total payoff in the five period dynamic game. However, the structure of the payoffs makes the cost of sabotage smaller for the poor than for the rich

The medium effort level M is the *Nash* equilibrium effort of the "stage game", as in equation (5). This action is *selfish* in the sense that it maximises own monetary payoffs, under the assumption that all other players are also selfish. The high effort level H is the *co-operative* effort that maximises joint profits, as in equation (6). Since the game is a social dilemma, payoffs in co-operation are strictly better for all players, but cannot be sustained in a non-co-operative equilibrium. Note that choosing the Nash effort level M in all five periods of the dynamic game constitutes the Nash equilibrium of the dynamic game in our four treatments.[5]

[5] In one treatment, 1P25, there is a second equilibrium in which the rich always choose the Nash action M, while the poor choose cooperate H in the first period of the five period game.

4. Experimental Procedure

All sessions of the experiment took place in CentERlab, the computerised economics laboratory of the Center for Economic Research, at Tilburg University in the Netherlands. The subjects were student volunteers that were recruited in classes and on campus. Most of the subjects were first year students of economics and business. Amongst other majors were law and social sciences. Upon entering the laboratory, the subjects were randomly assigned cubicles in which they were seated. The written instructions (included in the appendix) were passed out and read aloud. Questions were answered in private at the cubicle.

The experiment software was written using RatImage (Abbink and Sadrieh 1995). On screen, each subject's own data was presented in the first position (in red colour). The data on the other two subjects, called "Green" and "Blue," followed in the next columns (see the screen shot in the appendix). Obviously, within a multi-period game, the positions were fixed, so that actions could be attached to player roles unambiguously. Note, however, that the information on which particular subject played which role was never disclosed.

By typing in hypothetical future choices both for themselves and for the other two players, subjects could use the software to "look forward" through all five periods of the dynamic game. It was explained to them that the hypothetical future choices they typed in were not made known to the other subjects (i.e. no signalling was possible) and had no effect on the actual choices made in later periods (i.e. choices were made sequentially as the experiment proceeded). To avoid anchoring subjects' decisions and beliefs, the software was configured in a way that none of the hypothetical choices was pre-selected at the start.

No explicit time limit was given to subjects. However, since subjects had signed up for an experiment with a duration of about two hours, they (correctly) perceived the decision time as being limited. In all but one session the subjects managed to complete the four repetitions of the dynamic game that had been planned. Only the session using the treatment 2P10 had to be stopped after the end of the third play of the dynamic game, because the announced experiment time had elapsed. All other sessions took about 90 – 120 minutes to complete. Payments to the subjects ranged from 12 to 28 Euros with an average of about 20 Euros.

In total 93 subjects participated in the experiment. Since the dynamic game was played more than once, a random rematch of the subjects at the end of each run was necessary. To allow for as many independent observations as possible, the subjects present at a session were divided into cohorts of six. Because all re-matching took place within these cohorts, contagion across cohorts was not possible. Unfortunately, in some sessions not enough subjects showed up to allow for this matching scheme to work perfectly. In these cases, an additional smaller cohort of three subjects was formed in which no re-matching took place. (The number of subjects in all sessions was a multiple of three.) However, it should be noted that subjects were not aware of these details of the matching scheme. They were only told that they will be randomly matched to other subjects in the session. Hence, the subjects both in the re-matched and in the fixed cohorts thought that they are being randomly re-matched. In analysing the data, we have nevertheless checked for possible effects of the small cohorts. No significant differences were found. Thus, we do not report results conditioned on this parameter.

Table 2 summarises the treatment information on subjects, independent observations, and repetitions. The statistical tests that are presented in the next section generally use data on the level of the independent observations.

Table 2 – Subjects and Observations

	Treatment				
	1P10	1P25	2P10	2P25	total
subjects	21	30	18	24	93
independent observations	4	5	3	5	17
plays of the dynamic game	4	4	3	4	

5. Results

Table 3 contains our data, aggregated on the level of independent observations and presented as deviations from equilibrium predictions. The first two columns specify the treatment parameters of the observation, i.e. the number of poor and the Gini-coefficient. For each independent cohort, the columns three to five indicate the average action chosen by the poor, the rich, and in total. (Note that for the data analysis the action choices are coded as follows: *sabotage* = –1, *Nash* = 0, *co-operation* = 1. Actual choices were discrete on the three levels, but taking averages leads to non-integer values.) Columns six to eight display the average deviations of observed accumulated capital from the accumulated capital expected in equilibrium. Column nine contains the deviation of the observed from the expected Gini-coefficient. Finally, the last three columns of table 3, display the average deviation of the observed from the expected growth rates.

Our first important result is that on average total contribution to the public good is above equilibrium. There is only one of seventeen cases in which the average choice of the rich is sabotage and the ratio is four of seventeen even for the poor. In total, there are only two cases with an overall negative average action choice, i.e. cases in which slightly more sabotage actions were chosen than co-operative actions. The distribution of action choices shown in figures 1a and 1b indicate that most subjects simply choose the Nash equilibrium action in all treatments. The second most frequent choice in all treatments is the co-operative action. The frequency of co-operative choices ranges from about 35 percent to about 10 percent of all choices, depending on the treatment and the player type. Finally, the sabotage action is clearly the one chosen least. In fact, applying the binomial test to the data on the level of independent observations we can reject the null hypothesis that action choices are equally likely to be below or above equilibrium level in favour of the alternative hypothesis that co-operative action choices are more likely. (The binomial test returns a probability of p = .006, one-tailed, when testing for the rich and p = .071, one-tailed, testing for the poor.)

Observation 1. Most action choices correspond to the Nash equilibrium strategies. But, when deviating from the equilibrium, subjects exhibit a significant tendency towards co-operation.

Table 3 – Deviations of Observed Variables from Equilibrium Predictions
(data aggregated on the level of independent observations)

number of poor	Gini of endow-ments	mean difference observed to equilibrium action*			mean difference observed to equilibrium capita			mean obs – eq Gini	mean difference observed to equilibrium growth		
		poor	rich	total	poor	rich	total		poor	rich	total
1	.10	0.00	0.05	0.03	2.05	-16.16	-10.09	0.01	-0.15	-0.55	-0.44
1	.10	-0.25	0.34	0.14	54.83	-3.65	15.84	-0.02	1.71	-0.12	0.37
1	.10	0.30	0.03	0.12	-7.08	15.75	8.14	0.02	-0.40	0.22	0.06
1	.10	0.25	0.40	0.35	81.95	58.88	66.57	-0.01	2.60	1.43	1.74
1	.25	-0.10	0.03	-0.02	-3.15	-4.95	-4.35	0.00	-0.26	-0.18	-0.19
1	.25	0.58	0.00	0.19	-12.20	10.08	2.65	0.03	-0.64	0.20	0.06
1	.25	0.18	0.06	0.10	3.80	17.74	13.09	0.01	0.18	0.40	0.36
1	.25	-0.08	0.16	0.08	21.58	5.03	10.54	0.00	1.06	0.08	0.24
1	.25	0.43	0.08	0.19	7.75	32.99	24.57	0.02	0.32	0.60	0.55
2	.10	0.08	-0.20	-0.01	-37.83	-11.30	-28.99	0.03	-1.13	-0.36	-0.82
2	.10	0.08	0.27	0.15	24.97	-6.83	14.37	-0.01	0.68	0.00	0.40
2	.10	0.23	0.03	0.17	-0.32	36.07	11.81	0.03	0.03	0.82	0.34
2	.25	0.08	0.23	0.13	18.79	-5.45	10.71	-0.01	0.72	-0.11	0.30
2	.25	0.13	0.00	0.08	5.41	30.88	13.90	0.02	0.20	0.50	0.35
2	.25	-0.06	0.23	0.03	7.95	-42.33	-8.81	-0.02	0.07	-0.77	-0.35
2	.25	0.33	0.65	0.43	73.83	13.90	53.85	-0.04	2.59	0.22	1.40
2	.25	0.05	0.10	0.07	16.83	5.80	13.15	-0.01	0.54	0.15	0.35

*) Action choices were coded: *sabotage* = –1, *Nash* = 0, *co-operation* = 1. Choices were discrete on those levels, but taking averages leads to non-integer values.

Observation 1 is also supported by our regression results reported in table 4. We ran two probit regressions to relate subjects' choices to the exogenous parameters of the game, i.e. the skew of the income distribution measured by the number of poor, the extent of inequality measured by the Gini coefficient, the experience of subjects in play measured by the round number, the stage in the dynamic game measured by the period number, and the initial wealth of players measured by their endowments. The regression summarised in the second column of table 4 relates the choice of the co-operative action to the exogenous parameters, while the regression in the third column relates the choice of the sabotage action to those parameters. Since the constant term explaining co-operation action choices is significantly positive, while the constant term explaining sabotage action choices is not significantly different from zero, we conclude that observation 1 is supported. There are significantly more co-operative action choices than there are sabotage action choices.

Table 4 – Decisions as a function of the inequality and time

	co-operation action choice	sabotage action choice
constant	.6751 (.3725)*	.2253 (.4054)
number of poor	-.0086 (.1720)	.0012 (.1643)
Gini-coefficient	-.0057 (.0123)	-.0130 (.0112)
endowment	-.0078 (.0013)**	-.0134 (.0018)**
round number	-.0317 (.0341)	-.0768 (.0435)*
period number	-.2431 (.0272)**	-.0120 (.0329)
number of observations	1770	1770
number of groups	31	31
log likelihood	-779.8538	-457.1783
χ^2	99.8	22.9

Probit coefficients are reported with standard errors in parentheses. The probits were run with group level random effects in order to account for the fact that the decisions within each group were not statistically independent. Excluding these random effects (or alternatively including subject fixed effects) does not lead to any substantially different results than reported here. * = coefficient is weakly significant at the 10%-level. ** = coefficient is significant at levels below .1%.

Table 4 also shows that neither co-operative nor sabotage action choices are significantly affected by the skew or the extent of inequality. That the action choice distributions are not very different across the treatments can also be visually verified in Figures 1a and 1b.

Observation 2. In general, no significant differences can be found between the distributions of action choices across treatments. Neither the degree of inequality, nor the skew of the income distribution affect the action choices.

The regressions in Table 4, however, also reveal that being wealthy has a significant negative effect both on the co-operation action choice and on the sabotage action choice. The coefficient on endowment is negative and highly significant in both regressions. This means that the poor players choose both co-operation and sabotage actions more frequently than their rich counterparts. In other words, for the complete set of data the decisions of the poor are characterized by a higher volatility than the decisions of the rich. There is some inconclusive evidence, however, that the effect is stronger for the high inequality cases, in which the distance between the poor and the rich is substantial.[6]

Observation 3. The action choices of the poor are more volatile that those of the rich.

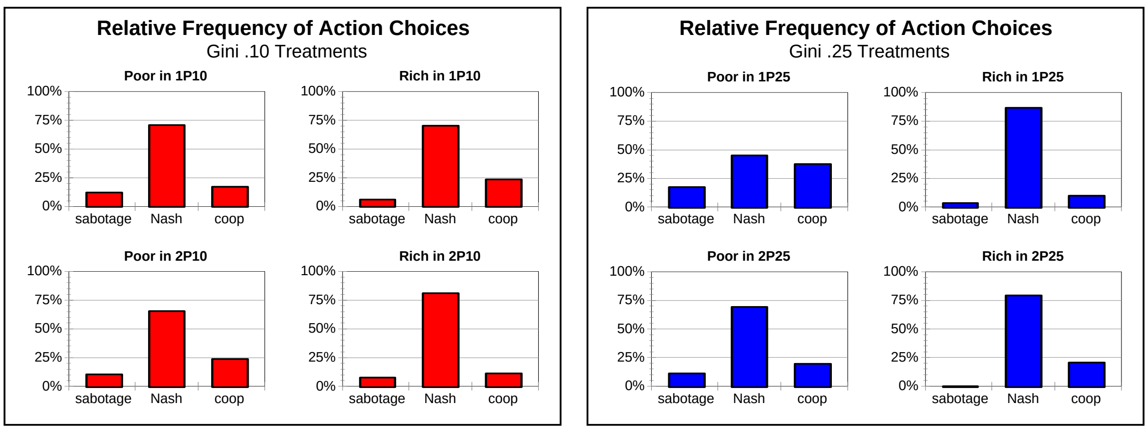

Figure 1a/1b. Distribution of action choices.

The observations above do not consider possible dynamic effects. Figures 2a and 2b below display the action choices over time for the poor and rich in the four treatments. The graphs clearly show that the pattern of behaviour in our dynamic public good game resembles the well known pattern of voluntary contributions in repeated static public good games: Subjects tend to start with above equilibrium contributions, which they reduce from period to period towards the end of the game. Note that in our dynamic context such behaviour can be "sensible," because early contributions have a higher growth leverage than late contributions, due to the longer duration in which they are effective. The significant negative coefficient of the period number in the co-operation probit (second column of table 4) gives statistical power to the visual impression leading to the following observation:

[6] Using the Mann-Whitney U-test to compare the variance of the choices of the poor versus the rich we receive a significant result only for the data of 1P25.

Observation 4. Subjects in all treatments and in both roles tend to make more co-operative choices in the first periods of the dynamic game than in the last. This decline of contributions to the public good is well in line with the typical declining pattern of contributions found in repeated static public good games. Furthermore, the decline of contributions can be explained by the growth dynamics that provide a higher growth leverage to early co-operation than to late co-operation.

How does the action choice behaviour affect growth? Figure 3 displays the average deviation of the observed from the equilibrium growth of the capital for each cohort. With one exception, all cohorts exhibit an overall growth rate that is higher than in equilibrium. Applying the binomial test to the data of all cohorts, we can show that this observation is significant: total growth is significantly greater than in the Nash equilibrium ($p = 0.05$, one-tailed). Comparing the deviation of growth rates from equilibrium growth across treatments, we find no significant differences whatsoever. This is not surprising, since no significance difference was detected in the distribution of action choices either.

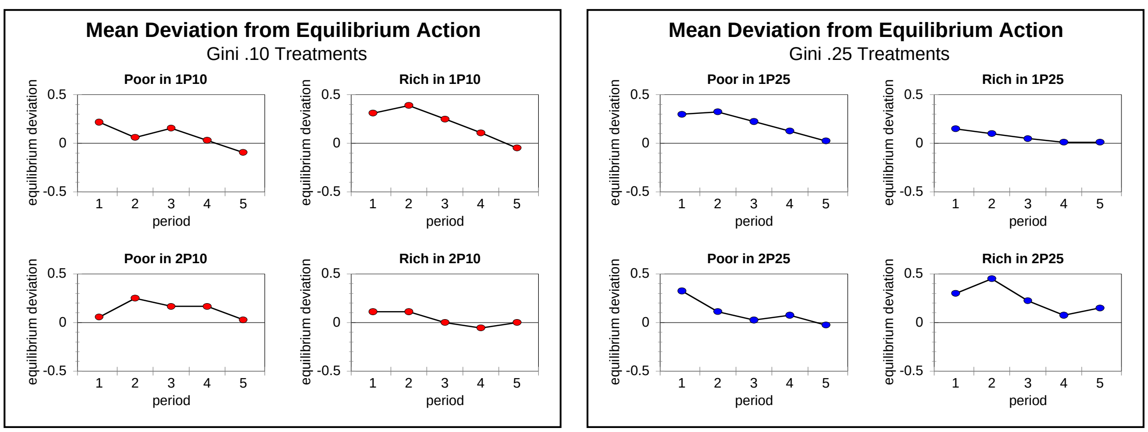

Figure 2a/2b. Development of action choices over the five periods of the game.

Observation 5. Growth rates in all treatments are above the rates expected in equilibrium. No significant treatment differences in growth are observed. Neither the degree of inequality, nor the skew of the distribution seem to affect the growth of capital.

From the analysis so far it seems clear that issues of distributional justice do not play a prominent role in the decisions of subjects. If distributional justice would have played a role, then we should have observed very different action choices (leading to different growth rates) that depend on the degree of inequality and on the role of the subject. So if distributional issues do not play a role, does reciprocity? We checked whether there is a significant tendency for the poor to react co-operatively to previous co-operative choices of the rich and vice versa. There is no significant tendency of either side to react "kindly" to previous "kind" actions. We also checked for negative reciprocity and, again, found no evidence for a tendency to react with sabotage to "unkind" actions of others. Thus, we find no evidence for "parallel reactions," i.e. "kind" behaviour receiving "kind" responses and vice versa.

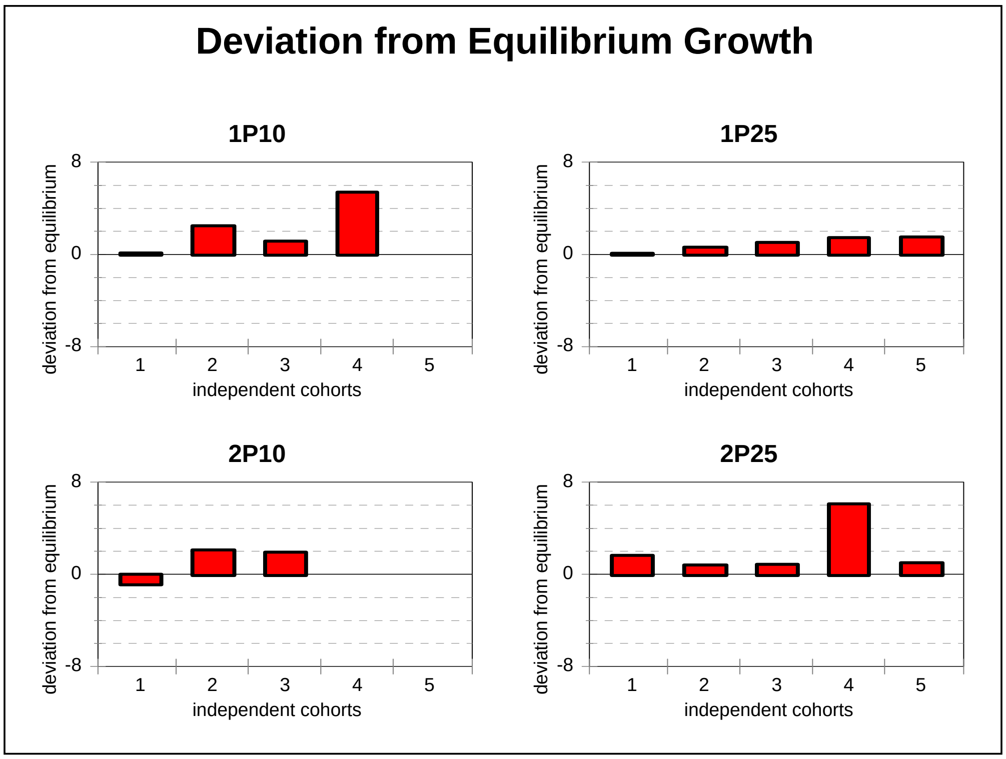

Figure 3. Observed versus equilibrium growth.

We do find some evidence for "teaching" behaviour, however. It seems that in some cases the sabotage action choices of the poor players actually lead to more co-operative action by the rich. Figures 4a and 4b show the action to payoff relationships in each of the independent cohorts for the poor and the rich players. For the rich the action to payoff relationship is straightforward: the more co-operative the rich are, the higher their payoffs. Note, however, that this simple positive correlation is not true for the poor players. The graph in figure 4a clearly shows a dip in payoffs at the Nash equilibrium action – especially for the low inequality treatments 1P10 and 2P10. In these treatments playing Nash is the worst choice.

Playing co-operative clearly yields higher payoffs. But, choosing the sabotage action also leads to higher payoffs than choosing Nash. It seems that the choice of sabotage action by the poor in these treatments "teaches" the rich to be more co-operative and, thus, enhances the payoff of the poor.

Observation 6. Reciprocal action is not observed in any treatment. Neither poor nor rich show a significant tendency to respond to "kindness" with co-operation or to "unkindness" with sabotage. However, in the low inequality treatments (1P10 and 2P10), we observe a tendency for the rich to respond co-operatively to sabotage by the poor. This "teaching" effect – on average – turns sabotage into a mildly profitable action choice for the poor.

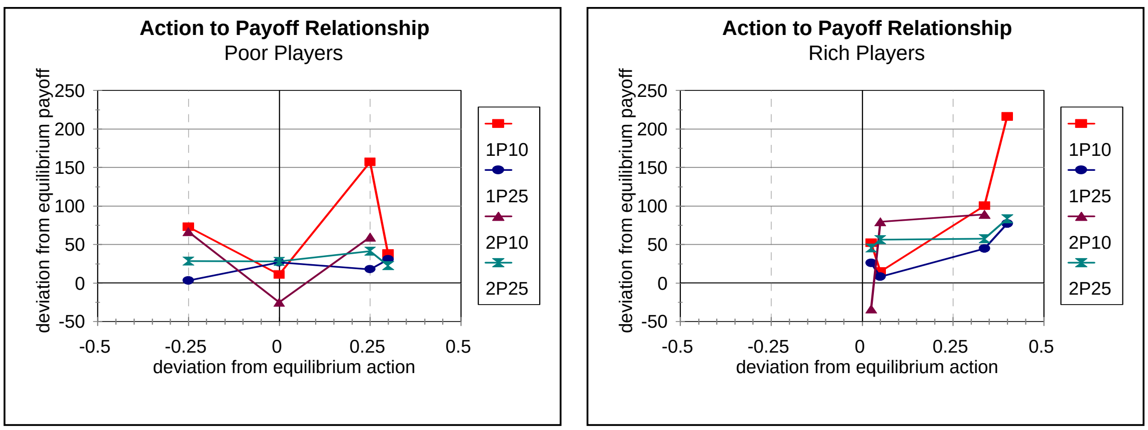

Figure 4a/4b. Action to payoff relationships.

7. Concluding remarks

We experimentally implemented a three-person dynamic public good game with the degree of inequality and the skew of the income distribution as treatment variables. The players' efforts contribute to social production that generates returns on the individually endowed capital. In equilibrium, both poor and rich players contribute positive efforts. Next to this Nash equilibrium effort, the choice set of the subjects in our experimental implementation also contained a co-operative and a sabotage action. Under the former type of behaviour higher returns for all will be generated, while under the latter type others' payoffs as well as one's own payoff are diminished below levels obtainable in the Nash equilibrium

We observe a substantial amount of co-operation in our experiment. As a result, there is significantly more growth than in equilibrium. However, we find no effect of the degree or the skew of inequality on the propensity to cooperate. Inequality is neutral to growth.

Interestingly, we find a pattern of declining contributions to the social production in our dynamic game that is very similar to the pattern of declining contributions frequently observed in repeated public good games. This seems to indicate that the dynamic link in our game (accumulated production capital) is not strongly influencing contribution behaviour compared to the repeated games without such a link. On the other hand, sabotage behaviour shows no trend over the rounds. Moreover, we find that poor players choose the sabotage action more frequently than the rich. By choosing sabotage they can actually induce more co-operative play by the rich. This leads to above equilibrium payoffs for the poor indicating that the usage of the sabotage action is mainly instrumental.

Trust is an important pre-condition for co-operation to emerge. If a subject can trust the others to provide above equilibrium efforts, then that subject may be willing to provide higher efforts as well. Hence, trust acts as a lubricant enhancing co-operation and growth. In their oft-cited paper, Knack and Keefer (1997) have shown that trust has a significant positive impact on aggregate economic activity. Our results confirm the finding that trust is essential to growth. But, we do not find income inequality to be an important determinant of trust. We do not observe significant differences in co-operative behaviour between treatments.

We should emphasize, however, that our results are not in conflict with the main finding of Zak and Knack (2001), namely that social heterogeneity determines the degree of trust in a society. Our results merely suggest that inequality might not be the right indicator for social heterogeneity. The social and historic origins of inequality may be the actual correlates of trust. If inequality has emerged from “unfair” circumstances (e.g. economic discrimination of a minority), it seems plausible to assume that the poor will exhibit less trust than they would, if inequality had been determined by a “neutral” market. In this respect, it should be noted that Zak and Knack (2001) find both an effect of income inequality and an effect of economic discrimination on trust, when each variable is separately included in a regression. The effect of inequality may be spurious, however, if economic discrimination is not only affecting trust, but also the distribution of income. The force of this argument should be tested experimentally, perhaps by conducting analogous experiments in societies in which the social history of inequality has been more strongly dominated by discrimination and segregation than in Western Europe. That will be subject to future research.

Finally, the policy implication that emerges from our findings seems to be that interpersonal trust will not be increased by reducing income inequality exogenously *within* a "fair" society.[7] In such societies, policies aimed at reducing the degree of inequality will merely lead to deadweight losses (as emphasised in the "classical" public economics analyses). As long as the existing income inequality is perceived to be "fair," no efficiency gains – and, thus no growth effects – can be expected from the reduction of the inequality. Moreover, if it is not income inequality *per se* that affects trust and cooperation, then other factors jointly account for inequality and the loss of trust. Hence, policies aimed at increasing growth should address those underlying factors (e.g. economic discrimination) rather than income inequality itself.

[7] Note that Forbes (2000) pointed out that, when analysing the correlation of inequality and growth, a distinction should be made between cross-cultural and within-cultural relationships. The effects found by Zak and Knack (2001) are based on cross-country regressions, and do not necessarily carry over to within-country settings.

References

Abbink, Klaus, Bernd Irlenbusch, and Elke Renner (2000): “The Moonlighting Game - An Experimental Study on Reciprocity and Retribution,” *Journal of Economic Behavior and Organization*, 42, 265-277.

Abbink, Klaus, and Abdolkarim Sadrieh (1995): “RatImage - Research Assistance Toolbox for Computer-Aided Human Behavior Experiments,” SFB Discussion Paper, B-325, University of Bonn.

Abbink, Klaus, Abdolkarim Sadrieh, and Shmuel Zamir (2002): “Fairness, public good, and emotional aspects of punishment behavior,” *CentER Discussion Paper*, 2002-38, Tilburg University.

Aghion, Philippe, Eve Caroli, and Cecilia García-Peñalosa (1999): “Inequality and Economic Growth: The Perspective of the New Growth Theories,” *Journal of Economic Literature*, 37 (4), 1615-1660.

Akerlof, George A. (1982): “Labor Contracts as Partial Gift Exchange,” *Quarterly Journal of Economics*, 97, 543-569.

Akerlof, George A. and Janet L. Yellen (1990): “The Fair Wage-Effort Hypothesis and Unemployment,” *Quarterly Journal of Economics*, 105, 255-283.

Axelrod, Robert (1984): “The Evolution of Cooperation,” New York: Basic Books.

Bolton, Gary E (1991): “A Comparative Model of Bargaining: Theory and Evidence,” *American Economic Review*, 81(5), 1096-1135.

Bolton, Gary E, and Axel Ockenfels (2000): “ERC - A Theory of Equity, Reciprocity and Competition,” *American Economic Review*, 90(1), 166-193.

Bosman, Ronald, and Frans van Winden (2002): “Emotional hazard in a power-to-take game experiment,” *Economic Journal*, 112, 147-169.

Chan, Kenneth S., Stuart Mestelman, Rob Moir, and Andrew Muller (1996): “The voluntary provision of public goods under varying income distributions,” *Canadian Journal of Economics*, 29(1), 54-69.

Chan, Kenneth S., Stuart Mestelman, Rob Moir, and Andrew Muller (1999): “Heterogeneity and the Voluntary Provision of Public Goods,” *Experimental Economics*, 2, 5-30.

Dufwenberg, Martin, and Georg Kirchsteiger (1998): “A Theory of Sequential Reciprocity,” *CentER discussion paper*, 9837, Tilburg University.

Durham, Yvonne, Jack Hirshleifer, and Vernon L. Smith (1998): “Do the Rich Get Richer and the Poor Poorer?” *American Economic Review*, 88(4), 970-983.

Fehr, Ernst and Simon Gächter (2000a): “Cooperation and Punishment in Public Goods Experiments,” *American Economic Review*, 90(4), September 2000, pages 980-994.

Fehr, Ernst and Simon Gächter (2000b): “Fairness and Retaliation: The Economics of Reciprocity,” *Journal of Economic Perspectives* 14, 159-181.

Fehr, Ernst, and Klaus M. Schmidt (1999): “A Theory of Fairness, Competition, and Cooperation,” *Quarterly Journal of Economics*, 114, 817-868.

Fershtman, Chaim, and Uri Gneezy (2000): “Trust and Discrimination in a Segmented Society: An Experimental Approach,” *Quarterly Journal of Economics*, 116(1), February 2001, pages 351-77.

Forbes, Kristin J. (2000): “A Reassessment of the Relationship Between Inequality and Growth,” *American Economic Review*, 90 (4), 869-887.

Glaeser, Edward L., David I. Laibson, José A. Scheinkman, Christine L. Soutter (2000): “Measuring Trust,” *Quarterly Journal of Economics*, 115(3), 811-846.

Hey, John D. (1991): “Experiments in Economics,” Oxford: Blackwell.

Inglehart, Ronald (1999): “World value surveys,” Institute for Social Research, University of Michigan, http://wvs.isr.umich.edu/index.html.

Keser, Claudia, and Frans van Winden (2000): "Conditional Cooperation and Voluntary Contributions to Public Goods," *Scandinavian Journal of Economics*, 102, 23-40.

Knack, Stephen, and Philip Keefer (1997): "Does Social Capital Have an Economic Payoff", *Quarterly Journal of Economics*, 112 (4), 213-214.

Loomes, Graham (1999): "Some Lessons from Past Experiments and Some Challenges for the Future," *Economic Journal*, 109, 35-45.

Persson, Torsten, and Guido Tabellini (1994): "Is Inequality Harmful for Growth?" *American Economic Review*, 84(3), 600-621.

Rabin, Matthew (1993): "Incorporating Fairness into Game Theory and Economics," *American Economic Review*, 83, 1281-1302.

Roth, Alvin E. (1995): "Introduction," in *Handbook of Experimental Economics* (John Kagel and Alvin E. Roth, Eds.), Princeton: Princeton University Press.

Starmer, Chris (1999): "Experimental Economics: Hard Science or Wasteful Tinkering?" *Economic Journal*, 109, 5-15.

Warr, Peter G. (1983): "The Private Provision of a Public Good is Independent of the Distribution of Income," *Economics Letters* 13, 207-211.

Zak, Paul J. and Stephen Knack (2001): "Trust and Growth", *Economic journal,* 111, 295-321.

Zweimüller, Josef (2000): "Inequality, Redistribution, and Economic Growth," *Empirica*, 27, 1-20.

Appendix

Instructions

This is an experiment on economic decision-making within groups over time. Each group consists of 3 participants, i.e. you are in a group with 2 others. A group remains together for 5 periods. In each period, each of the 3 group members makes exactly 1 decision. After the 5th period, the round ends and the groups are dissolved. For the next round of 5 periods new groups are formed randomly. [This means that the probability of having a former group member in your new group is positive but small.] After the 2nd round, again new groups are formed randomly. In total, you will participate in 4 such rounds, that means in 4 groups for 5 periods each.

At the beginning of a round, each group member has some amount of start capital. On your screen, you will see how much capital each of your group members (including yourself) has. The goal is to increase this capital as much as possible. The amount of capital you have after the 4th round is exchanged at the rate of Dfl 0.01 per point and paid to you in cash. The more capital you have at the end of the 5th period, the more money you will earn.

The development of your capital depends on your own decision and the decisions of the other members of your group. In each period, each group member can choose one of the three options: L ("low cost investment"), M ("medium cost investment"), or H ("high cost investment"). The decisions of all 3 group members influence the development of your capital. The table on the lower part of your screen shows for any possible constellation of decisions how much capital each member of your group will have after the 1st period. Once all 1st period decisions are made, a box will appear to mark the entry in the table that was actually reached. At the start of the 2nd period, the table changes and shows how much capital each member of your group will for any constellation of 2nd period choices. The same procedure applies to the 3rd, 4th and 5th periods.

Instead of just looking at the development possibilities for your capital (and for that of the others in your group) in the current period, you can also check the development possibilities up to the end of the round, i.e. until after the 5th period. To do so, you must first use the buttons on your screen labelled "L", "M", and "H" to enter the hypothetical decisions of yourself and of the others in your group for all the periods that have not passed yet. Next, you can use the buttons on your screen that are label "period 1" to "period 5" to choose the table that shows how much capital each group member will have after the corresponding period, if the corresponding decisions had actually been made. Please, take the time to study the effects of different choices on the development of capital carefully.

Generally, the higher the cost of your investment, the more the capital of all team members (including yourself) will grow. However, since you have to pay the entire cost of your own investment, the capital of the other group members will grow more than you own capital if you invest. This also means that if one of the other group members invests, your capital will grow more than the capital of the investor. Finally, note that the cost of investing more in some cases may be higher than the benefit, while the opposite is true in other cases.

Your own choices and capital are always displayed in red colour on screen. One of the other 2 members of your group is called "Green" and the other is called "Blue". Note that during any round, participant "Green" is always the same actual person and participant "Blue" is also always the same actual person (but a different person than participant "Green"). The actual persons behind these names change when a new round begins and new groups are formed randomly.

Decision Interface (Screenshot)

Below is the screenshot of the subject's decision interface. The presented game is fictitious. The players have the endowments 111, 222, and 333. The game is in round 3.