# Inter-Generational Thoughtfulness in a Dynamic Public Good Experiment

Jörg Spiller

Friedel Bolle

European University Viadrina Frankfurt (Oder)

Department of Business Administration and Economics

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Jörg Spiller* Friedel Bolle†

In a laboratory experiment we investigate inter-generational concerns and myopia in a dynamic Public Good game. Groups of four played a 15-period game where they could either invest in a green sector or in a more profitable brown sector that builds a pollution stock. We find that subjects are more cooperative when their final pollution stock will be inherited by another group in a later session. Furthermore, we observe that defection from a negotiated common plan is higher when subjects are in a loss frame, negotiated plans are more ambitious. We analyze our results in reference to several social preference theories and find that Linear Altruism is most supported in such a dynamic environment.

**JEL-Classification:** H41, C91

**Keywords:** Dynamic, Environmental Economics, Experimental Economics, Inter-Generation, Public Good

## 1. Introduction

In economic analyses the share of $CO_2$ and other greenhouse gases in the atmosphere is modelled as a global public bad. Avoiding the production of a unit of $CO_2$ is privately unprofitable but profitable for society at large. A special problem is that future generations who cannot influence today's greenhouse gas production will suffer from it as well. While the production or prevention of *local* public goods or bads can be optimized by national authorities, *global* public goods or bads are determined by voluntary individual acts and are under the influence of national measures, such as taxes and subsidies. Coordination of national measures vía negotiations are mainly cheap talk, since strong sanctioning mechanisms cannot be enforced due to the sovereignty of countries. In this situation we are confronted with at least four fundamental

*Corresponding author. European University Viadrina Frankfurt (Oder), c/o Prof. Daniel Becker. Große Scharrnstr. 59, 15230 Frankfurt (Oder), Germany. spiller@europa-uni.de

†European University Viadrina Frankfurt (Oder), Germany.

questions: 1. How efficient are purely voluntary contributions? How myopic or farsighted are decision makers in such a situation? 2. Do decision makers take into account the welfare of future generations? 3. Do negotiations, despite being cheap talk, have any impact on behavior? 4. If it turns out that the public good is underprovided, how can contributions be improved? Can explicit or implicit sanctioning mechanisms be created to force countries to "play by the negotiated rules"?

In this paper, we want to deal mainly with the first three questions and our method will be mainly experimental. There is a great amount of literature, theoretic and experimental, on the voluntary provision of public goods (avoidance of public bads), some of them even in the narrow framework of the climate problem. Only a few of these investigations, however, take into account that the climate problem shows two crucial dynamic features: first, that greenhouse gases constitute a stock and not a flow pollutant and, therefore, second, that today's pollution creates long-term damage for ourselves and also for future generations. Burning fossil fuels is basically a transfer of carbon from the lithosphere to the atmosphere, a process which is not reversible within a historically relevant time horizon.

In our experiment, 4 players can invest their 20 lab dollar endowment in either a clean *green* sector or a polluting *brown* sector with higher short-term profits. Pollution accumulates in a stock without depreciation and individual damage is proportional to the stock. Thus, the incentives in our dynamic version of the public bad game are rather different from the constant incentives in static games. In our experiment there is an initial phase (first three of fifteen periods) where it is individually rational to invest only in the green sector and there is a late phase (last three periods) where even efficiency requires investing only in the brown sector. In between the marginal per capita return, i.e. the incentive to not pollute, shrinks linearly. This structure models the natural incentives of short-lived individuals or governments. If people care about the world beyond their life-times then the introduction of a second generation should expand their time horizon and make them start polluting later or never.

Note that the current stock of the public bad should not have any influence on current behavior as it is a sunk cost. Only the aggregate future effect and thus only the remaining periods should be crucial under egoistic preferences as well as many versions of social preferences. "Psychologically", however, the level of the accumulated stock may be crucial, when evaluating previous behavior of one's own generation or a previous generation.

We keep the model as simple as possible. For example we did not introduce a depreciation of the stock. Furthermore, decision makers can be interpreted as governments or consumers. Both of these have limited lifetimes, which is why we modeled a fixed number of periods in each generation. A different approach would have been to simulate an infinite time horizon by introducing a game termination probability, which we did not choose for two reasons. Although the length of a lifetime (individual or governmental) is uncertain, it is clearly not infinite. On the other hand we investigate the effect of a future generation, not hedging against an uncertain end of the game. In these models, folk theorems apply which state that every individually profitable and feasible payoff vector can be reached by equilibrium strategies, but with both interpretations of decision makers a finite time horizon seems to be more appropriate. A "fantastic" interpretation in the spirit of the backstop technology in finite horizon natural resource models is the assumption of a technology (weather engineering, available at the end of the time horizon) which makes global warming concerns obsolete. Note that the effect of considering future generations can be tested much better when single generations have a limited life-span. Overlapping time horizons for different players might have been another, though rather complicated, option. Four players are rather common in public good experiments. Two-player groups would provide us with more (independent) data points but coordination is far easier in two than in four-person groups which are thus better suited to a many-decision maker world.

The time horizon $T$ may depend on the expected life span (or legislative period in the case of governments), or it may reach beyond the latter if we have concerns for future generations, i.e. people under future governments. If the previous generation invests an additional unit in the brown sector, the income of future generations is reduced by the marginal damage in one period times the lifetime span ($\delta T$). Under altruistic preferences this induces incentives for early generations to invest green. Whether or not this is the case, is a central question of this paper and should be highly relevant for environmental policy. Note that real public policy concerning environmental, educational, military, or financial issues often evokes the impression that governments act highly myopic as they face a time horizon equal to or even shorter than the legislative period. This belief may be true since many individual decisions concerning personal health or finances seem to be governed by extreme myopia. Hence, it is not surprising that Fischer et al. (2004) do not find a direct impact of the introduction of a second generation which suffers from today's actions, but find only an impact on the expectations concerning others' behavior in the same generation. Other than Fischer et al. (2004) we do not introduce uncertainty about the existence of future generations, which seems to be the reason why we contradict their findings.

From static public good experiments it is well known that communication (cheap talk) improves cooperation considerably. However, the strong impact of communication in laboratory experiments contradicts the rather limited success of climate negotiations. We should conclude from this discrepancy that the static experimental public good/bad models are oversimplified and we should vary the model in order to find out why, in reality, communication alone does not work. We, therefore, think it is worthwhile to include communication in our setting for two reasons. (i) On the one hand, we test for the influence of framing, namely minimizing losses (when a stock is inherited and losses are mostly inevitable) instead of maximizing gains (when no stock is inherited). (ii) On the other hand, we test whether deviations from the negotiated strategies differ between generations who do and those who do not experience losses. As expected, we find that communication is highly effective. However, we also observe that deviations from the negotiated strategies are significantly higher in the loss frame (future generation).

In the following section we review the literature on the climate problem as far as it is modeled as the voluntary provision of a public good or bad. Section 3 describes our experiments and derives equilibrium behavior under different assumptions about preferences. Section 4 reports the results of our experiments and evaluates the predictions from the different models, while section 5 concludes.

## 2. Literature

Common results of linear static public good experiments have been listed by Zelmer (2003) and Andreoni (1995): Contributions increase with higher marginal per capita return, communication, partner design, and positive framing; inequality (asymmetry) and experience with the game (repetitions) decrease the contributions. In the vast body of literature on static linear public goods there are also experiments with an environmental framework[1] which, however, usually do not provide insights beyond that of general public good experiments. An interesting deviation from the linear public good game is the threshold game model of climate change (Milinski et al., 2008; Tavoni et al., 2011), where not reaching a threshold by collective contributions to the public good results in a 50% probability of losing the entire income. Contrary to the unique subgame perfect equilibrium of the one-shot or finitely repeated linear public good game (zero contributions) threshold public good games have a multitude of pure and mixed strategy equilibria guaranteeing success with probabilities between 0 and 1. The common feature of linear and threshold public good experiments is that subjects seem to learn playing equilibrium, in partner designs repeated play results in decreasing contributions in the linear game and in an increasing frequency of successfully coordinated contributions in threshold games. Communication improves success rates also in threshold games.

There are two main strands of literature on dynamic social dilemma experiments: (i) Common Pool Resource (CPR) experiments, where two or more players decide how much to extract from a commonly accessible resource that yields the maximum payoff if players restrain their extraction; (ii) Public Good experiments, where two or more players can make public investments that yield an overall profit to the group, but a loss to the investor. "Dynamic" means that conditions and incentives change from period to period, either exogenously or endogenously. Endogenous changes may be observed even in "objectively" constant environments if people are guided by reciprocity or inequity aversion. As explained in the introduction, our experimental environment is characterized by exogenously changing monetary incentives over 15 periods and the introduction of a second generation which can be effective only vía social preferences.

A variation of dynamic social dilemma games are infinitely repeated games. There is a lot of theoretical and less experimental research. Dal Bó (2005) investigates behavior in a multi-period two-person prisoners' dilemma, where infinity is introduced by a continuation probability for the next period that can be interpreted as a discount factor.[2] In games with infinite time horizons, theoretically there are even more equilibria than in threshold games (namely infinitely many). Particularly interesting are the extreme equilibria "efficient cooperation" and "myopic Nash equilibrium" or Markov-perfect equilibrium. Investigations with an infinite time

[1] For an overview on experiments in environmental economics, see Sturm and Weimann (2006).

[2] See also Camera and Casari (2009), Dal Bó and Fréchette (2011) or Dal Bó and Fréchette (2013)

horizon (uncertain end) in a public bad environment are Sherstyuk et al. (2013), Pevnitskaya and Ryvkin (2011) and Pevnitskaya and Ryvkin (2013). All three papers investigate profitable private production that creates a negative dynamic stock externality. Pevnitskaya and Ryvkin (2013) find no difference between fixed end and uncertain end, except for the final round and stronger experience effects in the fixed-end treatment. Pevnitskaya and Ryvkin (2011) investigate different emission propensities in a dynamic two-player public good experiment. Like Pevnitskaya and Ryvkin (2011) they find behavior that lies between the Nash-Equilibrium and the social optimum but closer to the Nash equilibrium. These results might be an indication of myopic behavior in dynamic environments. Sherstyuk et al. (2013) find subjects to be more cooperative in intra-generational settings than in inter-generational settings.

Concerning social dilemmas with a finite time horizon, crucial experimental research has been done in the field of common pool resource games. Several experiments find indication of myopic behavior[3], i.e. behavior which does not take into account that tomorrow even the polluter will suffer from today's pollution. Furthermore, some experiments investigate the influence of future generations. Fischer et al. (2004) investigate behavior in an inter-generational CPR experiment. Their experimental design involves players with a one-period lifetime duration and contains treatments with slow and fast growing resource stocks. In their experimental design subjects do not know about their position in the generation chain. Eliciting beliefs about co-players' decisions, they find that subjects who face a slow growing resource expect more reservation from their co-players and, hence, extract more. They conclude that subjects are not led by concerns for future generations.[4] A similar experiment by Chermak and Krause (2002) investigates withdrawals from a CPR in an overlapping generations design. Players live for three of five periods and either know about their position in the generation chain or not. They report interdependency effects of information treatments and certain personal characteristics, e.g. religious affiliation.

Uncertainty plays a central role in these settings but is not connected to our research question, which is why we decided for both a finite time horizon and for giving the subjects the information which generation they are in. In a setting with an infinite time horizon subjects make decisions under uncertainty about how long they and a future generation will profit from "additional cooperation". The same applies to knowing one's own position in the generation chain. If subjects do not know whether there is a future generation or not, their decision about how much to increase cooperation is not solely based on inter-generational concerns but also on the probability of future generations to exist or respectively the number of future generations.

The generally positive effect of communication is well known and has been observed in a lot of experiments.[5] Even cheap talk, that does not change incentives, increases cooperation

[3] See, for example, Herr et al. (1997), Giordana and Willinger (2007), Giordana et al. (2010) or Van Veldhuizen and Sonnemans (2011).

[4] Vespa (2013) conducts a related CPR experiment. Contrary to Fischer et al. (2004) he finds higher cooperation when the resource stock rebuilds slower. The experiments of Jacquet et al. (2013) are difficult to compare with these and our experiments because they do not add a future generation (leaving the other incentives unchanged) but transfer the benefits to a future generation. They find that such transfers foster pollution.

[5] See, for example, Ostrom and Walker (1991).

to close to efficiency. It is important that our experiment supports this result in a dynamic environment. However, we also find that generations which inherit a pollution stock negotiate more investment in the green sector than generations which do not, but they are also more likely to break agreements.

## 3. Experimental Design and Hypotheses

### *3.1. Experimental Design*

In a laboratory experiment subjects played two 15-period Public Good games in groups of $n = 4$ players in a partners design. Each period they had to decide whether to invest their endowment of $E = 20$ lab dollars in either a green sector paying $\gamma = 1.2$ or in a brown sector paying $\beta = 2$ lab dollars for each lab dollar invested. Brown sector investments furthermore caused emissions of a stock pollutant that accumulated over time and persisted until the end of the game. Each stock unit $S$ (caused by 1 lab dollar of brown sector investment) reduced each individual's payoff by $\delta = \frac{1}{16}$ lab dollars per period in all subsequent periods. Equation 1 shows player $i$'s profit in period $t$ deciding on the brown sector investment $x_{it}$.

$$\pi_{it} = \beta x_{it} + \gamma(E - x_{it}) - \delta S_t \tag{1}$$

Note that the stock persists until the final period $T$. Hence, a brown sector investment reduces payoffs in all remaining $T - t + 1$ periods. The stock evolves according to

$$S_t = S_{t-1} + X_t \tag{2}$$

where $X_t = \sum_i x_{it}$ is the total brown sector investment in period $t$.

In the treatments BASE, RESTART (repetition of BASE), COMM (= BASE preceded by a 20-minute chatting phase within the group), and 1STG (= BASE with the information that the final stock of the pollutant would be inherited by a second generation) the initial stock of the pollutant was 0. In 2NDG and in 2NDGCOMM the initial stock was inherited from a 1STG group from a different session. To prevent subjects from going broke due to high stock damages they were given an initial capital stock of 100 lab dollars in all treatments and in order to provide subjects in the second generation treatments (2NDG, 2NDGCOMM) with about the same income as those in the first generation and, again, to prevent them from going broke, they were initially endowed with 1000 lab dollars.[6] In both cases bankruptcy was still hypothetically possible but never actually occurred.

Payments consisted of a show-up fee of 5 Euros and success dependent payments from both periods as described above. The wording in the instructions was "investing in the environmentally friendly/conventional sector" and "pollutant that remains in the atmosphere" with all the consequences as described above. The second generation was introduced as "another group

[6]Most players in the 2NDGeneration treatments (97.3%) had negative period pay-offs from the very first period on. Incentive structures were identical, though, since the inherited stock is a sunk cost.

of subjects who inherit your stock". No explicit relation to the climate problem was indicated. The rules of the games and endowments of all players were common knowledge. Aggregate but not individual investment decisions were communicated after each period as well as the stock of the pollutant and own profits or losses from the last period. When playing the first game the subjects did not know that there would be a second game and, when playing the second game, they did not know that the experiment would be terminated after the end of that game. (For the composition of first/second games see Table I).

The stock of the pollutant in a second generation game was inherited from another group who had played the first generation game. Players in a first generation game did not know that the second generation game was played with a higher initial endowment but they might have guessed that otherwise the second generation could have run out of money. We think that this is quite similar to reality: We know about the pollution we leave and (less exactly) about the damages it causes for our children but we know very little about their non pollution-related income (because the world changes also otherwise: technical progress, accumulation of public capital, etc.). If we would have provided subjects with the same high endowment in 1STG and 2NDG then either the incentives from investing brown or green would have had to be small or the final income differences would have been tremendous.

The experiment was implemented in a Z-Tree programm design (Fischbacher, 2007). Participants first read instructions explaining the game and were given the possibility to ask questions. Furthermore, 8 control questions had to be answered to ensure full understanding. In the case of false replies the experimenter approached the subject and explained the correct answer. Afterwards subjects played a complete 15-period non-incentivized version of the game. In each period they chose a brown sector investment while the remaining endowment was automatically invested in the green sector. After all subjects had confirmed their decisions they were informed about their payoffs in both sectors, the brown sector investment of the entire group, the resulting stock and their period payoff. After the instruction phase subjects played one of four treatment combinations: 1. BASE→RESTART, 2. BASE→COMM, 3. 1STG→2NDG, 4. 1STG→2NDGCOMM. When starting the first treatment, say BASE, they did not know that there would be a second one, say COMM. In total 248 graduate and undergraduate students participated in 28 sessions. Subjects were randomly assigned to groups of 4. These groups were fixed until the end of the session. Participants received a lump sum payment of 5 Euros as well as 2 Euros per 100 lab dollars they earned in the experiment. The experiment lasted between 70 and 120 minutes. Subjects earned between 9 and 34 Euros.

We chose a partner design within the 15-period phases because it is "natural" in the climate problem. We furthermore did not re-arrange groups between the first and the second phase for practical reasons (more independent data points) and because we were interested in the transfer of collective behavior from the first to the second phase. If there is learning from BASE to RESTART it is easier to detect within identical groups.

In non-parametric tests, hypotheses are tested mostly by comparing either the first 15-round treatments with one another or the second 15-round treatments with one another. So comparisons are not biased because of different amounts of experience. (The only exception is the

Table I: Descriptive Statistics Sessions

| | BASE→RESTART | BASE→COMM | 1STG→2NDG | 1STG→2NDGCOMM |
|---|---|---|---|---|
| Subjects | 96 | 44 | 48 | 40 |
| Groups | 24 | 11 | 12 | 10 |
| Ave earning | 15.48 | 18.76 | 20.77 | 23.22 |
| Min earning | 9.77 | 10.77 | 14.01 | 9.70 |
| Max earning | 22.99 | 22.35 | 33.47 | 31.90 |

comparison of BASE and RESTART in order to find out whether learning takes place.) In two of three second 15-round comparisons the first 15-round treatments are even identical. The lifetime duration of 15 periods was chosen in order to minimize final-round effects. Many finitely repeated public good experiments showed that in the last round(s) of public good experiments cooperation decreases significantly as there are only a few periods left for counter-defection. Using a shorter lifetime duration, this effect might have superimposed the potential effect of inter-generational concerns.

### *3.2. Hypotheses*

For our theoretical predictions we derive benchmark behavior from four different assumptions about preferences and rationality. The first approach combines rationality with egoistic preferences, the second and third approach combine rationality with social (inequality averse or altruistic) preferences, and the fourth approach suggests a semi-rational non-equilibrium model of best replies to adaptive expectations of the contributions of others when preferences are inequity averse. In a regression analysis we also test the possibility of general behavioral inertia and profit aspiration level behavior (without further theoretical underpinning of these behavioral concepts). Egoistic players want to maximize

$$\pi_i = \sum_t \pi_{it} \tag{3}$$

with $\pi_{it}$ from (1). Because of

$$\frac{\partial \pi_i}{\partial x_{it}} = \beta - \gamma - (T - t + 1)\delta \tag{4}$$

and because of our parameter choices ($\beta = 2$; $\gamma = 1.2$; $\delta = \frac{1}{16}$; $T = 15$) we find:

**Behavior of egoists**: *In all treatments, all players invest completely in the green sector in periods $t < 4$ and completely in the brown sector afterwards. This refers also to the communication treatments because no binding agreements can be concluded.*

Rational players $i$ with **linear altruistic preferences** are described by

$$\begin{aligned} U_i &= \text{own income} + a_i * (\text{co-players' average income}) \\ &= \pi_i + \frac{a_i}{n-1} \sum_{j \neq i} \pi_j \end{aligned} \tag{5}$$

with $0 \le a_i \le n-1$. Because of

$$\frac{\partial U_i}{\partial x_{it}} = \beta - \gamma - \delta(T-t+1) - a_i * \delta(T-t+1) \tag{6}$$

altruists have an incentive to switch to pollution later than egoistic players. The case of efficiency oriented players is covered by $a_i = n-1$. If there is a second generation, altruistic players of the first generation should switch even later to brown sector investment, but there is no inter-generational effect for the behavior of the second generation.

**Behavior of altruistic players**: *In all treatments, all players invest only in the green sector in* $t < 4$. *There is an individually different period* $4 \le t \le 12$ *(in* 1STG *possibly even later), where they switch from completely green to completely brown sector investment.* 1STG *players pollute less than players in* BASE. *They switch later from green to brown investment.* 2NDG *players' behavior does not differ from that of players in* RESTART.

Rational players $i$ with **inequality averse preferences** with respect to the co-players of their own generation are described by

$$\begin{aligned} U_i &= \text{own income} - f_i(\text{own income} - \text{others' average income}) \\ &= \pi_i - f_i\left(\pi_i - \sum\nolimits_{j \neq i} \frac{\pi_j}{(n-1)}\right) \end{aligned} \tag{7}$$

where $f_i$ is a convex function with a minimum at zero. Note that our subjects are informed only about the average income of their co-players in each (past) period. The second term of the utility function does not depend on the stock of the pollutant which, in our symmetric case, has the same additive impact on all players' incomes. Investing one unit in the brown instead of the green sector in period $t$ changes a player's utility by

$$\frac{\partial U_i}{\partial x_{it}} = (1 - f_i')(\beta - \gamma) - (T-t+1)\delta \tag{8}$$

where the argument of $f_i'$ is the expected aggregate income difference. In all cases all players behaving like egoists is an equilibrium. In the case of Fehr-Schmidt (FS) preferences (7), $f'$ takes only two values with $f_i' \le 0$ if the player expects to have less income than his co-players and $0 < f_i' < 1$ if a player expects to have more income than other players; i.e. $1 - f_i' > 0$ in both cases. Under the assumptions of Fehr and Schmidt (2010), there are 60% egoistic players and 40% FS-players with $f_i' = 0.6$ if advantaged (more income than the others) and $f_i' = -2$ if disadvantaged. Under these assumptions, all FS-players should switch to the brown sector in the sixth period or earlier. If they expect all others to invest in the green sector, they will follow them until period five. If they expect at least one other player to deviate, they will also deviate. With 40% egoists in the population, however, there is only a 21.6% chance to meet three other FS-players. Therefore, under incomplete information, no FS-type will extend his cooperation beyond period 3. With other $f_i'$-values and with other assumptions about the distribution of these values, however, more cooperative equilibria are possible. But they do not seem to be probable.

Therefore we expect inequality averse players to behave like egoists, at least as long as inequality averse preferences are restricted to co-players within the same 15-periods phase. It is plausible that other 15-period phases are not taken into account, except for the first generation/second generation treatment. There, players may have a utility function

$$\begin{aligned} U_i &= \text{own income} - f_i(\text{own income} - \text{co-players' average income})/2 \\ &\quad - f_i(\text{own income} - \text{other generation's average income})/2 \qquad (9) \\ &= \pi_i - 0.5 f_i\left(\pi_i - \sum\nolimits_{\text{own}, j\neq i} \pi_j/(n-1)\right) - 0.5 f_i\left(\pi_i - \sum\nolimits_{\text{other}, j} \pi_j/n\right) \qquad (10) \end{aligned}$$

with the implication for a first-generation player $i$

$$\frac{\partial U_i}{\partial x_{it}} = \beta - \gamma - (T-t+1)\delta - f_i'(\Delta_{i11})\frac{\beta-\gamma}{2} - f_i'(\Delta_{i12})\frac{\beta-\gamma+(t-1)\delta}{2} \qquad (11)$$

with $\Delta_{ijk}$ = income of player $i$ from generation j minus the average income of (other if $j = k$) players from generation $k$. The last term stems from the fact that $i$ suffers only $T-t+1$ periods from the pollution while the second generation suffers $T$ periods. Let us further assume that the first generation believes to have more income than the second generation, due to their smaller stock of pollution. Then $f_i'(\Delta_{i12})$ is positive and the marginal utility in (11) is smaller than in (8). Therefore the first generation should start polluting later if they know that there is a second generation (1STG compared to BASE). The second generation has no impact on the income of the first generation, so that a player $i$ from the second generation has a marginal utility of

$$\frac{\partial U_i}{\partial x_{it}} = \beta - \gamma - (T-t+1)\delta - f_i'(\Delta_{i22})\frac{\beta-\gamma}{2} - f_i'(\Delta_{i21})\frac{\beta-\gamma-(T-t+1)\delta}{2}. \qquad (12)$$

As (11), also (12) depends on $i$'s beliefs about income differences. If we assume that a generation plays symmetric strategies, increasing brown sector investments are connected with higher incomes compared to the co-players and therefore $f_i'(\Delta_{i22}) > 0$. If the second generation expects to have less income than the first generation, then $f_i'(\Delta_{i21} < 0)$. Because of the latter, a 2NDG player has a higher marginal utility from brown sector investments than a RESTART player, whose marginal utility is (8). If we do not assume $f_i'$ to be constant, then the magnitude of $f_i'(\Delta_{i21})$ may be proportional to the stock which the first generation leaves to the second.

**Behavior of inequality averse players**: *They behave like egoists except in the* 1STG *and* 2NDG *treatments.* 1STG *players pollute less than players in* BASE*; they switch later from green to brown investment.* 2NDG *players pollute more than players in* RESTART*; they switch earlier from green to brown investment. In the case of a loss function $f$ with $f'' > 0$ brown sector investments in the* *second generation should be positively correlated with the stock inherited from the first generation.*

This behavior does not change in the case of cheap talk. Therefore all models with rational players imply the same behavior in treatments with and without communication.

**Behavior of egoistic, altruistic, and inequality averse players**: *There is no difference between* COMM *and* RESTART *and between* 2NDGCOMM *and* 2NDG.

Deviations from these predictions may be caused by "behavioral noise" (random deviations) or by non-linear altruism or by other assumptions about social preferences (e.g. reciprocal players, value of promises in then no longer cheap talk). All these alternatives can prevent all-or-nothing strategies and some even prevent the unidirectional development from green to brown sector investment.

Let us now discuss predictions from models with "behavioral" elements which involve framing and non-equilibrium behavior. Most 2NDG players suffer losses from the first period on (97.3%). To prevent them from going broke, they were endowed with a higher initial capital stock of 1000 lab dollars instead of 100 lab dollars in the treatments without a former generation. Although the incentive structure is identical in the first and in the second generation, the first generation may have the impression that it maximizes income while the second generation minimizes losses. This relates to prospect theory (Kahneman and Tversky, 1979), which claims that people assess gains and losses differently. From the assumption, that the loss branch of the utility function is steeper than the profit branch, follows more cooperation in the 2NDG treatments than in RESTART. This implies predictions similar to inequality aversion: *The stock of pollution produced by a second generation is smaller than that of the* RESTART *players.*

As a last theoretical approach let us analyze a semi-rational non-equilibrium model. We assume that players are myopic and have adaptive expectations $\text{Exp}_t$ about their co-players' average brown sector investments

$$\text{Exp}_{it} = \alpha \text{Exp}_{i,t-1} + \frac{1-\alpha}{n-1} \sum\nolimits_{j \neq i} x_{j,t-1} \tag{13}$$

with $0 < \alpha < 1$. They choose a best reply under myopic preferences

$$\begin{aligned} U_{it} &= \sum\nolimits_t \text{own income}_t + a_i * (\text{own income}_t - \text{others' average income}_t)^2 \\ &= \pi_i + a_i(\beta - \gamma)^2 (x_{it} - \text{Exp}_t)^2 \end{aligned} \tag{14}$$

with $a_i < 0$. The stock of the pollutant has again no influence on the income differences. Player $i$ maximizes his utility by

$$x_{it} = \text{Exp}_{it} + \frac{1}{2a_i(\beta - \gamma)} \tag{15}$$

if this value is smaller than the endowment $E$. (15) implies conditional cooperation similar to that described by Fischbacher et al. (2001): every player wants to invest a little more in the brown sector than the others. (13) and (15) imply:

**Behavior of myopic inequality averse players with adaptive expectations**: *a players' brown sector investments are positively correlated with co-players' last period investments. There are no differences between treatments and no dependency on the period.*

A number of other behavioral biases may be observed. Without proposing further formal models we will check the possibility that inertia concerns own behavior (positive correlation between $x_{it}$ and $x_{it-1}$). In addition, players may be guided by target levels for profits: they want to reach these levels but not surpass them in order to limit pollution. Adaptation to such targets may have the consequence that $x_{it}$ increases with $\pi_{\text{target}} - \pi_{i,t-1}$ and is thus negatively correlated with $\pi_{i,t-1}$.

Note that a positive correlation between period $t$ and brown sector investments $x_{it}$ is implied by the first three models although they usually predict a jump to occur from completely green to completely brown investment. This jump may be smoothed by behavioral noise and is then substituted by transition periods with intermediate amounts of brown sector investment. In the next section we will conduct non-parametric tests and regressions in order to test our predictions. Additional tests will concern learning by comparing BASE and RESTART using a Wilcoxon test and by a dummy variable in regression models as well as a correlation of the stocks inherited and produced by the second generation.

## 4. Results

Table I shows descriptive statistics in the different treatment combinations. Note that earnings were higher in the inter-generational treatments, which is due to the fact that subjects acted more cooperatively and also that the initial endowment in the loss frame 2NDG was a bit too generous. 800 instead of 1000 lab dollars would have been sufficient to keep players from going broke and to let them earn similar amounts as 1STG subjects who started with 100 lab dollars. In order to minimize learning effects in the incentivized rounds, subjects played a complete non-incentivized version of the game before the game started. To still control for learning effects between the first and the second incentivized round we conducted the RESTART treatment. Average brown sector investments, stocks and total profits for all treatments are given in Table **??** in the appendix. Using a Wilcoxon rank-sum test, we find that group investments do not differ between BASE and RESTART ($p = 0.41$ overall). Concerning the behavior in the single periods, there is only one significant difference in the last period. Hence, we formulate

**Result 1**: There is no significant directional learning effect between two incentivized 15-period phases.

In order to control for other effects due to a longer history, in the following we compare only behavior between two first-phase plays or two second-phase plays. Note that, in all non-

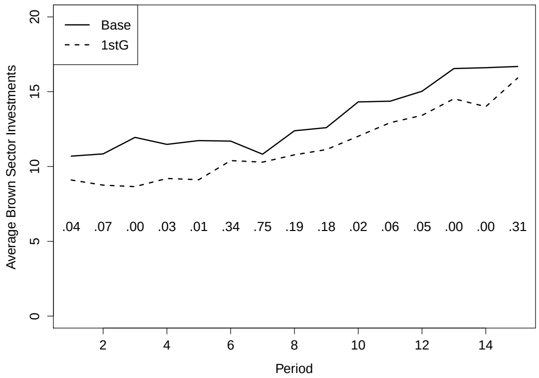


Figure 1: Brown sector investments with and without future generation (p-values of Wilcoxon rank sum test for each period in the diagram)

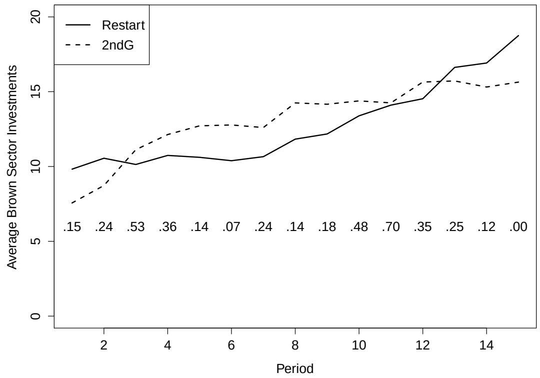


Figure 2: Brown sector investments with and without former generation (p-values of Wilcoxon rank sum test for each period in the diagram)

parametric tests we use one data point per group which guarantees the necessary independence.

**Result 2**: A generation invests significantly less in the brown sector, if they know that a future generation will inherit their pollution stock. The decreased pollution also significantly increases their own welfare.

Figure 1 shows the brown sector investments in BASE and 1STG. Using a Wilcoxon rank-sum test we find that group investments over 15 periods are significantly lower in 1STG. This goes for either comparing all investments ($p = 2.5 * 10^{-10}$) as well as for comparing group investments in each period. (Wilcoxon p-values for the single periods are given in Figure 1). The lower brown sector investments in 1STG are also reflected in the average pollution stocks and the total profit. Table **??** in the appendix shows that final pollution stocks are 14% lower and final total profits are 14% higher, when the stock is inherited by a future generation. We still observe the final round effect in 1STG. Groups get less cooperative in the late periods, as also observed by Pevnitskaya and Ryvkin (2013). Fischer et al. (2004) (1 period lifetime duration) and Chermak and Krause (2002) (3 periods lifetime duration) find virtually no effect of inter-generational concerns.

**Result 3**: Behavior does not change when the stock of pollution is inherited from a previous generation.

Although brown sector investments in RESTART are slightly lower than in 2NDG, this difference is not significant (Wilcoxon $p = 0.56$). With one exception in the last period, this is also true for single period comparisons (p-values given in Figure 2).

As in many other experiments, we find that communication works like a charm. Behavior in COMM and 2NDGCOMM is close to socially efficient.[7] Until the 12th period average brown

[7]Detailed information about the behavior can be found in Table **??** in the appendix.

Table II: Regression of brown sector investments in non-communication treatments

| | Estimate | Standard Error |
|---|---|---|
| $\beta_0$ | $4.51^{***}$ | (0.41) |
| $\mathbb{1}_{\text{RESTART}}$ | $-0.01$ | (0.20) |
| $\mathbb{1}_{\text{1STG}}$ | $-0.75^{*}$ | (0.30) |
| $\mathbb{1}_{\text{2NDG}}$ | $-0.31$ | (1.17) |
| $\mathbb{1}_{t>3}$ | $0.61^{*}$ | (0.28) |
| $\mathbb{1}_{t>12}$ | $-0.36$ | (0.27) |
| $t$ | $0.25^{***}$ | (0.04) |
| $S_0$ | 0.00 | (0.00) |
| $x_{i,t-1}$ | $0.59^{***}$ | (0.01) |
| $x_{j,t-1}$ | $-0.03$ | (0.02) |
| $\pi_{i,t-1}$ | $-0.004^{**}$ | (0.005) |

Random-Effects estimation. Random-Effects on group level. Standard errors in parentheses. $\beta_0$ – Intercept; $\mathbb{1}_{\text{RESTART}}$ – Treatment Dummy RESTART; $\mathbb{1}_{\text{1STG}}$ – Treatment Dummy 1STG; $\mathbb{1}_{\text{2NDG}}$ – Treatment Dummy 2NDG; $\mathbb{1}_{t>3}$ – Dummy Nash Equilibrium; $\mathbb{1}_{t>12}$ – Dummy Social Optimum; $t$ – Period; $S_0$ – inherited stock; $x_{i,t-1}$ – own brown sector investment in previous period; $x_{j,t-1}$ – others' average brown sector investment in previous period; $\pi_{i,t-1}$ – profit in previous period. Significance levels: $^{***} < 0.001$, $^{**} < 0.01$, $^{*} < 0.05$

sector investments are close to 0 and even though they do not "jump" to 20 afterwards, we find a sharp increase in the late periods of the game. In both treatments, brown sector investments are significantly lower than in their non-communication counterparts (RESTART and 2NDG). Compared to one another, though, we do not find a significant difference (Wilcoxon $p = 0.34$ for COMM vs. 2NDGCOMM). This does not imply, however, that the outcome of the negotiations in the chat phase is the same in both treatments.

To identify the negotiated strategy, we analyzed the chat protocols of the communication phases. To prevent the analysis from possible selective cognition, we paid three students, who were in no way related to the experiment, to analyze the chats. Their task was to read the protocols and extract the negotiated strategies for the following 15 periods, if possible. The students were paid a lump sum of 40 Euro for this work, which took them roughly 3 hours. If at least 2 students came to the same conclusion, we assumed the extracted strategy to be the actually negotiated strategy. In 16 cases all three students extracted the same strategy for a group, in 3 cases 2 students extracted the same strategy. For the remaining 2 groups all students found that no observable strategy was negotiated. The latter cases are not included in the analysis. Using a chat interface which forces the players to type in the negotiated strategy would have made the collection of these data easier. However, we figured that such an enforcement could have been misinterpreted by the subjects as some kind of bindingness, which could have biased the actual behavior.

Using a Wilcoxon rank-sum test, we find that negotiated strategies in 2NDGCOMM are significantly lower than in COMM. Figure 3 shows that negotiated strategies differ especially from the 8th period on, which seems to be triggered by a single group in 2NDGCOMM that negotiated an inverse "bang-bang" rule.[8] To control for a possible, coincidental outlier effect, we

[8] Figure 5 in the appendix shows graphs for all groups, containing the negotiated strategies and the actual behavior

Table III: Regression of deviations from negotiated strategies in communication treatments

| | Estimate | Standard Error |
|---|---|---|
| $\beta_0$ | −0.10 | (1.02) |
| $\mathbb{1}_{\text{2NDGCOMM}}$ | 2.96 | (3.79) |
| $\Delta x_{j,t-1}$ | 0.18* | (0.08) |
| $\Delta x_{j,t-1} * \mathbb{1}_{\text{2NDGCOMM}}$ | 0.24* | (0.10) |
| $\pi_{i,t-1}$ | 0.02 | (0.02) |
| $S_0$ | 0.00 | (0.01) |

Random-Effects estimation. Random-Effects on group level. Standard errors in parentheses. $\beta_0$ – Intercept; $\mathbb{1}_{\text{2NDGCOMM}}$ – Treatment Dummy 2NDGCOMM; $\Delta x_{j,t-1} * \mathbb{1}_{\text{COMM}}$ – others' average deviation in previous period (in COMM); $\Delta x_{j,t-1} * \mathbb{1}_{\text{2NDGCOMM}}$ – others' average deviation in previous period (in 2NDGNONCOMM); $\pi_{i,t-1}$ – profit in previous period; $S_0$ – inherited stock. Significance levels: *** $< 0.001$, ** $< 0.01$, * $< 0.05$

also ran the tests without this group. The outcome, however, remains the same, which leads us to the conclusion that negotiated strategies in 2NDGCOMM are in fact more ambitious than in COMM. A reason for this might be the loss framing in this treatment, telling that subjects show a higher willingness to cooperate when they experience losses.

**Result 4**: Under a loss frame, subjects signal higher cooperation. Actual behavior, however, remains the same.

Using a Wilcoxon rank-sum test, we find that deviations from the negotiated strategies are significantly higher in 2NDGCOMM than in COMM (2.89 vs. 0.34, $p = 0.01$). Figure 4 shows the average deviations by treatment. Graphs for the negotiated strategies and the actual behavior of the players by group can be found in Figure 5 in the appendix. The tendency to deviate from the negotiated strategy may be interpreted as a "spirit of backward induction", but it does not lead to a complete breakdown of cooperation as predicted from the cheap talk character of communication. The significantly higher deviations in 2NDGCOMM may occur due to the loss frame in this treatment. The Spearman rank-correlation of $\rho = 0.21$ indicates only a loose relationship between the inherited stock and the deviations from the negotiated strategy, which is, however, significant ($p = 0.02$). For further investigation we conducted a regression of the deviations from the negotiated strategies. The results are shown in Table III.

The main reason for deviations seems to be co-players who deviate in the first place kicking off quickly accelerating responses. A deviation of one unit in period t triggers $3 * 0.18 = 0.54$ additional units in $t + 1$ in COMM and $3 * (0.18 + 0.24) = 1.26$ in 2NDGCOMM (see, Table III). The co-players' deviations $\Delta x_{j,t-1}$ turn out to be significant in both treatments and show the expected sign. However, as the estimators for the deviations ($\Delta x_{j,t-1}$, $\Delta x_{j,t-1} * \mathbb{1}_{\text{2NDGCOMM}}$) suggest, subjects respond significantly stronger to deviations in 2NDGCOMM. We furthermore conducted alternative regressions, adding the subjects' profit in the previous period $\pi_{i,t-1}$ and other variables to control for additional effects. The added variables, however, were insignificant, while non of the other estimators changed significantly. Furthermore, the significance levels remained the same and a comparison of the model fits (Likelihood-Ratio test) indicated

of all group members in the COMM-treatments.

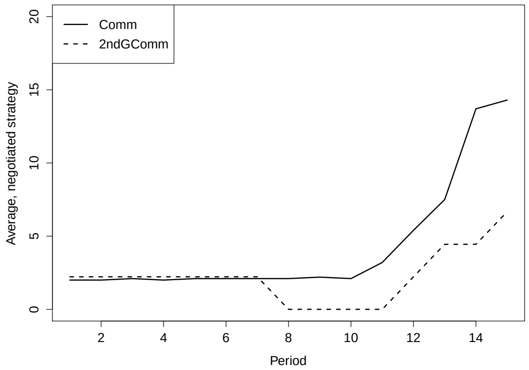


Figure 3: Negotiated strategies with and without former generation

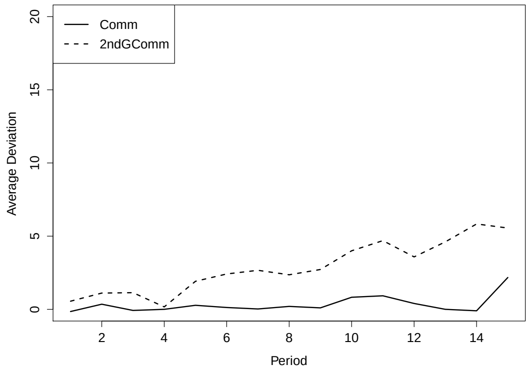


Figure 4: Deviations from negotiated strategies with and without former generation

no explanatory power of the added variables.

Theoretical predictions of egoistic behavior in the previous section suggest that a player's investment in the brown sector $x_{it}$ may depend on Nash-Equilibrium behavior $\mathbb{1}_{t>3}$, which is 0 for $t \leq 3$ and 1 for $t > 3$ and on $x_{j,t-1}$ (co-players' investments in the previous period). Behavior should not depend on $\mathbb{1}_{t>12}$ (social optimum behavior), $x_{i,t-1}$ (own investment in the previous period) and $\pi_{i,t-1}$ (own profit in the previous period). If, however, efficiency plays a role, then green sector investments should last until period 12. If the subjects' behavior shows inertia, $x_{it}$ should be positively correlated with $x_{i,t-1}$. We analyze these effects in a regression analysis. The results are given in Table II.

As expected from the non-parametric test, the treatment dummy variable for 1stG shows a significant negative estimator compared to Base, while the estimator for the Restart dummy does not. The estimators for Period ($t$) and last period's brown sector investment ($x_{i,t-1}$) are also significant, the latter indicating inertia in the subjects' behavior. In the non-communication treatments, we do not find an influence of the co-players' behavior in the previous period $x_{j,t-1}$.

In Table IV, the predictions of the previous section's theories are confronted with the results of the non-parametric tests and the regression analysis. It shows that a lot of the results support the different theories. Especially Linear Altruism is supported by the outcomes. However, except for Adaptive Inequality Aversion, none of the theories is in line with the outcome of $x_{i,t-1}$ in the regression analysis, which strongly indicates that inertia plays a major role for subject behavior. The interpretation of the influence of $\pi_{i,t-1}$ is difficult. There might be an effect of target levels for the profit, which leads to higher defection the lower the profit is.

## 5. Conclusion

Our investigation provides four main messages. First, as the communication treatments show, subjects seem to be aware of the socially optimal behavior. Most of the groups negotiated a "bang-bang" rule (entirely green until a certain period, entirely brown afterwards), though not all of them recognized the socially optimal period to switch. The non-communication treatments, however, show that subjects are not aware of the individually optimal green sector

Table IV: Comparison of theoretical predictions

| | | Test result | Egoistic | Linear Altruism | Inequality Aversion | Adaptive Inequality Aversion |
|---|---|---|---|---|---|---|
| non-parametric tests | BASE → 1STG | − | 0 | − ✓ | − ✓ | 0 |
| | RESTART → 2NDG | 0 | 0 ✓ | 0 ✓ | + | 0 ✓ |
| Regression | $\mathbb{1}_{t>3}$ | + | + ✓ | 0 or + ✓ | + ✓ | 0 |
| | $\mathbb{1}_{t>12}$ | + | + ✓ | + ✓ | + ✓ | 0 |
| | $t$ | + | 0 | + ✓ | 0 | 0 |
| | $\mathbb{1}_{\text{RESTART}}$ | 0 | 0 ✓ | 0 ✓ | 0 ✓ | 0 ✓ |
| | $\mathbb{1}_{\text{1STG}}$ | − | 0 | − ✓ | − ✓ | |
| | $\mathbb{1}_{\text{2NDG}}$ | 0 | 0 ✓ | 0 ✓ | + | 0 ✓ |
| | $x_{j,t-1}$ | + | 0 | 0 | 0 | + ✓ |
| | $S_0$ | 0 | 0 ✓ | 0 ✓ | + | 0 ✓ |
| | $x_{i,t-1}$ | + | 0 | 0 | 0 | 0 |
| | $\pi_{i,t-1}$ | − | 0 | 0 | 0 | 0 |

Comparison of theoretical predictions of brown sector investments with empirical results in 15-period phases without communication. In the non-parametric comparisons A → B, + indicates more investment in B and vice versa, in the regression analysis it indicates a positive coefficient (✓if confirmed).

investments in the first three periods. Secondly, subjects take future generations into account. The mere mentioning of inheritors leads to a 14% lower pollution stocks. With the result we qualify the findings of Fischer et al. (2004) and Chermak and Krause (2002). Neither of them find an inter-generational effect using short lifetime durations of 1 and 3 periods. We also find no effect in the last round of the game, which confirms their results. The occurrence of inter-generational thoughtfulness in our experiments rests probably on the longer lifetimes of our agents which gives them a better chance to think about the consequences of their behavior. The third message is that negotiations are more ambitious in a loss-frame. However, actual behavior remains the same, because deviations from the negotiated common plan of investment are higher. Fourth, behavior is influenced by inertia and (possibly) profit target levels.

We also tested several social preferences theories. Behavior in this dynamic environment is insufficiently described by all four of these benchmarks. A lot of the findings are covered by egoistic behavior and even more by altruistic behavior. However, none of the theories can explain the inertia and profit targeting in subjects' behavior.

Compared to static public goods experiments we have gained additional insight into the cognitive abilities and incentives of players in a long-term social dilemma situation. Still, none of the theoretical models implies all the behavioral facets we observe. The climate problem is exceptional as it requires cooperation of (almost) the whole of mankind; but it does not mean that people no longer rely on principles of behavior in their usual "toolbox". This is worrying but it also makes us confident that experimental economics can contribute to the understanding of the present state of overwhelming non-cooperation. As in our experiment, most people seem to realize what should be done to restrict the threatening global warming and they also express their concerns about the living conditions of future generations, but governments do not seem to be able to bargain a thoughtful policy and stick to it. During the Paris climate summit in 2015 the vast majority of countries agreed to a common goal, namely to restrict global warming to less than two degrees. The contributions of single countries, however, remained rather vague while our subjects negotiated specific (non-binding) restrictions of behavior. Our investigation shows that it is not only the complications of a dynamic environment which prevents successful bargaining solutions. Nonetheless we plead for keeping this environment when conducting experiments with further structural elements (e.g. asymmetric opportunity costs of investing green, asymmetric beliefs about global warming); for our environment is closer to the real problem and the interaction of dynamics with other features may turn out to be crucial.

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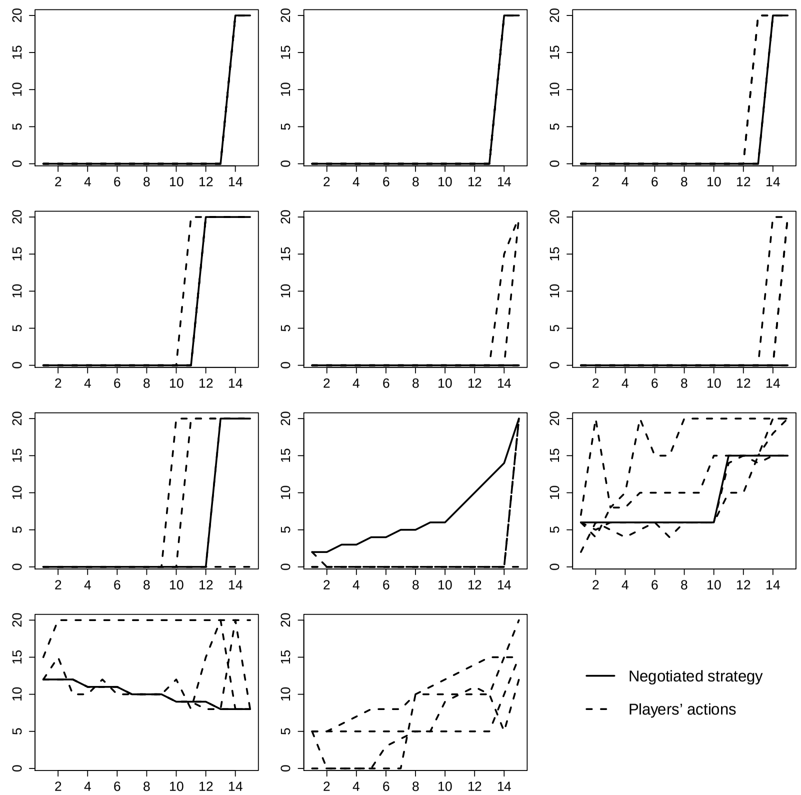
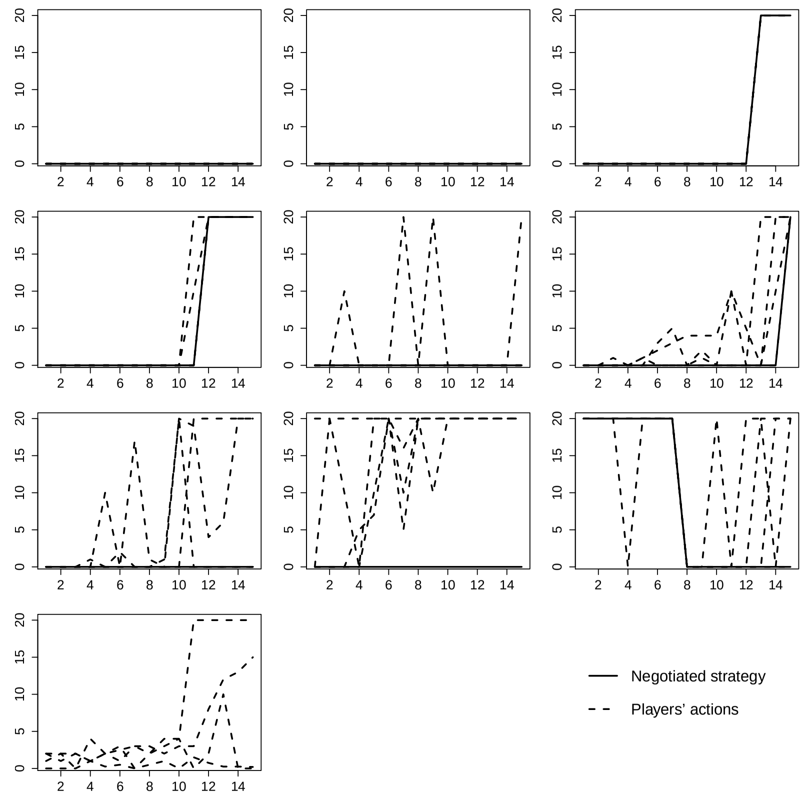
# A. Appendix




(a) Treatment COMM.




(b) Treatment 2NDGCOMM.

Figure 5: Negotiated strategies and actual behavior by group
(Last displayed group in either treatment did not negotiate an identifiable strategy.)

Table V: Average results by treatment

| avg. brown sector investments | Period | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Base | 10.7 | 10.8 | 11.9 | 11.5 | 11.7 | 11.7 | 10.8 | 12.4 | 12.6 | 14.3 | 14.4 | 15.0 | 16.6 | 16.6 | 16.7 |
| Restart | 9.8 | 10.6 | 10.1 | 10.7 | 10.6 | 10.4 | 10.7 | 11.8 | 12.2 | 13.4 | 14.1 | 14.5 | 16.6 | 16.9 | 18.7 |
| Comm | 2.0 | 2.4 | 2.1 | 2.1 | 2.5 | 2.4 | 2.3 | 2.8 | 2.8 | 3.5 | 4.6 | 6.2 | 7.7 | 13.4 | 16.4 |
| 1stG | 9.1 | 8.8 | 8.7 | 9.2 | 9.1 | 10.4 | 10.3 | 10.8 | 11.1 | 12.0 | 12.9 | 13.4 | 14.5 | 14.0 | 15.9 |
| 2ndG | 7.6 | 8.7 | 11.1 | 12.1 | 12.7 | 12.8 | 12.6 | 14.3 | 14.2 | 14.4 | 14.3 | 15.6 | 15.7 | 15.3 | 15.6 |
| 2ndGComm | 2.6 | 3.1 | 3.1 | 2.3 | 3.9 | 4.3 | 4.4 | 2.3 | 2.7 | 3.9 | 4.8 | 6.0 | 9.2 | 10.1 | 11.9 |

| avg. stocks | Period | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Base | 42.8 | 86.1 | 133.9 | 179.8 | 226.8 | 273.6 | 316.8 | 366.4 | 416.8 | 474.1 | 531.5 | 591.6 | 657.8 | 724.2 | 791.0 |
| Restart | 39.3 | 81.5 | 122.0 | 165.0 | 207.5 | 249.0 | 291.6 | 339.0 | 387.7 | 441.2 | 497.6 | 555.7 | 622.2 | 689.9 | 764.9 |
| Comm | 8.1 | 17.5 | 25.9 | 34.3 | 44.1 | 53.6 | 62.9 | 74.0 | 85.2 | 99.1 | 117.5 | 142.3 | 173.2 | 226.7 | 292.3 |
| 1stG | 36.4 | 71.4 | 106.0 | 142.8 | 179.3 | 220.9 | 262.0 | 305.2 | 349.7 | 397.8 | 449.5 | 503.2 | 561.3 | 617.3 | 680.9 |
| 2ndG | 30.2 | 64.5 | 109.0 | 157.6 | 208.4 | 259.5 | 310.0 | 367.0 | 423.6 | 481.1 | 538.2 | 600.7 | 663.6 | 724.9 | 787.4 |
| 2ndGComm | 10.5 | 22.9 | 35.4 | 44.7 | 60.2 | 77.6 | 95.8 | 105.1 | 115.9 | 131.4 | 150.7 | 174.7 | 211.5 | 251.8 | 299.4 |

| avg. total payoffs | Period | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Base | 129.9 | 157.2 | 182.4 | 204.3 | 223.5 | 239.8 | 252.6 | 263.6 | 271.7 | 277.5 | 279.8 | 278.8 | 274.9 | 267.0 | 254.9 |
| Restart | 129.4 | 156.8 | 181.2 | 203.5 | 223.0 | 239.8 | 254.1 | 266.4 | 275.9 | 283.0 | 287.2 | 288.1 | 286.5 | 280.9 | 272.1 |
| Comm | 125.1 | 149.9 | 174.0 | 197.5 | 220.7 | 243.3 | 265.2 | 286.8 | 307.7 | 328.3 | 348.6 | 368.7 | 388.0 | 408.6 | 427.4 |
| 1stG | 129.0 | 155.5 | 179.8 | 202.3 | 222.4 | 240.9 | 256.7 | 270.3 | 281.3 | 290.1 | 296.3 | 299.6 | 300.2 | 296.8 | 291.0 |
| 2ndG | 985.2 | 969.3 | 952.5 | 933.4 | 911.6 | 886.7 | 858.5 | 828.0 | 793.9 | 756.4 | 715.3 | 671.3 | 623.5 | 571.5 | 515.9 |
| 2ndGComm | 978.7 | 957.0 | 934.5 | 910.8 | 887.4 | 863.2 | 838.1 | 810.6 | 782.8 | 754.9 | 726.6 | 697.7 | 669.1 | 638.6 | 606.6 |

| avg. negotiated brown sector investments | Period | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Comm | 2.0 | 2.0 | 2.1 | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.1 | 3.2 | 5.4 | 7.5 | 13.7 | 14.3 |
| 2ndGComm | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 4.4 | 4.4 | 6.7 |

| avg. deviation from negotiated brown sector investments | Period | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Comm | -0.2 | 0.4 | -0.1 | 0.0 | 0.3 | 0.1 | 0.0 | 0.2 | 0.1 | 0.8 | 0.9 | 0.4 | 0.0 | -0.1 | 2.2 |
| 2ndGComm | 0.6 | 1.1 | 1.1 | 0.2 | 1.9 | 2.4 | 2.7 | 2.4 | 2.7 | 4.0 | 4.7 | 3.6 | 4.6 | 5.8 | 5.6 |

Brown sector investments, stocks total profits, negotiated brown sector investments and deviations from negotiated strategies by treatment and period. Note, that deviations do not equal investments minus negotiated investments in the Comm treatments. The reason is, that in both treatments for one group no negotiated strategy was identified.