Four Contributions to Experimental Economics

Inaugural-Dissertation

zur Erlangung des Grades eines Doktors der
Wirtschafts- und Gesellschaftswissenschaften durch die
Rechts- und Staatswissenschaftliche Fakultät der
Rheinischen Friedrich-Wilhelms-Universität
B o n n

vorgelegt von

Frank P. Maier-Rigaud

aus

Bonn

◇

Bonn 2007

Dekan:	Prof. Dr. Erik Theissen
Erstreferent:	Prof. Dr. Dr. h. c. mult. Reinhard Selten
Zweitreferent:	Prof. Dr. Armin Falk

Diese Dissertation ist auf dem
Hochschulschriftenserver der ULB Bonn
http://hss.ulb.uni-bonn.de/diss_online
elektronisch publiziert.

publication year: 2008

Acknowledgements

The papers drawn together for this dissertation have benefited from various presentations, from financial support received from different sources and the feedback of many people.

The second chapter was improved by comments and suggestions received during presentations at the Department of Economics of the University of Bonn, the Max Planck Institute for Research on Collective Goods in Bonn and the conference "Understanding Reciprocity" in Verbania, Italy, in 2007.

The third chapter was presented and received feedback from audiences at the Max Planck Institute for Research on Collective Goods in Bonn, the Center for Adaptive Behavior and Cognition, Max Planck Institute for Human Development in Berlin, the 2002 ESA Meetings in Strasbourg, the Strategic Interaction Group of the Max Planck Institute for Research into Economic Systems in Jena and at the 10th International Social Dilemma Conference in Marstrand, Sweden.

The paper on which chapter four is based has been published in the *Journal of Conflict Resolution* in 2006.[1] It has been improved based on comments and suggestions received during presentations at the Department of Economics of the University of Bonn, the Department of Economics of the University of Cologne, the Department of Economics and the Department of Political Science at Indiana University Bloomington, the Max Planck Institute for Research on Collective Goods in Bonn, and from feedback of two anonymous referees of the *Journal of Conflict Resolution*.

The research presented in chapter five is partly based on a publication in the *Competition Law Review* in 2006.[2] It has benefited from various discussions with colleagues in the Directorate General Competition of the European Commission and from comments and suggestions received during presentations at the Competition Law Scholars Forum in London, the Department of Economics at the University of Bonn and the 2006 EARIE Conference in Amsterdam.

The four chapters of this dissertation are based on research conducted together

[1] See Apesteguia and Maier-Rigaud (2006) "The Role of Rivalry: Public Goods versus Common-Pool Resources", *Journal of Conflict Resolution*, 50(5), 646-663.

[2] See Beckenkamp and Maier-Rigaud (2006) "An Experimental Investigation of Article 82 Rebate Schemes" *Competition Law Review*, 2(2), 1-31.

with my friends and colleagues Jose Apesteguia (chapter 3 and 4), Martin Beckenkamp (chapter 2 and 5) and Heike Hennig-Schmidt (chapter 2). I am indebted to them and to T. K. Ahn, Stefan Bechtold, Martin Dufwenberg, Armin Falk, Urs Fischbacher, Roy Gardner, Ben Greiner, Hendrik Hakenes, Martin Hellwig, Johannes Kaiser, Stefan Magen, Andreas Niklisch, Hans Normann, Axel Ockenfels, Axel Ostmann, Bruce Russett, Burkhard Schipper, Michael Stratmann, James M. Walker, Daniel Wiesen, and the library team of the Max Planck Institute for Research on Collective Goods.

I am particularly grateful to Christoph Engel, Elinor Ostrom and Reinhard Selten for their advice and support throughout the years.

Financial support from the Max Planck Institute for Research on Collective Goods, the European Union through the TMR research network ENDEAR (FMRX-CT98-0238), the Competition Law Scholars Forum (CLaSF) and the Spanish Commission of Science and Technology (SEC2003-08105) is gratefully acknowledged.

Contents

List of Figures

List of Tables

1 Introduction

In the following four chapters, distinct but related experimental research analyzing strategic and non-strategic economic behavior is presented.

Chapter 2, entitled "Cooperation in Symmetric and Asymmetric Prisoner's Dilemma Games" is a systematic study of behavior in symmetric and asymmetric prisoner's dilemma games. The prisoner's dilemma is one of the key models in many disciplines for now over five decades. Previous prisoner's dilemma experiments show that in contrast to theoretical predictions, cooperation rates are generally very high in the symmetric payoff variant of the game. Chapter 2 studies cooperation in the prisoner's dilemma in a more realistic scenario by systematically analyzing the effects of asymmetric payoffs. Already in the early nineties (Murnighan et al. 1990, p.181) noted that "research has been inexplicably absent on the effects of asymmetry". The present study takes this concern into account and focuses on this much broader type of conflict expanding the limited and rather unsystematic research conducted in this area. It analyzes and discusses the effect of asymmetry on cooperation in a 40 period prisoner's dilemma game in fixed partner design. A distinction is made between a high and low payoff symmetric prisoner's dilemma on the one hand and an asymmetric game combined out of both symmetric ones on the other hand. Asymmetry significantly decreases cooperation, as low-type players are more likely to defect after mutual cooperation while high-type players initiate cooperation more often than the former. Asymmetry also has a significant negative effect on the stability of cooperation rendering long sequences of mutual cooperation extremely rare. These results are not only a valuable addition to the existing (mostly symmetric) prisoner's dilemma literature but are also of relevance for understanding reciprocity, equity and fairness especially in light of recent theoretical developments based exclusively on symmetric experimental games.

Chapter 3, entitled "Assignment versus Choice in Prisoner's Dilemma Experiments" compares behavior in a repeated prisoner's dilemma game when players can choose between two different representations of the same prisoner's dilemma, to behavior when players are assigned to play a specific game. The chapter is concerned with the methodological question of the external validity of experimental research based on the assignment of participants to experimental games or decision situations.

Experimental findings may systematically misrepresent field outcomes if assigning participants to experiments has an impact on the decisions made by the participants in the experiment and if such an assignment does not occur in the field. The chapter therefore analyzes to what extent experimental deviations from actual situations due to the assignment of participants is based exclusively on the possibility of self-selection or sorting, or whether choice has an important behavioral effect in itself. The chapter extends the results obtained in the experimental psychology literature by analyzing whether choice effects are also found in strategic contexts, rendering them of particular interest to economic environments. Based on the idea that choice either via active modification of the strategic environment or by passive self-selection into a particular strategic environment may be an important property of many empirical problems studied using experimental methods, the research goal is to separate a choice effect from sorting or self-selection effects.

The experimental results clearly indicate that the mere fact that participants can choose the game they want to play has a statistically significant impact on behavior. Cooperation rates are up to 60% higher in the games that were not assigned to but chosen by participants. These findings are consistent with the robust evidence of the psychology literature on non-strategic contexts that choice increases motivation, trust, and performance. Given that in many contexts agents choose the strategic situation they get involved in, assigning participants to experiments may affect the external validity of some experimental findings.

Chapter 4, entitled "The Role of Rivalry - Public Goods versus Common-Pool Resources" moves from the 2 person prisoner's dilemma game structure to the analysis of behavior in a 4 person quadratic public good and a quadratic common-pool resource game.

Despite a large theoretical and empirical literature on public goods and common-pool resources, a systematic comparison of these two types of social dilemmas is lacking. In fact, there is some confusion about these two types of dilemma situations. As a result, they are often treated alike. An explicit example of this is provided by (Gintis 2000, pp.257-258) who argues that while "common pool resource and public goods games are equivalent for Homo Oeconomicus, people treat them quite differently in practice. This is because the status quo in the public goods game is the individual keeping all the money in the private account, while the status quo in the common pool resource game is that the resource is not being used at all."

In line with the theoretical literature, the chapter first establishes theoretically that public good and common-pool resource games as used in the experimental literature are two distinct types of social dilemmas, the fundamental difference between the two games being the degree of rivalry. It is shown that the distinguishing feature of these two types of games lies in the distributional factor that determines whether the good is rival or non-rival. This difference gives rise to two distinct strategic environments. Based on these theoretical differences an experiment is devised that tests whether the theoretical differences have an impact on behavior.

The results show that participants clearly respond to the differences in rivalry. Aggregate behavior in both games starts relatively close to Pareto efficiency and converges quickly to the respective Nash equilibrium. This clearly indicates that the differences in rivalry affect behavior, strengthening the importance of differentiating between the two types of games. Despite this difference reflecting the structure of the two games, there appear to be some behavioral similarities. In both games, aggregate behavior starts in the neighborhood of the Pareto optimum and moves rather quickly to the respective aggregate Nash equilibrium.

Chapter 5 entitled "Purchase Decisions with Non-linear Pricing Options under Risk" moves away from a strategic game setting to an analysis of decisions under risk. The chapter reports on an experimental investigation of purchase decisions with linear and non-linear pricing under risk. Standard economic theory suggests that customers should be indifferent to the format of a price reduction. In particular this implies that one would expect a customer to switch from one pricing scheme to another (one supplier to another) as long as there is at least an expected reduction in the effective purchase price. The recent surge in the use of rebates, discounts, bonus and point schemes implemented by retailers but also observed in other levels of the production chain begs the question of whether traditional economic explanations do fully account for the increased usage of non-linear pricing methods. An understanding of potential behavioral reasons for using such pricing schemes - as presented in this chapter - may not only be relevant for their design, but also for wider policy considerations.

The experiment presented is based on a single period stochastic inventory problem with endogenous cost. It extends classic binary lottery experiments to test standard decision theoretic predictions concerning purchasing behavior in a rebate and a discount scheme. The question to what extent customers continue to purchase under two mathematically isomorph formats of non-linear schemes even if switching to a linear pricing scheme is optimal is investigated. The results indicate that rebate and discount schemes exert a statistically significant attraction on customers. Given the increased role of non-linear pricing schemes, systematic deviations from optimal behavior are an important element in the design of such schemes and may raise consumer protection and competition policy issues. The chapter concludes with a discussion on how the results can be explained by decision heuristics.

2 Cooperation in Symmetric and Asymmetric Prisoner's Dilemma Games

Abstract: The chapter discusses the effect of asymmetry on cooperation in a 40 period prisoner's dilemma game in fixed partner design. A distinction between a high and low payoff symmetric prisoner's dilemma and an asymmetric game combined out of both symmetric ones is drawn. Asymmetry significantly decreases cooperation, as low-type players are more likely to defect after mutual cooperation while high-type players initiate cooperation more often than the former. Asymmetry also has a significant negative effect on the stability of cooperation rendering long sequences of mutual cooperation extremely rare.

2.1 Introduction

The prisoner's dilemma (PD) is an important model in economics, psychology, political science, sociology and biology as well as other disciplines for now over five decades. Previous PD experiments show that in contrast to theoretical predictions, cooperation rates are generally very high in the symmetric payoff variant of the game. The present paper studies cooperation in the PD in a more realistic scenario by systematically analyzing the effects of asymmetric payoffs.

Almost all studies investigating the PD are designed in such a way that payoffs are identical for both players.[1] Asymmetry is, however, an important property of many economic and non-economic problems. Most real world interactions entail different outcomes for each player, even if all players choose cooperatively.[2] The same obviously applies if all decide non-cooperatively. Already in the early nineties (Murnighan et al. 1990, p.181) noted that "research has been inexplicably absent on the effects of asymmetry". The present study focuses on this much broader type of conflict expanding the limited and rather unsystematic research conducted in this area. We modified the symmetric payoff matrix in such a way that both the cooperation and the defection payoff for player i is either larger or equal to that of player j. We therefore depart from the standard approach to study social interactions characterized by conditions of symmetry and equality. A systematic analysis of the asymmetric PD is not only a valuable addition to the existing (mostly symmetric) PD literature but it is also of particular relevance for understanding reciprocity, equity and fairness especially in light of recent theoretical developments based exclusively on symmetric experimental games (see, e.g., Fehr & Schmidt (1999) or Fehr & Schmidt (2003)).[3]

An important implication of asymmetry is the increased complexity of the game

[1] See Flood (1958) for the first experimental analysis of the game that at the same time is also an exception to this rule.

[2] Asymmetry plays an important role in various areas spanning from, for instance, competition policy questions surrounding collective dominance or cartel stability issues (see Friederiszick & Maier-Rigaud (2007)) to governance questions surrounding collective action problems and the management of common-pool resources (see Ostrom (1990)).

[3] See also Hennig-Schmidt (2002) and de Jasay et al. (2004) for a critique of the "symmetry" approach.

that is likely to induce dynamics that are absent in symmetric settings. Referring to the classic strategy tournaments by Axelrod (1984), (Murnighan 1991, p. 464) writes:

> "Axelrod (1984) found that certain strategies (tit-for-tat) effectively train an opponent to choose cooperatively. As a result, both parties do well and the likelihood that they will fall into mutual non-cooperation is minimized. Axelrod posits that similar results as found in the two-person, symmetric, iterated games would follow from games that satisfy PD's requirements even if the players' payoffs differ. Findings on asymmetric PD's question the generality of Axelrod's claim."

According to Murnighan, asymmetric dilemmas require much more complicated negotiations than typical PD games. The dilemma no longer consists of a relatively simple choice between the risks of mutual cooperation and the regrets of mutual defection. The complexity of the game adds more dynamic considerations. Pairs who can implement schemes of alternations do much better in increasing their payoffs while simultaneously reducing the temptation to defect. As a result, the main hypothesis of this paper is that asymmetry reduces cooperation rates. Asymmetry also adds to the problem of cooperation the problem of reaching a mutual understanding of what a desirable outcome is. Given these considerations and given relatively stable and high cooperation rates in symmetric iterated PD games, the main hypothesis of this paper is that asymmetry reduces cooperation.

Asymmetry in PD games is not a well-defined concept, though. There is not only an infinite number of combinatorial possibilities but asymmetry can also be introduced in some cells only or in a design where no player has consistently higher payoffs than the other in each cell (c.f. Murnighan et al. (1990), and Murnighan & King (1992)). Finally, including negative payoffs adds an additional factor.[4] As the review of the literature on asymmetric PD games in Section 2.3 will show, cooperation rates are not easily comparable: not only do the payoff parameters vary across studies but also the number of repetitions, the matching protocol, the remuneration and the justification for the asymmetry presented to participants. As

[4] According to Kahnemann & Tversky (1979) and Tversky & Kahnemann (1981), negative payoffs can have a substantial impact.

Lave (1965) and others have shown, these factors can have an important influence on cooperation rates.

Given the problems of comparability, we chose a comprehensive experimental design to systematically compare behavior in symmetric and asymmetric situations (SYM, ASYM respectively) and to study the impact of asymmetry on dyad-level dynamics.

We analyze two symmetric and one asymmetric PD game played repeatedly with a fixed opponent over 40 periods under perfect information. In SYM, we consider two symmetric treatments with HIGH and LOW payoffs for both players where the payoffs in LOW equal $\frac{2}{3}$ of the payoffs in HIGH. ASYM is an asymmetric combination of both symmetric games where player i gets the high payoff and player j the low payoff of the SYM treatments.

We observed 70.00% cooperation in LOW, 59.17% in HIGH and 38.75% in ASYM, a substantial difference between treatments. Cooperation patterns remain unstable roughly until period 10 before stabilizing at a rather high level of about 80% in LOW, and 65% in HIGH. In ASYM, cooperation gradually rises to about 55%. The general finding that cooperation is increasing over time is in line with other studies (Rapoport & Chammah (1965), Lave (1965), Murnighan & King (1992), Brenner & Hennig-Schmidt (2006)).

As hypothesized, asymmetry indeed substantially decreases cooperation rates, pointing towards the higher complexity of the game, whereas symmetry has a positive effect on mutual cooperation. We also find that high-type players initiate cooperation more often than low-type players. Defection by low-type players, possibly motivated by the aim to equalize payoffs, is more readily tolerated by high-type players. With respect to the stability of cooperation, we find that asymmetry has a negative impact rendering long sequences of mutual cooperation extremely rare. Low-type players are more likely to defect after mutual cooperation than high-type players.

In addition to the hypothesized effect of asymmetry on cooperation, we also find that the stability of mutual cooperation under symmetry is higher once it has been reached, i.e. mutual cooperation (CC) is followed by CC more often in SYM than in ASYM.

The remainder of the paper is organized as follows. Section 2.2 presents the games studied. Section 2.3 reviews the relevant experimental literature on symmetric PDs and the limited experimental literature on asymmetric PDs. Section 2.4 gives a detailed description of the experimental design and the experimental protocol. Section 2.5 presents the results and section 2.6 concludes with a discussion of the main findings.

2.2 The Prisoner's Dilemma Game

Table 2.1 presents a typical 2-player matrix game in normal form where i denotes the row and j the column player. This game is a PD if and only if the following conditions are met for both player i's and j's payoffs:

$$a_k > b_k > c_k > d_k \tag{2.1}$$

and

$$2b_k > a_k + d_k \forall k = i, j \tag{2.2}$$

The second condition goes back to (Rapoport & Chammah 1965, p.34) who proposed it in the context of iterated (symmetric) PD's in order to eliminate the possibility of simple alternation between DC and CD providing higher payoffs than mutual cooperation thus removing the dilemma.[5]

The formal presentation in table 2.1 is more general than the presentations usually found because it also accounts for asymmetric payoffs. In symmetric games, the indexed payoffs are equivalent to each other such that e.g. $a_i = a_j = a \vee i \neq j$.

It is well known that both players defecting is the unique Nash equilibrium of the one-shot PD game. Applying the logic of backward induction, Luce & Raiffa (1957) showed that the unique Nash-equilibrium outcome in the finitely repeated PD game under perfect information is again the one in which both players defect in every single period. In fact, the unique subgame-perfect equilibrium is both players defecting in all periods.[6]

[5] There exist several experimental studies with iterated PD games that violate this assumption and thereby no longer allow a separation of effects due to asymmetry or payoff maximization through simple alternations. In the experiment by Lave (1965) and by McKeown et al. (1967) the condition is violated for one of the players. Murnighan et al. (1990) and Murnighan & King (1992) implement so-called asymmetric dilemmas knowing that a subset of the games discussed violates the condition either for one or for both players.

[6] For an overview of the theoretical literature see Binmore (1992) or Osborne & Rubinstein (1994).

Table 2.1: General 2×2 prisoner's dilemma game in normal form (PD)

	Cooperate	Defect
Cooperate	(b_i, b_j)	(d_i, a_j)
Defect	(a_i, d_j)	(c_i, c_j)

Note that the first element of the payoff vectors refer to the row player.

The general formulation of the PD makes no restriction as to symmetry or asymmetry of players' payoffs. The asymmetric PD can be operationalized in many ways as long as at least one of the payoffs a_i to d_i differs from a_j to d_j in table 1. Our present study assumes $a_i > a_j$, $b_i > b_j$, $c_i > c_j$, $d_i = d_j = 0$, that is, the payoffs of player j are 2/3 of the payoffs of player i. The parameters are given in table 3.2.

Table 2.2: Experimental parameters

	HIGH	
	Cooperate	Defect
Cooperate	(12,12)	(0,18)
Defect	(18,0)	(6,6)
	LOW	
	Cooperate	Defect
Cooperate	(8,8)	(0,12)
Defect	(12,0)	(4,4)
	ASYM	
	Cooperate	Defect
Cooperate	(12,8)	(0,12)
Defect	(18,0)	(6,4)

2.3 Experimental Research on Symmetric and Asymmetric PDs

Almost all studies investigating the PD analyze symmetric situations and only few studies are devoted to asymmetric settings. In the following subsection, we first refer to some relevant experimental work on symmetric PDs. In subsection 3.2, we will give an overview of the experimental literature on asymmetric PD games.

2.3.1 Experimental Research on Symmetric PDs

Rapoport & Chammah (1965) conducted a series of laboratory experiments in which participants played a PD game repeatedly over 300 periods. Depending on the parameters of the game, overall cooperation rates varied between 26.8% and 77.4%. The authors found mutual cooperation in 53% of all dyads and more than 23% in the last 25 periods. Mutual defection took place in 17% of the dyads. Cooperation in the first period varied between 45% and 70% decreasing in the second period to 35% - 65%. Inquiring into the dynamics of the decision process, Rapoport and Chammah found cooperation waning in the first half of the experiment. Thereafter, cooperation increased to roughly the level at the beginning of the experiment with mutual cooperation rising steadily. The authors attribute this phenomenon to the fact that "Learning goes both ways in Prisoner's Dilemma. First the subjects learn not to trust each other; then they learn to trust each other" (p. 201).

Studies on the PD with a much lower number of periods and restart effects show that average cooperation levels start relatively high between 40%-60%; and then gradually decline over time.

Selten & Stoecker (1986) investigated behavior in a prisoner's dilemma game where 35 participants played 25 supergames consisting of a ten-period PD in stranger design.[7] The most common pattern of behavior was initial periods of mutual cooperation followed by an end effect involving an initial defection that was then followed by non-cooperation in the remaining periods. The end effect is defined as at least four consecutive periods of mutual cooperation with no further cooperation following the first defection thereafter. A very striking result is

[7] Parameters are $a_i = a_j = 145$, $b_i = b_j = 60$, $c_i = c_j = 10$, $d_i = d_j = -50$.

the emergence of the first defection. Players start to defect earlier and earlier in subsequent supergames so that cooperation unravels from the end.[8]

Andreoni & Miller (1993) analyze a 10-period PD in partner design repeated 20 times with changing the co-player each repetition.[9] They also study how people behave if they have a 50/50 chance to meet a computer player playing a tit-for-tat strategy. Average cooperation rates start relatively high at around 60% and subsequently decrease until a sharp end effect is observed. Looking at the first period of defection over the 20 supergames there is a clear tendency for cooperation to last until later periods.

Maier-Rigaud & Apesteguia (2006) analyze a 20-period PD in partner design.[10] Average cooperation started at almost 70% and declined to below 30% in the first three periods. It rose to approximately 60% and then declined more or less steadily throughout the game to approximately 20% in the last period. Overall cooperation was 33%.

For surveys of the experimental literature on symmetric PD games, see Lave (1965), Rapoport & Chammah (1965), Oskamp (1971), Roth & Murnighan (1978), Roth (1995) and Ledyard (1995).

Despite the high number and large variation in experiments implementing the symmetric PD game our results are generally in line with the cooperation rates, the development of cooperation and the end game behavior found in that literature.

2.3.2 Experimental Research on Asymmetric PDs

There is only a small literature on asymmetric PD games exhibiting a substantial variation in experimental conditions.[11]

[8]For an extensive discussion of the paper see Roth (1995).

[9]Parameters are $a_i = a_j = 12$, $b_i = b_j = 7$, $c_i = c_j = 4$, $d_i = d_j = 0$.

[10]Parameters are $a_i = a_j = 400$, $b_i = b_j = 300$, $c_i = c_j = 100$, $d_i = d_j = 0$.

[11]The first PD experiment by Flood and Dresher (c.f. Flood (1958)) assumed asymmetry in the diagonal and in d, i.e. $b_i \neq b_j$, $c_i \neq c_j$, $d_i \neq d_j$, but $a_i = a_j$, i.e. $a_i = a_j = -1$, $b_i = 0.5$, $b_j = 1$, $c_i = 0$, $c_j = 0.5$, $d_i = 1$, $d_j = 2$.

Schellenberg (1964) ran symmetric and asymmetric experiments.[12] Two series of experiments of 20 periods each were conducted where participants were rewarded by course credit.

In the first series of experiments, participants played against "stooges" that either followed an initially cooperative and increasingly non-cooperative strategy or an initially non-cooperative and increasingly cooperative strategy. The main finding based on the first series of experiments is that participants are more cooperative in the high-type player role and less cooperative in the low-type player role in the asymmetric game, the symmetric baseline game yielding cooperation rates in-between. In the series of experiments where no "stooges" were used Schellenberg did not find higher cooperation rates for high-type players. Schellenberg explains this interaction effect by the low cooperation of low-type players compared to the baseline. The second series of experiments did not yield statistically significant differences between symmetric and asymmetric games.

Sheposh & Gallo (1973) ran symmetric and asymmetric experiments.[13] Participants played for real money. The authors hypothesized cooperation in the asymmetric treatment to be less than in the symmetric treatment. In particular, low levels of cooperation were expected from participants with lower payoffs as minimal cooperative play is the only option to minimize payoff disparity.

80 participants played the game for 50 periods with feedback information on payoffs in each period.

The asymmetric game produced less cooperative behavior than the symmetric game (31.1% vs. 39.2%). Low-type players cooperated significantly less than high-type players (25.1% vs. 37.1%).

The authors then conducted a data analysis in terms of the conditional probabilities of one player's response in a given period as a function of the other player's choice in the preceding period. Were participants concerned with relative outcomes and did they try to avoid being surpassed by the other player? The smaller

[12] Parameters are $a_i = a_j = 5$, $b_i = b_j = 3$, $c_i = c_j = 1$, $d_i = d_j = 0$ in the symmetric treatment. Asymmetry was obtained by multiplying the payoffs of one of the players by two, i.e. $a_i = 10$, $a_j = 5$, $b_i = 6$, $b_j = 3$, $c_i = 2$, $c_j = 1$, $d_i = d_j = 0$.

[13] The parameters in the symmetric treatments are $a_i = a_j = 5$, $b_i = b_j = 4$, $c_i = c_j = 1(-2)$, $d_i = d_j = 0(-3)$. Asymmetry was obtained by multiplying the payoffs of one of the players by three, i.e. $a_i = 5$, $a_j = 15$, $b_i = 4$, $b_j = 12$, $c_i = 1(-2)$, $c_j = 3(-6)$, $d_i = 0(-3)$, $d_j = 0(-9)$.

amount of cooperation in the asymmetric treatment was attributable to the significantly lower proportion of cooperative moves by participants in the low-type position. Sheposh and Gallo's tentative interpretation is that participants' concern centered on the relative payoff rather than absolute personal gain. Low-type players consequently avoided cooperative play in order to reduce other's actual payoffs. Participants were less concerned with the notion of increasing their own payoffs than with redressing the imbalance caused by the asymmetrical structure of the game.[14]

Talley (1974) conducted several experiments with 168 participants each under various combinations of asymmetry and information. Asymmetry was created as in Sheposh & Gallo (1973) by multiplying the payoffs of one of the players by three. Treatments varied also with respect to information concerning others' payoffs, i.e. symmetry or asymmetry was not always known. Results indicated that full information enhanced cooperation in the symmetric games, while it reduced cooperation in the asymmetric games. In particular, lower overall cooperation in the asymmetric game was attributable to lower amounts of cooperation by low-type players.

Croson (1999) compared behavior in a symmetric and an asymmetric PD game. 80 participants were divided into 4 treatments, two of them involving a regular symmetric PD game and two an asymmetric one.[15] Participants played 5 games each, 2 of them being the above mentioned PD games in a stranger design. Croson considers asymmetry in all cells, i.e. $a_i > a_j$, $b_i > b_j$, $c_i > c_j$, $d_i > d_j$. Participants were informed about their payoffs at the end of each period and were paid at the end of the session. Cooperation in the symmetric treatment was rather high with 77.5%. Cooperation in the asymmetric treatment was lower amounting to 62.5%. There was, however, no significant difference between high-type and low-type players.

The next papers focus on asymmetry without comparison to symmetric situa-

[14] This is our reading of the paper because the claim that "subjects were concerned less with the notion of winning more money than their opponent than with the notion of preventing their opponent from surpassing them" (p. 332) is unclear. It is not clear how low-types could avoid being surpassed by high-type players without defecting. Not being surpassed is a first step for low-types on the way to higher relative profits and the two motives can therefore not be distinguished.

[15] Parameters are $a_i = a_j = 85$, $b_i = b_j = 75$, $c_i = c_j = 30$, $d_i = d_j = 25$ in the symmetric and $a_i = 95$, $a_j = 75$, $b_i = 85$, $b_j = 65$, $c_i = 40$, $c_j = 20$, $d_i = 35$, $d_j = 15$ in the asymmetric game.

tions.

Murnighan et al. (1990)[16] conducted a series of asymmetric dilemma experiments only a few of which were asymmetric PD's.[17]

Participants in the experiment were students whose course credit depended on their performance in the game. No monetary payments were involved. Participants in three studies played in three-person groups and subsequently as individuals. They were allowed to exchange anonymous messages after the second period. The groups played the game between 8 and 20 periods, not knowing beforehand when the game would be terminated.[18] Based on our calculations, overall cooperation was 54%. Excluding the game where player type could not be consistently defined over all cells, low-type groups defected 45% and high-type groups 55% of the time.

In Murnighan & King (1992), nine different asymmetric dilemmas are considered only three of which fulfill the iterated PD condition and consequently are asymmetric PD games.[19] Participants had full information on all outcomes and communication was allowed. Based on our calculations, and aggregated over all three asymmetric PDs, cooperation rates were 64% over the first 8 periods (84% if the first two periods are excluded).

In Charness et al. (2007), asymmetric PD games are discussed although the focus of the paper is on two-stage modified PD games (coordination games) consisting of a first round where players simultaneously choose binding non-negative amounts to reward the counterpart for cooperation and a second round consisting of an asymmetric PD game.

Aggregate cooperation rates in the three control sessions not containing a first

[16] The experiment and the results are also reported in King & Murnighan (1988) and in Murnighan (1991).

[17] All asymmetric PD games involved identical off-diagonal cells with $a_i = a_j = 40$ and $d_i = d_j = 0$. One game implements $b_i > b_j$, with $b_i = 32$ and $b_j = 21$ but $c_i < c_j$, with $c_i = 2$, $c_j = 19$ and the other three $b_i > b_j$ and $c_i > c_j$ with $b_i, c_i = 30, 24; 24, 22; 28, 24$ and $b_j, c_j = 28, 20; 22, 4; 24, 4$ respectively. The respective games are Game 2 and 3 from the second experiment and Game 8 from the third. The game where player type could not be consistently defined over all cells is Game 4 of the second experiment.

[18] Note that the probabilistic nature of the game also affects the game theoretic prediction.

[19] All three games (called HIGH/HIGH in the paper) involved identical off-diagonal cells with $a_i = a_j = 40$ and $d_i = d_j = 0$. One game implements $b_i > b_j$, with $b_i = 36$ and $b_j = 24$ but $c_i < c_j$, with $c_i = 18$, $c_j = 20$ and the other two $b_i > b_j$ and $c_i > c_j$ with $b_i, c_i = 36, 4; 36, 32$ respectively and $b_j, c_j = 24, 20$ each time.

stage compensation mechanism are 15.8%, 17.5% and 10.8% for Game 1, 2 and 3 respectively.[20] Player types and pairing were randomized in each of the 25 periods of the game.

In Andreoni & Varian (1999), the first analysis of compensation mechanisms in the PD, the experiment consists of a 15-period asymmetric PD game[21] (in a give-some, take-some decomposition) followed by 25 periods of a two-stage modified PD game.[22] The aggregate cooperation rate in the relevant first 15 periods is 25.8%. Cooperation rates, however, differ significantly by player type. Players in the low-type position cooperate 16.7% of the time while the cooperation rate of high-types is 29.2%.

The next papers analyze asymmetric dilemma games that violate the iteration condition. Although technically not PD games, a brief discussion of the main findings is relevant to the present study given the alternation patterns observed.

Lave (1965) ran a symmetric and an asymmetric experiment where asymmetry was obtained by multiplying the payoffs of one of the players by 2.5 in case of mutual cooperation.[23] Participants played for 50 consecutive periods and no communication was allowed. Even though computer players were used in some of the treatments, participants were paired with each other in the asymmetric sessions. Lave found a decline of cooperation from 57.5% to 50% when comparing the symmetric with the asymmetric treatment.

Analyzing individual behavior, Lave observed three cooperation strategy patterns. In the first one, participants stayed with the CC pattern and were not concerned about asymmetry. In the second pattern, participants alternated between CD and DC to get an expected value of 2.5 each. Finally, one pair settled on the optimal way of gaining equal payoffs: they played CC for five periods and DC in the sixth period achieving an expected value of $\frac{10}{3}$. In most cases, however,

[20] The parameters are $a_i = 52$, $a_j = 60$, $b_i = 40$, $b_j = 52$, $c_i = 28$, $c_j = 24$ and $d_i = d_j = 8$ for Game 1, $a_i = 40$, $a_j = 60$, $b_i = 32$, $b_j = 52$, $c_i = 20$, $c_j = 24$, $d_i = 4$ and $d_j = 8$ for Game 2 and $a_i = 52$, $a_j = 44$, $b_i = 44$, $b_j = 36$, $c_i = 32$, $c_j = 28$, $d_i = 8$ and $d_j = 0$ for Game 3.

[21] The parameters are $a_i = 9$, $a_j = 11$, $b_i = 6$, $b_j = 7$, $c_i = 3$, $c_j = 4$ and $d_i = d_j = 0$.

[22] Note that the end of the game was presented as probabilistic (15-25 periods) in the instructions, thereby affecting the game theoretic predictions. Furthermore, players were rematched every period.

[23] The parameters are $a_i = a_j = 10$, $b_i = 2$, $b_j = 5$, $c_i = c_j = -3$, $d_i = d_j = -5$.

participants apparently failed to understand each others' signals and had great difficulties to settle on some stable cooperation strategy. Lave read participants' choices as being concerned about equal payoffs. They tried to achieve equality even though they had to pay a great deal of money to do so.[24] With costly unilateral defection ($d < 0$), and asymmetry in the CC cell ($b_j > b_i$), alternating patterns became very salient for participants concerned about equal payoffs.

According to the global summary of results in Murnighan et al. (1990), in particular taking into account the 10 additional games not being PD's, participants rarely fell into a deficient series of non-cooperative outcomes. They instead used the off-diagonal payoffs to increase the outcome of the low player by simple or complex patterns of alternation. They implemented what Pruitt (1981) termed "integrative solutions". The low-type player j chose cooperatively most of the time, yet defecting regularly. This was tolerated by the high-type player i who chose cooperatively in every period. Thus, they jointly gained more than they would otherwise have been able to had they decided competitively. Murnighan (1991) states that arriving at complex alternation patterns requires a series of cognitive discoveries. Players that do not loose much if both players defect must first discover their "power" and realize how to use it to increase their payoffs. If they succeed to establish such a pattern of complex alternation they also establish less temptation for either player to defect because they both would loose. Implementing complex integrative solutions was certainly facilitated by allowing players to communicate. This was further corroborated by Murnighan & King (1992), who found that cooperation was rare when communication was not allowed. Providing bargainers with information on possible strategies was clearly important for evoking alternations. Discovering complex alternation schemes was difficult. Once discovered and implemented, complex alternation was stable. Defections were rare compared to mutual cooperation.

McKeown et al. (1967) conducted an experiment operationalizing asymmetry in all but the CC cell, with $a_i > a_j$, $b_i = b_j$, $c_i > c_j$, $d_i > d_j$.[25] Participants received

[24] That participants in experiments may be willing to do so has also been shown by Güth et al. (2003).

[25] The parameters are $a_i = 110$, $a_j = 200$, $b_i = b_j = 100$, $ci = -150$, $c_j = 50$, $d_i = -200$, $d_j = 20$. Note that for consistency, we reversed the labels of player i and j. In McKeown et al. (1967) the i player was the low-type player.

feedback on the scores of every single period but did not get a cumulative score. Participation in the experiment fulfilled course requirement, thus no monetary payments were involved. Participants first played in the low-type position and then in the high-type position against a dummy over 100 trials. It was stressed in the instructions that they were playing in the weaker/stronger position. Their analysis showed that when participants are in the role of the low-type player, they are significantly more cooperative than in the role of the high-type player. Given that payoffs in the CC cell remain the same, such a result could also be explained by the fact that DD results in higher relative payoffs for the high-type player. In addition, the low- and high-type position was switched during the game, rendering complex patterns unnecessary to recalibrate outcomes.

Overall the number of asymmetric PD games analyzed experimentally is extremely limited. Most studies do not establish symmetric benchmarks, suffer from insufficiently many independent observations or involve pre-programmed strategies rendering general conclusions on the effects of asymmetry difficult. The following section presents a comprehensive experimental design aimed at systematically comparing behavior in a symmetric and an asymmetric PD setting.

2.4 Experimental Design

Our experiment is based on a 3×1 design running two symmetric (SYM) payoff treatments (HIGH) and (LOW) and one asymmetric treatment (ASYM). See table 2 for the payoffs chosen in our design.[26] HIGH is the normal form game already studied by Pruitt (1967) and Pruitt (1970) with $a_i = a_j = 18$, $b_i = b_j = 12$, $c_i = c_j = 6$, and $d_i = d_j = 0$. LOW is characterized by generally lower payoffs with $a_i = a_j = 12$, $b_i = b_j = 8$, $c_i = c_j = 4$, and $d_i = d_j = 0$.

In both treatments, $b = 2c$, and $a = 3c$. Moreover, $\frac{a_{HIGH}}{a_{LOW}} = \frac{b_{HIGH}}{b_{LOW}} = \frac{c_{HIGH}}{c_{LOW}} = \frac{3}{2}$. ASYM is the asymmetric game where player i (player j) has the same payoffs as both players have in HIGH (LOW). In that sense, ASYM is a composition of both symmetric games.

The experiment was conducted at the Experimental Laboratory of the University of Bonn. It was programmed in z-Tree (Fischbacher (1999)) using a modified

[26] In all experiments we used the neutral labels A and B, instead of cooperate and defect and the requirements for iterated PD's were satisfied (equation 2 above).

version of the program by Maier-Rigaud & Apesteguia (2006). At the beginning of each session, participants were randomly assigned to one of the 18 computer terminals. Before the session started, participants first had to read the instructions (see Appendix A.2), and then had to answer test questions to check if they understood the game they were about to participate in (see Appendix A.3). The experiment was started once all participants had correctly answered all test questions. On the decision screen participants could see the game in normal form, that is the two choice options A and B, their own highlighted payoffs and the payoffs of their counterpart (see Appendix A.2). Feedback information on own choice, choice of the other, period, remaining periods and payoff in the period as well as total payoff was given after every period. At the end of the experiment participants had to give reasons for their decisions in a questionnaire (see Appendix A.4).

In all treatments, it was common knowledge that participants played the same game against the same opponent for 40 periods. In each treatment, we had nine independent observations.[27] We chose 40 periods in partner design to enable the development of cooperation over time. In particular, we wanted to study whether asymmetry continues to be relevant in later periods of the game or whether it can be viewed as an initial complication loosing importance over time.

A total of $2 \times 9 \times 3 = 54$ students mainly majoring in law or economics participated in the experiment. The experiment took 40 minutes on average. Taler (the experimental currency) were transformed into Euro at the exchange rate of 1 Taler = €0.04.[28] The average payoff over all treatments was €12.44.[29]

---

[27] Throughout the paper, the two players playing together over the 40 periods are also termed a dyad or a group.

[28] At the time the experiment was run €1.00 roughly corresponded to $1.00 Purchasing power was, however, higher.

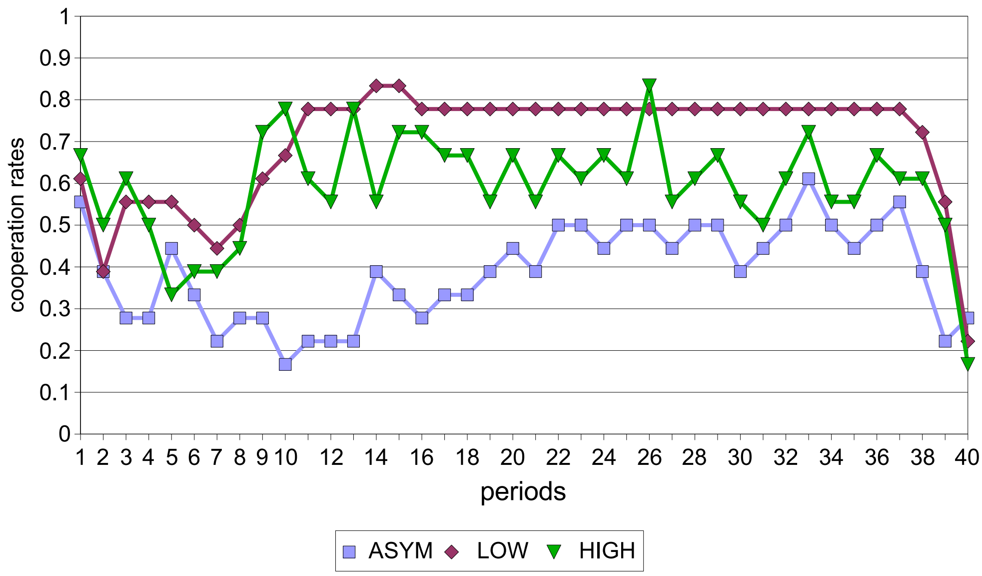
[29] Average payoffs range from €10.92 in LOW, €11.06 in ASYM to €15.33 in HIGH. Low-type players received on average €9.28 and high-types €12.85. In comparison to payoffs under mutual cooperation low-types achieved 72.5% and high-types 66.9% compared to 85.3% in LOW and 79.8% in HIGH.

2.5 Results

2.5.1 Cooperation Rates over Time

We first describe behavioral tendencies in the three treatments. Over all periods, we observe 70.00% cooperation in LOW, 59.17% in HIGH and 38.75% in ASYM. We found unstable patterns of cooperation and defection until roughly period 10 with cooperation in ASYM declining to 15%. Cooperation then stabilizes at a rather high level of about 80% in LOW, and 65% in HIGH. In ASYM, cooperation gradually rises to about 55% until period 33. In all treatments, we see an end effect starting in period 38 (see figure 2.1).

Figure 2.1: Cooperation rates in ASYM, LOW and HIGH.



Aggregated over all treatments ($3 \times 9 = 27$ independent observations), cooperation amounts to 61.11% in period 1, declining to 42.59% in period 2. After period 8, cooperation recovers and varies around 60% until period 38. In the last two periods, we observe the well-known end-game effect.

Appendix A.1 gives a detailed account of all dyads in all three treatments. Stability of cooperation is higher in the symmetric treatments (HIGH and LOW) than in ASYM. Long-lasting cooperating dyads are characterized by long ranges on the CC-line, i.e. on the x-axis. The stability of the cooperation rate in LOW from period 16 to 37 in figure 2.1 is due to polarization. Appendix A.1 shows that these periods are characterized either by mutual cooperation (7 dyads) or defection (2 dyads).

Long sequences of mutual cooperation (i.e. more than 20 periods) are extremely rare in ASYM (1 dyad). The idea that mutual cooperation is less desirable in ASYM also shows up in the answers given in the final questionnaire. As a reason for the choices made, one player for instance states: "Alternating between A and B was the most effective decision for both players." Another participant states the goal "to maximize profits under the condition that both players receive equal payoffs".

2.5.2 Comparison of Cooperation Rates

In this subsection, we are interested in how asymmetry affects cooperation. It has been pointed out in the literature that players may try to even out the asymmetric payoff structure and aim for equal payoffs (Lave (1965), Murnighan et al. (1990), Murnighan & King (1992), and de Herdt (2003)). If this were indeed the case for both players then a complicated alternation strategy of full cooperation for the high-type player (i) and defection of the low-type player (j) on every fourth move should be observed. But even if such a complicated pattern is not observed players may (try to) alternate between cooperation and defection to get more equal payoffs than by mere cooperation and higher payoffs than by mutual defection. Such behavioral patterns would lead to lower cooperation rates in ASYM. We therefore hypothesize that asymmetry leads to lower cooperation rates.

RESULT 1: Asymmetry leads to lower cooperation rates.

SUPPORT: Pooling the data of the symmetric conditions LOW and HIGH and comparing it to ASYM, we find that cooperation rates in ASYM are substantially lower. A Mann-Whitney U test, comparing the cooperation rates in the respective 9 ASYM and 18 SYM groups results in a significant finding ($p \leq 0.047$; one-sided). An additional Mann-Whitney U test for a detailed comparison yields that cooperation in LOW is significantly higher than in ASYM ($p \leq 0.047$; one-sided).[30]

[30] A similar result is obtained using a Fisher-Pitman permutation test yielding a significant result for SYM vs. ASYM ($p \leq 0.035$; one-sided) and for LOW vs. ASYM ($p \leq 0.031$; one-sided). HIGH vs. ASYM yields ($p \leq 0.095$; one-sided) and no significant result is obtained comparing LOW vs. HIGH ($p \leq 0.519$; two-sided). See Kaiser (2007) for a description of the Fisher-

2.5.3 Analysis of Dyads

Our main focus in this subsection is on in-dyad dynamics. We first investigate how mutual cooperation is affected by asymmetry and payoff structures. We then study the behavior of player types over treatments.

Strategic interactions in our three treatments are summarized in tables 2.5 - 2.3. Column 1 shows the four possible choice combinations of both players. The first letter characterizes player i's choice, e.g. DC reads that player i, the high-type player in ASYM, defected (D) and player j, the low-type player in ASYM, cooperated (C). Columns 2 - 5 display how players responded to the move in the previous period aggregated over the first 39 periods. Column 6 shows choices in the last period separately because no move followed.

Table 2.3: Strategic interactions in HIGH (frequencies).

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	146	7	15	4	1	173
CD	8	3	14	11	0	36
DC	6	12	8	17	1	44
DD	9	12	5	74	7	107
Sum	169	34	42	106	9	360

Table 2.5 presents strategic reactions in ASYM while tables 2.4 and 2.3 deal with LOW and HIGH respectively. For instance CC is followed by CC in ASYM with a probability of 0.859 (67/78[31]), in LOW with a probability of 0.957 (224/234) and in HIGH with a probability of 0.849 (146/172). Although the tables are informative, they cannot be used as a basis for statistical tests as individual periods are not independent observations. All following statistical tests will therefore be based on dyad-level (independent) observations.

Pitman test.

[30]Note that choices in each treatment sum up to 360 observations only because the two moves of both players in one period (CC, CD, DC, DD) are aggregated into one observation, e.g. we have $40 \times 9 = 360$ aggregated choices.

[31]Column 7 minus column 6, e.g. $CC : 80 - 2 = 78$.

Table 2.4: Strategic interactions in LOW (frequencies).

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	224	7	2	1	1	235
CD	1	6	1	14	1	23
DC	5	4	0	1	1	11
DD	2	2	7	74	6	91
Sum	232	19	10	90	9	360

Table 2.5: Strategic interactions in ASYM (frequencies).

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	67	9	2	0	2	80
CD	3	11	25	26	1	66
DC	7	16	13	17	0	53
DD	2	26	9	118	6	161
Sum	79	62	49	161	9	360

We first test whether asymmetry influences mutual cooperation.

RESULT 2: Symmetry has a positive effect on mutual cooperation.

SUPPORT: For this test, we compute the percentage of CC-choices in each dyad. We then aggregate the dyads in HIGH and LOW and compare the resulting 18 independent observations on cooperation rates with the 9 independent observations in ASYM. The Mann-Whitney U test ($p \leq 0.015$; one-sided) yields a significant difference in that the percentage of cooperation in SYM-dyads is significantly higher than in ASYM-dyads.[32] When comparing the 9 independent observations of the symmetric treatment HIGH with those of LOW we find no significant difference ($p \leq 0.245$; one-sided).

RESULT 3: Asymmetry reduces the stability of mutual cooperation.

[32] The tests for HIGH vs. ASYM and LOW vs. ASYM are ($p \leq 0.056$; one-sided) and ($p \leq 0.020$; one-sided) respectively.

SUPPORT: Long sequences of mutual cooperation (i.e. more than 20 periods) are extremely rare in ASYM (1 out of 9 dyads), whereas such long sequences are found 4 times in HIGH and 7 times in LOW. A Fisher exact test shows that this difference is significant ($p \leq 0.018$; one-sided). There is, however, no significant difference between the symmetric treatments ($p \leq 0.167$; one-sided). Again, these findings clearly indicate that symmetry matters for the stability of cooperation.

RESULT 4: Mutual cooperation is more frequently followed by mutual cooperation in SYM than in ASYM.

SUPPORT: We compute for each dyad the relative frequencies of CC-moves followed by CC-moves, i.e. the left most cells in table 3 - 5 for each group. A Mann-Whitney U test comparing 18 dyads in SYM and 9 dyads in ASYM yields ($p \leq 0.043$; one-sided). Cooperation once reached is therefore higher in SYM than in ASYM. The same test yields ($p \leq 0.370$; two-sided) comparing HIGH and LOW, ($p \leq 0.014$; one-sided) comparing ASYM and LOW and ($p \leq 0.212$; one-sided) comparing ASYM and HIGH.[33] Thus, the stability of cooperation once reached is also higher in LOW than in ASYM whereas no significant difference can be found between HIGH and LOW and between ASYM and LOW.

Based on Pruitt's considerations on integrative solutions and the experimental results by Schellenberg (1964), Sheposh and Gallo (1973) and Talley (1974), we conjecture that the player type may have an impact on the pattern of cooperation in ASYM. In particular, one might expect that low-type players are more likely to shift from mutual cooperation to one-sided defection than high-type players, and that high-type players are more likely to initiate cooperation after mutual defection than low-type players. Even though there is no significant difference in behavior with regard to the above conjectures, high-type players cooperate more frequently than low-type players. We state these findings in the following observations.

Observation 1: Low-type players defect more frequently after mutual cooperation than high-type players.

SUPPORT: We compare cooperation behavior of high-type and low-type players after mutual cooperation. Aggregated over all 9 dyads, mutual cooperation is maintained in 67 cases (see table 3.8). Mutual cooperation never directly leads

[33] A corresponding Fisher-Pitman permutation test yields ($p \leq 0.014$; one-sided) for SYM vs. ASYM ($p \leq 0.072$; one-sided) for HIGH vs. ASYM, ($p \leq 0.011$; one-sided) for LOW vs. ASYM and ($p \leq 0.351$; two-sided) for LOW vs. HIGH.

to mutual defection in the succeeding period. One-sided defection after mutual cooperation is observed 9 times for low-type players (CD) and only 2 times for high-type players (DC). The overall cooperation rate of 38.75% in ASYM is due to low-type players cooperating 36.9% whereas high-type players cooperate 40.6%. [34]

Analyzed on a dyad basis, 3 dyads exhibit no mutual cooperation and 1 dyad shows no defections after mutual cooperation (see Appendix A.1). One-sided defection of low-type players is observed in 3 dyads, while one-sided defection of high-types is observed only once. In one dyad, both types of one-sided defection can be observed once.

Observation 2: High-type players initiate cooperation more frequently after mutual defection than low-type players.

SUPPORT: We compare cooperation behavior of high-type and low-type players after mutual defection. Aggregated over all 9 dyads, high-type players choose cooperatively after mutual defection in 28 cases while this happens only 11 times with low-type players (see table 5).

Analyzed on a dyad basis, mutual defection is followed by cooperation of the high-type player in 6 dyads and by cooperation of the low-type player in 2 dyads. In one dyad, deviations from mutual defection never occurred (see Appendix A.1).

2.5.4 Analysis of Alternating Strategies

Instead of playing the subgame-perfect equilibrium of DD minimizing the payoff difference[35] or the cooperative solution of CC maximizing joint payoff[36] in all 40 periods, players may pursue different goals in asymmetric games. Players may try to even out the asymmetric payoff structure and aim for equal payoffs (c.f. de Herdt (2003)).[37] In our setting, equal payoffs are attainable by a rather complicated alternation pattern: if the high-type player cooperates all the time, and the low-type player defects in every fourth period both players get an average per-period

[34] Cooperation rates in LOW and HIGH are 70% and 59.17% respectively.

[35] $(40 \times 6) + (40 \times 4) = 400$, payoff difference 80.

[36] $(40 \times 12) + (40 \times 8) = 800$, payoff difference 160.

[37] See also the literature on inequity aversion, for instance Fehr & Schmidt (1999) or Bolton & Ockenfels (2000).

payoff of 9.[38]

We found only one dyad (number 7) that succeeded in establishing an alternation sequence yet providing a Pareto inferior solution without achieving payoff equality (see appendix A.1). The coordinated strategy of alternating between DC and CD in each period, thus yielding an average per-period payoff of 6 to the low-type player and of 9 to the high-type player was much simpler and the pattern lasted for the final 20 periods.[39]

2.6 Conclusion

The basic hypothesis analyzed in this paper concerns the frequency of cooperative play in asymmetric (ASYM) versus symmetric (HIGH and LOW) PD games. As conjectured we find asymmetry to reduce cooperation rates by up to 41 percentage points. LOW induces the highest cooperation rates followed by HIGH and finally ASYM with significantly lower cooperation rates. Moreover, cooperation rates in ASYM increase with a substantial delay compared to other treatments.

From the evidence gathered it seems that in symmetric games individual players' ranking of outcomes is likely to be the same for both players. In asymmetric games, however, this seems not to be the case because for the low-type player the CC-outcome in all periods may not be as attractive thereby rendering coordination on a mutually compatible outcome more difficult. In particular, player's perception of what constitutes a fair outcome is likely to diverge. In the asymmetric PD, low-type and high-type players appear to have a different initial understanding of what constitutes a mutually acceptable outcome (or series of outcomes, for example in an alternation strategy) reducing cooperation rates. It appears that equality arguments are important and depend on the relative position of the player. As a low-type player, occasional defection may be a salient choice, "justified" by the idea that this redresses the unmotivated asymmetry in payoffs. This is in line with the finding by Roth & Malouf (1979) and Roth & Murnighan (1982) from bargaining experiments. They found that bargaining strategies depend on the

[38]Playing CC for three periods gives 36 to the high-type player and 24 to the low-type player. Playing CD in the fourth period adds another 12 to the low-type's account.

[39]There exist a few failed attempts of other groups that could be interpreted as trying to establish an alternation pattern.

counterpart's payoffs. In particular the low-type position is used to argue for special advantages.[40] High-type players may in contrast initially focus on mutual cooperation as the salient choice rejecting responsibility for the assignment of types that low-types try to redress. Such a self-serving bias resulting from the lack of a mutually acceptable salient outcome reduces cooperation.[41]

Although cooperation rates in ASYM eventually increase, indicating some coordination of strategies, they do not reach the levels found in symmetric games. Essentially, asymmetry reduces the frequency of cooperation and the stability of cooperation in dyads. Low-type players are more likely to defect after mutual cooperation than high-types, and high-types initiate cooperation more often than low-types. From this perspective, there seems to be at least a tendency to accommodate lower payoffs by low-types.

In our design asymmetry is imposed without being specifically motivated. This may allow low-types to insist on occasional defection not being counted as such (entailing no retaliation by high-types) because the assignment of the high- or low-type position may be perceived as arbitrary. If asymmetry is motivated and motivation is treated as an experimental design variable this line of argument could further be tested. An experimental study designed along these lines may allow the manipulation of fairness norms and is an important issue for further research.

[40] As found in Talley (1974), information about other player's payoffs has a positive effect on cooperation in symmetric games while decreasing cooperation of low-types in asymmetric games.

[41] See Babcock et al. (1995) and Babcock & Loewenstein (1997) for a discussion of the negative effects of self-serving biases in bargaining.

3 Assignment versus Choice in Prisoner's Dilemma Experiments

Abstract: The chapter presents an experimental investigation comparing behavior in a repeated prisoner's dilemma (PD) game when players can choose between two different representations of the same PD, to behavior when players are assigned to play a specific game. The main finding is that cooperation rates are up to 60% higher in the games that were chosen. These findings are consistent with the robust evidence of the psychology literature on non-strategic contexts that choice increases motivation, trust, and performance. Given that in many contexts agents choose the strategic situation they get involved in, assigning participants to experiments may affect the external validity of some experimental findings.

3.1 Introduction

The present study is concerned with the methodological question of the external validity of experimental research based on the assignment of participants to experimental games or decision situations. Experimental findings may systematically misrepresent field outcomes if assigning participants to experiments has an impact on the decisions made by the participants in the experiment and if such an assignment does not occur in the field.

We experimentally analyze to what extent the very possibility of choosing the game one is about to participate in, may have an important effect on behavior and outcomes. To that end, we design an experiment based on a prisoner's dilemma (PD) game. We conduct five different treatments, divided into two categories: the assignment treatments and the choice treatments. In the three assignment treatments, participants play an externally imposed version of a PD game. The three versions of the PD game are different representations of exactly the same game. That is, they have the same number of players, the same action space, the same information structure, the same payoffs, and the same Nash equilibrium. In the two choice treatments, participants can choose the version of the PD game they want to play from a binary set.

The experiment is related to the economic literature on freedom of choice. According to (Sen 1988, p. 290), "one reason why freedom [of choice] may be important is that 'choosing' may itself be an important functioning ... if all alternatives except the chosen one were to become unavailable, the chosen alternatives will not, of course, change, but the extent of freedom would be diminished, and if the freedom to choose is of intrinsic importance, then there would be a corresponding reduction of the person's advantage".[1] In our context, this is to say that, aside from the particulars of a game, it matters whether the game is assigned, or if it is chosen from a set of games. Whereas the literature on freedom of choice is concerned with an effect on utility, we are interested in a potential behavioral impact of choice.

Such a behavioral impact of choice has been studied in the psychology literature in non-strategic contexts for several decades. The availability of choice is typically

[1] There is a literature that axiomatizes this line of thought (see Bossert et al. (1994), or Pattanaik & Xu (2000)).

understood as a form of decision control, i.e. the possibility to decide about a forthcoming event that can involve choice among a set of alternatives or the regulation of an event's timing and duration. Several empirical studies support the notion that people who have choice experience "more intrinsic motivation, greater interest, less pressure and tension, more creativity, more cognitive flexibility, better conceptual learning, a more positive emotional tone, higher self-esteem, more trust, greater persistence of behavior change, and a better physical and psychological health" ((Deci & Ryan 1987, p. 1024)). In a classic experiment exposing two groups to a recording of loud, unpredictable noises, Glass & Singer (1972) found strong choice effects. Whereas participants in one group had no choice but to listen to the recording, participants in the other group could choose to stop the tape at any time by flipping a switch. These participants were told, however, that the experimenters would prefer that they not stop the tape, and most subjects honoured this preference. Following exposure to the noise, participants with access to the control switch made almost 60 percent fewer errors than participants helplessly exposed to the noise on a proofreading task and made more than four times as many attempts to solve a difficult puzzle.[2]

Related to our experiment are also some recent studies demonstrating the effect a random assignment of participants has on outcomes in experimental games in contrast to situations where participants have the option to self-select. These studies aim at separating participants by types and are based on the notion that in many field situations that are scrutinized in the laboratory, people have the possibility of avoiding the situation they are confronted with in the experiment. Screening mechanisms used to select employees, customers and insurers are examples of situations where self-selection and/or sorting are essential features of the strategic environment.

Charness (2000) for instance exogenously separated subjects on the basis of performance in a dictator game prior to playing a bargaining game. Bohnet & Kübler (2005) attempt to sort out conditional cooperators and egoists by giving

[2]Similarly Elffers & Hessing (1997) found evidence that offering taxpayers a choice between full itemized deduction and a comparable overall standard deduction enhances tax compliance. In a classic experiment on learned helplessness Seligman (1974) found that loss of choice (control) is experienced as aversive and has detrimental effects on people's emotions, motivation and cognition.

the possibility to bid for participation in a PD game with higher out of equilibrium payoffs than the status quo PD game in an auction. Lazear et al. (2006) design an experimental dictator game with an outside option to separate between players. Eriksson & Villeval (2004) (see also Königstein & Villeval (2005)) experimentally study a labor market where workers can choose the incentive scheme according to which they are paid. They show that high skill workers separate from low skill workers by choosing performance pay firms.[3]

Of some relevance to the present work, is also the literature on group membership. In a classic experiment Tajfel (1970) allowed participants to identify with a group based either on the preference for a painting by Kandinsky or Klee or the tendency to over or underestimate the number of dots displayed on a screen prior to allocating money between one in-group member and one out-group member.[4] The effects of group membership and what is necessary to trigger such effects has recently been systematically analyzed by Charness et al. (2006) in the context of a battle of the sexes and PD game.

Finally, our paper relates to an emerging literature that criticizes the standard methodology used in experimental economics in light of the possible lack of external validity with respect to some experimental results obtained (see, notably, List & Levitt (2005) and references therein, Lazear et al. (2006) and Harrison & Rutström (2005)).

In contrast to the literature on self-selection/sorting and group membership, we analyze to what extent experimental deviations from actual situations due to the assignment of participants is based exclusively on the possibility of self-selection or sorting, or whether choice has an important behavioral effect in itself. The present paper extends the results obtained in the experimental psychology literature on control and choice by analyzing whether choice effects are also found in strategic environments, rendering them of particular interest to economic environments.

[3]Besides this literature, see for example the experimental studies by Niederle & Vesterlund (2005) in the context of occupational gender differences, Cadsby et al. (2004), Eriksson et al. (2005), and Dohmen & Falk (2006) in the context of worker-self-selection and productivity. Although not directly concerned with sorting, Orbell & Dawes (1993) provided participants in a one shot PD game the choice of not playing the game. Hauk (2003) provided an outside option in a repeated PD game context. Cox et al. (2001) analyze endogenous entry and exit in common value auctions.

[4]See also Tajfel et al. (1971), Yamagishi et al. (1999) and Yamagishi & Kiyonari (2000).

Based on the idea that choice either via active modification of the strategic environment[5] or by passive self-selection into a particular strategic environment may be an important property of many empirical problems studied using experimental methods, we are interested in separating a choice effect from sorting or self-selection effects.

We analyze the behavioral importance of the possibility of choosing the game to be played in a scenario where the differences between the alternatives available are kept to a minimum. We conjecture that a behavioral effect when players are given the possibility of choosing between two games that in standard game theoretic terms are equivalent, and differ only in the presentation of the game, may be even more pronounced if differences between games are more substantial, and for instance allow self-selection and sorting.

The experimental results clearly indicate that the mere fact that participants can choose the game they want to play has a statistically significant impact on behavior. Cooperation rates are higher when players can choose the game they want to play as compared to when players are assigned to the game. The increase in cooperation rates is in some cases even 60%. As an immediate consequence, the current laboratory practice of assigning participants to experimental games may, even absent the possibility of sorting, provide biased results. This finding adds an additional reason why experimental results cannot directly be extrapolated to the field.

The organization of the rest of the paper is as follows. The next section introduces the three versions of the PD that are used in this paper, Section 3 contains the experimental procedure, Section 4 reports the experimental results and Section 5 concludes.

3.2 The Games

3.2.1 The Prisoner's Dilemma Game

Table 1 presents a typical 2-player matrix game in normal form. This game is a PD if and only if, the following conditions are met: $a > b > c > d$ and $2b > a + d > 2c$.

[5] See the literature on self-governance, for instance Ostrom (1990) or Scott (1998).

Table 3.1: General 2×2 prisoner's dilemma game in normal form (PD).

	Cooperate	Defect
Cooperate	(b, b)	(d, a)
Defect	(a, d)	(c, c)

Note: The first element of the payoff vectors refer to the row player. In the experiment $a = 400$*,* $b = 300$*,* $c = 100$ *and* $d = 0$*.*

It is well known that both players playing defection is the unique Nash equilibrium of the one-shot prisoner's dilemma game. Applying the logic of backward induction, Luce & Raiffa (1957) showed that the unique Nash equilibrium outcome in the finitely repeated prisoner's dilemma game under perfect information is again the one in which both players defect in every single period. In fact, the unique subgame-perfect equilibrium is both players defecting in all periods regardless of the prior history of play (see, e.g., Binmore (1992)).

The experimental analysis of the prisoner's dilemma involves over thousand experiments mainly in Psychology, Economics, Biology and Political Science. It has been shown that behavior is sensitive to subtle changes in the experimental conditions. Factors like repetition, experience, information, relative payoffs, monetary incentives, fixed or random opponents and framing, play an important role in the experimental behavior.[6]

In this paper we will analyze a prisoner's dilemma game repeated over 20 periods with a fixed opponent under perfect information. Earlier experimental studies with assigned treatments show that average cooperation levels start relatively high, between 40%-60%, and then gradually decline through time. We will see that our experimental results conform to this general pattern.

3.2.2 The Decomposed Prisoner's Dilemma Game

Evans & Crumbaugh (1966*a*), Evans & Crumbaugh (1966*b*), and Pruitt (1967) independently proposed the decomposed prisoner's dilemma game. Consider the game depicted in table 3.2. The game is played as follows: Both players face the

[6] Good overviews of the experimental literature are found in Lave (1965), Rapoport & Chammah (1965), Roth & Murnighan (1978), Roth (1988), and Kagel & Roth (1995).

same matrix. Each player must choose between actions Cooperate or Defect.[7] Each choice provides a payoff to the player in the self column, and a payoff to the other player in the other column. Hence, if for example player 1 chooses C and player 2 chooses D, then player 1 gets $w + z$, while player 2 gets $y + x$.

The game in table 2 is a decomposed form of the PD game introduced earlier (table 5.1) if and only if the following conditions hold: $a = x + y$, $b = w + x$, $c = y + z$ and $d = w + z$. Substituting these into the conditions that define the PD game, the following conditions must be satisfied for the DPD game: $y > w$, $x > z$, and $w + x > y + z$. These inequalities impose constraints on the PD, namely that $b + c = a + d$. As a result only certain PDs are decomposable.[8]

Table 3.2: Schematic representation of a 2×2 PD game in decomposed form (DPD).

	Self	Other
Cooperate	(w)	(x)
Defect	(y)	(z)

Since the initial research by Evans & Crumbaugh (1966*a*), Evans & Crumbaugh (1966*b*), Crumbaugh & Evans (1967), and Pruitt (1967) there have been a series of studies, mainly conducted in the 1970ies, that analyzed different decompositions of the PD game. In particular, the studies by Pruitt (1970), Pruitt (1981), Guyer et al. (1973), Tognoli (1975), Pincus & Bixenstine (1977), Komorita (1987), and Beckenkamp et al. (2006) analyzed the effects of different decompositions on cooperation rates in prisoner's dilemma games.[9] These studies largely revealed that the type of decomposition has a significant impact on cooperation rates. While some decompositions elicited less cooperation than the normal form game, others showed a substantial increase in cooperative behavior. The generally accepted hypothesis for this finding is that different decompositions arouse different motives in the players. Based on the type of decomposition, decomposed games are either referred to as take-some or give-some games, where take-some games evoke lower and give-

[7] In all the experimental games we used labels A and B, instead.

[8] Not all PDs are decomposable but a decomposable PD can be decomposed into an infinite number of DPDs. The conditions for decomposing a PD game are also referred to as seperability conditions (Hamburger (1969)).

[9] Decomposed PD games are also discussed in Selten (1978) and Selten (1998).

some games higher levels of cooperation than the normal form game. Typically, in a give-some decomposition payoffs in the "self" column are lower than payoffs in the "other" column, and vice versa for the take-some decomposition. According to the psychological literature, give-some games evoke a higher level of cooperation because they provide an opportunity to signal a willingness to cooperate at some cost to self, and thus elicit trust and mutual cooperation. Take-some games in contrast are supposed to heighten the competitive motivation of the players due to their punishment aspect inflicted on the other player in case of defection.

Table 3.3: 2 × 2 prisoner's dilemma game in give-some decomposition

	Self	Other
Cooperate	(0)	(300)
Defect	(100)	(0)

Table 3.4: 2 × 2 prisoner's dilemma game in take-some decomposition

	Self	Other
Cooperate	(150)	(150)
Defect	(250)	(−150)

We evaluate the behavioral consequences of a choice of game in both settings. The two decompositions of the standard prisoner's dilemma game presented in table 1 that will be analyzed experimentally are shown in tables 3 (give-some) and 4 (take-some). Note that both decompositions add up to the same parent game presented in table 1.

3.3 Experimental Design

The experiments were conducted at the Experimental Economics Laboratory at the University of Bonn using a program based on the z-Tree software developed by Fischbacher (1999). At the beginning of each session participants were randomly assigned to one of the 18 computer terminals. Before the session started, participants first had to read the instructions (see Appendix B.1), and then had to answer test questions to check if they understood the game they were about to participate in. The experiment was started only once all participants had correctly answered all test questions. We run two treatment conditions: choice (C) and assignment, that is, no choice ($\sim C$). In the assignment condition participants were told the game they were going to participate in, while in the choice condition participants were informed about the two games they could subsequently choose from. In the assignment condition we conducted three different treatments; one implementing the prisoner's dilemma in normal form of table 1 ($\sim Cn$), and the other two implementing the decomposed prisoner's dilemma games of tables 3 and 4 ($\sim Cg$ and $\sim Ct$). In the choice condition, two different treatments were conducted. In the first treatment coded as Cng participants could choose between the normal form and the give-some decomposition of the prisoner's dilemma game. In the second treatment coded as Cnt participants could choose between the normal form and the take-some decomposition of the prisoner's dilemma game.

All treatments where participants were assigned to play a specific game are coded by $\sim C$, that is, $\sim Cn$ for the normal form, $\sim Cg$ for the give-some decomposition and $\sim Ct$ for the take-some decomposition of the prisoner's dilemma. The treatments where participants had the possibility to choose the game they wanted to play are coded by C, where the following letters indicate the two choice options i.e. treatment Cng allows participants to choose between the normal form and the give-some game, and treatment Cnt allows participants to choose between the normal form and the take-some game. Table 5 summarizes the experimental treatments, and gives information on the number of groups, i.e. the number of independent observations in each treatment.

In all treatments participants played against the same opponent for 20 periods. In the choice treatments participants were randomly matched to play against a player who chose the same game. In case choices did not allow matching all participants according to choices made, two participants from each group were randomly excluded. All this information was common knowledge.

A total of 126 students, mainly law or economics students, took part in the experiment. The experiment took 45 minutes on average. Taler (the experimental currency) were transformed into Euro at the exchange rate of 1000 Taler = €2. Average payoffs were €9.92.

Table 3.5: Experimental Treatments conducted and number of groups in each treatment.

Treatment	Game	Groups
$\sim Cn$	No choice, **n**ormal form	9
$\sim Cg$	No choice, **g**ive-some decomposition	9
$\sim Ct$	No choice, **t**ake-some decomposition	9
Cng	Choice, **n**ormal form vs. **g**ive-some decomposition	17*
Cnt	Choice, **n**ormal form vs. **t**ake-some decomposition	18

** In the choice treatments players were grouped randomly after they had chosen the game they wanted to play. In this case the amount of players who chose a particular game was not even, so that one player from each group was randomly drawn to be excluded.*

3.4 Results

We now analyze the central hypothesis of this paper. That is, if allowing participants to choose the game from a binary set of games with identical game theoretic properties, as opposed to assigning them to the game, has a behavioral impact.

Table 3.6 gives information on the games chosen by players in the choice treatments. Participants generally preferred the normal form as opposed to the decomposed prisoner's dilemma.

Table 3.6: Number of groups choosing the PD and the DPD in the choice treatments.

Treatment	Groups choosing the PD	Groups choosing the DPD
Cng	14	3(give-some)
Cnt	13	5(take-some)

Note that there is no clear mechanism to separate players by types of preferences. For example, it has been shown in the literature (and replicated here) that the give-some representation evokes more cooperative behavior. Then, cooperators may choose the give-some decomposition over the normal form. Egoists, however, may anticipate this behavior and go for the give-some decomposition too, and therefore cooperators would think it twice before going for the give-some decomposition. Hence, in contrast to the sorting literature mentioned above, it is not clear for cooperators how to sort out from egoists, and for egoists how to match cooperators in this study. In fact, if sorting were present in our data, some games in the choice treatments would exhibit higher cooperation rates and others should show lower cooperation rates. We will immediately see, however, that this is not the case. As a result our experiment allows the separation of a choice effect from other factors such as sorting that have been found to influence experimental findings based on a random assignment of participants.

An alternative explanation of the findings could in principle be due to in-group effects as analyzed in the minimal group literature mentioned above. In line with recent findings by Charness et al. (2006) who find that "purely minimal group identification is insufficient" to find group membership effects in their PD and battle of the sexes experiment, this explanation is unlikely to be capable of explaining the significant treatment effects we observed.

We compare behavior exhibited in the assigned normal form game (treatment $\sim Cn$) with the behavior of those players that chose the normal form game in the choice treatments ($Cng : n$ and $Cnt : n$). Analogously we contrast behavior in the two versions of the assigned decomposed games (treatments $\sim Cg$ and $\sim Ct$) to the behavior of those players that chose the corresponding decomposed prisoner's dilemma game in the choice treatments ($Cng : g$ and $Cnt : t$).

Figures 3.1, 3.2, 3.3, and 3.4 plot the time series of the average cooperation rates in treatments $\sim Cn$ and $Cng : n$, $\sim Cn$ and $Cnt : n$, $\sim Cg$ and $Cng : g$, and finally $\sim Ct$ and $Cnt : t$. Table 7 reports the average cooperation rates.

Figures 3.1, 3.2, and 3.4, and table 3.7 clearly show the strong behavioral effect on relative cooperation levels of allowing players to choose the game they want to play.

In the cases where the normal form game was chosen (treatments $Cng : n$ and $Cnt : n$), the increase in cooperation rates compared to the assigned prisoner's dilemma (treatment $\sim Cn$) is dramatic. In both cases there is an increase of about 60% in the rate of cooperation. The permutation test (Siegel & Castellan (1988)) yields significance levels at .1% and .5% respectively.

Table 3.7: Average cooperation rates by treatment.

$\sim Cn$	$\sim Cg$	$\sim Ct$	$Cng : n$	$Cng : g$	$Cnt : n$	$Cnt : t$
0.33	0.80	0.66	0.83	0.82	0.88	0.91

Figure 3.1: Time series of average cooperation rates in $\sim Cn$ and $Cng:n$.

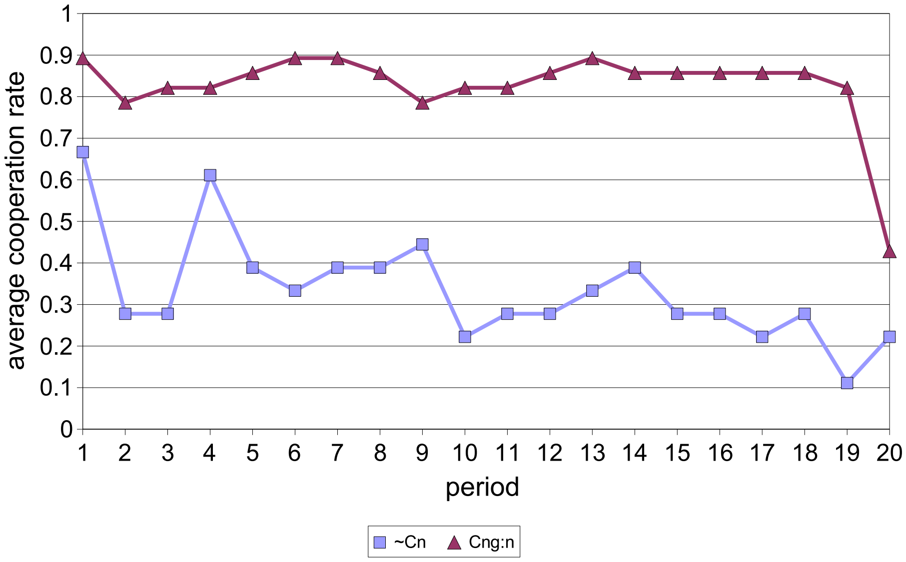
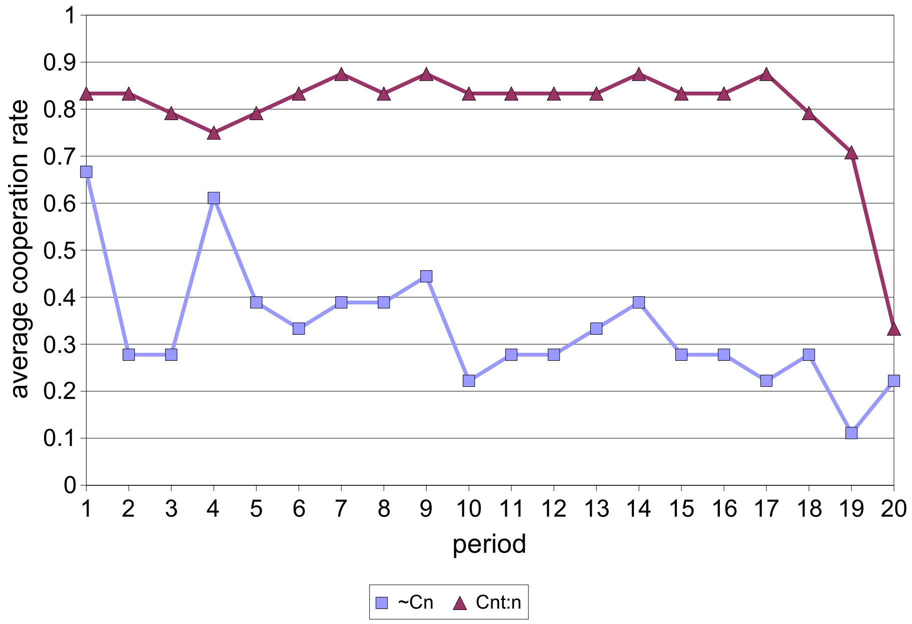


Table 3.8: Gains from Cooperation.

Treatment	Aggregate efficiency
$\sim Cn$	40.84
$\sim Cg$	80.00
$\sim Ct$	65.56
$Cng:g$	81.67
$Cng:n$	82.68
$Cnt:t$	91.00
$Cnt:n$	81.35

When analyzing the differences in behavior between the decomposed prisoner's dilemma in the assigned condition (treatments $\sim Cg$ and $\sim Ct$) and the decomposed prisoner's dilemma in the choice condition (treatments $Cng:g$ and $Cnt:t$), the effect is not as strong. Clearly, behavior in the decomposed games in the assignment conditions (treatments $\sim Cg$ and $\sim Ct$) is highly cooperative, rendering it difficult to reach even higher cooperation levels in the choice treatments. Furthermore, the statistical tests suffer from the relatively small number of decomposed games chosen by players (see table 6). Nevertheless, cooperation rates in the takesome groups where participants freely choose the game (treatment $Cnt:t$) are

Figure 3.2: Time series of average cooperation rates in $\sim Cn$ and $Cnt : n$.



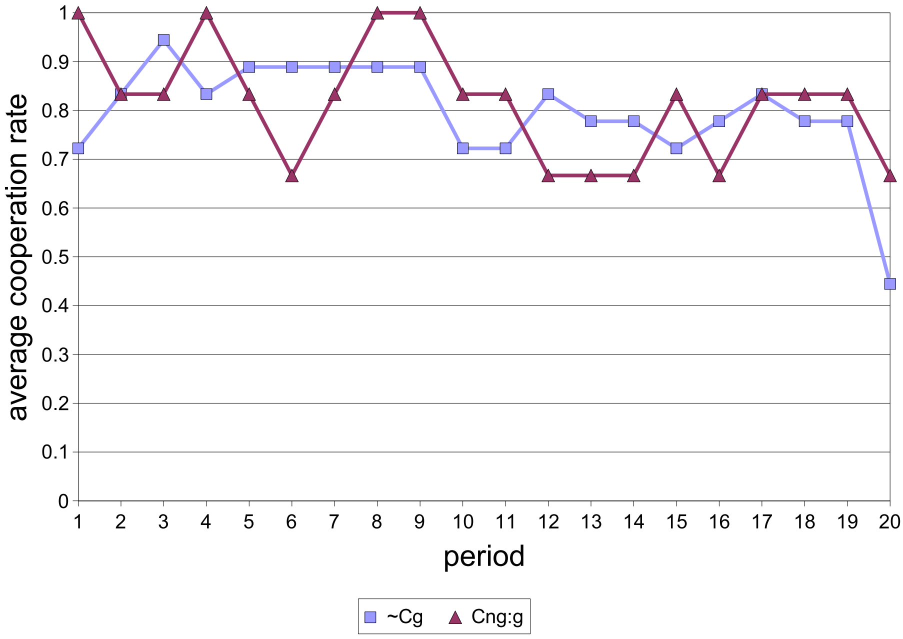
close to 30% higher than in the assigned take-some game (treatment $\sim Ct$). This is a remarkable increase in the cooperation rate, (the permutation test yields a 0.1258 significance level, one sided). In the case of the give-some game (treatment $\sim Cg$ vs. treatment $Cng : g$) the increase is just 2.2%, clearly not significant.

Finally, we note that, as expected, framing significantly impacts behavior. Comparing the behavior between the three assigned treatments, it is clear that both decompositions of the prisoner's dilemma have a significant positive impact on cooperation rates (with significance levels of .5% each). In the give-some treatment $\sim Cg$ participants achieve cooperation rates that result in roughly 80% of possible profits being extracted - a 100% increase compared to the normal form treatment $\sim Cn$.

3.5 Conclusion

There exist many economic and non-economic situations where agents make choices that impact the incentive structure they face afterwards. In fact, choice is a fundamental economic reality. Based on this fact and motivated by the findings of the psychological literature on choice in non-strategic settings and the literature

Figure 3.3: Time series of average cooperation rates in $\sim Cg$ and $Cng:g$.



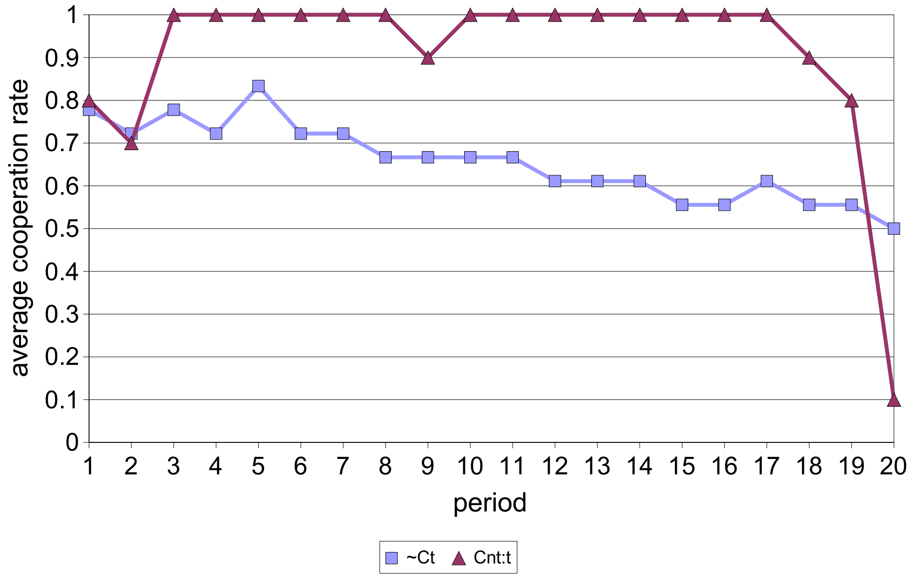
on freedom of choice, we conjectured that the very possibility of choosing the game one wants to get involved in may have a significant impact on behavior even absent any possibility of self-selecting, of sorting or of influencing the game.

In our experiment participants playing a PD game cooperate significantly more, even 60% more on average, when they are given the possibility of choosing between the PD game and a different representation of the same PD game, than when they are directly assigned to play that game.

The set of games from which participants could choose contained two different representations of a strategically identical game. Our data shows that despite this narrow difference the change in behavior was dramatic. It can be hypothesized that if the set of games to be chosen from not only consists of games differing with respect to their representations, but also with respect to their strategic character, resulting differences in behavior may even be more substantial.

Our findings indicate that motivational aspects inherent in the design and choice of games, even absent the possibility of sorting, can have a significant impact on outcomes. Although the choice effect identified in this paper is important, we cannot directly separate it from a possible cognitive effect that may be due to the fact that participants in the choice treatments were confronted with both presentations

Figure 3.4: Time series of average cooperation rates in $\sim Ct$ and $Cnt:t$.



of the game allowing them, for instance, a more thorough understanding of the properties of the game. In order to further explain the choice effect and separate between a pure choice effect and a cognitive effect associated with the knowledge of alternatives, additional experiments are required. Nevertheless, our results confirm one of the basic tenets in psychology, namely that choice and loss of choice have a substantial impact on human behavior. As shown by our results, choice not only has an impact on outcomes in non-strategic environments but also in strategic situations. An immediate consequence for experimental research is to exert caution in extrapolating results to the field. In contrast to the recent literature on sorting that identifies the random selection of participants as a potential source of experimental bias, at least in those situations where self-selection is an essential feature in the field, we show that the assignment as such can have an impact irrespective of any possible additional effects due to sorting.[10] Until further experimental scrutiny, it remains open whether this is (partially) due to cognitive effects of presenting different options or whether this is due to choice as such.

[10]From that perspective it may not be sufficient to allow for sorting by assigning participants to a game based on the performance in a prior one, although such a setting may allow a direct comparison of the impact of sorting versus choice that is outside the scope of the present study.

4 The Role of Rivalry - Public Goods versus Common-Pool Resources

Abstract: Despite a large theoretical and empirical literature on public goods and common-pool resources, a systematic comparison of these two types of social dilemmas is lacking. In fact, there is some confusion about these two types of dilemma situations. As a result, they are often treated alike. In line with the theoretical literature, it is argued that the degree of rivalry is the fundamental difference between the two games. Furthermore, an experimental study of the behavior in a quadratic public good and a quadratic common-pool resource game with identical Pareto optimum but divergent interior Nash equilibria is provided. The results show that participants clearly perceive the differences in rivalry. Aggregate behavior in both games starts relatively close to Pareto efficiency and converges quickly to the respective Nash equilibrium.

4.1 Introduction

Despite the seminal papers by Musgrave (1959), Musgrave (1969) and Samuelson (1954) and a large theoretical and empirical literature on social dilemmas in general, and public goods and common-pool resources in particular, it appears not to be generally accepted in the experimental/behavioral literature that both types of games are distinct. A typical example of a public good is national defense, while a typical example of a common-pool resource is a fishery. Clearly, while it is not possible to restrict the enjoyment of the former, the fish caught by one individual is not available to other users anymore.[1] This distinction has led many authors to propose a categorization of goods on the basis of excludability and rivalry.[2] According to the latter, a public good has two essential attributes: non-excludability and non-rivalry in consumption. A common-pool resource, however, is non-excludable but rival. The possibility of non-rival consumption by multiple consumers is the major feature distinguishing public goods from common-pool resources. Non-excludability, that is, the difficulty of excluding non-paying consumers from consumption, is a feature that both types of goods share.

Non-excludability, together with the fact that public goods and common-pool resources can be reduced to a prisoner's dilemma game[3] (Ledyard (1995), Ostrom

---

[1] There exist many empirical applications of the two concepts that demonstrate that the distinction is crucial for policy and institutional design (see, e.g., Ostrom (1990), Seabright (1993), Ostrom et al. (1994) or Cornes & Sandler (1996)). Gaspart & Seki (2003) provide a good example for the two types of games describing a fishery. Typically fisheries are common-pool resources but the local fishery analyzed by them institutionally transforms this common-pool resource into a public good by equally distributing the catch among villagers after each day of fishing.

[2] Samuelson (1954) introduced the polar definition of private versus public goods based on their non-rivalry in consumption and Musgrave (1959), Musgrave (1969) suggested the criterion of exclusion in addition to rivalry adding common-pool resources and club goods to the definition. See also Samuelson (1955) and Musgrave (1983) as well as for example Taylor (1987), Cornes & Sandler (1996), and Bowles (2003).

[3] Consider a game that belongs to the broad class of symmetric games with a symmetric Nash equilibrium, Pareto dominated by a different symmetric action profile that is not an equilibrium. If one reduces such a game to a 2×2 game where the symmetric Nash equilibrium is Pareto dominated by the alternative symmetric action profile, the latter not being a Nash equilibrium, then it is obvious that one gets the structure of a prisoner's dilemma game. Clearly, symmetric common-pool resource games and public good games belong to the above mentioned class of games. Note also that symmetric Cournot games, and Bertrand games also belong to this class of games.

(1990), Gintis (2000), Camerer (2003), Sandler & Arce (2003), have led many authors to treat both social dilemma games as equivalent. Among these authors are some that claim that both games are strategically equivalent (see e.g. Ledyard (1995), (Gintis 2000, p.257) and (Camerer 2003, pp.45-46)). Based on this belief the difference between public goods and common-pool resources has often been reduced to frames or different representations of one and the same game. From that perspective commons, resource or common-pool dilemmas are considered to be take-some frames of public good games, whereas the term public good is reserved for a give-some frame of the same game[4] (see e.g. Brewer & Kramer (1986), Fleishman (1988), Van Dijk & Wilke (1995), McCusker & Carnevale (1995), Sell & Son (1997), Elliott & Hayward (1998), Van Dijk et al. (1999), and Van Dijk & Wilke (2000)). In summary, there is a literature that claims that common-pool resources and public goods are the same, and consequently uses the label "common-pool resource" for a particular type of framed public good game.[5]

An explicit example of this is provided by (Gintis 2000, pp.257-258) who writes:

> "While common pool resource and public goods games are equivalent for Homo Oeconomicus, people treat them quite differently in practice. This is because the status quo in the public goods game is the individual keeping all the money in the private account, while the status quo in the common pool resource game is that the resource is not being used at all. This is a good example of a framing effect, since people measure movements from the status quo and hence tend to undercontribute in the public goods game and overcontribute (underexploit) in the common pool resource game, compared to the social optimum."

In this paper we first establish theoretically that public good and common-pool resource games as used in the experimental literature are two distinct types of social dilemmas. We show that the distinguishing feature of these two types of

[4] A give-some frame presents the dilemma situation as one in which individually owned resources have to be contributed to a common undertaking, whereas in a take-some frame the dilemma consists in leaving resources in the common undertaking. For an experimental analysis of give-some and take-some framing effects in a public good environment see Andreoni (1995a), Sonnemans et al. (1998), Willinger & Ziegelmeyer (1999), or Park (2000).

[5] Note that different labels may not be problematic as long as authors are aware of the difference and explicitly state that identical labels are used for different games.

games lies in the distributional factor that determines whether the good is rival or non-rival. This difference gives rise to two distinct strategic environments. Based on these theoretical differences we devise an experiment that tests whether the theoretical differences have an impact on behavior in the two games. That is, our aim is to assess whether the theoretical difference between the two types of goods also has behavioral implications. For that purpose, we contrast a quadratic public good game with interior Nash equilibrium (see, e.g., Chan et al. (1996), Sefton & Steinberg (1996), Isaac & Walker (1998) and Laury et al. (1999), with a standard common-pool resource game (see, e.g., Ostrom et al. (1994), Keser & Gardner (1999), Beckenkamp (2002), and Casari & Plott (2003)). We chose parameters in which the differences between the two types of games are reduced to a minimum. First, to guarantee that the structural differences between the two games cannot be attributed to framing, both games are framed as give-some games. Second, the Pareto solutions in both games are identical in terms of actions and payoffs, third, the symmetric interior Nash predictions are located at symmetric points from the extremes of the individual action space and involve the same payoffs. The experimental results clearly show that starting from cooperative levels, aggregate behavior in both games tends to the respective Nash equilibrium. This clearly indicates that the differences in rivalry affect behavior, strengthening the importance of differentiating between the two types of goods.

The paper is organized as follows. The first subsection of section 4.2 introduces the typical public good and common-pool resource games found in the experimental literature. The second subsection discusses the role of rivalry as the distinguishing feature between public goods and common-pool resource games in a general setting. Section 4.3 discusses the experimental design. In section 4.4 the experimental findings are presented, and section 4.5 concludes with a discussion and summary.

4.2 Public Goods and Common-Pool Resource Games

4.2.1 The Experimental Games

In this section we introduce two particular games that represent a public good and a common-pool resource game. These games are taken from the experimental literature, and are the games that we will subsequently analyze experimentally. We also introduce a first theoretical comparison of the two games, showing that the distinguishing feature between both games is the degree of rivalry.

A Public Good Game

In the following we introduce a quadratic public good game with an interior symmetric Nash equilibrium. We concentrate on such a class of public good games because common-pool resource games are typically characterized by an interior Nash equilibrium. Since we are interested in the role of rivalry as the critical difference between the two types of games, we keep the differences between the two games as minimal as possible.

The following formulation draws from Isaac and Walker (1998).[6] There are n identical players, $N = \{1, \ldots, n\}$, each one with an endowment of $e \in \mathbb{R}_{++}$. Each player i must decide how much to invest in the public good y, $x_i \in [0, e]$. The level of the public good is determined according to the technology

$$y = g(x) = \left[a \sum_{h \in N} x_h - b \left(\sum_{h \in N} x_h \right)^2 \right] \frac{1}{n}, \tag{4.1}$$

where $x \in [0, e]^n$. All resources not invested in the public good are allocated to a private account with a constant marginal return c. Hence, individual i's payoff function is given by

$$u_i(x) = \left[a \sum_{h \in N} x_h - b \left(\sum_{h \in N} x_h \right)^2 \right] \frac{1}{n} + c(e - x_i), \tag{4.2}$$

Individual i's best-reply function is

---

[6] For other formulations of quadratic public good games with interior Nash equilibria see Sefton & Steinberg (1996) (in their NE treatment), Chan et al. (1996) and Laury et al. (1999). Keser (1996), Sefton & Steinberg (1996) (in their DE treatment), Willinger & Ziegelmeyer (1999), Willinger & Ziegelmeyer (2001) and Falkinger et al. (2000) study public good games with a unique interior dominant strategy equilibrium by making the private account quadratic. Although this manipulation resulted in a quadratic payoff function, the underlying public good remained linear. Quadratic public good games without interior Nash equilibrium have been analyzed by Isaac & Walker (1991) and Isaac et al. (1985).

$$x_i^{PG}(x_{-i}) = \arg\max \left\{0, \frac{a-cn}{2b} - \sum_{h \neq i} x_h \right\}, \tag{4.3}$$

where $x_{-i} = (x_1, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n)$. Solving (3) under symmetry, one gets the unique symmetric Nash equilibrium

$$x_i^{*PG} = \frac{a-cn}{2bn} \forall i \in N. \tag{4.4}$$

It is well known that applying the logic of backward induction to the finite repetition of the public good game results in (4) being also the unique symmetric subgame perfect equilibrium of the finitely repeated public good game.

The unique symmetric Pareto solution of the public good game is obtained by optimizing $\sum_{h \in N} u_h(x)$ over $\sum_{h \in N} x_h$:

$$x_i^{PG-P} = \frac{a-c}{2bn} \forall i \in N. \tag{4.5}$$

A Common-Pool Resource Game

The following is a standard formulation of a common-pool resource game that draws from Walker et al. (1990).[7] Denote by $i \in N = 1, \ldots, n$ the i-th player in the CPR game that is endowed with $e \in \mathbb{R}_{++}$, and has to decide how much of his or her endowment to allocate to the common-pool resource $x_i \in [0, e]$. Player i's payoff for the resources allocated to the common-pool are represented by

$$h(x)\frac{x_i}{\sum_{h \in N} x_h} = \left[a \sum_{h \in N} x_h - b(\sum_{h \in N} x_h)^2\right] \frac{x_i}{\sum_{h \in N} x_h}. \tag{4.6}$$

[7] For other formulations of quadratic common-pool resource games see Clark (1980), Walker & Gardner (1992), Ostrom et al. (1994), Herr et al. (1997), Beckenkamp & Ostmann (1999), Keser & Gardner (1999), Walker et al. (2000), Beckenkamp (2002), Casari & Plott (2003), Margreiter et al. (2005) and Apesteguia (2006). In the psychological literature common-pool resource games are generally implemented as linear threshold CPRs alternatively known as Nash demand games. See for example Suleiman & Rapoport (1988), Budescu et al. (1995), Budescu & Au (2002). There also exist experimental CPR studies in non-strategic, decision-theoretic environments (see e.g. Hey et al. (2004)).

As in the case of the public good game, all resources not invested in the common-pool are allocated to a private account with a marginal return of c. Hence, player i's total payoff function is

$$v_i(x) = \left[a \sum_{h \in N} x_h - b \left(\sum_{h \in N} x_h \right)^2 \right] \frac{x_i}{\sum_{h \in N} x_h} + c(e - x_i). \quad (4.7)$$

Individual i's best reply function, the unique symmetric Nash equilibrium, and the unique symmetric Pareto solution in the common-pool resource game are respectively

$$x_i^{CP}(x_{-i}) = \arg\max \left\{ 0, \frac{1}{2} \left[\frac{a-c}{b} - \sum_{h \neq i} x_h \right] \right\}, \quad (4.8)$$

$$x_i^{*CP} = \frac{a-c}{b(n+1)} \forall i \in N, \quad (4.9)$$

$$x_i^{CP-P} = \frac{a-c}{2bn} \forall i \in N, \quad (4.10)$$

Note that the symmetric Pareto solution is the same in both games. Table 4.1 gives the theoretical predictions for the public good and common-pool resource games for the parameters used in the experimental study.

Table 4.1: Experimental parameters and theoretical benchmarks.

	Nash Equilibrium		Pareto Solution	
	x_i	Individual Payoffs	x_i	Individual Payoffs
Public Good	20	180	50	225
Common-pool Resource	80	180	50	225

The parameters used in the experimental study are: $n = 4$, $a = 6$, $b = .0125$, $c = 1$, $e = 100$.

The values of the parameters were chosen so that (1) all predictions are in integer numbers; (2) payoffs from playing the symmetric Nash equilibria are the same in both games, and, since the symmetric Pareto solution is the same for both games, the gain in efficiency associated with a switch from Nash equilibrium to the Pareto solution is also the same in both games (an increase in payoffs of 20%); and (3) the symmetric Nash predictions in the public good and common-pool resource games are located at symmetric points from the extremes of the individual strategy space.

Figure 4.1: Best-Response (BR) Functions.

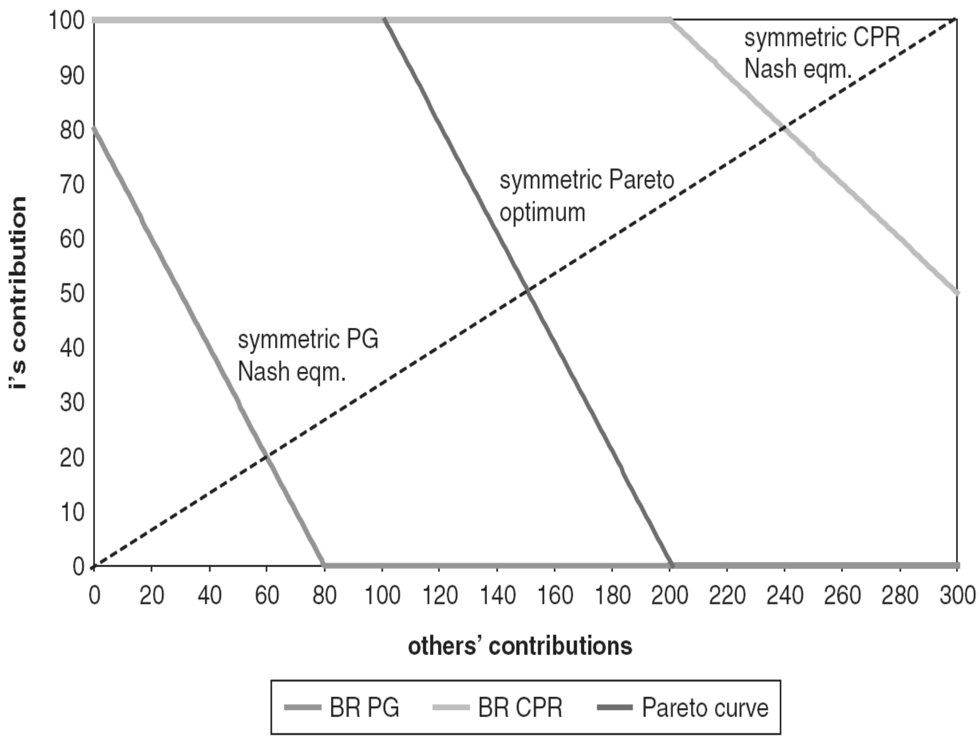


Figure 4.1 draws the best reply functions in both games, together with the Pareto reply function, common to both games. It displays the unique symmetric Nash equilibrium in the CPR game, as well as the unique symmetric Nash equilibrium in the PG game at the intersections of the respective best reply functions with the symmetry line. In addition the figure shows the symmetric Pareto efficient allocation for both games at the intersection of the symmetry line with the individual Pareto reply function.

Public Good versus Common-Pool Resource Games

The only difference between the two games is reflected in equations (1) and (6). Equation (1), the individual payoff function from allocations to the public good, reflects the non-rivalry property of public goods. The payoffs derived from the public good on the part of a player do not reduce the payoffs derived from the other players. In other words, for any $x \in [0, e]^n$, all $i \in N$ have exactly the same payoff from the public good.

On the other hand, equation (6), the individual payoff function from allocations to the common-pool, captures the rivalry property by introducing an *individual distributional factor* $\frac{x_i}{\sum_{h \in N} x_h}$.[8] In this case $\frac{xi}{\sum_{h \in N} x_h}$ represents a proportional distribution. The higher x_i in relation to $\sum_{h \in N} x_h$, the higher the appropriation of i from the common-pool resource. Therefore, in the case of the common-pool, the returns from the contributions of all players $[a \sum_{h \in N} x_h - b(\sum_{h \in N} x_h)^2]$ are fully distributed to the individual players on the basis of the individual distributional factor $\frac{x_i}{\sum_{h \in N} x_h}$. That is, the units from the common-pool consumed by player i are not available anymore to any other player $j \neq i$.

4.2.2 The Role of Rivalry

Section 2.1 introduced two particular games, a quadratic public good game and a common-pool resource game that we will subsequently study experimentally. The preceding section also pointed to the differences between the two types of social dilemmas. In the following we introduce general definitions of public good and common-pool resource games. In these general definitions we do not impose any restriction on symmetry, nor on the production functions from the public good, the common-pool, and the private accounts. The only assumption we make concerns the individual distributional factor from the common-pool. We will assume a proportional distributional factor, although we do not restrict it to a symmetric distributional factor. Of course, other distributional factors could be (and in fact

[8] The term distributional factor is used to distinguish it clearly from institutional arrangements designed to manage a particular resource. From that perspective terms such as appropriation rule or sharing rule, often found in the literature, may be a misleading term to describe properties of the good.

sometimes are) used.[9] Then, by restricting the classes of possible public good and the common-pool resource games we show that these two types of games cannot be taken in general to be equal, and hence they are fundamentally different.

We introduce the following notation. The set $N = \{1, , n\}$, $n \geq 2$, is the set of players, indexed by i, $X_i = [0, e_i]$ is player i's strategy space, $e_i \in \mathbb{R}_{++}$, $x_i \in X_i$, $X = X_1 \times \ldots \times X_n$, and $x = (x_1, \ldots, x_n) \in X$.

Definition 1 (public good game): Denote by $\Gamma_1 = (N, X, U)$ the public good game where the sets N and X are defined as above, and $U = U_1 \times \ldots \times U_n$, where $U_i : X \to \mathbb{R}$ is the payoff function of player i that is decomposed into functions $G : X \to \mathbb{R}$ (the public good production function) and $C_i : X_i \to \mathbb{R}$ (the private account payoff function), according to $U_i(x) = G(x) + C_i(x_i)$.

Definition 2 (common-pool resource game): Denote by $\Gamma_2 = (N, X, V)$ the common-pool resource game where the sets N and X are defined as above, and $V = V_1 \times \ldots \times V_n$, where $V_i : X \to \mathbb{R}$ is player i's payoff function that is decomposed into functions $H : X \to \mathbb{R}$ (the aggregated common-pool production function) and $D_i : X_i \to \mathbb{R}$ (the private account payoff function), according to $V_i(x) = H(x)\frac{\alpha_i x_i}{\sum_{h \in N} \alpha_h x_h} + D_i(x_i)$, $\sum_i \alpha_i = 1$, and $\alpha_i \geq 0\ \forall i \in N$.

Proposition 1: There is no configuration of functions G, C_i, H, and D_i, such that $\Gamma_1 \equiv \Gamma_2$.

Proof: To show that in general $\Gamma_1 \equiv \Gamma_2$ does not hold, we only need to find a domain where such identity cannot hold. For simplicity, we do this by restricting ourselves to the classes of CPR and PG games were the private accounts are linear, the aggregated common-pool production function is strictly concave in $\sum_{h \in N} x_h$, and $\alpha_i = \alpha_j$ for every $i, j \in N$. Now, assume, by way of contradiction, that there exist $G(x)$, $C_i(x_i)$, $H(x)$, and $D_i(x_i)$ such that $U_i(x) \equiv V_i(x) \forall i \in N$, and for all $x \in X$. Then, take any $x \in X$ and $i, j \in N$, $i \neq j$ with $x_i \neq x_j$. Hence, $U_i(x) \equiv V_i(x)$ and $U_j(x) \equiv V_j(x)\ \forall x \in X$ imply that

$$G(x) = H(x)\frac{x_i}{\sum_{h \in N} x_h} + [D_i(x_i) - C_i(x_i)], \tag{4.11}$$

[9] For a detailed discussion of different distributional factors and their consequences for the type of game, see Beckenkamp (2006) and Rapoport & Amaldoss (1999). Gunnthorsdottir & Rapoport (2006) conducted an experimental study of a proportional and an egalitarian distributional factor in an inter-group competition game based on a linear public good.

$$G(x) = H(x)\frac{x_j}{\sum_{h \in N} x_h} + [D_j(x_j) - C_j(x_j)]. \tag{4.12}$$

Setting (11) and (12) equal and solving for $H(x)$, one gets

$$H(x)\frac{(x_i - x_j)}{\sum_{h \in N} x_h} = [D_j(x_j) - D_i(x_i)] - [C_j(x_j) - C_i(x_i)] \tag{4.13}$$

Now, since D_h and C_h are assumed to be linear, let $D_h(x_h) = a + bx_h$ and $C_h(x_h) = c + dx_h$, where a, b, c, and d are real value parameters. Hence, (13) implies that

$$H(x) = (d - b)\sum_{h \in N} x_h, \tag{4.14}$$

which contradicts our initial assumption on the strict concavity of the aggregated common-pool production function. □

The proof of Proposition 1 shows that public good and common-pool resource games cannot be taken in general as identical social dilemma games by restricting the production function of the CPR game to be concave, and the private accounts to be linear. Clearly, such classes of public good and the common-pool resource games are considerably broad since they encompass the class of experimental games studied in this paper, the standard and intensively studied linear public good games, and the standard CPR experimental games.

4.3 Experimental Design

The experiments were conducted at the Experimental Economics Laboratory at the University of Bonn using the z-Tree software developed by Fischbacher (1999). At the beginning of each session participants were randomly assigned to one of the 16 computer terminals. Before the session started, participants first had to read the instructions. In order to check if participants understood the instructions, three test questions were given.[10] The values used in the test questions were publicly drawn

[10] Both the instructions and the test questions are available at http://jcr.sagepub.com/cgi/content/full/50/5/646/DC1.

by randomly chosen participants from two urns and announced. The experiment was started only once all participants had correctly answered all test questions.

We ran two sessions for each game, for a total of 8 independent observations respectively. In each session 16 participants were randomly divided into groups of 4 to play a give-some frame of either the CPR or the PG game for 20 periods.[11] Participants knew that they would remain in the same group for 20 periods but they did not know with whom they were playing. At the end of each turn, participants received information on their decision, aggregate decisions of all other players, the payoffs from Account 1 (the common-pool or public good account) and 2 (the private account), the sum of the payoffs from both accounts in that period, and their total payoff so far. The parameterization of the PG game based on the payoff function (2) was:

$$u_i(x) = \left[6\sum_{h\in N} x_h - \frac{1}{80}\left(\sum_{h\in N} x_h\right)^2\right]\frac{1}{4} + (100 - x_i). \tag{4.15}$$

The parameterization of the CPR game based on the payoff function (7) was:

$$v_i(x) = \left[6\sum_{h\in N} x_h - \frac{1}{80}\left(\sum_{h\in N} x_h\right)^2\right]\frac{x_i}{\sum_{h\in N} x_h} + (100 - x_i). \tag{4.16}$$

Communication was not allowed throughout the experiment.

4.4 Results

We begin by addressing the main question investigated in this paper[12], namely, whether the investment level in PG games significantly differs from the investment level in CPR games. Table 4.2 reports summary statistics on average investments for the entire experiment, as well as for the first and the second half. Also, the

[11] One urn contained all entries of the Y column of the total payoff table and the other contained all values of the X row. Even though participants were equipped with calculators, the numbers were chosen such that the test questions could be answered based on the entries in the tables provided.

[12] Note that section 4.4 Results deviates from the published version.

average payoffs, the standard deviations of the average allocations in the eight groups, and the average of the standard deviations at the individual level, are reported in the table.

Table 4.2: Summary Statistics.

	PG	CPR
Average allocation (periods 1 to 20)	21.4	74.8
Average allocation (periods 1 to 10)	23.3	72.2
Average allocation (periods 11 to 20)	19.5	77.4
Average payoffs (periods 1 to 20)	179.4	189.3
Standard deviation of average allocations	4.0	3.6
Average of standard deviation of individual behavior	21.7	20.4

Note: PG = public good; CPR = common-pool resource.

Result 1: Aggregate investment in the PG game is statistically different from investment in the CPR game.

Support to Result 1: The permutation test on the basis of the average allocations per group yields a significance of 0.01% (two-sided).[13] Further, consider Figure 4.2 where the time series of average allocations per treatment are shown, and Figure 4.3 where the histogram of all individual decisions by treatment are reported.

Clearly, investment decisions in both games sharply differ. This indicates that players are sensitive to the different incentive structures determined by the distributional factor.

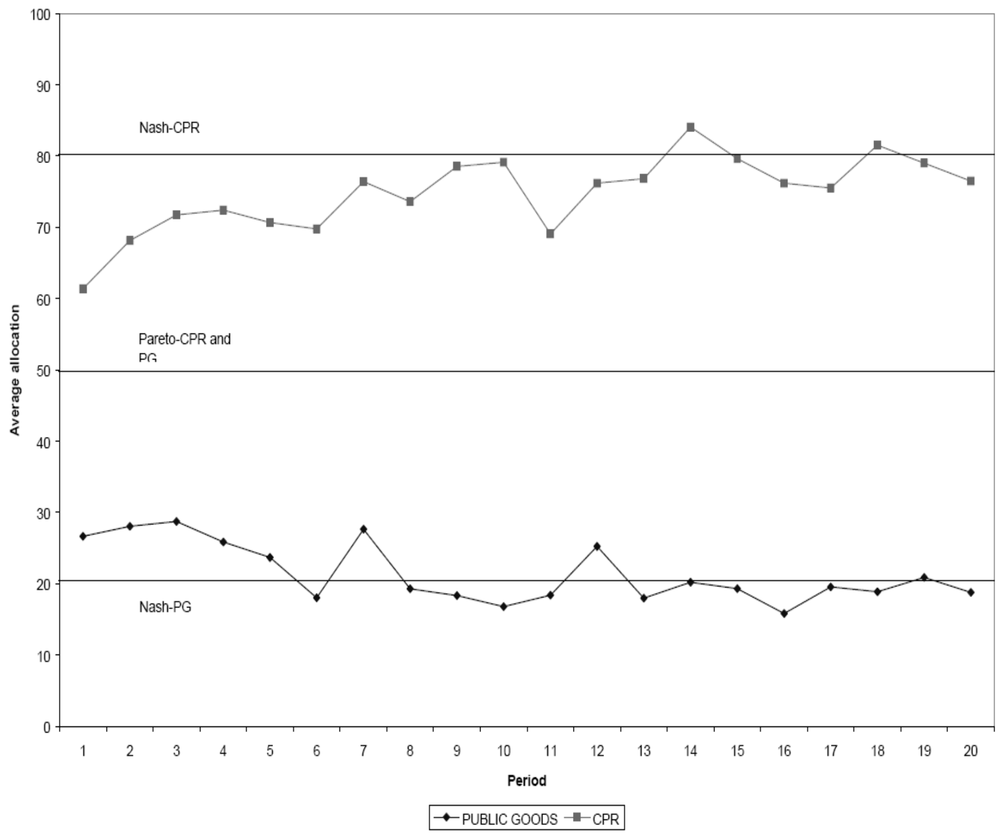
Having shown that investment decisions differ between games, it remains to be shown whether the pattern of behavior exhibited by players also differs between games. The distinction between investment levels (investment decisions) and the pattern of behavior is important. Even though investment levels clearly differ, behavioral strategies may still be the same.

Result 2: The pattern of behavior in both games is qualitatively similar.

Support to Result 2: Figure 4.2 shows that aggregate allocations in both, PG and CPR games, start at levels in between the symmetric Pareto solution and the respective Nash equilibria, and tend to converge to the respective Nash equilibria. In fact, with respect to the tendency, average investment per group in the first half

[13]See Siegel & Castellan (1988) for a reference on the statistical tests used in this paper.

Figure 4.2: Time Series of Average Allocations Per Treatment.

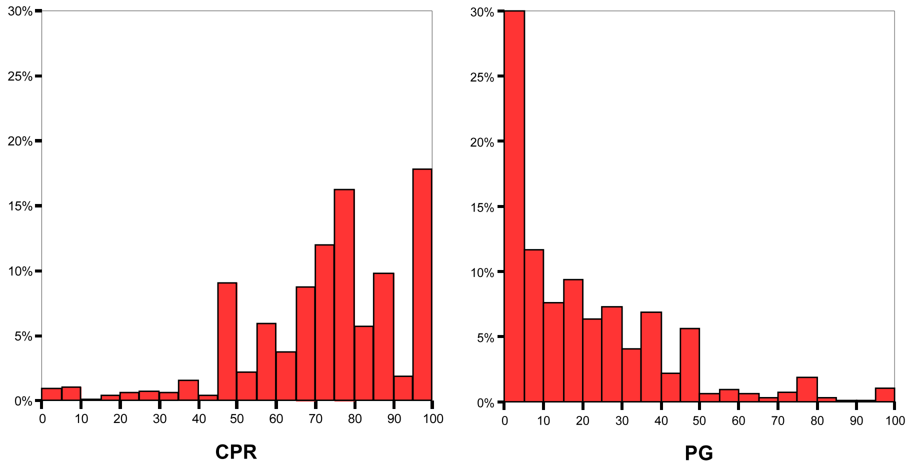


of the PG experiments are higher than those in the second half, while in the CPR experiments the relation is the opposite. The Wilcoxon signed-ranks test yields significance on the 0.0386 level for the PG case and on the 0.0039 level for the CPR case (both one-sided). Furthermore, in both games, the null hypotheses of no difference between average allocations in the second half of the experiment at the group level with respect to the respective Nash equilibrium cannot be rejected at a 5% significance level.

It is illuminating that average payoffs in the CPR experiment do not significantly differ from those in the PG game. The permutation test does not reject at a 5% significance level the null hypothesis of equal average payoffs between the PG and CPR experiments.

However, this does not imply that behavior in CPR experiments is the mirror image of behavior in PG experiments. In fact, when considering the distribution of individual decisions between the PG experiments and the truncated distribution

Figure 4.3: Histograms of Individual Investments in the Public Good (PG) and the Common-Pool Resource (CPR) Experiments.



of the CPR experiments in Figure 4.3, differences appear to exist.[14] Testing the difference of averaged squared deviations from the respective Nash equilibrium for all periods on the group level using a Fisher-Pitman permutation test does, however, not yield a significant result ($p \leq 0.122$; one-sided).

We conclude that participants in the experiments were sensitive to the unique difference between the two games: the degree of rivalry as captured by the distributional factor. Hence, it appears not only that both types of games are theoretically and conceptually different, but that these differences are also reflected in different investment levels. Nevertheless, the pattern of behavior seems to be qualitatively similar when the Pareto solution and the Nash equilibrium are taken as reference points.

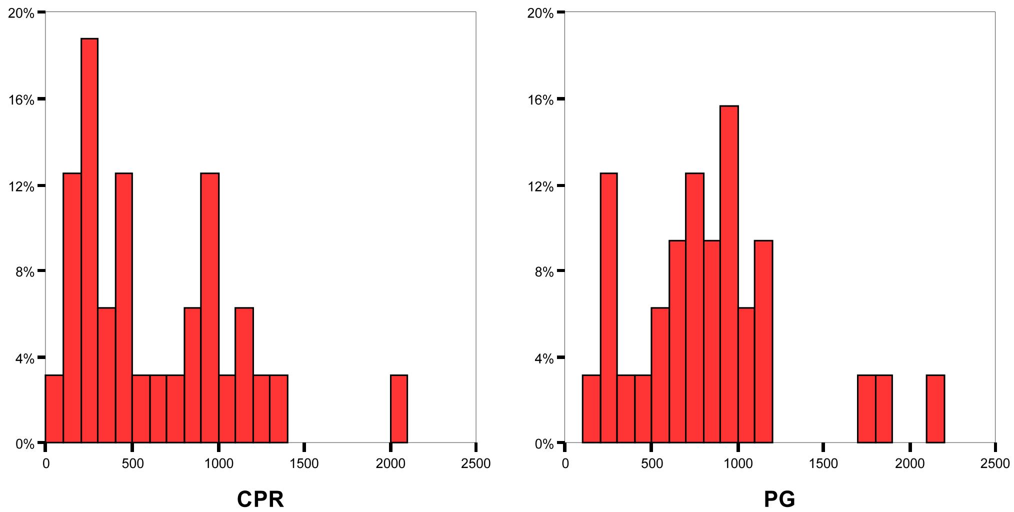
4.4.1 Individual Differences

So far the analysis was based on group level data. In this subsection we turn to individual behavior. It has consistently been shown that behavior at the individual

[14]Note, however, that the Figure depicts a total of 320 dependent allocation decisions (8 groups $\times$ 20 periods $\times$ two games) whereas the number of independent observations is 16, i.e. 8 groups per game.

level is very heterogeneous in dilemma experiments. To check for this regularity found in the literature, we compute for the respective game (equations (3) and (8)) the average of the squared differences between the observed data and the individual best-reply functions over all periods at the individual level. Figure 4 reports the distribution of the individual average squared differences.

Figure 4.4: Histograms of Individual Average Squared Differences between Observed Data and Best-Reply Predictions in the Public Good (PG) and the Common-Pool Resource (CPR) Experiments



The range in Figure 4.4 goes from 0 to a maximum of 2500,[15] with 25 intervals of length 100. Note that the distributions in Figure 4 are quite dispersed. The mean deviation in the CPR (PG) experiments is 635.3 (839.5) with standard deviation 455.4 (462.1).

Classifying individuals as best-repliers if they deviate 15% or less from the best reply in action space, about 20% of participants in the CPR experiments, and about 10% of participants in the PG experiments fall in that category. However, if we were to take players as exhibiting behavior substantially deviating from the

[15]Note that if we take the individual decision and the best-reply prediction as uniform random variables, the difference in expectation of the order statistics is 100/3, implying a squared difference of about 1,110.

best-reply when they deviate by 30% or more in action space[16] from the best-reply prediction, about 18% of the players in the CPR experiments, and about 25% in the PG experiments are characterized that way. Consequently, it appears that, consistent with previous findings, individual behavior in our experiments is quite diverse.

4.4.2 Sequential Dependencies

Our experimental games were conducted in partner design, that is, the same group of individuals interacted throughout the entire experiment. By doing so we adhered to the early experimental practice in both PG and CPR experiments, allowing us to gain a relatively high number of independent observations for the statistical analysis. A natural alternative to our design choice is to use random matching. Random matching has very important advantages since it minimizes reputation effects and other sequential dependencies. As a result, it is interesting to analyze to what extent sequential dependencies were present in our data. Of course, the ultimate test for such a question encompasses the comparison of experiments with and without random matching. Such a comparison is out of the scope of the present paper, but we can, nevertheless, make some tests in this respect.[17]

Individuals received feedback on the behavior of the opponents, in form of aggregate contributions in the group, throughout the experiment. In Figure 4.1 we showed that according to best-reply a negative relation between others' allocations and one's allocation should hold. On the other hand, a positive relation could indicate some kind of sequential dependency; for example a taste for conformity with the behavior of others.

We measure such (first-order) dependencies by computing the Spearman rank-order correlation coefficient for each individual between the individual allocation decisions and the last observed sum of allocations of the opponents. Of the 32 individual coefficients in the PG (CPR) experiments 12 (19) were negative. A binomial test yields no difference at standard significance levels between the number of positive and negative coefficients in both experiments. That there is not a predominantly negative relation is not surprising given the remarkable deviations from

[16]See the previous footnote.

[17]Botelho et al. (2005) study these sort of questions in the context of public good games.

best-reply that we could observe at the individual level in Figure 3. Further, the no significance result suggests that (first-order) sequential dependencies between individuals seem not to be significantly present in our data.

4.4.3 Related Literature

Our experimental findings in the quadratic PG and the quadratic CPR game are generally in line with previous experimental evidence.

The literature on quadratic public good games reports similar investment patterns to those observed here: behavior starts around the Pareto solution and then declines towards the Nash equilibrium with repetition. Interestingly, both (1) experimental studies of quadratic public good games where the interior Nash equilibrium is in dominant strategies (see Keser (1996), Falkinger et al. (2000), and Willinger & Ziegelmeyer (1999) and (2) those without an interior Nash equilibrium in dominant strategies (see Isaac & Walker (1998) and Laury et al. (1999)[18], show the mentioned pattern from Pareto to Nash, but at lower rates than those found here. That is, the convergence to Nash that we observe is quicker than the convergence reported in the literature. The determinants of such a difference are difficult to identify since there are many design differences between our experiments and those mentioned above.[19] However, this is an interesting observation that should be investigated in future research.[20]

For the CPR game, there is conflicting evidence on the tendency of aggregate decisions through time. This seems to depend on a variety of issues such as the endowment, the group size, etc. Nevertheless, the general pattern of an increase

[18]See Anderson et al. (1998) for a theoretical discussion of these results. Laury & Holt (n.d.) provide an overview of the PG literature with interior Nash equilibrium. For recent experimental studies of linear public good games see for example Maier-Rigaud et al. (2005), Brandts & Schram (2001), Keser & van Winden (2000), Gächter & Fehr (1999), Palfrey & Prisbrey (1997), Andreoni (1995b), and Laury et al. (1995).

[19]Charness et al. (2004) have shown that payoff tables reduce cooperativeness in the context of gift exchange experiments. Gürerk & Selten (2006) find the opposite effect in the context of oligopoly experiments. In Laury et al. (1999) conversion was quicker in the treatments with more detailed information containing payoff tables than in the treatments without. In our experiment conversion is even quicker than in their detailed information treatment.

[20] For an experimental study on the rates of convergence to equilibrium in 3×3 games see Ehrblatt et al. (2005).

of investment towards the Nash equilibrium has also been observed in the low endowment treatment in Walker et al. (1990), Ostrom & Walker (1991), Ostrom et al. (1994) and Apesteguia (2006). Whereas, Keser & Gardner (1999), Gardner et al. (1997), Walker et al. (1990) in the high endowment treatment, and Casari & Plott (2003), find investments above the Nash equilibrium.

Inspired by the theoretical results of Rapoport & Amaldoss (1999), Gunnthorsdottir & Rapoport (2006) study the two distributional factors analyzed here in the context of an inter-group competition game. The game within the group was a linear public good game with corner solution that determined the probability of winning a fixed award that afterwards was either split according to a proportional or an egalitarian distributional factor. The proportional distributional factor corresponds here to the CPR experiment, while the egalitarian distributional factor corresponds to the PG experiment. Although there are many differences in the design of their experiment and ours, their findings for the proportional distributional factor are similar to the pattern observed in the present CPR game. The main difference concerns the egalitarian distributional factor, where Gunnthorsdottir and Rapoport found significantly higher contributions that only slowly converged to the Nash equilibrium in their experiment.

4.5 Conclusion

The aim of this study was to shed some light on the commonalities and differences between common-pool resources and public goods. We designed a public good and a CPR game with identical quadratic production function in order to compare both games on a theoretical and experimental level.

We show that, in contradiction to the common belief that CPR and PG games are theoretically identical, the two games are in fact distinct games. We show that this difference is based on rivalry as captured by a proportional distributional factor.

The experimental results clearly support the theoretical result that both games are different. Investment decisions in the public good experiments are statistically different to those in the common-pool resource ones. Given that both games were framed as give-some games, this difference can not be attributed to framing. Hence, the results clearly indicate that participants were sensitive to the rivalry structure of the strategic situation. Despite this difference reflecting the structure of the two games, there appear to be some behavioral similarities. In the CPR game the aggregate Nash equilibrium investment level is above the Pareto efficient one, whereas in the PG game the aggregate Nash equilibrium is below the Pareto efficient level. In both games, aggregate investment approaches the Nash equilibrium over time. At the beginning the Pareto optimum and later the Nash equilibrium appear to be behaviorally relevant. Aggregate behavior in both games is surprisingly similar in the sense that it starts in the neighborhood of the Pareto optimum and moves rather quickly to the respective aggregate Nash equilibrium.

5 Purchase Decisions with Non-linear Pricing Options under Risk

Abstract: Purchase decisions with linear and non-linear pricing under risk are the focus of this chapters experimental analysis. The experiment is based on a single period stochastic inventory problem with endogenous cost. It extends classic binary lottery experiments to test standard decision theoretic predictions concerning purchasing behavior in a rebate and a discount scheme. In particular, it is investigated to what extent customers continue to purchase under two mathematically isomorph formats of non-linear schemes even if switching to a linear pricing scheme is optimal. The results indicate that rebate and discount schemes exert a significant attraction on customers. Given the increased role of non-linear pricing schemes, systematic deviations from optimal behavior are an important element in the design of such schemes and may raise consumer protection and competition questions of substantial policy relevance. The chapter conlcudes with a discussion on how the results can be explained by decision heuristics.

5.1 Introduction

Standard economic theory suggests that customers should be indifferent to the format of a price reduction. In particular this implies that one would expect a customer to switch independently of the scheme in use from one pricing scheme to another (one supplier to another) as long as there is at least an expected reduction in the effective purchase price. The recent surge in the use of rebates, discounts, bonus and point schemes implemented by retailers but also observed in other levels of the production chain begs the question of whether traditional economic explanations do fully account for the increased usage of non-linear pricing methods. An understanding of potential behavioral reasons for using such pricing schemes may not only be relevant for their design, but also for consumer protection and competition policy issues.[1]

This paper focuses on the analysis of behavioral responses triggered by rebate and discount schemes in a decision theoretic context similar to the classic lottery experiments conducted by Kahnemann and Tversky. In our analysis we consider two mathematically identical formats of such schemes. In the "discount" format a reduced price is granted from the start and the discount has to be reimbursed at the end of a reference period if a quantity threshold has not been reached. In the "rebate" format a reduced price is granted retroactively once a quantity threshold has been reached. The effects of these two formats are experimentally tested by confronting participants with different price schemes in a formally identical risky decision-making environment.[2] The discount and rebate schemes are contrasted to a conventional linear price scheme.

Of relevance to this paper is the extensive literature in operations research on what is called the newsvendor problem, i.e. the problem of determining the expected profit maximizing stocking decision under stochastic demand of a product

[1] In competition policy for instance, one of the most controversial aspects of the recent review of the European Commissions approach to abuse of dominance under Article 82 ECT concerns potential foreclosure effects in rebate schemes. See Beckenkamp & Maier-Rigaud (2006) for an experimental discussion of rebate schemes in the context of Article 82 ECT. A more general discussion of the antitrust issues surrounding rebate schemes can be found in Maier-Rigaud (2006).

[2] Although rebate and discount schemes need not be formally identical (such as for example under discounting) our experiment is designed so that both schemes are isomorph.

that becomes obsolete at the end of a single period.[3] The optimal solution is characterized by a balance between expected cost of understocking and the expected cost of overstocking. The newsvendor problem has also recently been analyzed experimentally.[4] The main result of the experimental literature is that procurement quantities for low profit products were higher than expected profit maximizing quantities while orders for high profit products were lower than expected profit maximizing quantities.

Also related to our study is the paper by Eckel & Grossman (2003) analyzing different formats for charitable contributions. They report much higher charity receipts under a matching condition, where the experimenter matched any individual contribution at a preannounced rate than under a mathematically equivalent rebate condition where a portion of the contribution was paid back. Davis & Millner (2005) similarly focus on the effects of changes in the format of identical prices by offering chocolate bars under a rebate and a matching condition. They find that participants purchase significantly more chocolate bars under the matching condition, confirming the result by Eckel & Grossman (2003).[5]

The paper is organized as follows. Section 5.2 discusses rebate, discount and linear pricing schemes in a simple vertical (upstream producer, downstream retailer) relationship. Two hypotheses for the experimental results are considered: The risk neutral maximization of expected profits and boundedly rational behavior as described for instance by prospect theory. Section 5.3 describes the experimental design, the hypotheses and the experimental results and section 5.4 concludes.

[3] The newsvendor problem is the fundamental building block of stochastic inventory theory. See for instance Arrow et al. (1951) or Mills (1959). Overviews can be found in Porteus (1990) and Petruzzi & Dada (1999).

[4] See Schweitzer & Cachon (2000), Brown & Tang (2000), Bolton & Katok (2005), Lurie & Swaminathan (2005), Ben-Zion et al. (2005), and Katok et al. (2006).

[5] See also Davis (2006), Eckel & Grossman (2006), and Davis et al. (2005). Karlan & List (2006) show that the offer to match contributions to a non-profit organization increases the likelihood and amount an individual donates in a field experiment.

5.2 Theoretical Background

5.2.1 Rebate, discount and linear pricing schemes

Consider two upstream firms that produce a homogenous product at marginal cost c. The product is bought by a downstream retailer, that sells the good to final consumers.[6] The upstream firms are referred to as A and B. Denote by $T_i(q_i)$ the downstream firm's payment to upstream firm i depending on the amount of units q_i bought.

The *upstream firm A offers a rebate scheme*, that is, $T_A(q_A) \equiv wq_A$ if $q_A < \bar{q}$ and $(1-\alpha)wq_A$ otherwise, where $w > 0$, $\alpha \in (0,1)$ and $q_A \equiv \sum_{t=1}^{\tau} q_{At}$, where τ denotes the final subperiod of the reference period. In this scheme, the downstream firm's average per unit price and marginal price equals w at the end of τ if $q_A < \bar{q}$ units are purchased and $(1-\alpha)w$ otherwise. Since $\alpha > 0$ the downstream firm is rewarded for purchasing at least $\bar{q}$ units. This implies that firm A uses a rebate scheme where α is the percentage discount off the list price w once $\bar{q}$ units have been bought.[7]

The *upstream firm B* in contrast *offers a conventional price scheme*, i.e. a linear pricing schedule implying a cost of $T_B(q_B) \equiv vq_B \; \forall q_B \geq 0$ for the downstream firm, where $q_B \equiv \sum_{t=1}^{\tau} q_{Bt}$.

Consider the following variation to firm $A's$ pricing strategy that we refer to as discount scheme. An upstream firm *C may offer a discount price schedule* $T_C(q_C) \equiv (1-\alpha)wq_C + F(q_C)$ if $q_C < \bar{q}$ and $(1-\alpha)wq_C$ otherwise, where $q_C \equiv \sum_{t=1}^{\tau} q_{Ct}$. This scheme is mathematically equivalent to the rebate scheme if $F(q_C) = \alpha w q_C \; \forall \; q_C$. The only difference is that the reduced price $(1-\alpha)wq_C$ is paid from the first unit on and $F(q_C)$ is only paid if $q_C < \bar{q}$ at the end of τ.[8]

The downstream firm buying the good incurs only the cost of its purchases from

---

[6] Although it is rather standard to treat firms as individual decision makers and we will also do so in the theoretical as well as experimental part of the paper, it is still noteworthy that typically, a corporate decision making process underlies the behavior of the firm.

[7] Note that from a modelling perspective the pricing behavior of the upstream firms is the result of a profit maximizing calculus based on behavior downstream (retailer and final consumers). We neither model this vertical relationship nor competition upstream explicitly because it unnecessarily complicates the exposition without adding any particular insight to the question at hand.

[8] Note that due to this isomorphism we will be able to concentrate on rebate schemes in the following theoretical exposition. All results directly apply to discount schemes as well.

the upstream firm(s) when it purchases $q_i > 0$ units of the good. Let p denote the retail price and $q_t(p, X)$ the consumers demand function with $q_t(p, X) \geq 0 \; \forall \; p, X$, where $X \sim N(\mu, \sigma)$ is a censored normally distributed (i.e. an approximately normally distributed) random variable cut at zero with a mean of μ and a standard deviation of σ.[9]

The upstream firms profits are given by $\pi_i^u \equiv T_i(q_i) - cq_i$ and the downstream firm profit is given by $\pi^d \equiv \sum_{t=1}^{\tau} \pi_t^d$, where π_t^d is given by:

$$\pi_t^d \equiv \begin{cases} q_t(p,x)p - \sum_{i \in \{A,B\}} T_i(q_i) & \text{if } s_t + \sum_{i \in \{A,B\}} q_i \geq q_t(p,x) \\ p(s_t + \sum_{i \in \{A,B\}} q_i) - \sum_{i \in \{A,B\}} T_i(q_i) & \text{otherwise.} \end{cases} \tag{5.1}$$

The level of stock at time t is denoted by s_t.[10] Let $E(p^*)$ denote the expected profit maximizing price and $E(q) \equiv E(q_t(p^*, X))$ the corresponding expected profit maximizing quantity.

Based on the price scheme information of the upstream firms and the demand function, the downstream firm calculates its expected profit maximizing price. Given that price, it can determine the corresponding expected quantity that final consumers will buy and order accordingly. We consider the case where pricing of the downstream retailer exerts some inertia, that is, for example, due to menu cost, prices are fixed at the beginning of the reference period for the whole period.[11] Ordering decisions can, however, be taken at least twice during the reference period.

We consider the reference period to be divided into τ subperiods, with subperiod $t \in \{1, ..., \tau\}$. The demand in each subperiod $q_t(p^*, X)$ is a random variable from one and the same random process and we assume that the demand in each subperiod is independent from each other. This implies that we consider the special case where the cumulated expected sales in each subperiod increase linearly and proportionally in time.[12]

---

[9] The corresponding probability density function is given by $f(x)$. Note that demand in each subperiod is therefore not only dependent on price but also on the normally distributed random term X whose realization is denoted by x.

[10] $s_0 \equiv 0$ and $s_{t+1} \equiv \sum_{i \in \{A,B\}} q_{it} + s_t - q_t(p, x)$.

[11] Assuming fixed retail prices simplifies the decision problem of the retailer as pricing is eliminated from his strategy set.

[12] For a competition policy discussion of time in the context of rebate schemes see Maier-Rigaud

5.2.2 Risk neutral maximization of expected profits

We are now interested in the question under what conditions it is profit maximizing for the downstream firm to switch from supplier A or C to supplier B. In order to simplify we consider the situation in the τ'th subperiod with $v = (1-\alpha)w$, where the retailer has already bought $\sum_{t=1}^{\tau-1} q_t^o$ units, sold $\sum_{t=1}^{\tau-1} q_t$ units and therefore holds a stock of $s_\tau = \sum_{t=1}^{\tau-1}(q_t^o - q_t)$ units.[13] In that case, $\hat{q}_\tau \equiv \bar{q} - \sum_{t=1}^{\tau-1} q_t$ units would need to be bought to reach a purchase quantity equal to the threshold.

In order to determine under what constellation it is optimal to leave the rebate scheme, we need to calculate the optimal quantity a profit maximizing risk neutral retailer would want to have available. If the retailer chooses to remain in the rebate scheme, the optimal quantity $q_R^* > 0$ the firm should keep available for serving demand is

$$q_R^* \equiv \arg\max_{q_R \geq \hat{q}_\tau} \left[\begin{array}{r} p^* \left(\int_{-\infty}^{q_R} x f(x)dx + q_R \int_{q_R}^{\infty} f(x)dx + \sum_{t=1}^{\tau-1} q_t \right) \\ -(1-\alpha)w \left(q_R + \sum_{t=1}^{\tau-1} q_t \right) \end{array} \right]$$

or

$$q_R^* \equiv \arg\max_{q_R < \hat{q}_\tau} \left[\begin{array}{r} p^* \left(\int_{-\infty}^{q_R} x f(x)dx + q_R \int_{q_R}^{\infty} f(x)dx + \sum_{t=1}^{\tau-1} q_t \right) \\ -w \left(q_R + \sum_{t=1}^{\tau-1} q_t \right) \end{array} \right],$$

depending on whether

$$\max_{q_R \geq \hat{q}_\tau} \left[p^* \left(\int_{-\infty}^{q_R} x f(x)dx + q_R \int_{q_R}^{\infty} f(x)dx + \sum_{t=1}^{\tau-1} q_t \right) - (1-\alpha)w \left(q_R + \sum_{t=1}^{\tau-1} q_t \right) \right]$$

(2005).

[13] Due to the recursive nature of the problem over time solving for the expected profit maximizing stock at τ requires dynamic programming. We assume here that q_t^o has been chosen in an optimal fashion for all $t \in \{1, ..., \tau-1\}$. Given the stochastic nature of the process, any arbitrary $\sum_{t=1}^{\tau-1} q_t^o$ could be the outcome of an optimal process, albeit with different probabilities.

$$\gtreqless \max_{q_R < \hat{q}_\tau} \left[p^* \left(\int_{-\infty}^{q_R} x f(x) dx + q_R \int_{q_R}^{\infty} f(x) dx + \sum_{t=1}^{\tau-1} q_t \right) - w \left(q_R + \sum_{t=1}^{\tau-1} q_t \right) \right].$$

Note that the latter case (equation 5.2) only arises if past sales were substantially lower than expected, that is, $\hat{q}_\tau$ is large ($\sum_{t=1}^{\tau-1} q_t$ is small) compared to the underlying distribution of potential expected sales.[14]

If the retailer decides to switch, the optimal quantity the firm should keep available for serving demand is

$$q_S^* \equiv \arg\max_{q_S} \left[\begin{array}{c} p^* \left(\int_{-\infty}^{q_S} x f(x) dx + q_S \int_{q_S}^{\infty} f(x) dx + \sum_{t=1}^{\tau-1} q_t \right) \\ -w \left(\sum_{t=1}^{\tau-1} q_t + s_\tau \right) - v(q_S - s_\tau) \end{array} \right].$$

Based on the optimal quantity[15] (composed of the remaining stock plus newly bought quantities, i.e. $q_R^* = s_\tau + q_\tau^o$), expected profits given the retailer remains in the scheme[16] is given by

$$E(\pi|R) \equiv \begin{cases} p^* \left(\int_{-\infty}^{q_R^*} x f(x) dx + q_R^* \int_{q_R^*}^{\infty} f(x) dx + \sum_{t=1}^{\tau-1} q_t \right) & \\ -(1-\alpha) w \left(q_R^* + \sum_{t=1}^{\tau-1} q_t \right) & \text{if } q_R^* \geq \hat{q}_\tau, \\ p^* \left(\int_{-\infty}^{q_R^*} x f(x) dx + q_R^* \int_{q_R^*}^{\infty} f(x) dx + \sum_{t=1}^{\tau-1} q_t \right) & \\ -w \left(q_R^* + \sum_{t=1}^{\tau-1} q_t \right) & \text{otherwise,} \end{cases} \tag{5.2}$$

where, given that $v = (1-\alpha)w$, it is trivial that the retailer would prefer to switch if $q_R^* < \hat{q}_\tau$ and therefore $E(\pi|R)$ is strictly dominated by $E(\pi|S)$ in the latter

[14] Note that expected sales are potential as sales can only be made if sufficient quantity is held available.

[15] The analysis suggests that optimal orders and stocks are dependent on the variance of the distribution of expected sales, not only expected sales as such.

[16] We explicitly exclude the possibility of buying from both, firm A and B in τ. In fact eliminating this option is only relevant if $v < (1-\alpha)w$, as the retailer would then strictly prefer firm B for quantities above the threshold (if the remain option is optimal). As $v = (1-\alpha)w$, the retailer is indifferent between A and B for quantities above the threshold.

expression, and it is trivial that the retailer would prefer to remain if $q_R^* > \hat{q}_\tau$ and therefore $E(\pi|S)$ is strictly dominated by $E(\pi|R)$.

Expected profits given the retailer decides to switch to the linear pricing scheme offered by firm B while planning the corresponding optimal quantity of $q_S^* = s_\tau + q_\tau^o$ is

$$E(\pi|S) \equiv p^* \left(\int_{-\infty}^{q_S^*} x f(x) dx + q_S^* \int_{q_S^*}^{\infty} f(x) dx + \sum_{t=1}^{\tau-1} q_t \right) - w \left(\sum_{t=1}^{\tau-1} q_t + s_\tau \right) - v(q_S^* - s_\tau), \tag{5.3}$$

If $E(\pi|R) = E(\pi|S)$, the downstream firm is indifferent between S (switching supplier, i.e. choosing firm B) and R (remaining with the current firm, i.e. firm A).

Solving for q_τ^o, we obtain the relevant switching threshold where the retailer is indifferent between schemes. The relevant numerical values based on the parameters used in the experiment will be presented in a later section together with a more detailed explanation.

5.2.3 Boundedly rational behavior

A classical example of "*framing effects*"[17] is the change from risk-averse to risk-seeking behavior depending on whether the consequences of a decision problem (such as vaccination) are presented as a gain (200 of 600 threatened people will be saved) or as a loss (400 of 600 threatened people will die).[18]

Framing effects, however, are not simply the result of mistakes, i.e. unsystematic deviations around some true values, but are the result of systematic *biases*.

[17] See Tversky & Kahnemann (1981). Selten & Berg (1970) referred to such effects as presentation effects.

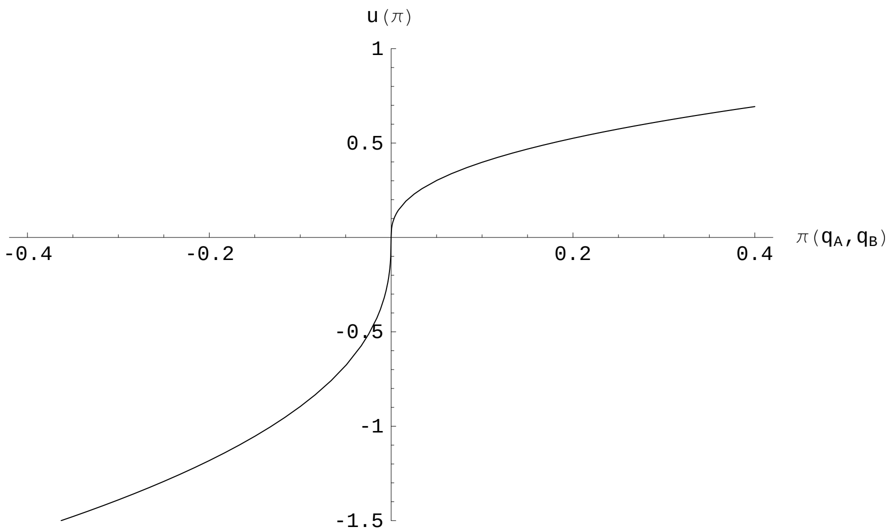
[18] Another framing effect concerns the order of play. Rapoport (1997), for example, has shown that sequential quantity decisions in a duopoly context push market shares towards the Stackelberg result even if these quantity decisions are not announced to the competitor and the game therefore remains isomorph to its simultaneous play version.

Boundedly rational decision makers[19] under- or overestimate certain decision options systematically (and predictably).

In the original formulation of *prospect theory* developed by Kahnemann & Tversky (1979), the term prospect referred to a lottery. Prospect theory suggests an explanation for framing effects, for example changes from risk-seeking to risk-averse behavior and vice versa, by assuming that the evaluations around losses and gains are based on a reference point.

According to prospect theory, the mapping of payoffs into utilities is not linear, but the value of gains or losses follows a nonlinear, "S"-shaped function (See Figure 5.1). The consequence is that decision makers who evaluate a decision framed as a loss will tend to take decisions that are risk-seeking.

Figure 5.1: Mapping of payoffs according to prospect theory.



Note: The function $u(\pi)$ gives the subjective payoffs and is given by $u(\pi) \equiv \pi^{\alpha}$, $\forall\ \pi \geq 0$ (win frame) and by $u(\pi) \equiv -\gamma(-\pi^{\beta})$, $\forall\ \pi < 0$ (loss frame). The values of the parameters used in Figure 5.1 were $\alpha \equiv 0.4$ $\beta \equiv 0.4$ and $\gamma \equiv 2.25$.

Prospect theory has been widely used in behavioral economics in order to explain a diverse range of situations that appear inconsistent with standard economic

[19] The concept of bounded rationality was originally introduced by Simon (1955) with a view to the cognitive limitations of the human mind. At least since Selten (1978), the concept has broadened to encompass not only limitations of knowledge and computational capacity but genuinely different aspects such as motivation, adaptation and emotion.

theory, such as the equity premium puzzle, the status quo bias, various gambling and betting puzzles, inter-temporal consumption and the endowment effect. It can also be used to derive predictions concerning switching behavior.

In the domain of marketing, Folkes & Wheat (1995) observed changes in the perception of prices in dependence of pricing schemes. Mowen & Mowen (1991) developed a model of time and outcome valuation (TOV) that incorporates both theoretic considerations and empirical results from prospect theory and approach-avoidance-conflict theory (Miller (1959)).[20] By integrating the latter, the impact of time on the valuation process in win- and loss-frames can be explained. TOV assumes that the "S"-shaped function of prospect theory flattens over time with different gradients in the win- and in the loss-frame. Therefore, according to TOV both losses and gains in the future are "discounted" compared to immediate gains and losses, with different discount rates respectively. TOV can be used to derive predictions concerning differences between rebates and discounts.

5.3 The Experiment

5.3.1 Design

The experiment was conducted at the experimental laboratory of the University of Bonn (Bonn$E$con$L$ab) using a computer program based on z-Tree (Fischbacher (1999)). A total of 118 students ($N = 118$ independent observations) participated in the experiment. In all treatments participants were in the position of a retailer having to choose from what firm (A or B; C or B) to procure and what quantity to procure for the fourth quarter, i.e. $\tau = 4$. The fact that the quantity of the first three quarters had already been bought either from firm A (offering a rebate scheme) or firm C (offering a discount scheme) was imposed.[21]

A table containing the highest possible sales quantities for the last 10 years

[20] See also the empirical analysis by Juliusson et al. (2005) and Miller (1959).

[21] It is important to note that participants decided for the first time in the fourth quarter and that the decision for the first three quarters was attributed to another retail manager in the instructions and not to themselves. This presentation was explicitly chosen in order to reduce a possible confirmation or status quo bias (see for instance Samuelson & Zeckhauser (1988)) although such a bias can obviously not be excluded as the status quo bias may not only be based on cognitive dissonance.

was also available to the participants. This table was constructed according to the random variable X (cf. footnote 9), i.e. the table was constructed from a censored normally distributed variable (as will be described below, one half of the participants received a table with low variance and the other half a table with high variance - the expected demand was held constant).

In order to ensure that participants orientate themselves according to this random model, they were also informed that demand for the product is season independent, but that there are differences in demand per year, and that their marketing research department expects a quarterly demand corresponding to our random model, i.e. 300 units (for further details see the translated instructions in Appendix C.1).

Altogether, participants were assigned to 10 different treatments. The treatments were based on three different experimental factors that were partially crossed over (Scheme-condition (REBATE, DISCOUNT) x Variance-condition (LOW, HIGH) x Switch-condition (STRONG REMAIN, WEAK REMAIN, SWITCH)).

The following table summarizes the design of the experiment composed of two main stages. Participants were split up in two different *chronologies*. Half of the participants were in a rebate scheme (A) in the first stage and had to decide whether to switch to a linear scheme (B). The other half of the participants began with a discount scheme (C) and had to decide whether to switch to a linear scheme (B). After this decision they had to decide about the quantity they wanted to buy. Once that choice was made, they were asked to make a quantity decision based on the counterfactual, i.e. what quantity they would have chosen if they had not decided to remain or switch. In the second stage participants were confronted with the respective other scheme, i.e. discount instead of rebate and rebate instead of discount.

The second experimental factor in our design was the *variance* of demand, i.e. the highest possible sales during the last ten years. In both, the *high* and *low* condition, the average was held constant. This was made possible by constructing the demand table with high variance out of the low variance table by multiplying the distance from the average over ten years (300 units) with the factor 2.[22] For exam-

[22]Technically, such distributions can be created by taking standard-normalized values (with mean

ple, instead of 315 units in the fourth quarter 2005 in the low variance condition you find a value of 330 in the high variance condition.

Table 5.1: Overview of experimental treatments.

treat. (n)	**chronology**	**variance**	**optimal**
1 (12)	AB-CB	High	strong Remain
2 (12)	AB-CB	High	weak Remain
3 (11)	AB-CB	Low	strong Remain
4 (11)	AB-CB	Low	Switch
5 (12)	AB-CB	High	Switch
6 (12)	CB-AB	High	strong Remain
7 (12)	CB-AB	High	weak Remain
8 (12)	CB-AB	High	Switch
9 (12)	CB-AB	Low	strong Remain
10 (12)	CB-AB	Low	Switch

The third experimental factor concerned the quantities of the first three quarters that were manipulated in such a way that it would either be rational to *remain* within the rebate or discount scheme, or to *switch* to the linear scheme.

In the first stage participants were confronted with the actual realized sales in the first three quarters. Based on the three different treatment conditions: either more than $\frac{2}{3}$ (strong remain, $\sum_{t=1}^{\tau-1} q_t = 854$), exactly $\frac{2}{3}$ (weak remain, $\sum_{t=1}^{\tau-1} q_t = 800$) or less than $\frac{2}{3}$ (switch, $\sum_{t=1}^{\tau-1} q_t = 746$) of the total expected demand were sold in the first three quarters (and the rest was stocked).

If participants had chosen to continue to buy from the firm with the rebate or discount scheme this implied that participants could either buy a sufficiently large quantity to meet the yearly threshold in order to get an overall unit price of $(1-\alpha)w = 0.9$ or order a lower quantity entailing an overall unit price of $w = 1$. If participants choose to switch to the firm with the linear scheme, they would pay $v \equiv (1-\alpha)w = 0.9$ per unit for the quantity bought in the fourth quarter and $w = 1$ for the quantity bought in the first three quarters.

= 0 and variance = 1) and by transforming these z-values by multiplying them with a constant a and adding a constant b in condition 1 and by multiplying with a' ($a' > a$) and adding the constant b in condition 2. In our case, $a = 25$, $a' = 50$ and $b = 300$

After these two decisions [23] were made participants were asked to decide upon a quantity in the counterfactual.

Following these decisions, a number was randomly drawn. The random process corresponded to the model underlying the distribution of demand in the quarters. The number drawn determined the maximum potential sales for the fourth quarter at price $p^* = 1.5$. Participants were paid according to their decisions. If a higher quantity was bought than could be sold, the input costs were lost. If realized demand could not be met because an isufficiently high amount was bought, profits were foregone.

The second stage corresponded to the first stage, except for the scheme, that is, those in the rebate scheme were now in the discount scheme and vice versa.

The third stage of the experiment consisted in a measurement of risk preferences.[24]

5.3.2 Hypotheses

Our *central hypothesis* (c.f. Hypothesis 1 below) is the expectation that participants in both rebate and discount schemes develop a status quo bias that a non-behaviorally informed standard economic theory would not predict. This ‘status quo bias consists in a high reluctancy to quit rebate or discount schemes, even in the switch condition where it is rational to switch to the linear scheme. This expectation is based on the assumption that participants evaluate the situation as a *sunk cost* situation. If this assumption is adequate, a status quo bias in the discount and the rebate scheme that is due to the salience of the losses if the rebate scheme is left should be found.[25]

In addition to the central hypothesis, we expect a higher bias in the rebate condition compared to the discount scheme due to discounting effects of losses over

[23] The two decisions refer to the price scheme and the quantity decision.

[24] See Holt & Laury (2002). Since exactly the same instructions translated into German were used in order to elicit risk attitudes in the present experiment, we do not replicate the instructions here.

[25] Note that this is likely to be more pronounced in the field than in our experiment where participants had no influence on sales. With the possibility to influence sales at a given price, the perception that the threshold is within reach may be further strengthened.

time.[26] In the following we will motivate these expectations, that can essentially be derived from prospect or any other theory that postulates a convex transformation of payoffs.

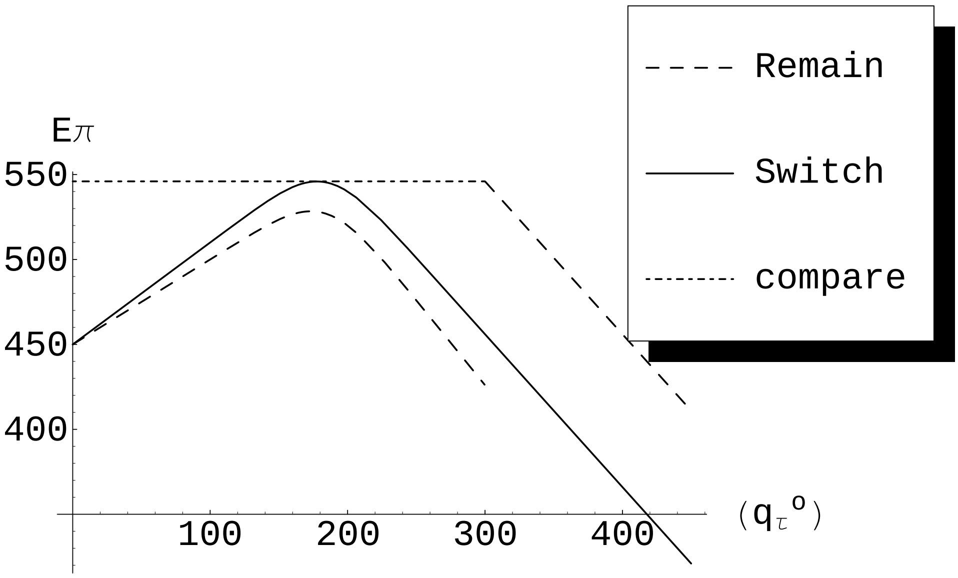
In our decision tasks, we conjecture that participants consider a negative payoff, i.e. the order payments. Therefore, we expect that participants are focussed on the loss-frame of the valuation function.[27] In other words, we conjecture that participants focus on the prices that have to be paid. From this point of view the following situation is salient for the participants: Either to change from the rebate/discount scheme into a linear price scheme and thus incur “a loss” (i.e. an additional (negative) payment of 90 units) with certainty (the lost rebates/discounts for three quarters), or to stay in the rebate/discount scheme and maintain the possibility to reduce the payments. In both *remain* conditions this consideration is optimal, in the *switch* condition, however, this consideration results in suboptimal decisions.

Both in rebate and in discount schemes participants have to compare the expected profits given they choose to remain in the rebate scheme with the profits in case of a switch to the linear price scheme. In our experiment the quantity to be ordered in τ depends only on the size of the stock in case of a switch as it is always optimal to purchase up to the threshold in the non-linear scheme. A salient difference between the linear price scheme and the rebate/discount scheme is that the decision to switch to B is a decision that implies an additional cost of 90 (i.e. 0.1×900) with certainty. Furthermore, a switching decision allows to order the optimal quantity without regard to the threshold. In contrast, the decision to remain in the rebate/discount scheme corresponds to a decision, where the quantity ordered is not optimal but may allow higher profits through two channels. First, a higher quantity increases expected sales (this is due to the fact that at most the total available quantity can be sold) and second, the rebate/discount advantage over the quantity bought in the past is not lost. Now consider the point where expected profits in both schemes are equal, i.e. the indifference point. In our sce-

[26]Remember the framing difference between rebate and discount scheme, i.e. the respective risk of either not getting the rebate (A) or having to pay back the discount already received (C).

[27]It is misleading to tag this part of the valuation-function as “loss-frame”. Prospect-theory maps payoffs on subjective valuations of these payoffs. Negative payoffs are not necessarily “losses”. For example, investments can be analyzed with prospect theory as well, for instance in studies of the Concorde fallacy (sunk cost fallacy).

Figure 5.2: Expected payoffs at the indifference point ($\sum_{t=1}^{\tau-1} q_t = 784$) in the low variance condition.



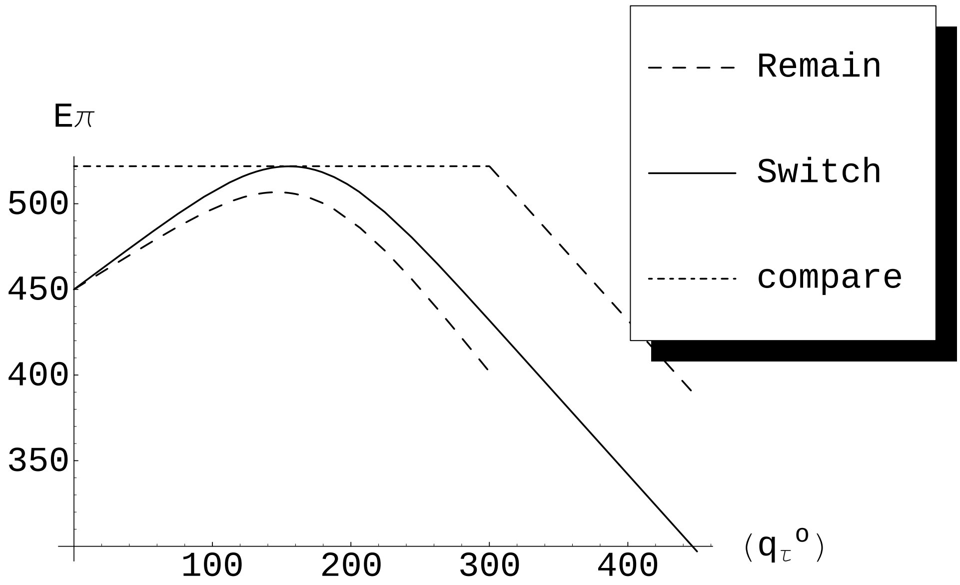
nario this point corresponds to a quantity sold in the first three quarters of the year of $\sum_{t=1}^{\tau-1} q_t = 784$ with $s_\tau = 116$ for the low variance condition (see figure 5.2) and $\sum_{t=1}^{\tau-1} q_t = 768$ with $s_\tau = 132$ for the high variance condition (see figure 5.3).[28] Both figures depict expected profits as a function of q_τ^o. The continuous function in each figure depicts the expected profits under the linear scheme (i.e. implying a switch) and the function with the discontinuity at $q_\tau^o = 300$ represents the expected profits under the rebate or discount scheme.

Due to identical expected profits at the indifference point, both options are on one and the same point of prospect theory's valuation function within the loss-frame.[29] The participant's decision to change into the linear price scheme, where

[28] The optimal q_τ^o is calculated by taking the derivative with respect to q_τ^o of equation 5.3 (note that $q_R^* = s_\tau + q_\tau^o$) as the optimal order quantity under the rebate scheme is always $q_\tau^o = 300$ in this experiment. Inserting the optimal order quantities in both expected profit equations (5.2 and 5.3) and setting them equal yields the sales quantity $\sum_{\tau=1}^{\tau-1} q_t$ at which both schemes result in identical expected profits.

[29] In figure 5.2 expected profits in both schemes are 546 if the corresponding optimal quantities

Figure 5.3: Expected payoffs at the indifference point $(\sum_{t=1}^{\tau-1} q_t = 768)$ in the high variance condition.



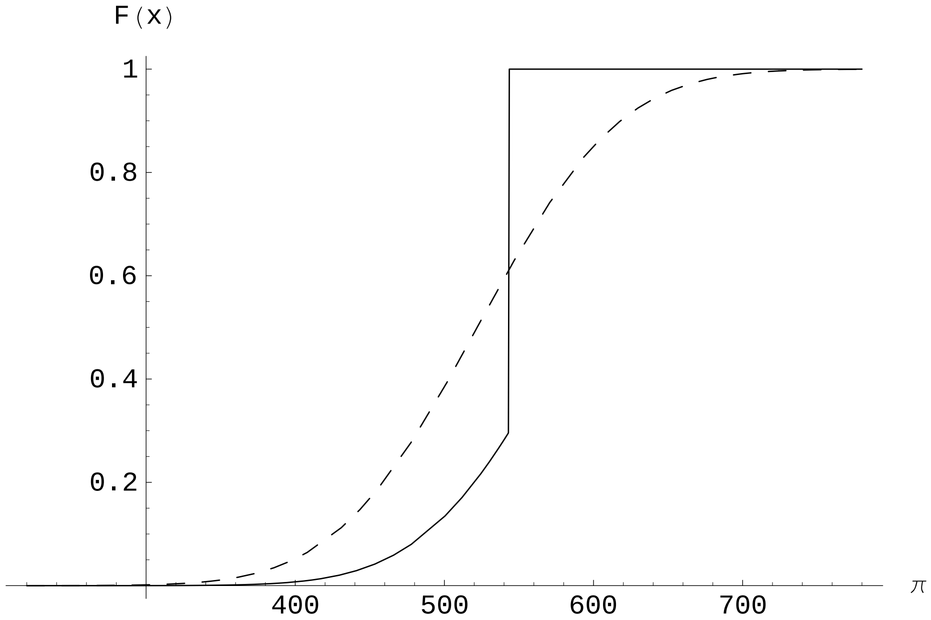
the optimal quantity to buy in the fourth quarter is always $q_t^o = 294 - s_\tau = 178$ for the low variance condition and $q_t^o = 287 - s_\tau = 155$ for the high variance condition, is also a decision to incur a loss with certainty. In this case, the sunk costs are eliminated and an optimal quantity for the fourth quarter can be planned. However, the participants decision to remain in the rebate/discount scheme leaves a chance to reduce the losses. Figure 5.4 gives the two density functions/probabilities for the expected losses in case of remaining in the rebate scheme versus switching if the optimal quantities are purchased (high variance condition). Expected profits are 522 under both schemes.

Thus, our experiment gives an interesting extension of classic lottery experiments, because the choice to remain in the rebate/discount scheme does not merely consist in either paying a fixed amount with probability ρ or paying another fixed value with probability $1 - \rho$, but that both the area of lower profits and the area of higher profits are partly continuously distributed.

Hypothesis 1: In line with prospect theory we expect risk-seeking behavior

are purchased. In figure 5.3, expected profits are 522.

Figure 5.4: Choice at the indifference point under the high variance condition.



Note: The solid cumulative density function represents the linear price scheme. It jumps at 543*. The area under this cumulative density function to the left of* 543 *is* 0.4 *and* 0.6 *to the right. The dashed cumulative density function represents the non-linear scheme.*

at the indifference point, because losses loom larger than gains. Therefore, given two price schemes A (or C) and B such that rational actors should be indifferent between the two options, we expect a preference for choosing option A or C - the rebate or discount scheme - because in this case losses (i.e. a higher price for the units of the first quarters) have not yet been realized and the chance to compensate losses by gains is maintained. We expect that this tendency is strong enough to find a reluctancy to switch to the linear price scheme even if this were the optimal choice. In other words, we expect that a substantial proportion of participants in the *switch* condition remain within the rebate or discount scheme, although this is not an optimal choice and that this proportion is above a common error level. We also expect that participants in the two *remain* conditions have a strong tendency to remain in the rebate or discount scheme.

The analysis so far does not allow distinct predictions for rebate and discount schemes. The analysis is also independent of the exact point participants focus on as long as they are in the "loss-frame". This makes our predictions rather general and robust against differences in anchors. Our interpretation of prospect theory's valuation function is non-parametric and does, therefore, not entail any estimation of parameters.[30] As a result, any arbitrary *convex* transformation of payoffs would yield the same predictions.

Hypothesis 2: The following hypothesis is much more sensitive with respect to foci (i.e. salient features) that are set within the instruction set. It is derived from the TOV model due to Mowen & Mowen (1991) who conjecture that both, gains and losses are discounted over time. As a consequence, the moment in time where losses are realized is relevant. According to our *time framing hypothesis* we expect stronger effects in rebate than in discount schemes because in the former losses are immediate, whereas in the latter there is a time lag between the decision and the loss.[31] In other words, the price $v \equiv (1-\alpha)w$ is paid right from the start in discount schemes whereas in rebate schemes a price $w > v$ is paid.

An alternative explanation could postulate different anchors of discount compared to rebate schemes within the valuation function of prospect theory. In this case, the assumption is that in case of the rebate scheme the participants have invested to earn the rebate. This would be sunk costs and this is why they should stick to their earlier decision, whereas in case of the discount scheme they risk an additional out of pocket payment. This should lead to risk-averse behavior and higher orders. Based on our setting, such different anchors are implausible, because we tried to prevent the sunk-cost-phenomenon as much as possible by instructing participants that they are new in the firm and make their decision for the first time (cf. footnote 21). Furthermore, this hypothesis does not imply an exact prediction of the strength of the effects of the discount-scheme compared to the rebate-scheme, because in both cases participants should buy more and the loss aversion in case of the discount-scheme should lead - seemingly paradoxically - to risk-seeking behavior, i.e. increased orders to prevent from losses. In summary, this type of explanation postulates two different mechanisms that are at work in case of the discount-scheme compared to the rebate-scheme, but both mechanisms lead to

[30] We only need the properties of the shape of the function not its functional form.

[31] Note, that although this time lag might be relevant in practice, in our experiment this lag consisted in 1) the understanding of the instructions and thus the imagined time lag and 2) in a minimal lag in the discount condition because the loss is not immediate but only becomes apparent with the next feedback form the participant receives.

similar effects and estimating such effects requires an exact parametrization of the mechanisms. On the other hand, TOV allows clear comparisons between rebate and discount schemes and makes clear predictions. We expected corresponding effects in our experiment.

Hypothesis 3: Besides the hypotheses mentioned above, we were also tentatively interested in the influences of risk-seeking and risk-averse behavior in such price schemes. Therefore, we introduced an experimental variation of variances. We also used a test that measures risk attitudes. Measuring risk preferences is also important from a theoretical point of view because neoclassical theory now typically involves conditional predictions that depend on risk attitudes.[32] Due to the fact that higher variances incorporate higher risks we should find some differences between the situation with a high variance compared to the situation with a low variance, because risk-aversion should be more pronounced in the situation with a high variance.

5.3.3 Experimental Results

Besides the general confirmation of our hypotheses we found a high amount of suboptimal decision making, leading to a high "noise"-rate. Given the complexity of the task, this is not overly surprising. The total error rate of suboptimal switches (instead of remaining) and suboptimal remaining (instead of switching) is 29% ($N = 118$) in the first stage, 27% ($N = 118$) in the second stage and 28.0% ($N = 236$) overall.[33] A total of 8 participants, that is, 6.78% ($N = 118$) of all participants made mistakes in both stages, 26 participants, that is, 22% ($N = 118$) made mistakes in the first stage and slightly less, 24 participants, that is, 20.34% ($N = 118$) in the second stage. Considering participants that at any moment

[32] It is not clear, however, whether such attitudes should be understood as a personal trait or as a disposition mostly triggered by the situation (i.e. a personal state).

[33] In a follow up study we would adapt our instructions by making it more salient that there may be good contextual reasons for the order strategies of the predecessor such as capacity constraints or simply that it was reasonable to order from A or C because the alternative firm could not offer this price from the beginning. Ex post we believe that some of our participants may have been irritated by the fact that the alternative firm offers the same price without any further conditions for the fourth quarter and that no plausible explanation for the ordering behavior in the previous quarters was given. If this conjecture is right, reactance may have caused at least part of the high noise-rate.

during the experiment either remained in the non-linear scheme and ordered less than 300 or switched and ordered more than 300, as inconsistent, 26 participants of 118 fall in that category.

Our central hypothesis concerns status quo biases created by rebate or discount schemes. In the weak remain condition we found only 11 participants, that is, 45.83% ($N = 24$) that switched to a linear price scheme while in the strong remain condition only 18 participants, that is, 38.3% ($N = 47$) switched at least once. Furthermore, we expected that the error rate is even higher in those cases where it would be optimal to switch from a rebate or discount scheme into the linear price scheme. Indeed, in this case 29 participants, that is, 61.7% of all ($N = 47$) participants remained at least once in the rebate or discount scheme although it would have been optimal to switch to the linear price scheme.

Result 1: Testing the independence of the rates of optimal or suboptimal behavior and the switch-conditions (where it is either optimal to stay or optimal to switch) using a 3 and a 4 category measure[34] yields a weakly significant result ($p \leq 0.091$; two-sided; $N = 118$) based on a Fisher exact test for the 3 categories measure and a weakly significant result ($p \leq 0.080$; two-sided; $N = 118$) based on a Fisher exact test for the 4 categories measure.[35]

A more detailed analysis of the switch conditions comparing strong remain vs. switch yields a significant result in the 3 categories measure ($p \leq 0.028$; two-sided; $N = 118$) and a weakly significant result in the 4 categories measure ($p \leq 0.064$; two-sided; $N = 118$) using a Fisher exact test.[36] Therefore, it could be demonstrated that besides the high error rates that can be observed in our scenario we find a status quo bias that keeps participants from switching into the linear

[34]In order not to violate independence requirements in the statistical analysis, the data cannot simply be pooled but optimal and suboptimal behavior in both stages has been coded in the following two ways. In the 3 categories measure there are participants who never switched, those who switched twice and those who switched once. In the 4 categories measure, a further distinction between participants who switched once is made based on in what stage the switch occurred.

[35]The corresponding χ^2 tests yield ($\chi^2 = 8.465$; $p \leq 0.074$; $N = 118$) based on the 3 categories measure and ($\chi^2 = 11.596$; $p \leq 0.069$; $N = 118$) based on the 4 categories measure; both weakly significant.

[36]The corresponding χ^2 tests are ($\chi^2 = 7.342$; $p \leq 0.026$; $N = 118$) and ($\chi^2 = 7.343$; $p \leq 0.062$; $N = 118$).

scheme.

Result 2: We could not find a higher "attraction" effect within the first stage rebate condition compared to the first stage discount condition (34.78% versus 41.67%, $N = 47$).[37]

Result 3: A closer look at the variance conditions also yielded the interesting result, that errors are more frequent in the high variance condition. Whereas in the low variance condition 47.83% of all participants made a mistake neither in the first nor in the second stage, only 29.17% of participants were error free in the high variance condition.[38] This could be attributed to the fact that a higher available quantity is subjectively perceived as being more attractive under high variance of demand because it reduces the perceived risk of not being able to fully serve demand.

Result 4: With respect to risk preferences, we were unable to find any correlation between decisions in the main experiment and the particular risk attitude test applied, suggesting that risk preferences are a state rather than a personal trait.

5.4 Conclusion

In the experiment conducted we found that discount and rebate schemes as defined in this paper exert an "attraction" on participants. This status quo bias is in line with prospect theory or any alternative theory that postulates a convex transformation of payoffs.

The experimental findings presented indicate that standard economic theory relying on risk neutral profit maximizing behavior tends to underestimate the effects of rebate and discount schemes on customer behavior. This is in line with recent experimental findings in Operations Research analyzing single period stochastic inventory problems. In the experimental literature on the newsvendor problem with low profit products procurement quantities were also found to be higher than

[37]Note that in order not to violate independence, the first and second stage cannot be pooled. As second stage results are potentially influenced by first stage decisions, the comparison focusses on the first stage. The percentages of the second stage, arguably made by more experienced participants, do, however, suggest a higher "attraction" effect within the rebate condition compared to the discount condition (45.84% versus 26.09%, $N = 47$).

[38]Note, however, that neither the Fisher exact, nor the χ^2 test are significant.

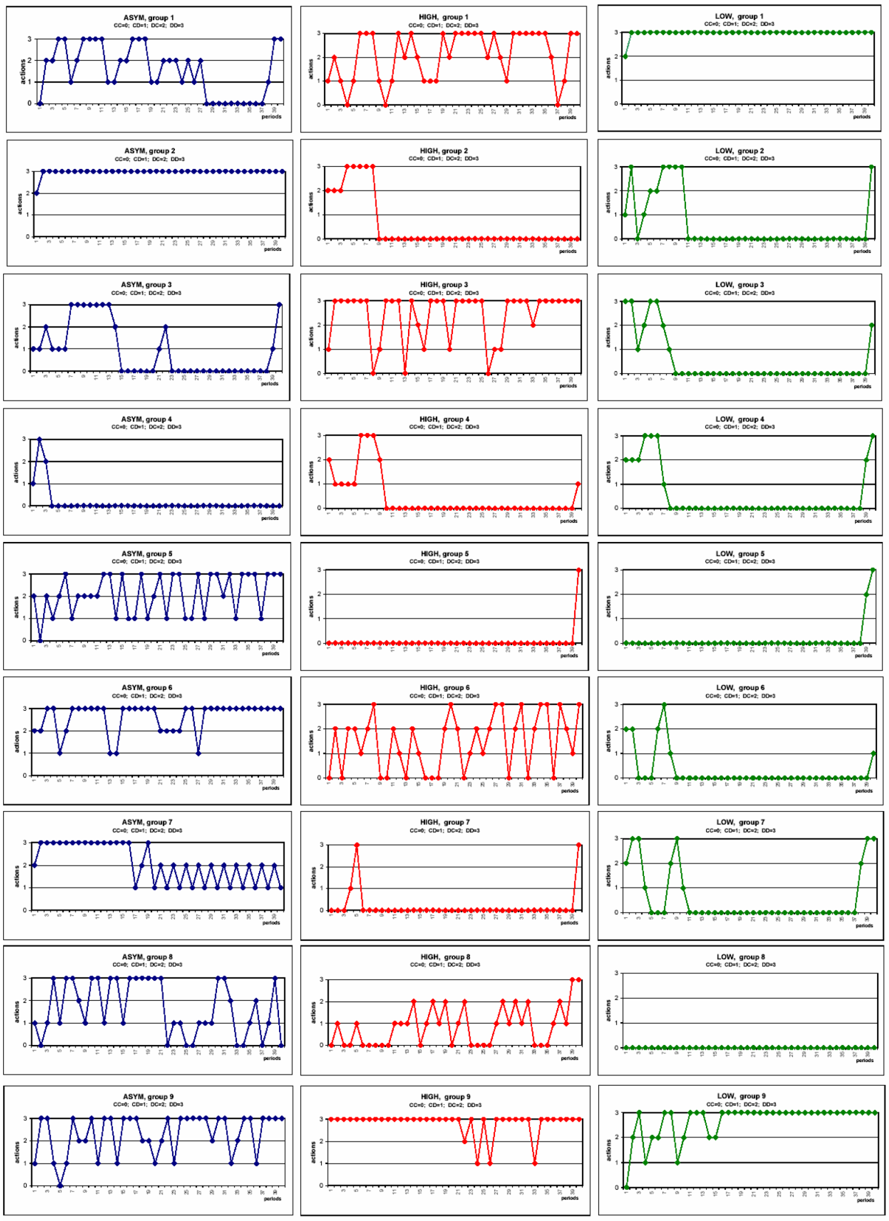
expected profit maximizing quantities.

Concerning the external validity of these findings one has to bear in mind, for example, that the analysis focusses on individual decision-making whereas decisions in firms are typically the outcome of a corporate decision-making process. Whether a corporate decision-making process improves or reduces “rationality” remains highly debated in the literature and appears to depend largely on the exact circumstances of the process. Based on the strength of the effects found, we would, however, be surprised not to encounter similar decision patterns in a corporate environment.

Finally, we believe that part of the recent surge in non-linear pricing especially in relations with non-professional buyers may be due to the behavioral effects identified in this paper. If empirical evidence of a status quo bias in certain non-linear pricing schemes is further corroborated, such effects may not only play an important role in the design of pricing schemes but should also be taken into account in the design of consumer protection and competition policy. An interesting extension of this paper would be to experimentally distinguish between a (possibly less pronounced) status quo bias in a linear scheme versus the “attraction” exerted by the non-linear schemes discussed.

A Appendix

A.1 Choices in all Dyads



A.2 Instructions

[In All Treatments]

Note:

- You have 5 minutes to read the instructions. If you have any questions after you have read the instructions, please contact one of the experimenters. Communication with other participants is not allowed during the experiment.
- After the 5 minutes you will be asked to fill out a test questionnaire about the experiment you will be part in. Once all participants have correctly answered all questions, the experiment will start.
- After completion of the experiment you will be asked to complete a computerized questionnaire
- Please do not leave your seat before you have filled out the questionnaire and your terminal number has been announced

The experiment:

The experiment consists of a decision situation in which you and another person will choose between A and B for 40 periods. Your position as well as the person you are interacting with is randomly assigned to you at the beginning of the experiment. The decision situation, as well as the person you interact with is identical in each period. You will see the decision made by the other person in each period after you made your own decision.

In each period, by deciding between a choice of A or B, you can decide the amount of Taler that you and the other person will receive. The following graph depicts the decision screen, you will see during the experiment.

In the left half you see the consequences of your own two decision options and below your decision buttons.

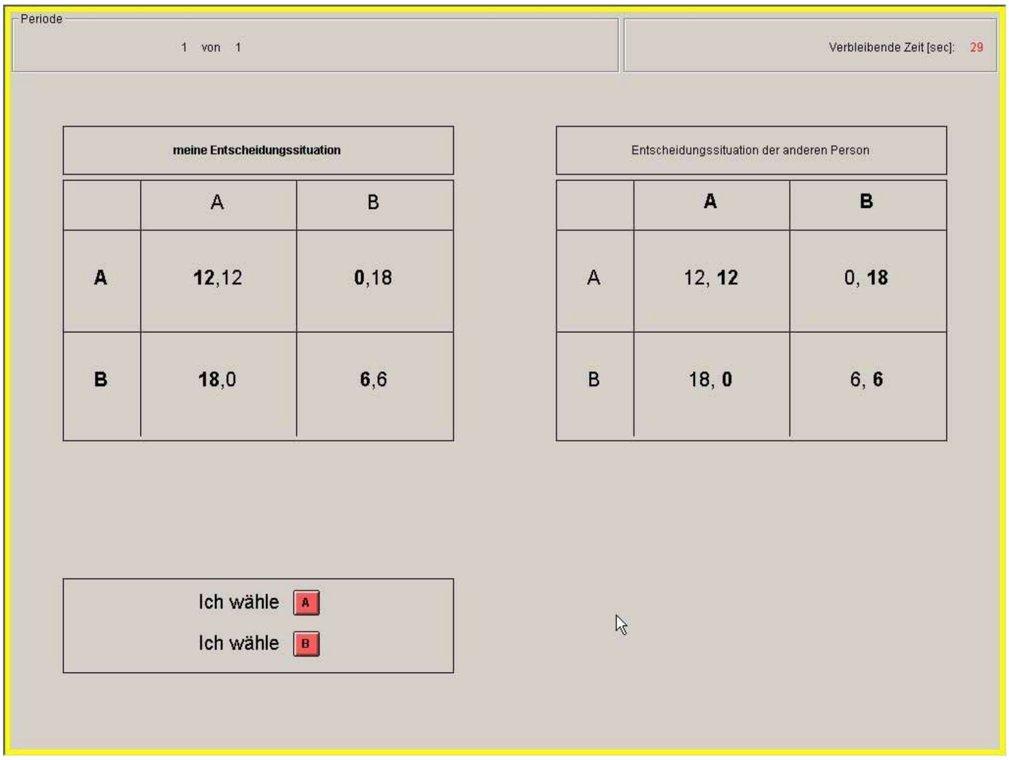
In the right half of the screen you see the decision options of the other person.

[In the LOW treatment only]

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you both receive 8.
- If you choose B and the other person as well, you both receive 4.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 12.
- If you choose B and the other person chooses A you receive 12 and the other person receives 0.

[In the HIGH treatment only]



The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you both receive 12.
- If you choose B and the other person as well, you both receive 6.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 18.
- If you choose B and the other person chooses A you receive 18 and the other person receives 0.

[In the ASYM treatment for the low-type player only]

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you receive 8 and the other person receives 12.
- If you choose B and the other person as well, you receive 4 and the other person receives 6.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 18.
- If you choose B and the other person chooses A you receive 12 and the other person receives 0.

[In the ASYM treatment for the high-type player only]

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you receive 12 and the other person receives 8.
- If you choose B and the other person as well, you receive 6 and the other person receives 4.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 12.
- If you choose B and the other person chooses A you receive 18 and the other person receives 0.

[In all treatments] After each period you will be given information on: your last decision, the last decision of the other person, the number of Talers you earned in the last period, and the total number of Talers you have earned so far.

Payment:

The total number of Taler earned will be paid out anonymously to you at the end of the experiment 1 Taler corresponds to 0.04 Euro.

Thank you very much for your participation!

A.3 The Computerized Questionnaire

Question	Question
1	Terminal number?
2	Major?
3	Job?
4	Semester?
5	Age?
6	Sex?
7	Did you ever take a microeconomics course?
8	Did you ever take a game theory class?
9	Please describe briefly the reasons for your choices
10	Did your decision behavior change during the experiment? If yes, how?
11	I believe that the main goal of this experiment was to maximize my own advantage [I fully agree, I strongly disagree]
12	I believe that the main goal of this experiment was to maximize the group advantage [I fully agree, I strongly disagree]
13	What daily life situation did this experimental situation remind you of the most?
14	You now have the opportunity to formulate any additional comments, suggestions or criticism you may have

A.4 Test Questions

- How high is the profit of the other person, if she chooses A and you too?
- How high is your profit, if you choose B and the other person A?
- How high is the profit of the other person, if she chooses A and you B?
- How high is your profit, if you choose A and the other person too?
- How high is the profit of the other person, if she chooses B and you too?
- How high is your profit, if you choose B and the other person too?
- How high is the profit of the other person, if she chooses B and you choose A?
- How high is your profit, if you choose A and the other person chooses B?

B Appendix

B.1 The Written Instructions For Treatment Cng

Note:

- You have 5 minutes to read the instructions. If after reading the instructions you have any question, please contact one of the experimenters. Communication with other participants is not allowed during the experiment.
- After the 5 minutes you will be asked to fill out a test questionnaire about the experiment. Once all participants have correctly answered all questions, the experiment will start.
- After completion of the experiment you will be asked to fill out a computerized questionnaire.
- Please do not leave your seat before you have filled out the questionnaire and your terminal number has been announced.

The experiment: The experiment is composed of two phases.

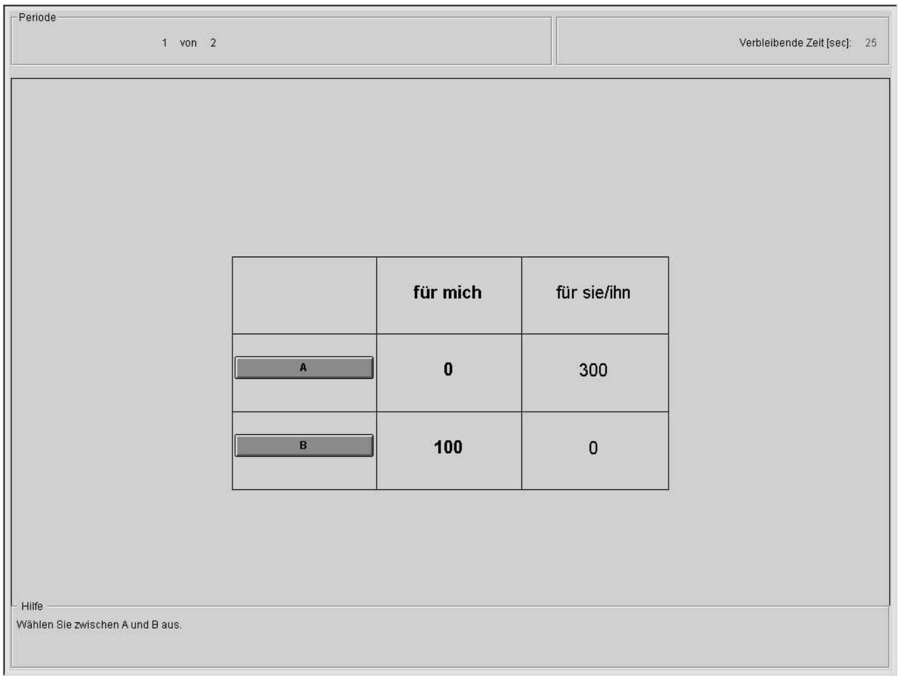
In phase I you have the choice between two experimental situations. Both experimental situations have the following in common:

- You play during 20 periods with another person. The decision situation, as well as the other person are identical in each period.
- You have to choose between A and B in each one of the 20 periods.
- The amount of Talers you earn in each period depends on your decision, and the decision of the other person.
- In each period, you will not know the choice of the other person before you have made your own choice.

- After each period you will be given information on: your last decision, the last decision of the other person, the number of Talers you earned in the last period, and the total number of Talers you have earned so far.

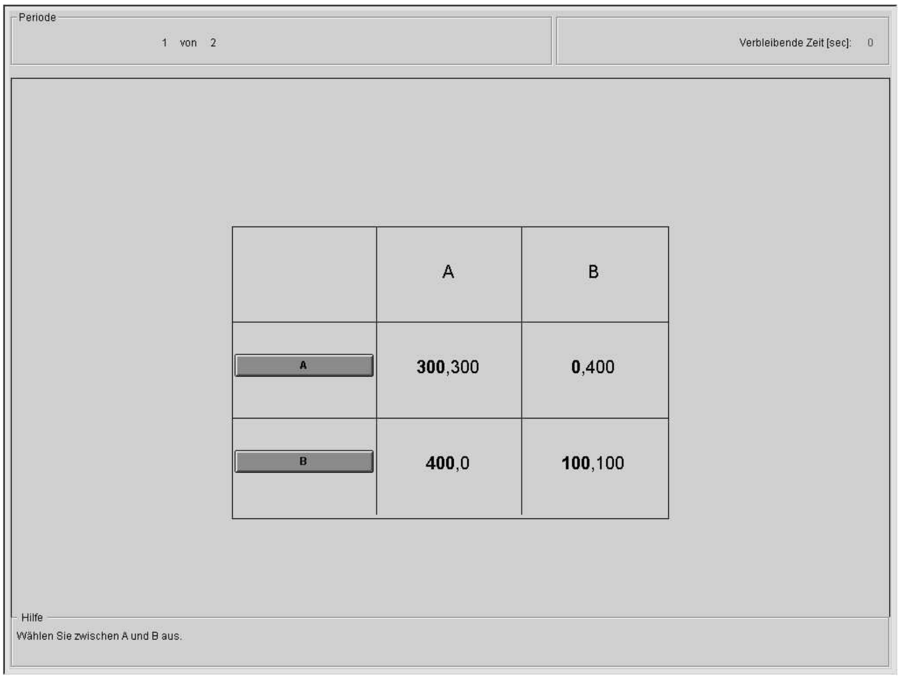
Particular to Decision Situation I:

Every period you will have the opportunity to decide how many Talers you give to yourself and how many Talers you give to the other person by choosing between A and B. The Talers you earn in one period are determined by the amount of Talers you give to yourself plus the amount of Talers the other person gives to you. The other person faces exactly the same decision situation.



- If you choose A you give 0 to yourself and 300 to the other person.
- If you choose B you give 100 to yourself and 0 to the other person.
- If the other person chooses A, he/she gives you 300 and 0 to him/herself.
- If the other person chooses B, he/she gives you 0 and 100 to him/herself.

Particular to Decision Situation II:



- If you choose A and the other person as well, you both get 300.
- If you choose B and the other person as well, you both get 100.
- If you choose A and the other person chooses B, you will get 0 and the other person will get 400.
- If you choose B and the other person chooses A you will get 400 and the other person will get 0.

In Phase II after you have decided what experimental situation you would like to participate in, you will be randomly paired with a participant who choose the same experimental situation.

In case the number of participants who choose a particular experimental situation is odd, a randomly determined participant will have to leave the experiment. This person receives Euro 4.

Payment:

You will be privately paid on the basis of the total Talers accumulated in all the experiment. 1000 Taler equal 2 Euro.

Thank you very much for your participation!

C Appendix

C.1 Instructions

[all]

In the following experiment you will be in the role of a newly hired procurement manager of a retailer for the year 2005. This retailer sells a product of daily use. The sales of the product are not subject to seasonal fluctuations. There are no indications for changes in the market. Your role consists in generating profits for the retailer in the year 2005. Your sales price is fixed at 1,50 ECU. Your remuneration in this experiment is based on the profits of the retailer transformed into Euro based on an exchange rate. Given that the sales price is given, the procurement price (see section I) and the sales quantity (see section II) is crucial in determining profits.

I. PROCUREMENT

[Instructions CB only]

You have the choice between firm C and firm B to procure the product. Firm C offers a discount of 10% and B offers a constant price.

Firm C offers the following discount: The discounted price per unit is 0,90 ECU. If you procure at least 1200 units from that firm within the year, you do not have to repay the discount of 0,10 ECU per unit, that you would otherwise have to repay for every unit received at discounted price.

[Instructions AB only]

You have the choice between firm A and firm B to procure the product. Firm A offers a rebate of 10% and B offers a constant price.

Firm A offers the following rebate: The price per unit is 1,00 ECU. If you procure at least 1200 units from that firm within the year, you receive a rebate of 0,10 ECU per unit for all units bought within the year, otherwise your price remains at 1,00 ECU per unit.

[all]

Firm B offers the following price: Irrespective of the quantity you procure within the year, you always pay 0,90 ECU per unit.

As new manager of procurement in your retail company, you decide for the first time in the 4th quarter 2005 from what company you would like to order and how many units you would like to order. For your decision it is important to note that 900 units where bought from

[Instructions CB only]

Firm C in the first three quarters at the preliminary price of 0,90 ECU.

Examples:

- If you decide to procure 300 units from firm C in the 4th quarter, you pay 270 ECU for the last 300 units. For the total year, you have procured 1200 units and paid 1080 ECU.
- If you decide to procure 300 units from firm B in the 4th quarter, you pay 270 ECU for the last 300 units. Since overall you bought less than 1200 units from firm C, you have to repay the discount of 90 ECU to firm C. For the total year, you have paid 1170 ECU.
- If you decide to procure 150 units from firm C in the 4th quarter, you pay 135 ECU for the last 150 units. Since overall you bought less than 1200 units from firm C, you have to repay the discount of 105 ECU to firm C. For the total year, you have paid 1050 ECU.
- If you decide to procure 150 units from firm B in the 4th quarter, you pay 135 ECU for the last 150 units. Since overall you bought less than 1200 units from firm C, you have to repay the discount of 90 ECU to firm C. For the total year, you have paid 1035 ECU.

[Instructions AB only]

Firm A in the first three quarters at the preliminary price of 1 ECU.

Examples:

- If you decide to procure 300 units from firm A in the 4th quarter, you pay 300 ECU for the last 300 units minus the rebate of 10% on all 1200 units. This is a rebate of 120 ECU. As a result you have to pay 180 ECU for the 300 units bought in the 4th quarter. For the total year, you have procured 1200 units and paid 1080 ECU.
- If you decide to procure 300 units from firm B in the 4th quarter, you pay 270 ECU for the last 300 units. Since overall you bought less than 1200 units from firm A, do not qualify for the rebate. For the total year, you have paid 1170 ECU.
- If you decide to procure 150 units from firm A in the 4th quarter, you pay 150 ECU for the last 150 units. Since overall you bought less than 1200 units from firm A, you do not qualify for the rebate offered. For the total year, you have paid 1050 ECU.
- If you decide to procure 150 units from firm B in the 4th quarter, you pay 135 ECU for the last 150 units. Since overall you bought less than 1200 units from firm A, you do not qualify for the rebate offered. For the total year, you have paid 1035 ECU.

[all]

II. SALES

As procurement manager you have to estimate how many units you will be able to sell and procure units accordingly. In the appendix you find quarterly demand information of the last 10 years. During the experiment you will receive the sales information of the first three quarters of 2005. After your decision you will be informed about demand in the fourth quarter. As mentioned before, 900 units have been procured in the first three quarters of 2005. This corresponds to 300 units per quarter as calculated by your market research department. Despite demand fluctuations in every quarter demand is expected to be 300 units on average per quarter. Your market research department could not identify seasonal fluctuations and there exists no pattern in yearly fluctuations either. Concerning your quarterly demand, you should therefore orient yourself on a sales volume of 300 units irrespective of any information. At the beginning of 2005 your stocks were empty. If demand in the first three quarters was below 900 units you have stocks. It is now your task to decide from what firm to buy and how many units to buy there based on information on sales and current stocks

III. PROFIT CALCULATION

Profit is calculated from yearly procurement and sales. The number of sold units is multiplied with the sales price of 1,50 ECU. In order to obtain the profits, the costs of all procurement are deducted from that amount. Positive stocks are lost at the end of the 4th quarter.

If you do not have any further questions, please click on START. You will then be asked to fill out control questions

Once you have answered the control questions, please wait until the experiment is started.

The sales situation in the last 10 years was:

[all High Variance]

year	**quarter**	**demand (highest possible sales)**
1996	1	276
	2	54
	3	540
	4	30
1997	1	126
	2	252
	3	552
	4	192
1998	1	474
	2	54
	3	336
	4	570
1999	1	90
	2	210
	3	324
	4	132
2000	1	504
	2	540
	3	366
	4	228
2001	1	462
	2	420
	3	288
	4	228
2002	1	582
	2	312
	3	282
	4	360
2003	1	492
	2	438
	3	0
	4	378
2004	1	18
	2	336
	3	360
	4	330

[all Low Variance]

year	quarter	demand (highest possible sales)
1996	1	288
	2	177
	3	420
	4	165
1997	1	213
	2	276
	3	426
	4	246
1998	1	387
	2	177
	3	318
	4	435
1999	1	195
	2	255
	3	312
	4	216
2000	1	402
	2	420
	3	333
	4	264
2001	1	381
	2	360
	3	294
	4	264
2002	1	381
	2	360
	3	294
	4	264
2003	1	396
	2	369
	3	150
	4	339
2004	1	159
	2	318
	3	330
	4	315

Bibliography

Anderson, S. P., Goeree, J. K. & Holt, C. A. (1998), 'A theoretical analysis of altruism and decision error in public goods games', *Journal of Public Economics* **70**, 297–323.

Andreoni, J. (1995a), 'Cooperation in Public Goods Experiments: Kindness or Confusion?', *American Economic Review* **85**(4), 891–904.

Andreoni, J. (1995b), 'Warm-glow versus cold-prickle: The effects of positive and negative framing on cooperation in experiments', *Quarterly Journal of Eonomics* **110**, 1–21.

Andreoni, J. & Miller, J. H. (1993), 'Rational cooperation in the finitely repeated prisoner's dilemma: Experimental evidence', *Economic Journal* **103**, 570–585.

Andreoni, J. & Varian, H. (1999), 'Preplay contracting in the prisoners' dilemma', *Proceedings of the National Academy of Sciences of the United States of America* **96**, 10933–10938.

Apesteguia, J. (2006), 'Does information matter in the commons? experimental evidence', *Journal of Economic Behavior and Organization* **60**, 55–69.

Arrow, K., Harris, T. & Marschak, J. (1951), 'Optimal inventory policy', *Econometrica* **19**, 250–272.

Axelrod, R. (1984), *The Evolution of Cooperation*, Basic Books, New York.

Babcock, L. & Loewenstein, G. (1997), 'Explaining bargaining impasse: The role of self-serving biases', *Journal of Economic Perspectives* **11**(1), 109–126.

Babcock, L., Loewenstein, G., Issacharoff, S. & Camerer, C. (1995), 'Biased judgements of fairness in bargaining', *American Economic Review* **85**(5), 1337–1343.

Beckenkamp, M. (2002), *Sanktionen im Gemeingutdilemma*, Beltz Verlag, Weinheim, Basel.

Beckenkamp, M. (2006), 'A game theoretic taxonomy of social dilemmas', *Central European Journal of Operations Research* **14**, 337–353.

Beckenkamp, M., Hennig-Schmidt, H. & Maier-Rigaud, F. P. (2006), Framing in symmetric and asymmetric prsisoner's dilemma games, Technical report, Max Planck Institute for Research on Collective Goods.

Beckenkamp, M. & Maier-Rigaud, F. P. (2006), 'An experimental investigation of Article 82 rebates', *Competition Law Review* **2**(2), 1–31.

Beckenkamp, M. & Ostmann, A. (1999), Missing the target? sanctioning as an ambiguous structural solution, *in* M. Smithson, ed., 'Resolving Social Dilemmas', Taylor and Francis, pp. 165–180.

Ben-Zion, U., Cohen, Y., Peled, R. & Shavit, T. (2005), Decision-making and the newsvendor problem - an experimental study, Technical report.

Binmore, K. (1992), *Fun and Games. A Text on Game Theory*, Lexington, MA: Heath.

Bohnet, I. & Kübler, D. (2005), 'Compensating the cooperators: Is sorting in the prisoner's dilemma possible?', *Journal of Economic Behavior and Organization* **56**, 61–76.

Bolton, G. E. & Katok, E. (2005), Learning-by-doing in the newsvendor problem, Technical report, Penn State University.

Bolton, G. E. & Ockenfels, A. (2000), 'A theory of equity, reciprocity and competition', *American Economic Review* **100**, 166–193.

Bossert, W., Pattanaik, P. & Xu, Y. (1994), 'Ranking opportunity sets: An axiomatic approach', *Journal of Economic Theory* **63**, 326–346.

Botelho, A., Harrison, G., Costa Pino, L. M. & Rutström, E. E. (2005), Testing static game theory with dynamic experiments: A case study of public goods, Technical report, University of Central Florida.

Bowles, S. (2003), *Microeconomics: Behavior, Institutions, and Evolution*, Princeton University Press, Princeton.

Brandts, J. & Schram, A. (2001), 'Cooperation and Noise in Public Goods Experiments: Applying the Contribution Function Approach', *Journal of Public Economics* **79**, 399–427.

Brenner, T. & Hennig-Schmidt, H. (2006), Belief learning in the prisoner's dilemma game - an experimental study of cognitive processes, Technical report, University of Bonn.

Brewer, M. B. & Kramer, R. M. (1986), 'Choice behavior in social dilemmas: Effects of social identity, group size, and decision framing', *Journal of Personality and Social Psychology* **50**, 543–549.

Brown, A. O. & Tang, C. S. (2000), Decisions, operations, and technology management, Technical Report CT30, UCLA, Anderson Graduate School of Management.

Budescu, D. V. & Au, W. T. (2002), 'A model of sequential effects in common pool resource dilemmas', *Journal of Behavioral Decision Making* **15**, 37–63.

Budescu, D. V., Rapoport, A. & Suleiman, R. (1995), 'Common pool resource dilemmas under uncertainty: Qualitative tests of equilibrium solutions', *Games and Economic Behavior* **10**, 171–201.

Cadsby, C. B., Song, F. & Tapon, F. (2004), The effects of compensation schemes on self-selection and work productivity: An experimental investigation, Technical report. Working Paper.

Camerer, C. (2003), *Behavioral Game Theory*, Princeton University Press, Princeton.

Casari, M. & Plott, C. R. (2003), 'Decentralized management of common property resources: Experiments with a centuries old institution', *Journal of Economic Behavior and Organization* **51**, 217–247.

Chan, K., Mestelman, S., Moir, R. & Muller, A. (1996), 'The voluntary provision of public goods under varying income distributions', *Canadian Journal of Economics* **29**, 54–69.

Charness, G. (2000), 'Bargaining efficiency and screening: An experimental investigation', *Journal of Economic Behavior and Organization* **42**, 285–304.

Charness, G., Frechette, G. R. & Kagel, J. H. (2004), 'How robust is laboratory gift exchange?', *Experimental Economics* **7**, 189–205.

Charness, G., Fréchette, G. R. & Qin, C.-Z. (2007), Endogenous transfers in the prisoner's dilemma game: An experimental test of cooperation and coordination, Technical report, forthcoming in Games and Economic Behavior.

Charness, G., Rigotti, L. & Rustichini, A. (2006), Individual behavior and group membership, Technical report. Working Paper.

Clark, C. W. (1980), Restricted access to common-property fishery resources: A game theoretic analysis, *in* P.-T. Liu, ed., 'Dynamic Optimization and Mathematical Economics', Plenum, New York, pp. 117–132.

Cornes, R. & Sandler, T. (1996), *The Theory of Externalities, Public Goods and Club Goods*, Cambridge University Press, Cambridge.

Cox, J. C., Dinkin, S. & Swarthout, J. T. (2001), 'Endogenous entry and exit in common value auctions', *Experimental Economics* **4**, 163–181.

Croson, R. T. A. (1999), 'The disjunction effect and reason-based choice in games', *Organizational Behavior and Human Decision Processes* **80**, 118–133.

Crumbaugh, C. M. & Evans, G. W. (1967), 'Presentation format, other-person strategies, and cooperative behavior in the prisoner's dilemma', *Psychological Reports* **20**, 895–902.

Davis, D. D. (2006), 'Rebate subsidies, matching subsidies and isolation effects', *Judgement and Decision Making* **1**(1), 13–22.

Davis, D. D. & Millner, E. L. (2005), 'Rebates, matches, and consumer behavior', *Southern Economic Journal* **72**(2), 410–421.

Davis, D. D., Millner, E. L. & Reilly, R. J. (2005), 'Subsidy schemes and charitable contributions: A closer look', *Experimental Economics* **8**, 85–106.

de Herdt, T. (2003), 'Cooperation and fairness: The Flood-Dresher experiment revisited', *Review of Social Economy* **56**, 183–210.

de Jasay, A., Güth, W., Kliemt, H. & Ockenfels, A. (2004), 'Take or leave? Distribution in asymmetric one-off conflict', *Kyklos* **57**, 217–236.

Deci, E. L. & Ryan, R. M. (1987), 'The support of autonomy and the control of behavior', *Journal of Personality and Social Psychology* **53**, 1024–1037.

Dohmen, T. & Falk, A. (2006), Performance pay and multi-dimensional sorting - productivity, preferences and gender, Technical report. Working Paper.

Eckel, C. C. & Grossman, P. J. (2003), 'Rebates vs. matching: Does how we subsidize charitable contributions matter?', *Journal of Public Economics* **87**, 681–701.

Eckel, C. C. & Grossman, P. J. (2006), 'Subsidizing charitable giving with rebates or matching: Further laboratory evidence', *Southern Economic Journal* **72**(4), 794–807.

Ehrblatt, W., Hyndman, K., Özbay, E. & Schotter, A. (2005), Convergence: An experimental study, Technical report, New York University.

Elffers, H. & Hessing, D. J. (1997), 'Influencing the prospects of tax evasion', *Journal of Economic Psychology* **18**, 289–304.

Elliott, C. S. & Hayward, D. M. (1998), 'The expanding definition of framing and its particular impact on economic experimentation', *Journal of Socio-Economics* **27**, 229–243.

Eriksson, T., Teyssier, S. & Villeval, M.-C. (2005), Does self-selection improve the efficiency of tournaments?, Technical report. Working Paper.

Eriksson, T. & Villeval, M.-C. (2004), Other-regarding preferences and performance pay - an experiment on incentives and sorting, Technical report. Working Paper.

Evans, G. W. & Crumbaugh, C. M. (1966*a*), 'Effects of prisoner's dilemma format on cooperative behavior', *Journal of Personality and Social Psychology* **3**, 486–488.

Evans, G. W. & Crumbaugh, C. M. (1966*b*), 'Payment schedule, sequence of choice, and cooperation in the prisonner's dilemma game', *Psychonomic Science* **5**, 87–88.

Falkinger, J., Fehr, E., Gächter, S. & Winter-Ebmer, R. (2000), 'A simple mechanism for the efficient provision of public goods: Experimental evidence', *American Economic Review* **90**, 247–264.

Fehr, E. & Schmidt, K. M. (1999), 'A theory of fairness, competition and cooperation', *Quarterly Journal of Economics* **14**, 815–868.

Fehr, E. & Schmidt, K. M. (2003), Theories of fairness and reciprocity - evidence and economic applications, *in* M. Dewatripont, L. P. Hansen & S. J. Turnovsky, eds, 'Advances in Economics and Econometrics', Cambridge University Press, Cambridge, pp. 208–257.

Fischbacher, U. (1999), Z-tree. Zürich toolbox for readymade economic experiments, Technical report, University of Zürich.

Fleishman, J. A. (1988), 'The effects of decision framing and other's behavior on cooperation in a social dilemma', *Journal of Conflict Resolution* **32**, 162–180.

Flood, M. M. (1958), 'Some experimental games', *Management Science* **5**, 5–26.

Folkes, V. & Wheat, R. (1995), 'Consumers' price perceptions of promoted products', *Journal of Retailing* **71**, 317–328.

Friederiszick, H. W. & Maier-Rigaud, F. P. (2007), 'Triggering inspections ex officio: Moving beyond a passive EU cartel policy', *Journal of Competition Law and Economics* . forthcoming.

Gächter, S. & Fehr, E. (1999), 'Collective action as social exchange', *Journal of Economic Behavior and Organization* **39**, 341–369.

Gardner, R., Moore, M. R. & Walker, J. M. (1997), 'Governing a groundwater commons: A strategic and laboratory analysis of western water law', *Economic Inquiry* **35**, 218–234.

Gaspart, F. & Seki, E. (2003), 'Cooperation status seeking and competitive behavior: Theory and evidence', *Journal of Economic Behavior and Organization* **51**, 51–77.

Gintis, H. (2000), *Game Theory Evolving. A Problem-Centered Introduction to Modeling Strategic Interaction*, Princeton University Press, Princeton.

Glass, D. C. & Singer, J. E. (1972), *Urban Stress: Experiments on Noise and Social Stressors*, Academic Press, New York.

Gunnthorsdottir, A. & Rapoport, A. (2006), 'Embedding social dilemmas in intergroup competition reduces free-riding', *Organizational Behavior and Human Decision Processes* **101**, 184–199.

Gürerk, Ö. & Selten, R. (2006), The effect of payoff tables on experimental oligopoly behavior, Technical report, University of Erfurt.

Güth, W., Kliemt, H. & Ockenfels, A. (2003), 'Fairness versus Efficiency: An Experimental Study of (Mutual) Gift Giving', *Journal of Economic Behavior and Organization* **50**, 465–475.

Guyer, M., Fox, J. & Hamburger, H. (1973), 'Format effects in the prisoner's dilemma game', *Journal of Conflict Resolution* **17**, 719–744.

Hamburger, H. (1969), 'Seperable games', *Behavioral Science* **14**, 121–132.

Harrison, G. W., L. M. I. & Rutström, E. E. (2005), 'Risk attitudes, randomization to treatment, and self-selection into experiments'. Working Paper.

Hauk, E. (2003), 'Multiple prisoner's dilemma games with(out) an outside option: An experimental study', *Theory and Decision* **54**, 207–229.

Hennig-Schmidt, H. (2002), The impact of fairness on decision making - an analysis of different video experiments, *in* F. Andersson & H. Holm, eds, 'Experimental Economics, Financial Markets, Auctions and Decision Making', Kluwer Academic Publishers, Dordrecht, pp. 185–210.

Herr, A., Gardner, R. & Walker, J. M. (1997), 'An experimental study of time-independent and time-dependent externalities in the commons', *Games and Economic Behavior* **19**, 77–96.

Hey, J., Neugebauer, T. & Sadrieh, A. (2004), An experimental analysis of optimal renewable resource management: The fishery, Technical report, University of York.

Holt, C. & Laury, S. (2002), 'Risk aversion and incentive effects', *American Economic Review* **92**, 1644–1655.

Isaac, R. M., McCue, K. & Plott, C. (1985), 'Public goods provision in an experimental environment', *Journal of Public Economics* **26**, 1–74.

Isaac, R. M. & Walker, J. M. (1991), 'On the suboptimality of voluntary public goods provision: Further experimental evidence', *Research in Experimental Economics* **4**, 211–221.

Isaac, R. M. & Walker, J. M. (1998), 'Nash as an organizing principle in the voluntary provision of public goods: Experimental evidence', *Experimental Economics* **1**, 191–206.

Juliusson, E., Karlsson, N. & Gärling, T. (2005), 'Weighing the past and the future in decision making', *European Journal of Cognitive Psychology* **17**, 561–575.

Kagel, J. H. & Roth, A. E. (1995), *Handbook of Experimental Economics*, Princeton: Princeton University Press.

Kahnemann, D. & Tversky, A. (1979), 'Prospect theory: An analysis of decision under risk', *Econometrica* **47**, 263–292.

Kaiser, J. (2007), An exact and a Monte Carlo proposal to the Fisher-Pitman permutation tests for paired replicates and for independent samples, Technical report, University of Bonn.

Karlan, D. & List, J. A. (2006), Does price matter in charitable giving? evidence from a large scale natural field experiment, Technical Report 12338, NBER.

Katok, E., Thomas, D. & Davis, A. M. (2006), 'Inventory service level agreements as coordination mechanisms: The effect of review periods'.

Keser, C. (1996), 'Voluntary contributions to a public good when partial contribution is a dominant strategy', *Economics Letters* **50**, 359–366.

Keser, C. & Gardner, R. (1999), 'Strategic behavior of experienced subjects in a common pool resource game', *International Journal of Game Theory* **28**, 241–252.

Keser, C. & van Winden, F. (2000), 'Conditional Cooperation and Voluntary Contributions to Public Goods', *Scandinavian Journal of Economics* **102**, 23–39.

King, T. R. & Murnighan, J. K. (1988), Stability and outcome tradeoffs in asymmetric dilemmas: Conditions promoting the discovery of alternating solutions, *in* R. Tietz, W. Albers & R. Selten, eds, 'Bounded Rational Behavior in Experimental Games and Markets', Springer Verlag, Berlin, pp. 85–94.

Komorita, S. S. (1987), 'Cooperative choice in decomposed social dilemmas', *Personality Social Psychology Bulletin* **13**, 53–63.

Königstein, M. & Villeval, M.-C. (2005), The choice of the agenda in labor negotiations: Efficiency and behavioral considerations, Technical report. Working Paper.

Laury, S. K. & Holt, C. A. (n.d.), Voluntary provision of public goods: Experimental results with interior nash equilibria, *in* C. Plott & V. Smith, eds, 'Handbook of Experimental Economics Results', Elsevier, New York.

Laury, S. K., Walker, J. M. & Williams, A. W. (1995), 'Anonymity and the voluntary provision of public goods', *Journal of Economic Behavior and Organization* **27**, 365–380.

Laury, S. K., Walker, J. M. & Williams, A. W. (1999), 'The voluntary provision of a pure public good with diminishing marginal returns', *Public Choice* **99**, 139–160.

Lave, L. B. (1965), 'Factors affecting co-operation in the prisoner's dilemma', *Behavioral Science* **10**, 26–38.

Lazear, E. P., Malmendier, U. & Weber, R. A. (2006), Sorting in experiments, Technical report. Working Paper.

Ledyard, J. O. (1995), Public Goods: A Survey of Experimental Research, *in* J. H. Kagel & A. E. Roth, eds, 'The Handbook of Experimental Economics', Princeton, NJ: Princeton University Press.

List, J. A. & Levitt, S. D. (2005), What do laboratory experiments tell us about the real world?, Technical report. Working Paper.

Luce, R. D. & Raiffa, H. (1957), *Games and Decisions*, New York: Wiley.

Lurie, N. H. & Swaminathan, J. M. (2005), Is timely information always better? the effect of feedback frequency on performance and knowledge acquisition, Technical report, University of North Carolina at Chapel Hill.

Maier-Rigaud, F. (2005), 'Switchings Costs in Retroactive Rebates - What's time got to do with it?', *European Competition Law Review* **26**(5), 272–276.

Maier-Rigaud, F. (2006), 'Article 82 rebates: Four common fallacies', *European Competition Journal* **2**(2), 85–100.

Maier-Rigaud, F. P. & Apesteguia, J. (2006), Assignment versus choice in prisoner's dilemma experiments, Technical report, Max Planck Institute for Research on Collective Goods.

Maier-Rigaud, F. P., Martinsson, P. & Staffiero, G. (2005), Ostracism and the provision of a public good: Experimental evidence, Technical report, Max Planck Institute for Research on Collective Goods.

Margreiter, M., Sutter, M. & Dittrich, D. (2005), 'Individual and collective choice and voting in common pool resource problems with heterogeneous actors', *Environmental and Resource Economics* **32**, 241–271.

McCusker, C. & Carnevale, P. J. (1995), 'Framing in resource dilemmas: Loss aversion and the moderating effects of sanctions', *Organizational Behavior and Human Decision Processes* **61**, 190–201.

McKeown, C. D., Gahagan, J. P. & Tedeschi, J. T. (1967), 'The effect of prior power strategy on behavior after a shift of power', *Journal of Experimental Research in Personality* **2**, 226–233.

Miller, N. (1959), Liberalization of Basic S-R Concepts: Extensions to Conflict Behavior, Motivation, and Social Learning, *in* S. Koch, ed., 'Psychology: The Study of a Science', McGraw-Hill New York, pp. 196–292.

Mills, E. S. (1959), 'Uncertainty and price theory', *Quarterly Journal of Economics* **73**, 116–130.

Mowen, J. & Mowen, M. (1991), 'Time and outcome valuation: Implications for marketing decision making', *Journal of Marketing* **55**, 54–62.

Murnighan, J. K. (1991), 'Cooperation when you know your outcomes will differ', *Simulation and Gaming* **22**, 463–475.

Murnighan, J. K. & King, T. R. (1992), The effects of leverage and payoffs on cooperative behavior in asymmetric dilemmas, *in* W. B. G. Liebrand, ed., 'Social Dilemmas, Theoretical Issues and Research Findings', Pergamon Press, pp. 163–182.

Murnighan, J., King, T. R. & Schoumaker, F. (1990), The dynamics of cooperation in asymmetric dilemmas, *in* E. Lawler, B. Markovsky, C. Ridgeway & H. Walker, eds, 'Advances in Group Processes', number 7, JAI Press, Greenwich, Conn., pp. 179–202.

Musgrave, R. A. (1959), *The Theory of Public Finance*, MacGraw-Hill, New York.

Musgrave, R. A. (1969), Provision for social goods, *in* J. Margolis & H. Guitton, eds, 'Public Economics', McMillan, London, pp. 124–144.

Musgrave, R. A. (1983), Public goods, *in* E. C. Brown & R. M. Solow, eds, 'Paul Samuelson and Modern Economic Theory', McGraw-Hill, New York, pp. 141–156.

Niederle, M. & Vesterlund, L. (2005), Do women shy away from competition? do men compete too much?, Technical report. Working Paper.

Orbell, J. M. & Dawes, R. M. (1993), 'Social welfare, cooperators' advantage, and the option of not playing the game', *American Sociological Review* **58**, 787–800.

Osborne, M. J. & Rubinstein, A. (1994), *A Course in Game Theory*, Cambridge: MIT Press.

Oskamp, S. (1971), 'Effects of programmed strategies on cooperation in the prisoner's dilemma and other mixed-motive games', *Journal of Conflict Resolution* **15**(2), 225–259.

Ostrom, E. (1990), *Governing the Commons. The Evolution of Institutions for Collective Action*, Cambridge: Cambridge University Press.

Ostrom, E., Gardner, R. & Walker, J. M. (1994), *Rules, Games, Common-Pool Resources*, Ann Arbor: University of Michigan Press.

Ostrom, E. & Walker, J. M. (1991), Communication in a commons: Cooperation without external enforcement, *in* T. S. Palfrey, ed., 'Laboratory Research in Political Economy', University of Michigan Press, pp. 287–322.

Palfrey, T. R. & Prisbrey, J. E. (1997), 'Anomalous Behavior in Public Goods Experiments: How Much and Why?', *American Economic Review* **87**, 829–846.

Park, E.-S. (2000), 'Warm-glow versus cold-prickle: a further experimental study of framing effects on free riding', *Journal of Economic Behavior and Organization* **43**, 405–421.

Pattanaik, P. & Xu, Y. (2000), 'On ranking opportunity sets in economic environments', *Journal of Economic Theory* **93**, 48–71.

Petruzzi, N. C. & Dada, M. (1999), 'Pricing and the newsvendor problem: A review with extensions', *Operations Research* **47**(2), 183–194.

Pincus, J. & Bixenstine, V. E. (1977), 'Cooperation in the decomposed prisoner's dilemma game: A question of revealing or concealing information', *Journal of Conflict Resolution* **21**, 519–530.

Porteus, E. L. (1990), Stochastic inventory theory, *in* D. P. Heyman & M. J. Sobel, eds, 'Handbooks in OR and MS', Vol. 2, Elsevier, North-Holland, pp. 605–652.

Pruitt, D. G. (1967), 'Reward structure of cooperation: The decomposed prisoner's dilemma game', *Journal of Personality and Social Psychology* **7**, 21–27.

Pruitt, D. G. (1970), 'Motivational processes in the decomposed prisoner's dilemma game', *Journal of Personality and Social Psychology* **14**, 227–238.

Pruitt, D. G. (1981), *Negotiation Behavior*, Academic Press.

Rapoport, A. (1997), 'Order of play in strategically equivalent games in extensive form', *International Journal of Game Theory* **26**, 113–136.

Rapoport, A. & Amaldoss, W. (1999), Social dilemmas embedded in between-group competitions: Effects of contest and distribution rules, *in* M. Foddy, M. Smithson, S. Schneider & M. Hogg, eds, 'Resolving Social Dilemmas: Dynamic, Structural, and Intergroup Aspects', Psychology Press, pp. 67–85.

Rapoport, A. & Chammah, A. M. (1965), *Prisoner's Dilemma: A Study in Conflict and Cooperation*, University of Michigan Press, Ann Arbor.

Roth, A. E. (1988), 'Laboratory experimentation in economics: A methodological overview', *Economic Journal* **98**, 974–1031.

Roth, A. E. (1995), Introduction to experimental economics, *in* J. H. Kagel & A. E. Roth, eds, 'The Handbook of Experimental Economics', Princeton University Press, Princeton, New Jersey, pp. 3–109.

Roth, A. E. & Malouf, M. W. K. (1979), 'Game theoretic models and the role of information in bargaining', *Psychological Review* **86**, 574–594.

Roth, A. E. & Murnighan, J. K. (1978), 'Equilibrium behavior and repeated play of the prisoner's dilemma', *Journal of Mathematical Psychology* **17**, 189–198.

Roth, A. E. & Murnighan, J. K. (1982), 'The role of information in bargaining: An experimental study', *Econometrica* **50**, 1123–1142.

Samuelson, P. (1954), 'The pure theory of public expenditure', *Review of Economics and Statistics* **36**, 387–389.

Samuelson, P. (1955), 'Diagrammatic exposition of a theory of public expenditure', *Review of Economics and Statistics* **37**, 350–356.

Samuelson, W. & Zeckhauser, R. (1988), 'Status quo bias in decision making', *Journal of Risk and Uncertainty* **1**(1), 7–59.

Sandler, T. & Arce, D. G. (2003), 'Pure public goods versus commons: Benefit cost duality', *Land Economics* **79**, 355–368.

Schellenberg, J. A. (1964), ‘Distributive justice and collaboration in non-zero-sum games’, *Journal of Conflict Resolution* **8**(2), 147–150.

Schweitzer, M. E. & Cachon, G. P. (2000), ‘Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence’, *Management Science* **46**(3), 404–420.

Scott, J. (1998), *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*, Yale University Press, New Haven.

Seabright, P. (1993), ‘Managing local commons: Theoretical issues in incentive design’, *Journal of Economic Perspectives* **7**, 113–134.

Sefton, M. & Steinberg, R. (1996), ‘Reward structure in public good experiments’, *Journal of Public Economics* **61**, 263–287.

Seligman, M. E. P. (1974), Depression and learned helplessness, *in* R. J. Friedman & M. Katz, eds, ‘The Psychology of Depression: Contemporary Theory and Research’, Winston Wiley, Washington, DC, pp. 83–113.

Sell, J. & Son, Y. (1997), ‘Comparing public goods with common pool resources: Three experiments’, *Social Psychology Quarterly* **60**, 118–137.

Selten, R. (1978), ‘The chain store paradox’, *Theory and Decision* **9**, 159–172.

Selten, R. (1998), ‘Features of experimentally observed bounded rationality’, *European Economic Review* **42**, 413–436.

Selten, R. & Berg, C. (1970), Drei experimentelle Oligopolspielserien mit kontinuierlichem Zeitablauf, *in* H. Sauermann, ed., ‘Beiträge zur experimentellen Wirtschaftsforschung II’, Mohr, Tübingen, pp. 162–221.

Selten, R. & Stoecker, R. (1986), ‘End behavior in sequences of finite prisoner’s dilemma supergames’, *Journal of Economic Behavior and Organization* **7**, 47–70.

Sen, A. (1988), ‘Freedom of choice: Concept and content’, *European Economic Review* **32**, 269–294.

Sheposh, J. P. & Gallo, P. S. (1973), 'Asymmetry of payoff structure and cooperative behavior in the prisoner's dilemma game', *Journal of Conflict Resolution* **17**, 321–333.

Siegel, S. & Castellan, N. J. J. (1988), *Nonparametric Statistics for the Behavioral Sciences*, Singapore: McGraw-Hill.

Simon, H. (1955), 'A behavioral model of rational choice', *Quarterly Journal of Economics* **69**, 99–118.

Sonnemans, J., Schram, A. & Offerman, T. (1998), 'Public good provision and public bad prevention: The effect of framing', *Journal of Economic Behavior and Organization* **34**, 143–161.

Suleiman, R. & Rapoport, A. (1988), 'Environmental and social uncertainty in single-trial resource dilemmas', *Acta Psychologica* **68**, 99–112.

Tajfel, H. (1970), 'Experiments in intergroup discrimination', *Scientific American* **223**, 96–102.

Tajfel, H., Billig, M., Bundy, R. & Flament, C. (1971), 'Social categorization in intergroup behaviour', *European Journal of Social Psychology* **1**, 149–178.

Talley, M. B. (1974), Effects of Asymmetry of Payoff and Asymmetry of Information in a Prisoner's Dilemma Game, PhD thesis, University of Texas at Arlington.

Taylor, M. (1987), *The Possibility of Cooperation*, Cambridge University Press, Cambridge.

Tognoli, J. (1975), 'Reciprocation of generosity and knowledge of game termination in the decomposed prisoner's dilemma game', *European Journal of Social Psychology* **5**, 297–312.

Tversky, A. & Kahnemann, D. (1981), 'The framing of decisions and the psychology of choice', *Science* **211**, 453–458.

Van Dijk, E. & Wilke, H. (1995), 'Coordination rules in asymmetric social dilemmas: A comparison between pubic good dilemmas and resource dilemmas', *Journal of Experimental Social Psychology* **31**, 1–27.

Van Dijk, E. & Wilke, H. (2000), 'Decision induced focusing in social dilemmas: Give-some, keep-some, take-some, and leave-some dilemmas', *Journal of Personality and Social Psychology* **78**, 92–104.

Van Dijk, E., Wilke, H., Wilke, M. & Metman, L. (1999), 'What information do we use in social dilemmas? environmental uncertainty and the employment of coordination rules', *Journal of Experimental Social Psychology* **35**, 109–135.

Walker, J. M. & Gardner, R. (1992), 'Probabilistic destruction of common-pool resources: Experimental evidence', *Economic Journal* **102**, 1149–1161.

Walker, J. M., Gardner, R., Herr, A. & Ostrom, E. (2000), 'Collective choice in the commons: Experimental results on proposed allocation rules and votes', *Economic Journal* **110**, 212–234.

Walker, J. M., Gardner, R. & Ostrom, E. (1990), 'Rent dissipation in a limited-access common-pool resource: Experimental evidence', *Journal of Environmental Economics and Management* **19**, 203–211.

Willinger, M. & Ziegelmeyer, A. (1999), 'Framing and cooperation in public good games: An experiment with an interior solution', *Economics Letters* **65**, 323–328.

Willinger, M. & Ziegelmeyer, A. (2001), 'Strength of the social dilemma in a public goods experiment: An exploration of the error hypothesis', *Experimental Economics* **4**, 131–144.

Yamagishi, T., Jin, N. & Kiyonari, T. (1999), 'Bounded generalized reciprocity: Ingroup favoritism and ingroup boasting', *Advances in Group Processes* **16**, 161–197.

Yamagishi, T. & Kiyonari, T. (2000), 'The group as the container of generalized reciprocity', *Social Psychology Quarterly* **63**(2), 116–132.