FOUR ESSAYS IN EXPERIMENTAL ECONOMICS:

INFORMATIONAL ASYMMETRIES IN MARKETS AND ENDOWMENT HETEROGENEITY IN PUBLIC-GOOD GAMES

Dissertation

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I INTRODUCTION

Most economic activities take place on "uneven playing fields" (ECLAC, 2003) which are characterized by asymmetries in various dimensions. These asymmetries strongly determine available strategies of decision makers, or more generally, the basic conditions of economic interaction. Furthermore, they are decisive in determining the likeliness of ultimate economic success of countries, companies, groups, and individuals.

Asymmetries in the economic sphere are rather the rule than the exception. Due to this omnipresence, asymmetries should be reflected in all economic disciplines. In macroeconomics, international and regional asymmetries in terms of income, economic growth, the business cycle, and socio-economic differences, among many others, should be considered in the analysis of economic and cooperative relations. In microeconomics, it should be considered that market participants encounter informational asymmetries with respect to myriad properties, have different wealth at their disposal, possess asymmetrical preferences, differ in their bargaining and market power, and face diverse cost structures etc. throughout their economic interactions. However, economic theory and analysis regularly focus on symmetrical situations. Such situations are easier to model mathematically and offer through their simplicity a seemingly better access to complex issues. Often the assumption of symmetry, however, at best provides a raw approximation to the asymmetrical reality (Scitovsky, 1978).

A multitude of real-life situations involve "unequal" settings. For example, financial markets are the playground for market participants with highly diverse information and financial skills. The question is, whether the prices, which are generated by these markets, correctly reflect the underlying fundamentals in the face of these asymmetries. Given the numerous observed real-life bubble phenomena (as, for example, the recent U.S. housing bubble of 2007) this is often at most questionable. A further example, in which asymmetries play a major role, is the still ongoing and stalled bargaining on the global reduction of greenhouse gas emissions. These negotiations take place among parties with highly diverse interests and economic backgrounds (to mention only two of the differences). The variance in characteristics of the involved parties strongly influences the respectively held point of view and thus impedes a global agreement on individually binding commitments concerning the reduction of emissions.

These two short examples indicate that it is necessary to incorporate asymmetries in economic analyses for a better understanding of the economic and social world around us. The abstraction from asymmetries in economic and social contexts definitively reduces the ability to make proper behavioral predictions and hence limits the meaningfulness of economic and social studies.

In this vein, the present dissertation strives to unravel the impact of two dimensions of asymmetry in two different economic situations by the experimental examination of a laboratory asset-market and a public-good game. Given the experimental-economic focus, this dissertation concentrates on dimensions which easily can be controlled in the laboratory and which impact could otherwise hardly be investigated in real-life settings. The game-theoretic modeling of situations which involve economic decisions allows the variation of all constituent features of a game and to establish asymmetries in three core elements: The set of strategies which is available to each player, the set of information which is known to each player, and the payoff function of each player. This dissertation studies the two former.

The dissertation comprises four studies, which are presented in the following four chapters. Chapter II deals with informational asymmetry on an experimental asset market. Chapters II to V deal with the asymmetry in endowments in public-good game settings.

"Informational Asymmetries in Laboratory Asset Markets with State-Dependent Fundamentals"[1] (Chapter II)

This study examines asymmetry in the set of information which is available to each player in an experimental asset market. More concretely, it considers an asymmetry in information about the fundamentals of the traded asset. Such asymmetries, although widely present on financial markets and decisive for the market-price formation on these markets, are hard to study in real markets. The unknown and uncontrollable information distribution among market participants and the blurry nature of asset fundamentals renders a meaningful investigation almost impossible.

The study investigates how the asset-price formation process and trading profits of (differently informed) traders are affected by the content of information in a market in a new experimental setting. The setting is innovative in that it combines two literature strands. The first strand contains asset markets with multi-period assets which are characterized by declining fundamental values (see, for example, the seminal paper of Smith et al. (1988)). The second strand contains asset markets with one-period assets which are characterized by state-contingent and trader-type dependent fundamentals (dividends), and in the cases where insider information is investigated, asymmetric distributions of state information (see, for example, Camerer and Weigelt (1991)). The presented setting involves multi-period assets in an environment with uncertainty about market fundamentals which are determined by two possible states of nature. The study analyzes how informational aspects, including the presence of inside knowledge (which is defined as the knowledge of the state), influence market performance and trading profits. Thereby, price formation in markets with and without an informational asymmetry about the true state of nature is compared.

More concretely, the experiment involves assets which pay a dividend in each of the 15 trading periods. The dividend has four possible values and is the same for all traders. However, in each period, the dividend is stochastic and its distribution function depends upon one of the two possible "states of the world". The "state of the world" is determined at the beginning of the experiment and stays the same over all periods.

[1] Joint work with Claudia Keser. *cege* Discussion Paper, No. 207, University of Göttingen, May 2014. Download: http://wwwuser.gwdg.de/~cege/Diskussionspapiere/DP207.

Traders generally do not know the state, and hence fundamentals, but are informed that the ex-ante probability of each state is 50 percent. In some markets an informational asymmetry is established via the random assignment of cost-free information about the true state to some inside traders. Based on the observed dividends during the experiment, however, also uninformed traders are theoretically able to update the ex-ante probability of both states, and hence the assessment of fundamentals, according to Bayes' rule.

In this study, we are particularly interested in two informational aspects: (1) the role of traders who are informed about the true state (insiders), and/or (2) the impact of the provision of Bayesian updates of the assets' state-dependent fundamental value to all traders. Additionally, we ask all participants in every period to state their market price expectations for the current and all future periods.

The main results of the study can be summarized as follows. With respect to the focal informational aspects we find that markets with asymmetrically informed traders exhibit smaller price deviations from fundamentals, implying higher market efficiency, and that the provision of BFVs has little to no effect. The first finding can possibly be explained by the fact that uninformed traders act more prudent in order to avoid being exploited, when they are aware of the fact that some traders have an advantage. The second finding in contrast is puzzling. Probably the mere assistance in the assessment of the state is not sufficient to improve market performance because participants are already able to intuitively anticipate BFVs.

As expected, behavior of in- and outsiders clearly differs in early periods but converges over the course of trading as a result of revelation of the state information over time. The differences in behavior materialize in lower (higher) average limit buy/sell prices of outsiders in the "good" ("bad") state compared to the limit buy/sell prices of insiders. Consequently, we find that outsiders on average hold less (more) assets in "good"-state ("bad"-state) markets which enables informed traders to exploit their superior position and to earn higher profits. With regard to the elicited price expectations, we find that the precision of forecasts of outsiders seems to be impeded by the presence of insiders, while the provision of BFVs seems to have no impact on forecast quality.

Since the higher market efficiency in markets, where insiders are present is based on the expense of outsiders, we support the position of proponents of insider trading regulation to maintain the confidence in the fairness of financial markets. Without the implementation of laws against insider trading, it is likely that deprived market participants would lose faith in the securities' markets and conceivably withdraw all or part of their capital, rendering the market less liquid.

Studies on Endowment Asymmetries in Public-Good Games (Chapters III – V)

The three studies, presented in the third to fifth chapter, deal with the asymmetry in the set of strategies, which is available to each participant, in a public-good game framework that constitutes a social dilemma. We more precisely examine the impact of asymmetries in endowments, which can be distributed between two investment alternatives (a private and a public investment), on cooperation. Numerous studies investigated cooperation in symmetrical public-good experiments, in which all players possess the same endowments. Studies that examine public-good games with asymmetric endowments are relatively rare, though. How cooperation in these games is affected by inequalities in the wealth level, which is represented by the exogenously given endowment, is, however, not completely understood.

The study "***The Social Costs of Inequality – Heterogeneous Endowments in Public-Good Experiments***"[2] ***(Chapter III)*** examines cooperation in a linear public-good experiment in which contributions under a symmetric, a weakly asymmetric, and strongly asymmetric distribution of endowments are compared. This study is innovative in that in the strongly asymmetric situation one player (a super-rich player) has no interest to achieve the group optimum.

As the study shows, contributions by players seem to follow a "fair-share" rule with equal contributions relative to the endowment, as long as all players have an interest in the social optimum. This result seems to be quite robust for contributions in linear public-good experiments (see, for example, also Hofmeyr et al. (2007)).[3]

Furthermore, total group contributions are on average not statistically different between the cases with symmetric and weakly asymmetric distributions of endowments. This result is also consistent with the study of Hofmeyr et al. (2007). In contrast, we observe in the strongly asymmetric setting, in which the super-rich player has a higher endowment than the three other players together, that group contributions are on average significantly lower than in the other two settings. This super-rich player does contribute on average the same amount as the other players and thus a much lower proportion of his endowment. We interpret this difference in the behavioral patterns between the weakly and strongly asymmetric settings as a shift in the contribution norm from a relative to an absolute equality of contributions.

[2] Joint work with Claudia Keser, Martin Schmidt, and Cornelius Schnitzler. *cege* Discussion Paper, No. 217, University of Göttingen, October 2014. Download: http://wwwuser.gwdg.de/~cege/Diskussionspapiere/DP217.

[3] Whether this "rule" is, for the case of weakly asymmetric endowments, also robust to variations in the experimental environment, has yet to be investigated. This is done in the fourth and the fifth chapter of this dissertation.

The study **"Mandatory Minimum Contributions, *Heterogeneous Endowments, and Voluntary Public-Good Provision*"[4] *(Chapter IV)*** investigates if the previously mentioned "fair-share" norm may be influenced by different, potentially norm-changing, enforced minimum-contribution schedules with a fixed distribution of asymmetric endowments. These schedules meet some desired and reasonable criteria such that an increase in group contributions cannot solely be attributed to the required minimum contributions but must be caused by a behavioral norm shift of the participants. In particular, we employ a treatment which involves no enforced minimum contributions, a treatment which requires the same absolute minimum contribution from all players, a treatment which requires the same minimum contributions relative to the endowment from all players, and a treatment which imposes a progressive minimum-contribution schedule with higher minimum contributions for wealthier players.

The main results from this study are the following. The mandatory minimum contributions seem to exert a norm-giving character ("expressive power"). That means, they are able to coordinate individual beliefs, express a certain level of "fair contribution", i.e., break the usual "fair-share" norm of equal relative contributions, and thus lead to an increase of average group contributions. The progressive minimum-contribution schedule performs best. It increases average group contributions by more than 30 percent above the baseline treatment.

On the individual level, we find that average absolute contributions rise with the endowment in all treatments. We confirm the "fair-share" rule for the treatment where we impose the same relative minimum contribution on all participants. In contrast, we find for the treatment with the same absolute minimum contributions that average relative contributions are higher for less wealthy players and in the treatment with the progressive schedule that average relative contributions are higher for more wealthy players. In the latter two treatments players seem to follow a modified "fair-share" rule of equal relative contributions of the disposable endowment. Furthermore, we find that in the treatment with the progressive schedule contributions of the medium-wealthy player, for which mandatory contributions are the same in all three mandatory contribution treatments, are highest.

[4] Joint work with Claudia Keser and Martin Schmidt. *cege* Discussion Paper, No. 224, University of Göttingen, December 2014. Download: http://wwwuser.gwdg.de/~cege/Diskussionspapiere/DP224.

The study "***Recommended Minimum Contributions in a Public-Good Game with Heterogeneous Endowments***"[5] ***(Chapter V)*** supplementary augments the preceding investigation in that it refrains from the imposition of obligations. Instead, it uses recommendations concerning minimum contributions with a slight moral framing in the same setting. We focus on the progressive minimum-contribution schedule from the previous study, as the most promising environment. This schedule performed best in terms of the increase of group profits in comparison to the baseline treatment. By using this schedule, we test whether the transformation of the mandatory minimum contributions in mere recommendations is similarly able to increase average group contributions. At least, we expect that the recommendations increase group contributions in comparison to the baseline setting without any obligations or recommendations.

The main results from this study are the following. In contrast to the progressively staggered minimum contributions in the study in the fourth chapter, we find that the progressively staggered recommendations in this study do not exert a norm-giving character. Group contributions in the experiment, when recommendations are given, are not statistically distinguishable from the contributions in the baseline treatment (without recommendations or obligations) and significantly smaller than in the case when progressive obligations for contributions are imposed.

On the individual level, we confirm the "fair-share" rule for the treatment with the progressive recommendations. Thus, while the progressive obligations have a "positive" impact on the "fair-share" norm, recommendations fail to exert this desired effect. On the contrary, contributions in the case with progressive recommendations are smaller than contributions in the case of progressive obligations for all player types. In comparison to the baseline treatment, contributions of the poor players are significantly lower, while contributions of wealthy and rich players are statistically indistinguishable, when the recommendations are given. Furthermore, while recommendations reduce the proportion of zero contributions in comparison to the baseline treatment, they also exert a negative effect on full contributions.

Our results suggest that when it comes to "issues of cooperation" policy makers should rely on stronger institutions than pure recommendations to achieve more favorable social outcomes. However, this advice should be treated with caution; our findings should not be overgeneralized. Further work has to be done to cross-check our results in other environments. Given the differences of our results to other studies which analyze recommendations in public-good game settings, we at best conclude that the impact of recommendations is strongly context dependent; also the level of recommendations seems to play a crucial role.

[5] Joint work with Claudia Keser.

References

Camerer, C., Weigelt, K., 1991. Information Mirages in Experimental Asset Markets. The Journal of Business 64 (4), 463–493.

ECLAC, 2003. Globalization and Development: A Latin American and Caribbean Perspective. United Nations, Economic Commission for Latin America and the Caribbean. Stanford University Press and The World Bank, Santiago, Chile.

Hofmeyr, A., Burns, J., Visser, M., 2007. Income Inequality, Reciprocity and Public Good Provision: An Experimental Analysis. South African Journal of Economics 75 (3), 508–520.

Scitovsky, T., 1978. Asymmetries in Economics. Scottish Journal of Political Economy 25 (3), 227–237.

Smith, V.L., Suchanek, G.L., Williams, A.W., 1988. Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets. Econometrica 56 (5), 1119–1151.

II

INFORMATIONAL ASYMMETRIES IN LABORATORY ASSET MARKETS WITH STATE-DEPENDENT FUNDAMENTALS

with Claudia Keser

Abstract: We investigate the formation of market prices in a new experimental setting involving multi-period call-auction asset markets with state-dependent fundamentals. We are particularly interested in two informational aspects: (1) the role of traders who are informed about the true state and/or (2) the impact of the provision of Bayesian updates of the assets' state-dependent fundamental values (BFVs) to all traders. We find that markets with asymmetrically informed traders exhibit smaller price deviations from fundamentals than markets without informed traders. The provision of BFVs has little to no effect. Behavior of informed and uninformed traders differs in early periods but converges over time. On average, uninformed traders offer lower (higher) limit prices and hold less (more) assets than informed traders in "good"-state ("bad"-state) markets. Informed traders earn superior profits. The precision of market price forecasts is impeded by the presence of insiders.

JEL classification: C92, D47, D53, D82, G14

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1. Introduction

Financial markets are characterized by pronounced informational asymmetries. This is probably particularly true in times of market uncertainty following economic turbulences or in the wake of stock market launches (IPOs). Although insider trading is prohibited by law in all major financial markets, insider information is often a prominent cause of informational asymmetries.[1] Given that the allocative efficiency of a market crucially depends upon the correct pricing of its assets, insider trading could theoretically be seen as a positive. The more information the market price reflects, the higher is the informational and thus also the allocative efficiency of a market. As insiders potentially bring critical information to the market, the proponents of insider trading presume potentially positive effects on market efficiency. Opponents of the regulation of insider trading, however, counter that the integrity of financial markets is at stake, when no barriers on insider trading are imposed.[2]

In this paper, we study asset-price formation and the consequences of insider trading in a new experimental setting involving multi-period assets in an environment with uncertainty about market fundamentals. Specifically, we consider the existence of two possible states of nature. We compare price formation in markets with and without insiders that have information about the true state. We investigate to what extent our financial markets are informationally efficient and how informational asymmetries (due to insider information) impact market-price formation. Such an investigation would hardly be possible (if not impossible) on real market grounds, due to the blurry nature of underlying securities' values and the uncontrollable and incalculable information distribution among market participants. In the experiment, we can control the information available to market participants and the securities' fundamentals. Although the expectation formation of market participants remains difficult to grasp,[3] we can explicitly control the informational asymmetries between market participants, including the number of informed participants (henceforth also inside traders or insiders) relative to the uninformed (henceforth also outside traders or outsiders). We neither claim nor aim to resolve the debate between proponents and opponents of insider trading regulation but strive to fuel the discussion with the provision of new experimental evidence.

[1] Bris (2005) even finds, by using acquisition data from 52 countries between 1990 and 2000, that the introduction of laws that prohibit insider trading increases the occurrence and profitability of insider trading.

[2] In the ongoing debate, to date, neither efficiency nor fairness and equity arguments can mutually persuade the debating parties (Bainbridge, 1998; Fishman and Hagerty, 1992).

[3] How the available information disseminates through the market and is processed by the individual traders to build individual expectations remains a tremendous source of uncertainty. It resembles Keynes (1936) view of the stock market as a "beauty contest" in which traders are more concerned about the beliefs of others than about their own valuation based upon all available information. As good as the experimenters can control for the market parameters, as bad they can control the endogenous beliefs of participants about other participants' behavior (Noussair and Plott, 2008).

Since the seminal paper by Smith et al. (1988b) (henceforth, SSW) countless studies have investigated common stock valuation in experimental asset markets with multi-period assets characterized by declining fundamental values (FVs). However, relatively few studies consider informational asymmetries. If (experimental) markets are efficient, the market value should equal the risk-adjusted present value of the rationally expected future financial benefits conditioned on all available information. Asset price changes should only occur when new information is brought into the market, which changes expectations about the income stream (Shiller, 2003). Deviations from fundamentals, if at all, should be only temporary until the risk-adjusted expectations converge. Such kind of markets would approximate what Fama (1970), the originator of the efficient-market hypothesis (EMH), called "efficient". However, SSW-type markets predominantly resist showing efficiency and persistently exhibit bubbles, which hardly can be explained by differences in preferences or risk aversion. The observed bubble-and-crash phenomenon is found to be strikingly robust to changes in the experimental environment.[4] The only factor that fairly reliably impairs this widely observed pattern is experience (in the sense of repetition). Dufwenberg et al. (2005) have shown that even a fraction of experienced subjects in an experimental market is sufficient to reduce the occurrence of bubbles. However, this seems to hold only if the market environment (initial endowments and dividend structure) remains unchanged during the trials (Hussam et al., 2008).

On the basis of Dufwenberg et al. (2005), Sutter et al. (2012) hypothesize that, in addition to experience, an asymmetric distribution of information about an asset's imminent future dividends among the participants might serve to reduce mispricing, i.e., the magnitude of bubbles. They conjecture that the main driver of this alleviating effect might be the common knowledge of the existence of better informed or experienced traders. Implementing a SSW framework, they find information asymmetries to significantly reduce the size of price bubbles, implying higher market efficiency. Moreover, they do not detect a significant difference in profits between traders with different information levels. However, in an earlier study, King (1991) finds no evidence for asymmetric distribution of information to eliminate price bubbles in a SSW environment. In his study informed traders, likewise, could not capitalize their informational advantage through higher profits; they were just able to recoup the costs for the acquisition of the private information.[5]

Another experimental literature strand studies asymmetric information using an approach different from SSW. It is based on one-period Arrow-Debreu assets with state-contingent and trader-type dependent dividends, and in the cases where insider information is investigated, asymmetric distributions of state information (e.g., Forsythe et al. (1982; 1984), Plott and Sunder (1982; 1988), Ang and Schwarz (1985), Camerer

[4] See, e.g., King et al. (1993), Porter and Smith (1994), or Palan (2013) for comprehensive and salient reviews of the experimental "bubble" literature. For an overview of bubble definitions see, e.g., Siegel (2003).

[5] Unlike the work of Sutter et al. (2012), which uses randomly assigned and free private information, King (1991) investigates costly private information that is auctioned off before the markets start.

and Weigelt (1991a), Sunder (1992), Friedman (1993), Ackert et al. (1997), and Ackert and Church (1998)). The studies in this literature strand focus on the test of the "prior information equilibrium pricing prediction model" (PI) versus the "fully revealing rational-expectations equilibrium prediction model" (RE). Both prediction models will be explained in more detail in Section 3 below. In summary, this literature strand shows that markets are generally able to aggregate information quite successfully. PI predictions seem to be a good benchmark for trades in earlier repetitions of the market, whereas the RE predictions appear more accurate in later repetitions. Plott and Sunder (1988), for example, argue as follows: "*Rational expectations can be seen either as a static theory of markets (e.g., in the efficient market literature in finance) or as an end-point of a dynamic path of adjustment*." (p. 1104)

Our experiment is novel in that it combines both literature strands and introduces state-dependence in the SSW framework. In our new framework, insider information is defined as the knowledge of the state. The aim of our study is to analyze how informational aspects, including the existence of inside knowledge, influence price formation and market performance.

In our experiment, the dividend paid by an asset, in each of 15 periods, has four possible values and is the same for all traders. However, in each period, the dividend is stochastic and its distribution function depends upon one of two possible states of the world. In other words, the state determines the probabilities with which the respective dividends are drawn. The "state of the world" is determined at the beginning of the experiment and stays the same over all periods. Traders generally do not know the state but are informed that the probability of each state is 50 percent. This is the prior belief, which determines the ex-ante expected fundamental value of the assets. Based on the observed dividends during the experiment, this belief can be updated according to the method of Bayes, resulting in ex-post expected fundamental values (BFVs) of the assets. In some of the experimental markets informational asymmetry is established via a random assignment of cost-free information about the state to some inside traders.

In this framework, we investigate how information is processed and disseminated trough market prices. We are particularly interested in two informational aspects: (1) the role of traders who are informed about the true state (insiders), and/or (2) the impact of the provision of Bayesian updates of the assets' state-dependent fundamental value to all traders. We compare the outcomes in markets where two traders with insider information about the actual "state of the world" are present (and the presence is common knowledge) to the outcomes in markets without any insider information. Additionally, in half of the markets with insiders and half of the markets without insiders, we provide all traders in every period with updated BFVs. In all four resulting treatments, to scrutinize traders' ability to anticipate uncertain future outcomes, a key issue in financial markets, we elicit traders' expectations about the future market prices at the beginning of each period and provide monetary incentives for the accuracy of their predictions.

Our main results are surprising in that, in all treatments, we find bubbles to occur rarely, even though all traders are inexperienced and have never participated in a market experiment before. Markets with asymmetrically informed traders exhibit smaller price deviations from fundamentals, suggesting higher market efficiency. The provision of BFVs has little to no effect. Behavior of in- and outsiders differs in early periods but converges over the course of the markets. On average, we find outsider limit buy/sell prices to be lower (higher) in the "good" ("bad") state and outsiders to hold less (more) assets in "good"-state ("bad"-state) markets compared to insiders. Insiders manage to exploit their superior position and are able to earn higher profits. With regard to price expectations, we find forecasts and actual market prices to be highly correlated. Forecast precision, however, seems to be impeded by the presence of insiders, while the provision of BFVs seems to have no impact on the quality of the forecasts.

The remainder of this paper is structured as follows: Section 2 presents the experimental market design and describes the experimental procedures. Section 3 introduces two behavioral models and provides testable hypotheses. Section 4 reviews these hypotheses in the face of the experimental results. Section 5 gives a summary and concludes.

2. Laboratory Markets and Experimental Procedures

We conducted the computerized experiment in the *Göttingen Laboratory of Behavioral Economics* at the University of Göttingen, Germany, based on the z-tree software package (Fischbacher, 2007).

A total of 240 subjects participated in 40 markets with six traders, each. Participants were student volunteers recruited for a decision-making experiment via ORSEE (Greiner, 2004). All participants were bachelor or master students in business administration or international economics at the University of Göttingen and thus had some background in economics.

Each subject assumed the role of a trader in an asset market. Six participants (henceforth traders) participated in a market lasting 15 periods. Each experiment session involved two or three independent markets. At no time, traders did know the identity of other traders in the market. A market lasted 15 periods and involved trading in call auctions (for buying and selling) in each period.

The experimental sessions were conducted in two parts. In the first part, risk preferences were elicited using lottery choices following Holt and Laury (2002) (see Appendix A for more details). Trading in the call-auction market took place in the second part. For both parts traders were given detailed written instructions. For the first part, written instructions were individually provided. For the second part, instructions were read aloud in a briefing room and supplemented by a presentation of screenshots which included all screens traders encountered during the experiment. Instructions are provided in Appendix C. The whole process before the call-auction market started lasted on average about 45 minutes. During the entire session traders were not allowed to talk to each other.

2.1 Characteristics Common to All Sessions

At the beginning of each experimental market, each trader is endowed with 10 assets and 10,000 ECU working capital. We have chosen to provide the same endowment to all traders to prevent trading merely due to the desire to realign portfolios. King et al. (1993) found no significant effect of equal endowments on bubble formation. Each trader's initial endowment in ECU is large enough to buy at least a quarter of the other traders' assets in a market at initial fundamental values. Short selling is not permitted. The initial working capital has to be repaid at the end of the market session. Traders' asset and working capital holdings are carried over from one period to the next.

Prior to the trading stage, at the beginning of each period, traders have to state their expectations about the prospective market prices of the present and all subsequent trading periods. Thus, each trader has to state in each period $t \in (1, \dots, 15)$ a total of $(16 - t)$ forecasts. To create an incentive for participants to care about forecast precision, participants are rewarded (in ECU) for the accuracy of each forecast.[6] If the forecasted price is within a 10 percent, 10-20 percent or 20-30 percent range, a respective reward of 5 ECU, 2 ECU or 1 ECU is paid. For less accurate forecasts no reward is paid. Over the course of the 15 market periods, for any period t $(1 \leq t \leq 15)$ t predictions are requested and thus a reward may be obtained up to t times. In each period, after all traders have stated their predictions, trading commenced in a call-auction market, where traders also could use their rewards from the forecasts for asset trading.

Each of the 15 market periods on average lasted five minutes (including forecasts). In each period, assets with an initial lifetime of 15 periods can be traded. Each asset pays the same dividend to all its holders in a market. The dividend is randomly drawn after the trading at the end of each period. It can take a value of 10 ECU, 20 ECU, 40 ECU, or 80 ECU. The fundamental value of an asset is determined by the dividend stream that it generates to its holder. It corresponds to the sum of all expected future dividends. Consequently, the fundamental value declines to zero in the course of a market. After the final payment of the dividend in the last period the asset becomes worthless.

Since our research focus lies in the propensity of markets to aggregate and disseminate information, we incorporate state-dependency of assets, as in Camerer and Weigelt (1991a). Like in the SSW type markets, the dividend from holding an asset does not differ across traders. That means that markets have only one "type" of trader with regard to dividend value. However, the expected dividend depends upon the "state of the world", which is randomly drawn at the beginning of a market. There are two equally likely states. State 1 is called the "good" and State 2 the "bad" state. The set of possible dividend values is equal in both states of the world but dividend values occur with different probabilities. We have chosen probability distributions of the dividends in order to focus the subjects' attention on the two different expected values for the "good" and "bad" state and to determine two clearly distinguishable states of the world. Actual dividends originate from independent random draws out of the set $\{10, 20, 40, 80\}$ of possible dividends. The expected dividend per period in a given state is given by the probability weighted sum of the possible dividends. Table 1 provides the possible per period dividend values and the corresponding probabilities of occurrence under each of the two states. It also provides the expected per period dividend ED_S in each state $S \in (1, 2)$.

[6] We use incentivized belief elicitation because it can be expected that participants exert more effort to forecast correctly and that these forecasts are more accurate than non-incentivized, as was, for example, found by Gächter and Renner (2010).

Table 1: Possible Dividend Values and Probabilities

Possible Dividends	Probability in "Good" State ($S = 1$)	Probability in "Bad" State ($S = 2$)
10	0.1	0.4
20	0.2	0.3
40	0.3	0.2
80	0.4	0.1
ED_S	49	26

In the "good" state the probabilities of the higher dividends are larger than in the "bad" state, resulting in a higher expected dividend value per period and a higher FV in each period. The expected dividend per period is 49 in the "good" state and 26 in the "bad'" state. In the first period, with no information about the state at hand the expected dividend is 37.5. This value changes after each period's dividend draw according to Bayes' theorem, since the updated probability to be in one state or the other also changes according to this rule. For a given "state of the world", the FV is given by the product of the expected dividend per period and the number of remaining periods the dividend is paid. Formally, the FV in State S and period t is given by $(16 - t)ED_S$, assuming no discounting.

FVs in both states reduce after each period by the expected dividend per period. Given the ex-ante probabilities for the states and actual dividend draws Bayesian inference is possible due to the different drawing probabilities of the dividends in both states. The Bayesian fundamental value (BFV) in a given period is the probability-weighted mean of the FVs in the "good" and "bad" state in the respective period. The weights are given by the conditional probabilities based on Bayesian inference. The probabilities of dividends in both states of the world and the probabilities for both states are provided to all traders in the (read-aloud) experimental instructions and are thus considered as common knowledge. We additionally provided fundamental values for both states for participants to have common expectations about fundamentals (Cheung et al., 2014).

To have control over the drawn dividends and to render markets comparable, we follow the approach of Sutter et al. (2012). We randomly draw sequences of 15 realizations of the dividend (one for every period) with the respective probabilities in the "good" state and "mirror" this sequence for the realizations of the dividends in the "bad" state. This is easily feasible due to the symmetric framework. Among the randomly drawn sequences, we choose one that does not "fully" reveal the underlying state in early periods. This sequence (for the "good" state, or mirrored, for the "bad" state) is used for all markets.

Table 2: Sequence of Dividend Draws and Corresponding Fundamentals in the "Good" and "Bad" State

Period	"Good" State				"Bad" State				Cond. Prob.
	FV	D	AFV	BFV	FV	D	AFV	BFV	for the State
1	735	40	720	563	390	20	420	563	0.50
2	686	80	680	557	364	10	400	493	0.60
3	637	20	600	594	338	40	390	381	0.86
4	588	10	580	533	312	80	350	367	0.80
5	539	80	570	413	286	10	270	413	0.50
6	490	80	490	444	260	10	260	306	0.80
7	441	20	410	429	234	40	250	246	0.94
8	392	40	390	376	208	20	210	224	0.91
9	343	80	350	334	182	10	190	191	0.94
10	294	10	270	292	158	80	180	158	0.98
11	245	40	260	238	130	20	100	137	0.94
12	196	20	220	192	104	40	80	108	0.96
13	147	80	200	143	78	10	40	82	0.94
14	98	40	120	97	52	20	30	53	0.98
15	49	80	80	49	26	10	10	26	0.99

Notes: FV = Fundamental Values, D = Dividends, AFV = Actual Fundamental Values, BFV = Bayesian Fundamental Values.

In the experiment we have chosen the states in such a way that one half of the markets were in the "good" state and the other half in the "bad" state. Table 2 provides, for each state, the ex-ante expected FVs (if the state were known), the sequence of the actual dividend draws (Ds), the "ex-post" actual FVs (AFVs), and the (depending on the dividend draws) updated Bayesian FVs (BFVs). The last column of this table provides the conditional probabilities of the actually prevailing state at the beginning of the period.

The columns displaying the AFVs in Table 2 show that the selected sequences of dividends are not too optimistic or pessimistic with respect to the total value of dividends in comparison to the FVs. It can be thus assumed that both sequences properly represent the fundamentals of both states. As further can be seen, the dividends at the beginning correctly suggest the underlying state, then by period 5 reset state probabilities to 50:50, and subsequently again correctly suggest the underlying state. Toward the end, dividends reveal the state with almost certainty. This characteristic of the dividend stream has the desirable property to introduce initial uncertainty regarding the real state as it is surely frequently present on real markets.

Trading in the call market in each period lasts a maximum of 240 seconds. During the first 120 seconds traders have the opportunity to submit a purchase offer; in the second 120 seconds they have the opportunity to submit a sale offer. Each trader may determine one buy and one sell limit order per period to buy/sell a certain number of assets. A buy (sell) order consists of the maximum (minimum) price which a trader wants to pay (is willing to accept) per asset and the maximum number of assets the trader is willing to buy (sell) at that price. Traders are not obliged to submit buy and/or sell orders. In the case of a "zero order" no assets are bought and/or sold at any market price; traders just keep their stock of assets. At no point of time, traders get to know the offers of others.

All bids and asks within a period are submitted simultaneously and are aggregated into market demand and supply. The call market features a market-clearing condition such that demand equals supply in each trading period. Markets are cleared at unitary prices for all transactions within each period so that the trading volumes are maximized.[7] Transactions only take place as long as there are dealers who want to sell at a lower or the same price than other dealers are willing to pay. The market price is determined by the average of the lowest limit buy price and the highest limit sale price for which a transaction takes place. No trader has to pay more for an asset than he/she offered and no trader has to sell for less than he/she asked. If the aggregated market price lies above the chosen sale price the trader is a seller and if the market price lies below the chosen buy price the trader is a buyer. If, depending on the submitted buy and sell orders, no transactions can take place, there is no market price. In this case we referred to the market price as zero.

Ties on the demand and/or selling side are handled using an order precedence rule consisting of the price, quantity and entering time. On the buy (sell) side higher (lower) buy (sell) prices, higher quantities, and an earlier submission time are favored.[8] Traders are instructed that they might not get all or part of their buy/sell order fulfilled even if they hand in an adequate price.

During the choice of buy and sell offers, traders have to make sure that these are permissible. Firstly, they can never sell more assets than they have at the beginning of the period in their own portfolio. Secondly, never buy more assets as permitted by the available sum of asset holdings of the other traders in their group. Thirdly, never buy more assets at a certain price than permitted by the available trading capital. Fourthly, the limit sell order price must exceed the limit buy order price by at least one ECU.

At the end of the trading state in each period all possible individual transactions are completed, the drawn dividend is announced, and the updated account of asset and trading capital holdings along with the dividend earnings for the current period are presented to the traders. Additionally, the results for the accuracy of price forecasts along with the associated earnings are given for the current period. Furthermore, traders are provided with a complete history of relevant information concerning their

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[7] The call market institution has the advantage that it yields for each trader a unique trading price per period for all buy and sell orders. Furthermore, Liu (1992) found that call markets are more efficient than continuous double auction markets in settings were uninformed traders are present jointly with diversely informed insiders (Sunder, 1995).

[8] $\text{Index} = 100 \cdot R_{p_{D,S}} + 10R_{q_{D,S}} + E$, where $R_{p_{D,S}}$ is the price rank, decreasing with ascending (descending) buy (sell) price; $R_{q_{D,S}}$ is the quantity rank, decreasing in the buy (sell) quantity; and E is the entering order number. Lower rank numbers are favored and a lower index corresponds to a preferred offer.

portfolio (asset and cash holdings etc.) during both phases of the trading stage in each period.

The payout relevant profit (in ECU) to a subject is determined by the available trading capital at the end of the 15th period minus the initial working capital. It can be alternatively calculated as the sum of the period profits:

$$\begin{aligned}\text{Period profit} = {} & \text{Number of assets at end of the period} \times \text{dividend per asset} \\ & + \text{Proceeds from sold assets} \\ & - \text{Expenses for purchased assets} \\ & + \text{Remuneration of market-price forecast(s)}\end{aligned} \tag{1}$$

Following the method of induced value theory, we expect traders to exhibit a positive utility for money, i.e., to maximize their earnings. Demand for (Supply of) assets is hence induced by a preference for (higher) earnings (Smith, 1976).

All trading in the experiment was in terms of Experimental Currency Units (ECU). Earnings were converted into Euros at the end of the market, at a known rate of 0.003 €/ECU. Additionally, each trader was paid a show-up fee of 3 €. A session lasted on average about 2.5 hours. Traders' earnings averaged about 25 €[9].

2.2 Treatments

We conducted our experiment by using a 2 × 2 design. Firstly, the information structure of markets differed across sessions, i.e., the structure of informed and uninformed traders with respect to the true state of nature differed across markets. In the so called Nin(B)[10] sessions no participant was given a clue about the true state of nature and it was announced that no trader received information about the state. In the so called Tin(B) sessions two participants in a market are provided on the computer screen with information about the underlying "state of the world" at the beginning of the market. In these sessions it was publicly announced (common knowledge) that there will be two randomly chosen informed traders in each market and that their identity will remain secret to all other participants. The information given to the informed participants was identical and perfect in the sense that it would reveal the state of nature with certainty (this was also common knowledge). By virtue of the design of the markets, insiders and outsiders were the same traders throughout the entire markets. Secondly, we distinguish between sessions where participants were or were not provided with updated conditional probabilities for both states and the corresponding BFVs. The B after Nin and Tin indicates that in these markets all traders were provided with updated BFVs in each period.

[9] Despite of the compulsory repayment of the initial working capital, no participant actually faced a loss (earnings of zero). The minimum payout earned in the markets is 7.36 € (1453.5 ECU + 3 € show-up fee).
[10] When markets with or without insider information are considered together, regardless of the provision of BFVs, we refer to them simply as Tin(B) and Nin(B) markets.

Thirdly, we conducted a control treatment in that we used the same set of possible dividends $\{10, 20, 40, 80\}$, which were, however, equally likely to occur (25 percent). There was no uncertainty about the state, such that traders were in a sense all "insiders". Table 3 displays a summary of the design parameters of each of our 40 asset markets. Specifically, it gives an overview over the underlying state, the provision of BFVs, and the presence of insiders in each market.

Table 3: Markets and Information Levels

Treatment No.	Label	State	State Label	BFVs	Insiders (#)	Market No.
1	Nin	Good Bad	Nin+ Nin-	No	No	17, 19, 21, 23 18, 20, 22, 24
2	NinB	Good Bad	NinB+ NinB-	Yes	No	1, 3, 5, 7 2, 4, 6, 8
3	Tin	Good Bad	Tin+ Tin-	No	Two	25, 27, 29, 31 26, 28, 30, 32
4	TinB	Good Bad	TinB+ TinB-	Yes	Two	9, 11, 13, 15 10, 12, 14, 16
5	"SSW"	---	---	No	"Six"	33, 34, 35, 36, 37, 38, 39, 40

Note: Markets are numbered in the order how the observations were collected during the experimental sessions.

3. Informational Models and Hypotheses

3.1 Informational Models

Following the studies of, for example, Camerer and Weigelt (1991a) and Plott and Sunder (1982; 1988), we test two different models: the prior information equilibrium (PI) model and the fully revealing rational-expectations equilibrium (RE) model. Both models assume traders to be risk-neutral and give different forecasts about trading behavior of differently informed traders. These models can be formalized quantitatively and tested against each other.

The PI-model states that traders use their prior dividend information to build expectations about the state but do not learn from price signals. They ignore the informational content of market prices (reflecting the aggregated information held by others) and speculation possibilities based on the actions of other traders (Palan, 2009). Traders only use Bayes' rule to update their expectations about the true state.

The RE-model additionally states that in equilibrium all traders behave as if they are aware of the entire information of all traders in the market. Thus even uninformed traders have the ability to supplement their prior ("private") information with private information of others via price signals from the market that entail (perfect) information of insiders.[11] They are aware of the relationship between the market price, the underlying state, and their gains from trade and utilize the market price and their "private" information in their demand decision (Tirole, 1982).

In our experiment we chose dividends, prior probabilities of dividends, and states in a manner that fundamentals and hence predictions of the PI- and RE-models clearly differ in both states. Table 4 shows the expected FVs per asset with respect to information, state, and informational model. Independent of the state, when there is no inside information in the market, the PI- and the RE-models both predict no trade, when traders have identical risk preferences. According to both models, all traders have the same expectations about the FVs, which equal the BFVs. There are no evident gains from and thus no incentives to trade. Traders with different risk preferences, however, will trade since the more risk-loving traders would attribute a higher value per asset than the more risk-averse traders, leading to an asset flow from the latter to the former.

[11] The RE-model has a close connection to the efficient markets hypothesis. Bid/ask prices reflect diverse private information and thus induce trading actions identical to those if all traders had all market information (Harrison and Kreps, 1978).

Table 4: Expected FVs under PI and RE by Information and State

	No Information		Inside Information			
	"Good"	"Bad"	"Good"		"Bad"	
Period	PI = RE	PI = RE	PI	RE	PI	RE
1	563	563	**735** **[563]**	**735** **[563]**	390 [563]	390 [563]
2	557	493	686 [557]	686 [686]	364 [493]	**364** **[364]**
3	594	381	637 [594]	637 [637]	338 [381]	338 [388]
4	533	367	588 [533]	588 [588]	312 [367]	312 [312]
5	413	413	539 [413]	539 [539]	286 [413]	286 [286]
6	**444**	**306**	490 [444]	490 [490]	**260** **[306]**	260 [260]
7	429	246	441 [429]	441 [441]	234 [246]	234 [234]
8	376	224	392 [376]	392 [392]	208 [224]	208 [208]
9	334	191	343 [334]	343 [343]	182 [191]	182 [182]
10	292	158	294 [292]	294 [294]	156 [158]	156 [156]
11	238	137	245 [238]	245 [245]	130 [137]	130 [130]
12	192	108	196 [192]	196 [196]	104 [108]	104 [104]
13	143	82	147 [143]	147 [147]	78 [82]	78 [48]
14	97	53	98 [97]	98 [98]	52 [53]	52 [52]
15	49	26	49 [49]	49 [49]	26 [26]	26 [26]

Notes: Figures show for the case of insider information the known FVs for informed and expected FVs for [uninformed] traders. The bold figures identify the convergence period as defined in Subsection 4.1.

When insider information is present, both, the PI- and the RE-model, predict different expectations about fundamentals of in- and outsiders. For the RE-model this is only true for the first period. In addition to the differences in expectations, the occurrence of trade requires that outsiders do not behave rationally. Rational outsiders would not trade since they know that trading with insiders is only to their detriment. If trade occurs, the market price will approximately average the expected FVs under the assumption that in- and outsiders are strict payoff maximizers and place bid prices marginally below and ask prices marginally above their expected FVs.

Since in the first period the resulting market price is higher (lower) than the BFV of 563 in the "good" ("bad") state, outsiders update their prior information with this price signal and are able to infer the correct state under the RE-model assumptions. Informed traders can thus take advantage of their superior position in the first period only. Under the PI-model, with traders that do not behave in a fully rational way, trade may virtually take place throughout all periods, assuming availability of assets on the supply side and sufficient trading capital on the demand side. Since market participants ignore the informational content of market prices, expectations about fundamentals only converge slowly to the true value, which leads to a more persistent superior position of insiders. According to both models, trading will result in asset allocations where insiders hold more (less) assets in the "good" ("bad") state than outsiders, as long as traders have identical risk preferences and behave not fully rational. Heterogeneous risk preferences may additionally induce trading and enforce or mitigate the predicted asset allocation pattern.

3.2 Hypotheses

To facilitate the illustration of the results in the following section our analysis focuses around six hypotheses.

Hypothesis 1: *Trading prices converge toward the actual FV under all treatment conditions but the convergence is faster in markets with insider information and markets where traders are provided with BFVs.*

In our markets, convergence toward fundamentals depends substantially on the accuracy of the probability assessment. This is a complex task, especially in an experimental situation, where time is limited. Markets aggregate information. However, it will take time for prices to track the FV.[12] Following Romer (1993), the dissemination of privately held information and/or expectations is likely to cause lagged price movements. Proponents of the "efficiency camp" of insider trading argue that convergence of market prices toward fundamentals is faster when inside information is present (Engelen and Liedekerke, 2007; Manne, 1984; McGee, 2008). Sutter et al. (2012) and Dufwenberg et al. (2005) provide experimental evidence that markets where some traders have an informational/experiential edge above others show a significantly better performance in terms of market efficiency. Since people are unlikely to carry out Bayesian inference by themselves (Camerer, 1999; Kahneman and Tversky, 1972; Rabin and Schrag, 1999), we expect markets where traders are provided with BFVs to converge faster toward fundamentals than markets that are not.

Hypothesis 2: *Bubbles occur but the introduction of asymmetrically informed traders or the provision with BFVs significantly reduces the occurrence and extent of bubbles.*

[12] Forsythe et al. (1984) argue that "*investors bring only their private information to the market and only after traders have observed prices will they learn the information necessary to achieve the [fully revealing rational-expectations equilibrium].*" (p. 973)

A vast literature shows that the bubble-and-crash phenomenon is strikingly robust in SSW markets (see footnote 4). Since the introduction of insider information is expected to enhance market performance in terms of the duration of equilibrium adjustment of market prices, we expect markets with asymmetrically informed traders to be less prone to bubble formation than markets with symmetrically informed traders, a result also observed by Sutter et al. (2012) and Dufwenberg et al. (2005). Similarly, given that markets that are provided with BFVs are expected to converge faster toward fundamentals than markets that are not, we also expect them to exhibit smaller bubbles.

Hypothesis 3: *In early periods, trading behavior of uninformed traders differs from that of informed traders but converges along with the market price toward that of informed traders. Uninformed traders learn to grasp the correct state and to trade accordingly.*

Informed traders condition their trading behavior on private information and uninformed traders adapt their trading behavior based on the belief that informed traders only trade if it is advantageous for them to do so, thereby revealing gradually the underlying state. In a fully revealing RE all private information held by informed traders is (sooner or later) revealed via the market price (King, 1991). To the same extent as information is revealed, we expect that an adaptation of the trading behavior of in- and outsiders takes place.

Hypothesis 4: *In the "good" state, we expect insiders to hold more assets than outsiders, and in the "bad" state, outsiders to hold more assets than insiders.*

Given the different information structures of in- and outsiders, we expect the two types to show a significantly different buying and selling behavior. In Table 4 above we calculate the FV expectations of in- and outsiders. Based on these calculations we derive that insiders buy/hold more assets in the "good" state and outsiders in the "bad" state, under both the PI- and RE-assumption. The predicted asymmetric asset distribution should at least hold true in earlier periods, since we expect outsiders to learn in the course of the market.

Hypothesis 5: *Informed traders have a trading advantage and earn superior profits.*

Given that, especially in the beginning of the markets, insiders are able to buy and sell their assets for advantageous prices, they should benefit from their superior informational position.

Hypothesis 6: *Elicited price expectations and actual market prices are highly correlated. Thereby, we expect predictive power to be greater in markets with inside information and in markets where traders are provided with BFVs.*

There is a certain circularity in the market-price development process since current prices depend on expectations about future prices; but both are simultaneously influenced by current price levels and trends (Ball and Holt, 1998). Self-fulfilling price expectations can render observed market prices independent of the asset's fundamentals, leading to bubbles, in which even rational traders get involved in the expectation of even "greater fools".[13] Expectations should therefore provide crucial information about the market price development.

[13] Such bubbles are referred to as "rational growing bubbles" (Camerer, 1989) or simply "rational bubbles" (Diba and Grossman, 1988b). They "*reflect a self-confirming belief that the stock price depends on a variable (or a combination of variables) that is intrinsically irrelevant*" (Diba and Grossman, 1988a, p. 520). Porter and Smith (1995), however, find that "*subjects report a tendency to think that if the market turns [when the bubble bursts] they will be able to sell ahead of the others, but then are "amazed" at the speed with which the crash occurs*." (p. 513)

4. Experimental Results

4.1 Equilibrium Adjustment of Market Prices

Figure 1 illustrates the main findings of our experiment by showing the course of the average equilibrium market prices in our four treatments. Each curve in the four graphs represents four markets under equal conditions with respect to state, insider information, and the provision of BFVs. All four graphs show the tendency of convergence toward the correct state. Most intriguing, the ubiquitous tendency of earlier laboratory asset markets with well-defined declining fundamental value and inexperienced traders to exhibit a well-known bubble-and-crash pattern is not observed in this aggregated examination, independent of the provided information structure.

Strikingly, trade in both states starts, regardless of the presence of insiders and/or the provision of BFVs, on aggregate closer to fundamentals in the "bad" state, indicating risk aversion for the average trader.[14] Indeed, we find slight risk aversion for the average trader in our risk pretests and in the personal assessment of one's own attitude toward risk in the ex-post questionnaire (see Appendix A, Table A. 1 to Table A. 4). Given that average risk attitudes are very similar in all markets, we cannot find a significantly negative Spearman correlation between the average risk-aversion measure in a market and the 1st period market price.[15] However, when counting the number of risk-averse (not risk-neutral, or risk-loving) traders per market, we find a slightly significant Spearman correlation for Risk-Test 1 following Holt and Laury (2002) ($\rho = -.3049$, $p = .0897$, $N = 32$). Despite the substantial initial deviations from fundamentals (especially in the "good" state), we observe a clear tendency of convergence of aggregate market prices toward fundamentals of the actually underlying state around the fifth period. Intuitively, convergence starts in either state somewhere between the two fundamentals. This implies that we observe convergence from below in the "good" state and convergence from above in the "bad" state. In the following we explore Hypothesis 1.

While markets on aggregate show a clear convergence pattern, individual markets show substantial diversity. Some markets perform much better than others in terms of convergence toward the FV of the underlying state. Ten out of 32 markets even never converge to it.[16] We consider market prices as "converged" if they approach the respective FV as close as $\pm 20\%$ and stay in this range until the end of the market or no more trading takes place. For the very last periods, our definition of convergence requires at least two consecutive periods without trading, when market prices

[14] Since dividend draws can be considered as lotteries, trading prices below (above) fundamentals indicate risk aversion (loving) of the average market participant. Hence, the ratio of the realized price and the fundamental value can serve as a proxy for average risk attitude in a market (Chen et al., 2004).

[15] The algebraic signs point in the intuitive direction that higher risk aversion in a market leads to a lower starting price. Only for "Risk-Test 2b" the sign is counterintuitive.

[16] Markets 4, 6, 9, 10, 15, 21, 26, 28, 30, 32 never converged toward the FV of the actual underlying state using the applied convergence measure.

previously have deviated out of the range.[17] Figure 2 shows the course of individual market prices for all markets in the four treatments. As seen, market prices initially fluctuate more erratically but converge in most cases, sooner or later, toward the genuine state. Table 5 presents the average convergence period by treatment and the individual market convergence periods for the markets that have converged.

To test for general convergence, we count for each treatment the number of markets that have converged. Applying one-sided binomial tests to the number of converged versus the number of non-converged markets, we find a significant tendency of convergence only for Nin, where seven out of eight markets converge ($p = .0039$). The hypothesis of general convergence is neither confirmed for NinB nor for Tin or TinB markets, when analyzed separately.

When pooling the Nin and NinB markets, we observe 13 of 16 markets to converge, which yields statistical significance for general convergence ($p = .0106$, one-sided binomial test). Pooling Tin and TinB markets, we observe only 9 out of 16 markets to converge, implying no statistical significance. This indicates that the presence of insiders does not enhance but rather defer market convergence. On the other hand, confidence intervals for the absolute deviations from fundamentals are for the majority of periods narrower for Tin(B) than for Nin(B) markets. Although not statistically significant, this suggests that the lack of convergence in Tin(B) markets is driven by the small number of independent markets.

Result 1: *Using our simple counting measure, we only observe a general convergence toward fundamentals in Nin(B) markets. Our test for general convergence indicates that the presence of insiders defers convergence. This result, however, might be an artifact produced by the relatively small sample size. The provision of BFVs has no effect on convergence.*

[17] This "rule" has been relaxed/adjusted in some markets, where the measure in the last five periods trespassed the range in only one period, but was adhered to before, so that the assumption of convergence seems prudent. This "correction" has the aim to obtain a more "organic" and adequate measure of convergence. When no trading occurs, no pair of traders is willing to trade away from fundamentals, indicating that all traders are aware of the actual FV and that it is common knowledge (as defined by Aumann (1976)). There is no opportunity to "fool" another trader.

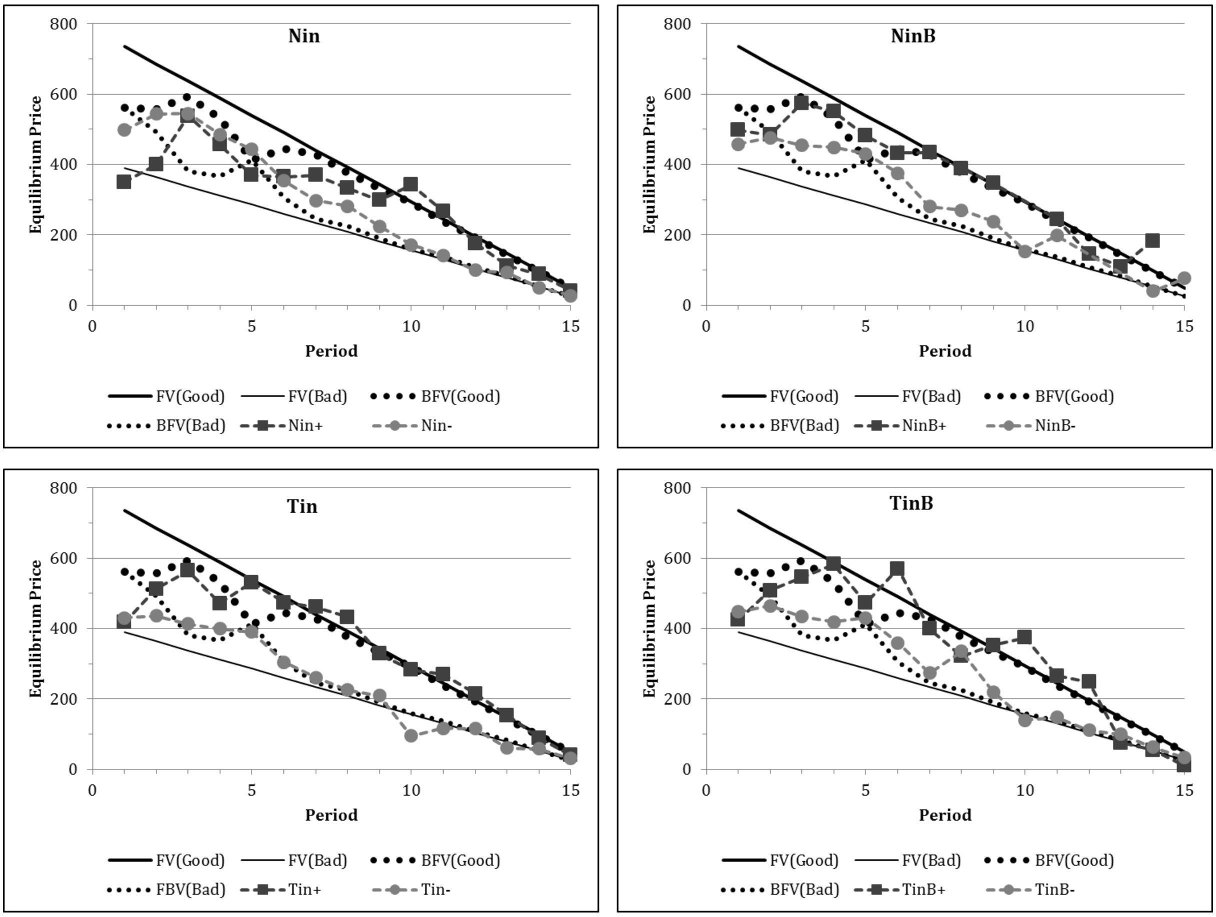

Figure 1: Average Market Prices

The trajectory of average market prices exhibits clear differences in comparison to most earlier experiments that use the SSW framework. Even in Nin markets the price course resembles that of markets with experienced traders or markets with a composition of traders with mixed information or experience levels (see, for example, Dufwenberg et al. (2005), Haruvy et al. (2007), Hussam et al. (2008), and Sutter et al. (2012)). Additionally, convergence, as we have defined it, occurs on average later than predicted by the PI- and RE-models,[18] except for NinB+ and Tin-. We thus conclude that neither the PI- nor the RE-model provide indeed good approximations of asset markets in our symmetric and asymmetric information settings. This finding stands in contrast to the previously mentioned literature on markets involving one-period assets and asymmetric information.

[18] Both, the PI- and RE-models, predict convergence to occur (as we define it) in the sixth period in both states, when no insiders are present. The PI-model predicts convergence in the first and in the sixth period and the RE-model predicts convergence in the first and in the second period, in the “good” and “bad” state, respectively, when insiders are present.

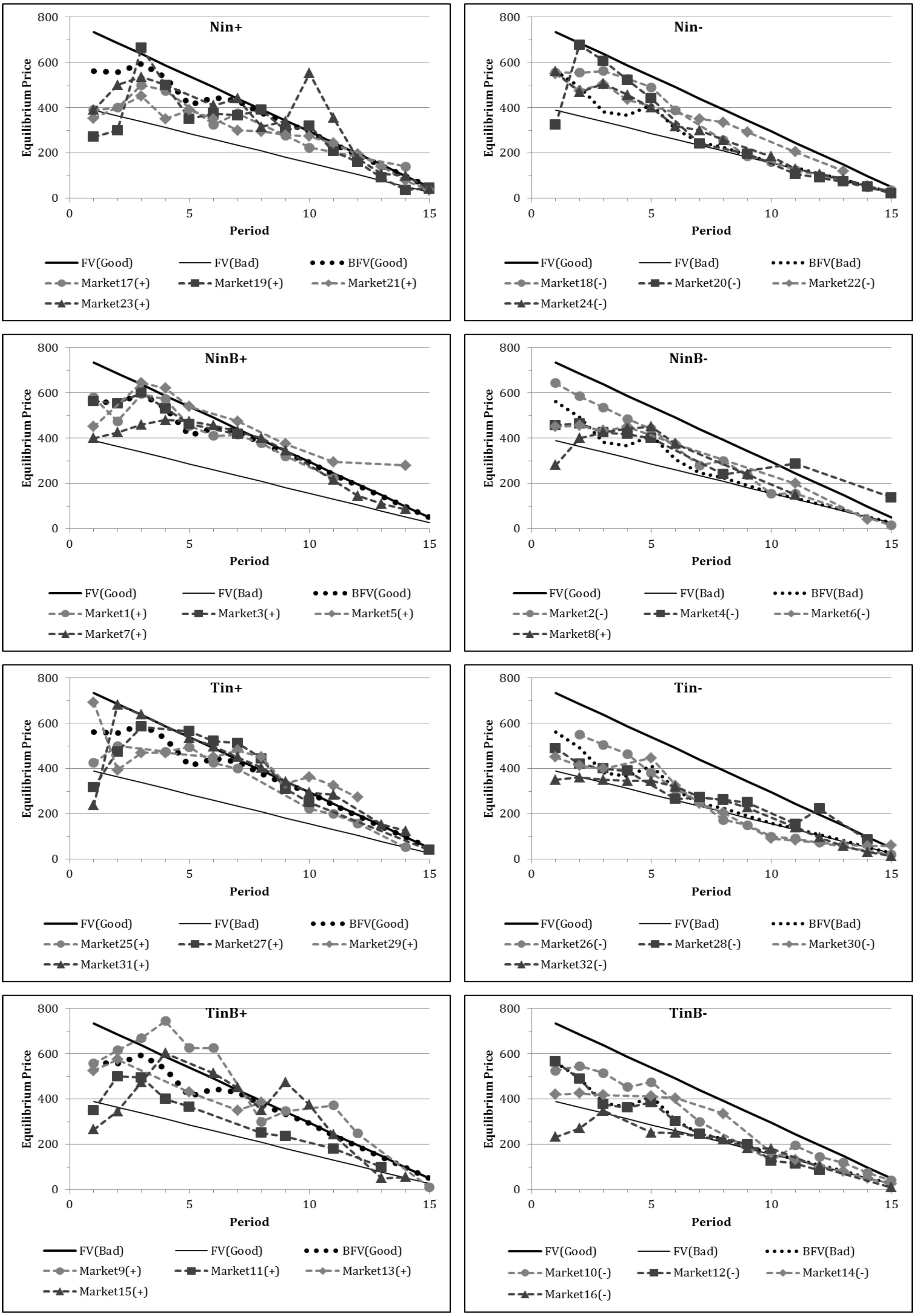

Figure 2: Individual Market Prices

Table 5: Periods of Convergence

State Label	Average Period of Convergence	Individual Markets Convergence Periods	Market No.
NinB+	5.3	3, 2, 2, 14	1, 3, 5, 7
NinB-	10.0	10, --, --, 10	2, 4, 6, 8
TinB+	11.0	--, 14, 8,--	9, 11, 13, 15
TinB-	6.0	--, 6, 9, 3	10, 12, 14, 16
Nin+	13.3	11, 15, --, 14	17, 19, 21, 23
Nin-	9.5	9, 6, 14, 9	18, 20, 22, 24
Tin+	7.3	11, 3, 13, 2	25, 27, 29, 31
Tin-	--	--, --, --, --	26, 28, 30, 32

Notes: Markets that did not converge are denoted by "--". Averages are computed using converged markets only.

4.2 Over- and Undervaluation of Market Prices

This chapter focuses on Hypothesis 2. As mentioned earlier, bubbles didn't occur in aggregated form. However, some markets exhibited patterns that, though smaller than in many previous experiments, could be considered as price bubbles. To gauge the severity of market-price deviations from fundamentals, i.e., differences in market performance, we employ two deviation measures,[19] both developed by Stöckl et al. (2010).

The applied average bias measure for a market calculates the relative deviation (RD) as the average difference between the market price (P_t) and the fundamental value (FV_t) normalized by the average fundamental value ($\overline{FV}$). It measures the average relative distance between the market price and the fundamental value. A value of ±0.1 indicates that the assets are on average overvalued (undervalued) by 10% relative to the average fundamental value.

$$RD = \frac{1}{15}\sum_{t=1}^{15}\left(\frac{P_t - FV_t}{\overline{FV}}\right) \quad (2)$$

The applied average dispersion measure for a market calculates the relative absolute deviation (RAD) as the average absolute difference between the market price (P_t) and the fundamental value (FV_t) normalized by the average fundamental value ($\overline{FV}$). It measures the average absolute distance between the period market price and the fundamental value. A value of 0.1 indicates that the assets price differs on average by 10% from the average fundamental value.

[19] Given the high correlation of these deviation measures with other calculated "bubble" measures, we restrain our analysis with the focus on these potentially most reliable measures, RD and RAD. These measures are robust to variations in the number of market periods, the determination of the FV and dividend distribution/variation.

$$RAD = \frac{1}{15}\sum_{t=1}^{15}\left(\frac{|P_t - FV_t|}{\overline{FV}}\right) \tag{3}$$

Both measures are used to get a first impression of differences in price deviations from fundamentals between treatments. We conduct two-sided Mann-Whitney U tests with the null hypothesis of no difference for both deviation measures. Table 6 displays the results. RDs are not significantly different when compared by treatment, due to the fact that negative deviations in the "good" and positive deviations in the "bad" state cancel each other out. The comparison of RADs shows that the provision of BFVs is only conducive to market performance when no insiders are present. The presence of insiders enhances performance compared to the situation without insiders, however, only when no BFVs are given. The performance of markets where insiders are present and BFVs are given together is indistinguishable to markets where only one of these features is at work.[20] [21]

To check the robustness of the results above and for a deeper understanding of potential factors that influence price formation and thus over- or undervaluation of equilibrium markets prices, we conduct panel-regressions with markets as cross sections ($m = 1, \dots, 32$). The dependent variable is derived from the above mentioned RD measure (Stöckl et al., 2010), denoted in percent. It is defined as:

$$RD_{mt} = \frac{P_{mt} - FV_t}{\overline{FV}}, \tag{4}$$

where RD_{mt} measures the difference between the market price of period t (P_t) and the respective fundamental value (FV_t), normalized by the average fundamental value ($\overline{FV}$) (Stöckl et al., 2010). The index m denotes the market.

[20] We also calculated the normalized absolute price deviation measure $ND = \frac{\sum_{t=1}^{15}|P_t - FV_t|}{60}$, which was introduced by King et al. (1993) and van Boening et al. (1993). ND sums up the deviations of the market prices from the FVs and normalizes this sum by the total number of assets outstanding in a market. Given that this measure yields qualitatively the same results as RAD, we refrain from a detailed presentation of the figures for this measure.

[21] Given the structure of our markets, it could be interesting to replace FV by BFV in both deviation measures. Since the results remain qualitatively very similar, we refrain from the presentation of these results.

Table 6: Relative and Absolute Deviation Measures from Fundamentals

Comparison by		Nin	NinB	p-value	Tin	TinB	p-value
Bayes[a]	RD	0.058	0.074	.8336	0.015	0.018	.9164
	RAD	0.291	0.195	**.0357**	0.176	0.200	.5286
		Nin	Tin	p-value	NinB	TinB	p-value
Insider[a]	RD	0.058	0.015	.8747	0.074	0.018	.5286
	RAD	0.291	0.176	**.0033**	0.195	0.200	.7527

Comparison by		Nin+	Nin-	p-value	NinB+	NinB-	p-value
State[b]	RD	-0.202	0.319	**.0209**	-0.095	0.243	**.0209**
	RAD	0.242	0.339	**.0209**	0.124	0.265	**.0433**
		Tin+	Tin-	p-value	TinB+	TinB-	p-value
State[b]	RD	-0.097	0.128	**.0209**	-0.113	0.148	**.0433**
	RAD	0.149	0.203	.1489	0.185	0.214	.7728
		Nin+	NinB+	p-value	Nin-	NinB-	p-value
Bayes[b]	RD	-0.202	-0.095	**.0833**	0.319	0.243	.2482
	RAD	0.242	0.124	**.0209**	0.339	0.265	.2482
		Tin+	TinB+	p-value	Tin-	TinB-	p-value
Bayes[b]	RD	-0.097	-0.113	.7728	0.128	0.148	.5637
	RAD	0.149	0.185	.3865	0.203	0.214	.7728
		Nin+	Tin+	p-value	Nin-	Tin-	p-value
Insider[b]	RD	-0.202	-0.097	**.0591**	0.319	0.128	**.0209**
	RAD	0.242	0.149	**.0209**	0.339	0.203	**.0209**
		NinB+	TinB+	p-value	NinB-	TinB-	p-value
Insider[b]	RD	-0.095	-0.113	.7728	0.243	0.148	.3865
	RAD	0.124	0.185	.2482	0.265	0.214	.3865

Notes: Mann-Whitney U test, two-sided: [a] $N = 16$ (8/8), [b] $N = 8$ (4/4).

We control for treatment effects by using dummy variables for different treatment features (considering Nin+ as the control group) and their interactions. In particular, we control for the "state of the world" ($State$, which is equal to one in the "bad" state and zero otherwise), for the provision of BFVs ($Bayes$, which is one when BFVs are given and zero otherwise), and for the presence of insiders ($Insiders$, which is equal to one, when insiders are present, and zero otherwise). Additionally, we control for autocorrelation by inclusion of the dependent variable with a lag of one period ($L.\,RD$), for a time trend within markets by inclusion of a period variable ($Period$), and for the trading volume ($Volume$). Furthermore we included the drawn dividend in the prior period ($L.\,Dividend$) and the number of risk-averse traders within a market ($\#\ Risk\ Averse$) as explanatory variables. The results are shown in Table 7.

Since both regression models shown in Table 7 display qualitatively the same results, we focus our analysis on Model 2. The model shows that price deviations are strongly path-dependent; a price deviation in the previous round ($L.\,RD$) has a significantly positive effect on the current price deviation. Price deviations decrease over time as participants gain trading experience. $Period$ has a significantly negative effect on price deviation. The last dividend ($L.\ Dividend$) has a significantly positive (euphoriant price boosting) effect, the higher the dividend in the previous period the larger the price deviation in the current period. Trading activity as measured by $Volume$ has no significant effect, just as the number of risk-averse traders within a market ($\#\ Risk\ Averse$).

Turning to the effects of treatment features, we see that "bad"-state markets exhibit significantly larger price deviations than "good"-state markets, a non-surprising finding, consistent with the prior nonparametric analysis. The provision of BFVs has no effect in both states, when the utilized control variables are considered. This contradicts the nonparametric result. We do not expect that this lack of difference is caused by the fact that traders were actually able to calculate BFVs in the setting where they were not provided. But traders seem to be intuitively able to anticipate approximated BFVs. The presence of insiders is only significant, i.e., exerting a negative (price deviation decreasing) effect in "bad"-state markets,[22] a finding that requires further analysis for a proper understanding.

We are able to calculate the treatment effects (coefficients), given that treatments are comprised of combinations of several features. These coefficients are presented in Table 8 in descending order in terms of the coefficient size. The calculated coefficients are equal to the ones that result out of a regression with treatments as dummy variables and Nin+ as baseline.

Using these coefficients, we are able to disentangle differences between treatments by conducting meaningful comparisons which consist of three comparisons for each treatment: (1) a comparison with the counterpart in the "bad"/"good" state, (2) a comparison with the counterpart where BFVs are/are not provided, and (3) a comparison with the counterpart where insiders are/are not present, respectively. We conduct Wald tests to test for the equality of estimated coefficients for these comparisons. The results can be retraced via Table 9, where all possible comparisons are shown and significant differences are highlighted as bold figures.

Our finding that "bad" state markets exhibit significantly larger price deviations than "good"-state markets is confirmed with the exception of Tin markets, where deviations in the "bad" state are larger, however, statistically insignificant. The result that the provision of BFVs has no effect is unambiguously confirmed. Moreover, as already seen, the presence of insiders significantly reduces price deviations in "bad"-state markets, leading to an improved market performance.

[22] This outcome is, as explained later, driven by the fact that Nin+ and Tin+ markets are not statistically different. In the comparison of NinB+ and TinB+ markets the presence of insiders is beneficial.

Table 7: Regressions for RDs of Market Prices from Fundamentals

Dependent Variable: RD_{mt}	Model 1	Model 2
Constant (Nin+)	6.30	-3.53
	(5.01)	(10.12)
$L.RD_{mt}$	0.56***	0.57***
	(0.05)	(0.04)
Period	-1.15***	-1.20***
	(0.41)	(0.57)
Volume	0.13	0.10
	(0.27)	(0.26)
State (Nin-)	22.30***	25.38***
	(7.03)	(8.22)
Bayes (NinB+)	-4.75	-2.68
	(4.08)	(4.87)
Insiders (Tin+)	4.43	4.66
	(4.87)	(5.10)
State×Bayes	6.56	3.12
	(6.54)	(9.12)
State×Insiders	-16.39**	-17.29*
	(7.93)	(10.09)
Bayes×Insiders	8.63	6.42
	(6.53)	(7.60)
State×Bayes×Insiders	-8.06	-3.05
	(9.41)	(12.98)
L. Dividend		0.12***
		(0.04)
# Risk Averse		0.92
		(1.68)
R^2	.7478	.7534
N	247	247

Notes: Prais-Winsten panel-regressions with heteroscedastic panels corrected standard errors and panel-specific autocorrelation (AR1) (Beck and Katz, 1995). 32 markets as cross sections with a maximum of 15 observations over time (unbalanced). Only periods where trade took place are considered. Standard errors are shown in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 8: Treatment Effects on RDs of Market Prices from FVs in Model 2

Treatment	Effect of…	Coefficient	p-value
NinB-	*S+B+SB*	25.82	**.000**
Nin-	*S*	25.38	**.002**
TinB-	*S+B+I+SB+SI+BI+SBI*	16.56	**.000**
Tin-	*S+I+SI*	12.75	**.004**
TinB+	*B+I+BI*	8.40	**.062**
Tin+	*I*	4.66	.361
Nin+	---	-3.53	.727
NinB+	*B*	-2.68	.582

Notes: *S* = State ("Bad"), *B* = BFVs (provided), *I* = Insiders (present).

Table 9: Wald Tests for Differences of Treatment Coefficients in Model 2

	NinB+	NinB-	TinB+	TinB-	Nin+	Nin-	Tin+	Tin-
NinB+	---	**.000**	**.018**	**.000**	.582	**.000**	.103	**.002**
NinB-		---	**.001**	**.032**	**.000**	.942	**.000**	**.003**
TinB+			---	**.077**	**.062**	**.027**	.469	.364
TinB-				---	**.000**	.175	**.016**	.379
Nin+					---	**.002**	.361	**.004**
Nin-						---	**.005**	**.087**
Tin+							---	.134
Tin-								---

Notes: p-values of Wald tests for the simple linear hypothesis of equality of estimated parameters are shown. Nin+ is the reference category. Bold figures show significant differences at the 10 % level.

Furthermore, the presence of insiders leads to an increase of the deviation measure in the “good” state, which, given that “good”-state markets tend to trade below fundamentals, leads to an improvement in market performance, i.e., deviations from FVs are smaller in absolute terms, when insiders are present; however, the difference between Nin+ and Tin+ is not significant. Thus, these findings confirm and broaden the prior findings of the nonparametric analysis.[23]

Result 2: *Bubbles occur but are infrequent. The nonparametric analysis indicates that the introduction of insiders reduces bubbles, measured by RD and RAD, however, only when BFVs are not provided. The provision with BFVs significantly reduces deviations, however, only when no insiders are present. The performance of markets where insiders are present and BFVs are given together is not distinguishable from markets where only one of these ingredients is at work. The panel analysis refines and demerges the previous results and indicates that the introduction of insiders improves market performance (measured by* RD_{mt}*) and that the provision of BFVs has no effect on market performance.*

For the sake of completeness, Figure 3 presents the course of the average trading volumes conditioned on information and the provision of BFVs. Each curve represents the average over four markets, in the “good” or “bad” state, respectively. The trading volume shows a tendency to decline on average with market duration. Trading volumes do not to differ significantly between different treatment conditions.

[23] The replacement of FV by BFV in the RD measure of the regressions yields qualitatively very similar results, we thus refrain from the presentation.

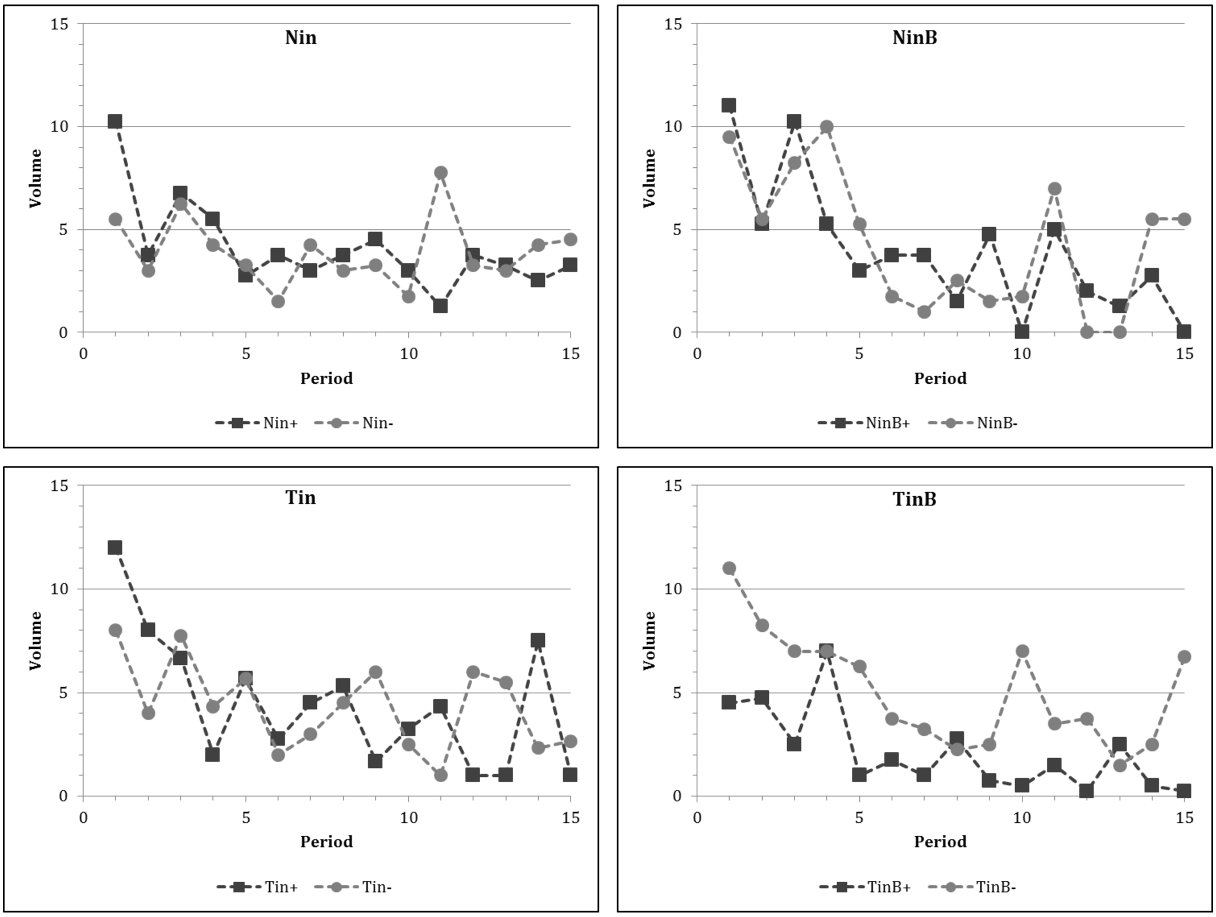

Figure 3: Average Trading Volume

4.3 Comparison of Insider and Outsider Behavior

Following the investigation of overall trading patterns, we now turn to the analysis of the trading behavior of in-and outsiders and explore Hypotheses 3 to 5. Figure 4 shows the course of average limit buy and sell order prices in the Tin and TinB markets.[24] As can be seen, in- and outsider limit bids and limit asks differ but not substantially. Limit buy and sell order prices only differ clearly in the first period(s) of the Tin+ and TinB- markets. In these cases both prices are lower for insiders in the TinB- markets (in the case of limit sell order prices "irrationally" low) and higher in the Tin+ markets, respectively. Furthermore, the following general patterns are visible. Firstly, both trader types, on average, want to pay less when buying and ask higher prices when selling assets compared to the actual FV in the TinB+ and Tin+ markets. Secondly, both trader types, on average, want to pay approximately the FV to buy assets but ask more than the actual FV to sell assets in the TinB- and Tin- markets.

Result 3: *Trading behavior of uninformed traders at the beginning differs from that of informed traders but converges with the market price during the market toward that of informed traders. Uninformed traders are able to grasp the correct state and to trade accordingly to it.*

We continue our analysis with nonparametric statistical tests on first-period bid and ask behavior of in- and outsiders, measured by the limit buy/sell order prices and quantities. First-period behavior of outsiders does not differ between the two states (using two-sided U tests), whether BFVs are provided or not. In other words, the starting positions of outsider bid and ask prices and quantities are the same in the "good" and "bad" state. First-period behavior of insiders, on the contrary, differs significantly between the two states, with higher bid/ask prices in the "good" state, and also larger bid/ask quantities, when BFVs are not provided (see Table A. 5 in Appendix A).

Comparing first-period behavior between in- and outsiders, we find outsider limit buy/sell order prices to be higher in TinB- markets and insider limit buy order prices and sale quantities to be higher in the Tin+ markets (using two-sided U tests). The differences in buy/sell order prices and quantities in TinB+ and Tin- markets are insignificant (see also Table A. 5 in Appendix A).

To identify overall differences in the buying and selling behavior of in-and outsiders, we conduct panel-regressions with traders as cross sections ($i = 1, \dots, 192$). The dependent variable used is again derived from the RD measure (Stöckl et al., 2010), denoted in percent, and is defined as:

$$RD_{it}^{D,S} = \frac{p_{it}^{D,S} - FV_t}{\overline{FV}}, \tag{5}$$

[24] Figures A. 1 and A. 2 in Appendix A additionally exhibit the average limit buy and sell prices of the Nin(B) and Tin(B) markets, whereby for the latter prices are averaged over both in- and outsiders.

where $RD_{it}^{D,S}$ measures the difference between the individual limit buy/sell order prices of period t ($p_{it}^{D,S}$) and the respective fundamental value (FV_t), normalized by the average fundamental value ($\overline{FV}$).

We control for trader type effects by using dummy variables for the trader types under all treatment conditions (resulting in $Nin + Outsider$ as the reference type). Additionally, we control for autocorrelation by inclusion of the dependent variable with a lag of one period ($L.\ RD$), for a time trend within markets by inclusion of a period variable ($Period$), for the bid/ask quantity ($Order\ Quantity$), for the amount of assets held in the portfolio ($Asset\ Holdings$), and for the trading activity in the previous period ($L.\ Bought\ Assets$, $L.\ Sold\ Assets$). Furthermore, we include the drawn dividend of the prior period ($L.\ Dividend$), a variable that measures the individually perceived understanding of the market ($Market\ Understanding$, elicited in the ex-post questionnaire, ranging from 0 to 10), a variable that measures individual risk aversion ($Risk\ Aversion$) (elicited following the approach of Holt and Laury (2002), ranging from -3 to 5), and $Gender$ (with women as reference category) as explanatory variables. The results are shown in Table 10. Given the similar results for each of both dependent variables, we focus our analysis respectively on the augmented Models 4 and 6.

The regression results for Model 4 show that bid price deviations (measured by $RD_{it}^{p^D}$) are path-dependent; $L.RD$ has a significantly positive effect. Traders bid relatively more eagerly in later periods; $Period$ has a significantly positive effect on bid prices. Traders are cautious when buying, the higher the bid quantity, the lower the bidding price; $Order\ Quantity$ (q_{it}^D) has a significantly negative effect. Current asset holdings (in the portfolio) and the quantity of sold assets in the prior period do not have an influence; $Asset\ Holdings$ and $L.\ Sold\ Assets$ are insignificant. Previous buying success, however, reduces bid prices; $L.\ Bought\ Assets$ has a significantly negative effect. The dividend drawn in the previous period has a slight price boosting effect, the higher the dividend in the previous period the larger the bid price in the current period; $L.Dividend$ is significantly positive. Individual $Market\ Understanding$ and $Risk\ Aversion$ have significantly negative effects on bid prices. Male traders bid higher prices compared to women; $Gender$ is significantly positive.

Comparing the bid prices of in- and outsiders, we see that on average insiders bid higher prices in the Tin+ and TinB+ markets and lower prices in the Tin- and TinB- markets. All differences are significant, except for TinB- (see Table 11).

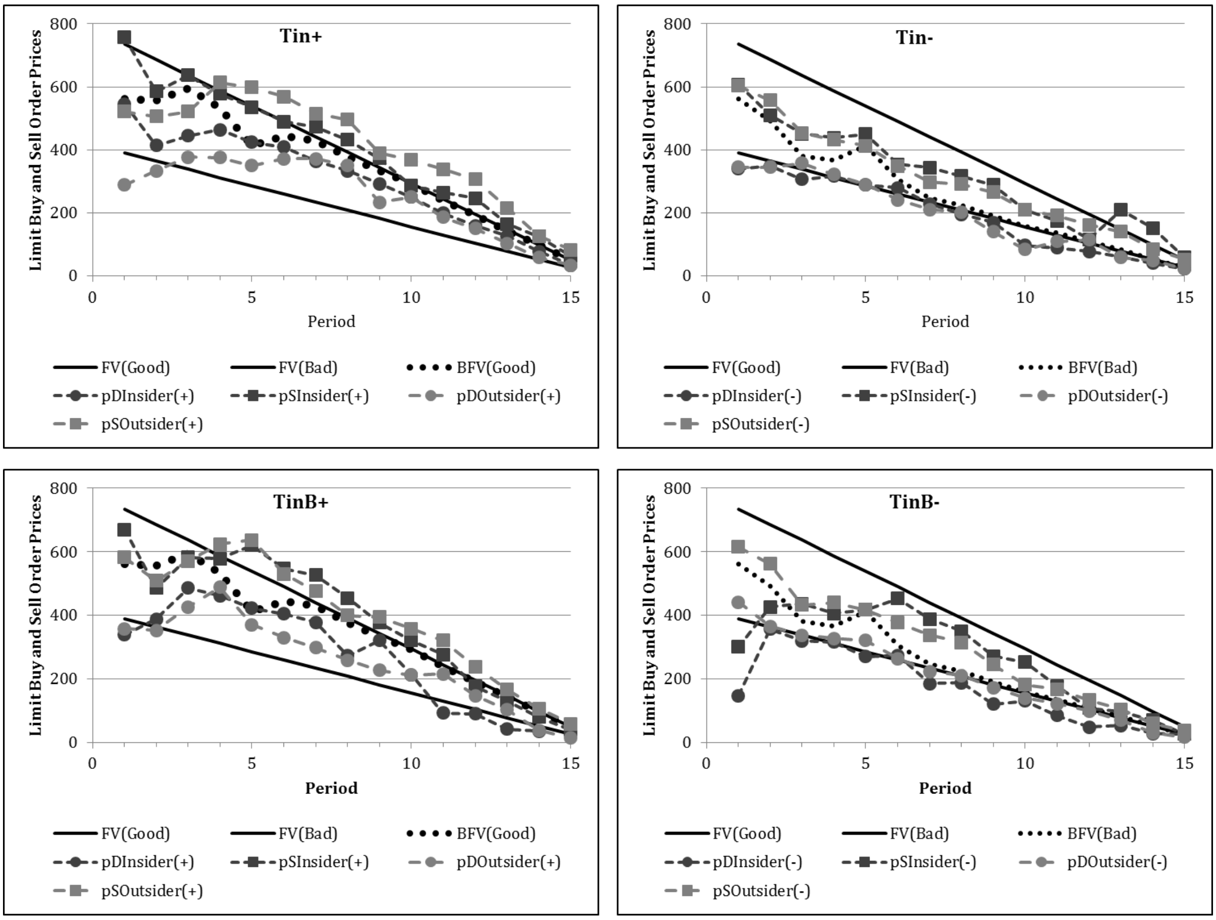

Figure 4: Insider and Outsider Limit Buy Order and Limit Sell Order Prices

The regression results for Model 6 show that ask prices (measured by $RD_t^{p^S}$) are strongly path-dependent (more path-dependent than bid prices); $L.RD$ has a significantly positive effect. Traders are satisfied with lower ask prices in later periods; $Period$ has a significantly negative effect. Traders seem not to be as cautious with regard to their portfolio when selling; $Order\ Quantity$ (q_{it}^S) and current $Asset\ Holdings$ do not to have a significant effect. On the other hand, previous buying success reduces ask prices, $L.\ Bought\ Assets$ is significantly negative, and previous sale success increases ask prices, $L.\ Sold\ Assets$ is significantly positive. The dividend drawn in the previous period again has a slight price boosting effect on the ask price in the current period; $L.\ Dividend$ is significantly positive. Individual $Market\ Understanding$, $Risk\ Aversion$, and $Gender$ have no significant effects on ask prices.

Looking at the comparison of ask prices between in- and outsiders we see that on average insiders ask higher prices in the Tin+, TinB+, and TinB- markets and lower prices in the Tin- markets. However, the differences are only significant for Tin+ and Tin- markets (see Table 11).

Table 10: Regressions for RDs of Limit Buy and Sell Prices from Fundamentals

Dependent Variable:	Model 3 $RD_{it}^{p^D}$	Model 4 $RD_{it}^{p^D}$	Model 5 $RD_{it}^{p^S}$	Model 6 $RD_{it}^{p^S}$
Constant (Nin+ Outsider)	-18.53***	-5.78	7.47**	23.40***
	(6.23)	(10.14)	(3.06)	(7.64)
L. $RD_{it}^{p^{D,S}}$	0.32***	0.31***	0.56***	0.56***
	(0.06)	(0.06)	(0.03)	(0.03)
Period	0.65*	0.62*	-0.72***	-0.72***
	(0.34)	(0.33)	(0.24)	(0.24)
Order Quantity (q_{it}^D, q_{it}^S)	-0.63***	-0.73***	-0.12	-0.11
	(0.12)	(0.13)	(0.23)	(0.22)
Asset Holdings	-0.14	-0.25	-0.12	0.01
	(0.18)	(0.17)	(0.23)	(0.20)
L. Bought Assets	-2.17***	-2.17***	-1.20***	-1.08***
	(0.36)	(0.36)	(0.39)	(0.38)
L. Sold Assets	-0.13	-0.18	2.36***	2.55***
	(0.46)	(0.45)	(0.46)	(0.46)
Nin- Outsider	41.83***	43.75***	25.94***	26.12***
	(7.08)	(7.18)	(4.52)	(4.31)
NinB+ Outsider	9.68**	10.12**	-0.17	0.09
	(3.90)	(4.05)	(2.76)	(3.09)
NinB- Outsider	37.68***	38.47***	25.18***	24.84***
	(6.84)	(6.94)	(4.42)	(4.55)
Tin+ Insider	4.63	10.77**	1.61	5.04
	(4.59)	(5.13)	(2.77)	(3.21)
Tin+ Outsider	3.29	1.14	-0.49	-3.38
	(3.91)	(4.13)	(2.93)	(3.21)
Tin- Insider	14.36***	13.15***	5.77	0.82
	(4.68)	(4.89)	(4.39)	(4.82)
Tin- Outsider	20.65***	21.88***	9.63***	9.25***
	(5.06)	(5.40)	(3.42)	(3.59)
TinB+ Insider	9.31*	10.35**	1.46	0.66
	(4.91)	(5.13)	(2.82)	(3.06)
TinB+ Outsider	0.53	-2.92	0.33	-1.83
	(4.04)	(4.83)	(2.85)	(2.86)
TinB- Insider	24.66***	22.87***	17.44***	15.62***
	(7.95)	(8.16)	(4.48)	(4.81)
TinB- Outsider	26.44***	25.60***	10.91**	9.62*
	(5.79)	(5.80)	(5.31)	(5.40)
L. Dividend		0.05*		0.07**
		(0.03)		(0.03)
Market Understanding		-2.98**		-3.69
		(1.29)		(1.13)
Risk Aversion		-1.57***		-0.34
		(0.51)		(0.53)
Gender (Male)		8.16***		0.05
		(2.45)		(1.99)
R^2	.3961	.4131	.6099	.6170
N	1597	1597	1742	1742

Notes: Prais-Winsten panel-regressions with heteroskedastic panels corrected standard errors and panel-specific autocorrelation (AR1) (Beck and Katz, 1995). 192 traders as cross sections with a maximum of 15 observations over time (unbalanced).). Only cases where buy/sell offers were made are considered. Standard errors are shown in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 11: Wald Tests for Differences of Treatment Coefficients in Models 4 & 6

Treatment (State Label)	Insider vs. Outsider $\bar{p}^D$ (4)	$\bar{p}^S$ (6)
Tin+	**.0291 (>)**	**.0280 (>)**
Tin-	**.0459 (<)**	**.0704 (<)**
TinB+	**.0080 (>)**	.4158
TinB-	.7135	.3083

Notes: p-values of Wald tests for the simple linear hypothesis of equality of estimated parameters are shown.

Aggregating the results for limit bid/ask prices, we conclude that, particularly in the beginning of the markets, insiders are the traders which tend to buy assets in the "good" state, when assets are relatively cheaply sold by outsiders and sell assets in the "bad" state, when they are relatively expensively bought by outsiders. Given this conclusion it is not surprising that asset holdings of in- and outsiders indeed differ significantly between "good"-state and "bad"-state markets, at least in the beginning of the markets, as it is theoretically predicted by both informational models (PI and RE).

In the "good"-state markets, insiders hold on average more assets during the entire markets and significantly more during the first six periods. In the "bad"-state markets outsiders hold on average more assets during the entire markets and significantly more during periods 3 to 13. All differences are significant at the 5-10% level, using the Wilcoxon matched pairs signed-rank test, $N = 16$ (8/8). Insiders are thus capable of using their superior informational position and buy relatively underpriced assets in the "good" state and sell relatively overpriced assets in the "bad" state. However, it should be noted that asset stocks of in- and outsiders align during the course of the markets in both states.

Result 4: *Insiders are those traders that hold more assets in the "good"-state markets and outsiders are those traders that hold more assets in the "bad"-state markets.*

Furthermore a concentration of assets with individual players over the course of the markets is evident. Over all markets the trader with the largest asset portfolio in one market holds on average 27.2 assets (with a standard deviation of 6.3) at the end of period 15. Concentration, however, is not automatically equated with a more remunerative trading strategy of the "hoarding" traders. Although, in eleven markets those traders which held the largest asset stock also earned the highest net-profit (total profit minus prediction earnings), a significant correlation cannot be detected between the asset stock of a trader at the end of a market and her/his net-profit. The Spearman's rank correlation coefficient is $\rho = .0263$ (p = .7174).

Although the behavior of in- and outsiders converges, insiders are able to benefit from their superior informational position. Insiders on average earn higher total profits in Tin+, Tin-, TinB+, and TinB- markets, though the difference to outsiders is only significant for Tin+ (see Table A. 6 in Appendix A). Aggregated over all treatments with informational asymmetry, insiders earn significantly higher total profits (6346 ECU vs. 5565 ECU, two-sided t-test, p = .0793, N = 96, 32/64).

Result 5: *Informed traders have a trading advantage that is revealed in superior profits. Summarized our data definitively indicates that traders in Tin(B) markets didn't incur what Camerer et al. (1989) call the "curse of knowledge".*

Our markets are not strong-form efficient, following the definition of Fama (1970), because insiders are able to earn "abnormal returns" from trading on the basis of their private (insider) information. This result supports the findings of Jaffe (1974).

4.4 Beliefs and Market Prices

Since optimal trading actions depend on beliefs about other players' decisions, which again depend on the beliefs of actions of others etc. (Palfrey and Wang, 2009),[25] we examine if stated beliefs on the market price are informative about the actual market price. We investigate to what extent elicited price expectations and actual market prices are correlated. Furthermore, we are interested in how expectations change if the available information and distribution of information changes.

We are aware that belief elicitation can alter decisions in the experiment. Gächter and Renner (2010) for example have shown that incentivized belief elicitation about contributions of others leads to higher contributions in a public-good experiment. However, the experimental asset markets investigated by Haruvy et al. (2007), who elicited beliefs about market prices in the same way as we do, closely resemble markets of previous studies without belief elicitation. Thus, we do not expect a large manipulation.

In the beginning of each period, participants were required to state their expectations about the prospective market prices of the present and all subsequent trading periods. In the following we denote the elicited beliefs in the form: B_t^f, where t denotes the period of elicitation, i.e., the period in which traders were asked to submit their price beliefs and f denotes the period forecasted, i.e., the period for which the price beliefs are stated.

[25] "*In a world of uncertainty "fundamentals" get replaced by expectations about fundamentals*" (Sunder, 1995, p. 468).

Figure 5 shows the average predicted price levels by treatment. Each bar in all eight graphs represents the average of four markets, i.e., 24 traders.[26] As can be seen, traders' expectations about the price trajectory contain the belief of declining prices as theoretically prescribed by fundamentals. This indicates that fundamentals are clearly interpreted as the expected value of the future dividend stream, as emphasized in the experimental instructions. In contrast to Lei et al. (2001), in our framework, a common dividend, and common knowledge thereof, seems to be sufficient to induce initial common expectations that are consistent with fundamentals. In contrast, traders in Haruvy et al. (2007) anticipated a flat price trajectory at the beginning, followed by an increasing trajectory in the middle, and a declining trajectory toward the end of the first round of their experiment. Our findings resemble their markets with most experienced traders.[27]

Individual beliefs for the first period (B_1^1) start under almost all conditions around the BFV in the 1st period, which is 563. A t-test for the null hypothesis of no difference shows only for Tin a significant difference, where the average is 465.7 ($p = .0036$, $N = 48$), compared to 547.4, 528.6, and 552.9 for NinB, TinB, and Nin respectively. Price assessments do not differ significantly by state within equal treatment conditions.

Within the insider treatments with and without the provision of BFVs, we find that insider B_1^1 are respectively significantly higher for the "good" state compared to the "bad" state (two-sided U tests, $N = 16$: 587.9 vs. 296.6, $p = .0098$; 596.5 vs. 488.8, $p = .0712$). Outsider beliefs on the other hand are, as we would expect, not significantly different between both states (two-sided U tests, $N = 32$: 548.2 vs. 595.4, $p = .4677$; 431.4 vs. 423.1, $p = .7773$), though clearly different with and without the provision of BFVs.

Applying our convergence measure, defined in Subsection 4.1, on the average last belief for each period ($\bar{B}_t^t$), we find that beliefs converge more slowly toward fundamentals than market prices. We find 21 out of 32 markets not to converge, compared to ten markets for prices. Convergence time is slower for all treatments, though the difference is only significant for Tin (two-sided Wilcoxon signed-rank test, $p = .0487$). This result is consistent with the findings of Haruvy et al. (2007) when traders had some experience. Comparing the RD and RAD measures for last beliefs (B_t^t) and market prices, we find that RD shows only a significant difference between beliefs and market prices in NinB, where it is larger for prices, while the RAD measure is significantly larger for beliefs in NinB, TinB, and Tin markets (two-sided Wilcoxon signed-rank test, respective p-values: .0687, .0251, and .0357). It seems that positive and negative deviations cancel out each other for RD for both, beliefs and prices, but that deviations are absolutely larger for beliefs as revealed by RAD. Markets seem to exert a kind of synergy effect on traders' beliefs that help prices to converge faster to the rational expectations equilibrium than

[26] Figure A. 3 in Appendix A illustrates the associated between-subject standard deviations of the market-price predictions.
[27] Participants in Haruvy et al. (2007) played four markets, consisting of 15 periods each, in a row.

beliefs. To further test whether better market-price predictions in a market, measured by the average total prediction earnings in a market, lead to lower price deviations from fundamentals, measured by RD and RAD, we use a Spearman correlation test. We find a negative, however insignificant relation for RD (ρ = -.1850, p = .3108), but a significantly negative correlation for RAD (ρ = -.3082, p = .0862). Better predictions thus seem to lower price deviations.

Since the most important characteristic of forecasts or predictions is their correctness, we now turn to the ability of forecasts to make inferences about future prices. To estimate the informational content contained in predictions of traders, we first estimate if and how the price level and the average belief about the market price are "correlated", using the following model:

$$P_{mt} = \alpha + \beta \bar{B}_{mt}^{t} + \gamma X + \epsilon_t, \tag{6}$$

where P_t is the market price in period t, $\bar{B}_t^t$ is the average stated belief for the market price of period t in period t. X is a vector of further explanatory variables, containing treatment dummies, a period variable ($Period$), and the drawn dividend in the prior period ($L.\ Dividend$). If short-term expectations of market prices are unbiased, then $\alpha = 0, \beta = 1$, and $\gamma = 0$ are the expected coefficients.

Furthermore, to test the correctness of average trader beliefs concerning the anticipation of the market price, we estimate the following model:

$$\frac{\bar{B}_{mt}^{t} - P_{mt}}{P_{mt}} = \alpha + \beta \left(\frac{\bar{B}_{mt-1}^{t-1} - P_{mt-1}}{P_{mt-1}} \right) + \gamma X + \epsilon_t, \tag{7}$$

where $(\bar{B}_t^t - P_t)/P_t$ denotes the deviation of the average belief in a market from the market price, relative to the market price. $(\bar{B}_{t-1}^{t-1} - P_{t-1})/P_{t-1}$ is simply the one-period lag of the dependent variable and X is defined as above. If short-term expectations are unbiased, i.e., correct, then $\alpha = 0, \beta = 0$, and $\gamma = 0$ are the expected coefficients.

The regression results of both models are shown in Models 7 and 8 in Table 12. As can be seen from Model 7 price expectations and actual market prices are strongly "correlated" with a highly significant coefficient of 0.9, which is however significantly different from one ($\beta \neq 1$, p = .0011). Model 8 shows that the forecast quality, i.e., the relative deviation of beliefs from market prices, is not auto-correlated since β is not statistically different from zero. Moreover, as it seems, the presence of insiders rather impedes forecast precision than enhances it. The three largest negative coefficients of treatment dummies, which hint on an underestimation of market prices, are all attributed to treatments where insiders are present (TinB+, Tin+, and Tin-).

This finding seems to be driven by the outsiders in the Tin(B) markets and is supported by the following: On aggregate over all treatments with informational asymmetry, we find a significant difference in prediction earnings between in- and outsiders (144.9 ECU vs. 115.3 ECU, two-sided t-test, p = .0735, N = 96, 32/64).[28] Prediction earnings of outsiders in the Nin(B) markets are, however, not significantly different from earnings of insiders in the Tin(B) markets; but they are also significantly larger than prediction earnings of outsiders in the Tin(B) markets (137.0 ECU vs. 115.3 ECU, two-sided t-test, p = .0562, N = 160, 96/64). The presence of insiders thus seems to psychologically impede the prediction ability of outsiders in the Tin(B) markets. This finding is consistent with Lovaglia et al. (1998), who found that a randomly assigned lower status impedes performance in a test of mental ability.

Given that the maximum possible amount for prediction earnings is 600 ECU, if all predictions lie in a range of $\pm 10\%$ of the market price, prediction earnings of both trader types are quite bad and close to another, with a mean of 125.2 ECU, a standard deviation of 76.3 ECU, and a minimum and maximum of 0 ECU and 396 ECU over all 192 traders, respectively. Nevertheless, although the difference in prediction earnings between in- and outsiders is not large, it indicates that the trading advantage of insiders is at least partially conveyed in a better ability to anticipate market prices.

Result 6: *Elicited price expectations and actual market prices are highly correlated. However, forecast quality (precision of beliefs) seems rather to be impeded by the presence of insiders. The provision of BFVs seems to have no impact on forecast quality.*

To test whether better predictors also earn higher total trading profits (total profits corrected for prediction earnings) we use a Spearman correlation test. Over all 196 traders we find a highly significant connection between individual prediction quality and trading profits (ρ = .2717, p = .0001). As we would expect, better predictors have more success in the market.

Additionally, we found men to make significantly higher earnings for predictions compared to women (139.5 vs. 118.5, two-sided t-test, p = .0432, N = 192, 113/79) and higher total trading profits, though here the difference is not significant (5800 vs. 5559, two-sided t-test, p = .4362, N = 192, 113/79). Alike, master students make significantly higher earnings for predictions compared to bachelor students (151.4 vs. 124.9, two-sided t-test, p = .0319, N = 181, 42/139) and also earn higher total trading profits (6372 vs. 5430, two-sided t-test, p = .0106, N = 181, 42/139).

[28] When Tin+, Tin-, TinB+, and TinB- markets are considered separately (see Table A. 6 in Appendix A), we find insiders to be slightly better predictors and earn on average higher prediction earnings, however, the difference to outsiders is not significant.

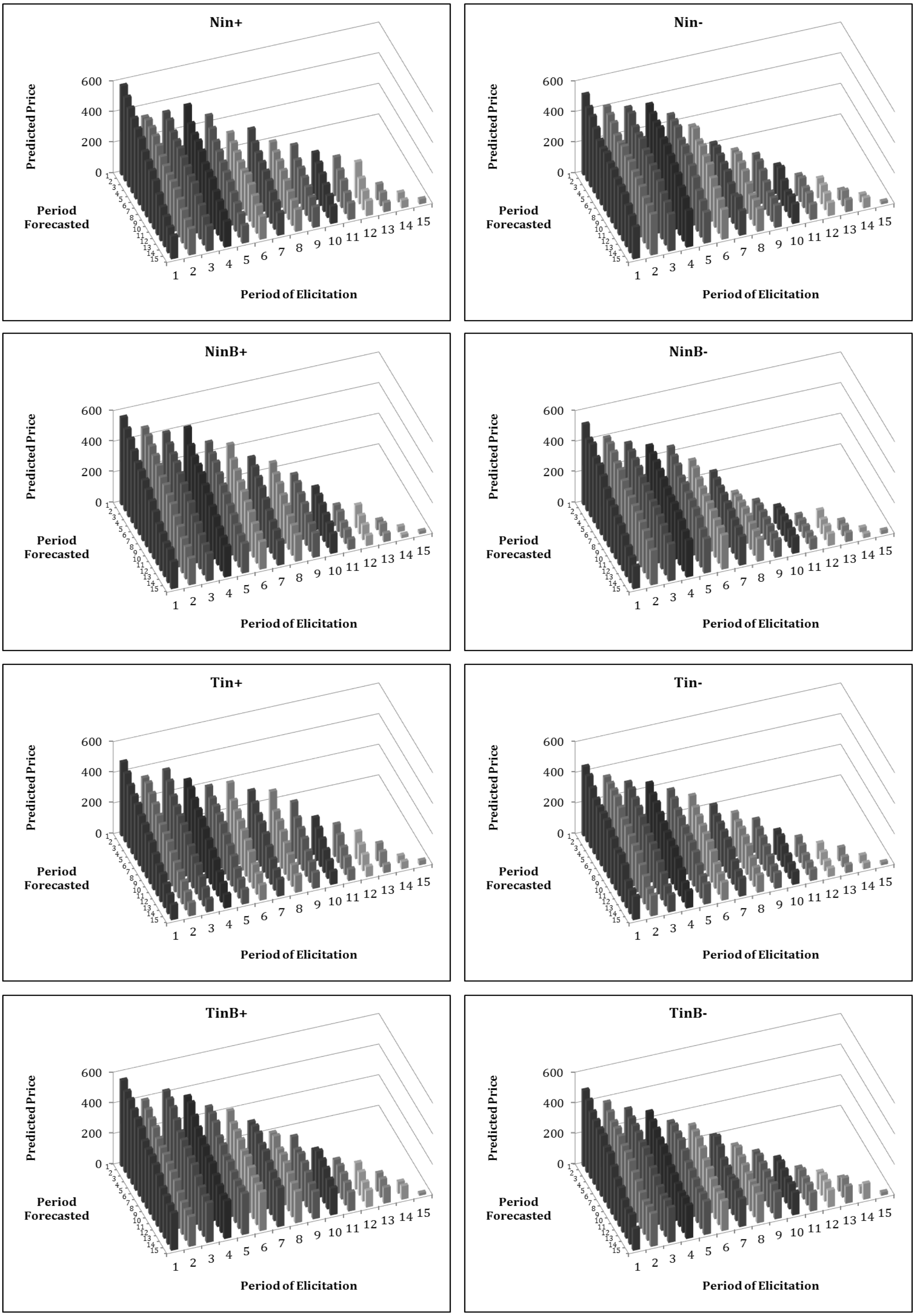

Figure 5: Average Predicted Market Prices

Table 12: Belief Regressions

Dependent Variable	Model 7 P_{mt}	Model 8 $(\bar{B}_{mt}^{t} - P_{mt})/\ P_{mt}$
Constant (Nin+)	21.59	3.08
	(15.35)	(5.60)
$\bar{B}_{mt}^{t}$	0.90***	
	(0.03)	
$(\bar{B}_{mt-1}^{t-1} - P_{mt-1})/P_{mt-1}$		-0.02
		(0.05)
Period		0.56
		(0.36)
L. Dividend	0.29**	-0.04
	(0.13)	(0.04)
NinB+	52.77***	-3.82
	(17.91)	(4.76)
NinB-	47.04**	-9.22*
	(19.04)	(5.12)
TinB+	40.51**	-12.88**
	(19.45)	(5.53)
TinB-	3.21	-2.09
	(13.43)	(5.13)
Nin-	12.47	-9.65*
	(17.45)	(5.21)
Tin+	71.08***	-22.26***
	(18.89)	(5.56)
Tin-	-7.62	-10.34*
	(13.08)	(6.12)
R^2	.8746	.1450
N	315	247

Notes: Prais-Winsten panel-regression with heteroskedastic panels corrected standard errors and panel-specific autocorrelation (AR1) (Beck and Katz, 1995). 32 markets as cross sections with a maximum of 15 observations over time (unbalanced). Only periods where trade took place are considered. Standard errors are shown in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5. Conclusion

Our study investigates price formation in a multi-period asset market with uncertainty about market fundamentals. This novel framework combines the SSW environment with a “state-environment” investigated by, for example, Camerer and Weigelt (1991a). It represents a “more realistic” market, although we are aware that real-life markets are not only characterized by uncertainty but also by ambiguity. In this newly designed uncertain SSW environment, we investigate whether (1) the existence of traders who are informed about the true state and/or (2) the provision of Bayesian updates of the assets’ state-dependent fundamental values lead to better market performance.

Our results differ from earlier studies in that we hardly find any bubbles under all treatment conditions, even though all subjects were inexperienced. Out of 32 markets only four reveal a bubble pattern. Our explanation is that possibly the two possible states exert a psychologically restraining effect on market prices and force participants to more carefully reflect on their trading decisions.

We find markets with asymmetrically informed traders to exhibit smaller price deviations from fundamentals, implying higher market efficiency. This result is consistent with the findings of Sutter et al. (2012), and is most likely attributed to the fact that uninformed traders act in a more prudent way to bypass exploitation, when they are aware of the fact that some traders have an advantage (of whatever kind).

The provision of BFVs has seemingly little to no effect. The mere assistance in the assessment of the state seems not to be sufficient to improve market performance.

Concerning the trading behavior of in- and outsiders, we find that it differs at the beginning but converges during the course of the markets, indicating that state information is revealed over time. In accordance with the predictions of the PI- and RE-models, we further find outsider limit buy/sell prices on average to be lower (higher) in the “good” (“bad”) state compared to the limit buy/sell prices of insiders. As a result, outsiders on average hold less (more) assets in “good”-state (“bad”-state) markets. Thus, informed traders are able to earn superior profits. Depending on the state, they buy cheaply from or sell expensively to outsiders and thus capitalize their superior position.

With regard to elicited price expectations, we find forecasts and actual market prices to be highly correlated. The precision of forecasts, however, seems to be impeded by the presence of insiders, while the provision of BFVs seems to have no impact on forecast quality.

We observe that the presence of insiders increases market efficiency. However, we have to be very cautious with this interpretation. We are not inclined to state that informational asymmetries are per se beneficial for market performance. In our experiment, the existence of insiders increases the information in the market. Increasing the level of information even more, we have conducted an additional experiment, in which we employed a standard SSW framework with a single state. Dividends again could take values of 10 ECU, 20 ECU, 40 ECU, or 80 ECU, however, with equal and fix probabilities of 25 percent, respectively. Traders did not face any uncertainty about the state, and were in a sense all insiders. These markets, again, hardly showed any bubbles.[29] Additionally they exhibited with -0.078 a smaller average RD than all our other treatments with two possible states (accounted for the state) and with 0.180 also the smallest average RAD. This seems plausible if we consider these markets as pure insider markets, since there are no traders with uncertainty about the state.[30]

We may conclude that increased information in a market tends to lead to more market efficiency. However, we have to be aware of the fact that informational asymmetries in markets are not beneficial in all aspects. The higher market efficiency in our markets, where insiders were present and could trade on their information, is based on the expense of outsiders. Given the differences in the trading behavior, particularly in the beginning of the markets, insiders on average manage to shift their asset holdings to the detriment of outsiders. In addition, the presence of insiders seems to confuse outsiders given their significantly inferior market price forecast capability. Taken together, it is likely that deprived market participants in such trading environments would lose faith and trust in the securities' markets and possibly withdraw all or part of their capital, rendering the market less liquid.

Hence, to maintain the confidence in the fairness of financial markets, we rather support the position of proponents of insider trading regulation, requesting traders and other market agents possessing material nonpublic information to make reasonable efforts to achieve public dissemination of the relevant information on the broadest possible basis (CFA Institute Code of Ethics & Standards of Professional Conduct, CFA Institute, 2010). We advocate all types of rules which are targeted towards faster and broader dissemination of information.

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[29] The general lack of bubbles might, besides the general difference of the structure of fundamentals, might be caused by the relatively small number of traders in our markets. This might decrease the incentives to speculate, in particular in combination with the call-auction trading mechanism, which tends to lead to a lower trading volume than continuous double-auction markets. Sutter et al. (2012) and Dufwenberg et al. (2005) observed bubbles with the same number of traders per market, however, by using double auctions; van Boening et al. (1993) and Haruvy et al. (2007) observed bubbles by using call auctions.

[30] Figure B. 1 in Appendix B shows the trajectory of individual market prices and Figure B. 2 the trajectory of the average price in this experiment.

References

Ackert, L.F., Church, B.K., 1998. Information Dissemination and the Distribution of Wealth: Evidence from Experimental Asset Markets. Journal of Economic Behavior & Organization 37 (3), 357–371.

Ackert, L.F., Church, B.K., Shehata, M., 1997. Market Behavior in the Presence of Costly, Imperfect Information: Experimental Evidence. Journal of Economic Behavior & Organization 33 (1), 61–74.

Ang, J.S., Schwarz, T., 1985. Risk Aversion and Information Structure: An Experimental Study of Price Variability in the Securities Markets. The Journal of Finance 40 (3), 825–844.

Aumann, R.J., 1976. Agreeing to Disagree. The Annals of Statistics 4 (6), 1236–1239.

Bainbridge, S.M., 1998. Insider Trading: An Overview. SSRN 132529.

Ball, S.B., Holt, C.A., 1998. Classroom Games - Speculation and Bubbles in an Asset Market. Journal of Economic Perspectives 12 (1), 207–218.

Beck, N., Katz, J.N., 1995. What to do (and not to do) with Time-Series Cross-Section Data. The American Political Science Review 89 (3), 634–647.

Bris, A., 2005. Do Insider Trading Laws Work? European Financial Management 11 (3), 267–312.

Camerer, C., 1989. Bubbles and Fads in Asset Prices. Journal of Economic Surveys 3 (1), 3–41.

Camerer, C., 1999. Behavioral Economics: Reunifying Psychology and Economics. Proceedings of the National Academy of Sciences 96 (19), 10575–10577.

Camerer, C., Loewenstein, G., Weber, M., 1989. The Curse of Knowledge in Economic Settings: An Experimental Analysis. Journal of Political Economy 97 (5), 1232–1254.

Camerer, C., Weigelt, K., 1991. Information Mirages in Experimental Asset Markets. The Journal of Business 64 (4), 463–493.

CFA Institute, 2010. Standards of Practice Handbook. CFA Institute, Charlottesville, VA, USA.

Chen, K.-Y., Fine, L.R., Huberman, B.A., 2004. Eliminating Public Knowledge Biases in Information-Aggregation Mechanisms. Management Science 50 (7), 483–994.

Cheung, S.L., Hedegaard, M., Palan, S., 2014. To See is to Believe: Common Expectations in Experimental Asset Markets. European Economic Review 66, 84–96.

Diba, B.T., Grossman, H.I., 1988a. Explosive Rational Bubbles in Stock Prices? The American Economic Review 78 (3), 520–530.

Diba, B.T., Grossman, H.I., 1988b. The Theory of Rational Bubbles in Stock Prices. The Economic Journal 98 (392), 746–754.

Dufwenberg, M., Lindqvist, T., Moore, E., 2005. Bubbles and Experience: An Experiment. The American Economic Review 95 (5), 1731–1737.

Engelen, P.-J., Liedekerke, L., 2007. The Ethics of Insider Trading Revisited. Journal of Business Ethics 74 (4), 497–507.

Fama, E.F., 1970. Efficient Capital Markets: A Review of Theory and Empirical Work. The Journal of Finance 25 (2), 383–417.

Fischbacher, U., 2007. z-Tree: Zurich Toolbox for Ready-made Economic Experiments. Experimental Economics 10 (2), 171–178.

Fishman, M.J., Hagerty, K.M., 1992. Insider Trading and the Efficiency of Stock Prices. RAND Journal of Economics 23 (1), 106–122.

Forsythe, R., Palfrey, T.R., Plott, C.R., 1982. Asset Valuation in an Experimental Market. Econometrica 50 (3), 537–567.

Forsythe, R., Palfrey, T.R., Plott, C.R., 1984. Futures Markets and Informational Efficiency: A Laboratory Examination. The Journal of Finance 39 (4), 955–981.

Friedman, D., 1993. Privileged Traders and Asset Market Efficiency: A Laboratory Study. The Journal of Financial and Quantitative Analysis 28 (4), 515–534.

Gächter, S., Renner, E., 2010. The Effects of (Incentivized) Belief Elicitation in Public Goods Experiments. Experimental Economics 13 (3), 364-377.

Greiner, B., 2004. The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics. University of Cologne, Working Paper Series in Economics 10 (23), 63–104.

Harrison, J.M., Kreps, D.M., 1978. Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations. The Quarterly Journal of Economics 92 (2), 323–336.

Haruvy, E., Lahav, Y., Noussair, C.N., 2007. Trader's Expectations in Asset Markets: Experimental Evidence. The American Economic Review 97 (5), 1901–1920.

Holt, C.A., Laury, S.K., 2002. Risk Aversion and Incentive Effects. The American Economic Review 92 (5), 1644–1655.

Hussam, R., Porter, D.P., Smith, V.L., 2008. Thar She Blows: Can Bubbles be Rekindled with Experienced Subjects? The American Economic Review 98 (3), 924–937.

Jaffe, J.F., 1974. Special Information and Insider Trading. The Journal of Business 47 (3), 410–428.

Kahneman, D., Tversky, A., 1972. Subjective Probability: A Judgment of Representativeness. Cognitive Psychology 3 (3), 430–454.

Keynes, J.M., 1936. The General Theory of Employment, Interest and Money, 2007th ed.: Palgrave Macmillan.

King, R.R., 1991. Private Information Acquisition in Experimental Markets Prone to Bubble and Crash. The Journal of Financial Research 14 (3), 197–206.

King, R.R., Smith, V.L., Williams, A.W., van Boening, M., 1993. The Robustness of Bubbles and Crashes in Experimental Stock Markets. In: Day, R.H., Chen, P. (Eds.). Nonlinear Dynamics and Evolutionary Economics: Oxford University Press, 183–200.

Lei, V., Noussair, C.N., Plott, C.R., 2001. Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge vs. Actual Irrationality. Econometrica 69 (4), 831–859.

Liu, Y.-J., 1992. Auction Mechanisms and Information Structure: An Experimental Study of Information Aggregation in Securities Markets.

Lovaglia, M.J., Lucas, J.W., Houser, J.A., Thye, S.R., Markovsky, B., 1998. Status Processes and Mental Ability Test Scores. American Journal of Sociology 104 (1), 195–228.

Manne, H.G., 1984. Insider Trading and Property Rights in New Information. Cato Journal 4, 933–957.

McGee, R.W., 2008. Applying Ethics to Insider Trading. Journal of Business Ethics 77 (2), 205–217.

Noussair, C.N., Plott, C.R., 2008. Bubbles and Crashes in Experimental Asset Markets: Common Knowledge Failure. In:Plott, C.R., Smith, V.L. (Eds.). Handbook of Experimental Economics Results, Volume 1. North Holland, 260–263.

Palan, S., 2009. Bubbles and Crashes in Experimental Asset Markets. Springer-Verlag, Berlin.

Palan, S., 2013. A Review of Bubbles and Crashes in Experimental Asset Markets. Journal of Economic Surveys 27 (3), 570–588.

Palfrey, T.R., Wang, S.W., 2009. On Eliciting Beliefs in Strategic Games. Journal of Economic Behavior & Organization 71 (2), 98–109.

Plott, C.R., Sunder, S., 1982. Efficiency of Experimental Security Markets with Insider Information: An Application of Rational-Expectations Models. The Journal of Political Economy 90 (4), 663–698.

Plott, C.R., Sunder, S., 1988. Rational Expectations and the Aggregation of Diverse Information in Laboratory Security Markets. Econometrica 56 (5), 1085–1118.

Porter, D.P., Smith, V.L., 1994. Stock Market Bubbles in the Laboratory. Applied Mathematical Finance 1 (2), 111–127.

Porter, D.P., Smith, V.L., 1995. Futures Contracting and Dividend Uncertainty in Experimental Asset Markets. The Journal of Business 68 (4), 509–541.

Rabin, M., Schrag, J.L., 1999. First Impressions Matter: A Model of Confirmatory Bias. The Quarterly Journal of Economics 114 (1), 37–82.

Romer, D., 1993. Rational Asset-Price Movements without News. The American Economic Review 83 (5), 1112–1130.

Shiller, R.J., 2003. From Efficient Markets Theory to Behavioral Finance. Journal of Economic Perspectives 17 (1), 83–104.
Siegel, J.J., 2003. What is an Asset Price Bubble? An Operational Definition. European Financial Management 9 (1), 11–24.
Smith, V.L., 1976. Experimental Economics: Induced Value Theory. The American Economic Review, Papers and Proceedings 66 (2), 274–279.
Smith, V.L., Suchanek, G.L., Williams, A.W., 1988. Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets. Econometrica 56 (5), 1119–1151.
Stöckl, T., Huber, J., Kirchler, M., 2010. Bubble Measures in Experimental Asset Markets. Experimental Economics 13 (3), 284–298.
Sunder, S., 1992. Market for Information: Experimental Evidence. Journal of the Econometric Society 60 (3), 667–695.
Sunder, S., 1995. Experimental Asset Markets: A Survey. In: John H. Kagel, Roth, A.E. (Eds.). The Handbook of Experimental Economics. Princeton University Press, 445–500.
Sutter, M., Huber, J., Kirchler, M., 2012. Bubbles and Information: An Experiment. Management Science 58 (2), 384–393.
Tirole, J., 1982. On the Possibility of Speculation under Rational Expectations. Econometrica 50 (5), 1163–1181.
van Boening, M.V., Williams, A.W., LaMaster, S., 1993. Price Bubbles and Crashes in Experimental Call Markets. Economics Letters 41 (2), 179–185.

Appendix A

Additional Tables and Figures

Attitudes Toward Risk

Table A. 1: Risk-Test 1

Decision #	Lottery A	Lottery B	Expected Payoff Difference	Risk Attitude (# safe choices)
1	1/10 of 50 , 9/10 of 40	1/10 of 96 , 9/10 of 2	29.6	-3
2	2/10 of 50 , 8/10 of 40	2/10 of 96 , 8/10 of 2	21.2	-2
3	3/10 of 50 , 7/10 of 40	3/10 of 96 , 7/10 of 2	12.8	-1
4	4/10 of 50 , 6/10 of 40	4/10 of 96 , 6/10 of 2	4.4	0
5	5/10 of 50 , 5/10 of 40	5/10 of 96 , 5/10 of 2	-4.0	1
6	6/10 of 50 , 4/10 of 40	6/10 of 96 , 4/10 of 2	-12.4	2
7	7/10 of 50 , 3/10 of 40	7/10 of 96 , 3/10 of 2	-20.8	3
8	8/10 of 50 , 2/10 of 40	8/10 of 96 , 2/10 of 2	-29.2	4
9	9/10 of 50 , 1/10 of 40	9/10 of 96 , 1/10 of 2	-37.6	5
10	1 of 50 , 0 of 40	1 of 96 , 0 of 2	-46.0	5

Notes: All payoffs are in ECUs. Lottery A is considered as the “safe” choice and Lottery B as the “risky” choice. -5 = extremely risk-loving, -4 = highly risk-loving, -3 = very risk-loving, -2 = risk-loving, -1 = slightly risk-loving, 0 = risk-neutral, 1 = slightly risk-averse, 2 = risk-averse, 3 = very risk-averse, 4 = highly risk-averse, 5 = stay in bed.
Market/subject mean = 1.750, market maximum (minimum) = 3.000 (0.500), subject maximum (minimum) = 5 (-3). Spearman’s rank correlation coefficient between the average risk attitude in one market and the market price in the 1st period: ρ = -0.0979, p = 0.5942 (negative relationship expected).

Table A. 2: Risk-Test 2a

Decision No.	Lottery A	Safe Payoff	Expected Payoff Difference	Risk Attitude (# safe choices)
1	**Lottery A:** 4/10 of 80 , 3/10 of 40 , 2/10 of 20 , 1/10 of 10.	20	29	-5
2		25	24	-4
3		30	19	-3
4		35	14	-2
5		40	9	-1
6		45	4	0
7		50	-1	1
8		55	-6	2
9		60	-11	3
10		65	-16	4

Notes: All payoffs are in ECUs. -5 = extremely risk-loving, -4 = highly risk-loving, -3 = very risk-loving, -2 = risk-loving, -1 = slightly risk-loving, 0 = risk-neutral, 1 = slightly risk-averse, 2 = risk-averse, 3 = very risk-averse, 4 = highly risk-averse, 5 = stay in bed.
Market/subject mean = -0.813, market maximum (minimum) = 0.167 (-2.167), subject maximum (minimum) = 4 (-5). Spearman’s rank correlation coefficient between the average risk attitude in one market and the market price in the 1st period: ρ = -0.0369, p = 0.8412 (negative relationship expected).

Table A. 3: Risk-Test 2b

Decision #	Lottery A	Safe Payoff	Expected Payoff Difference	Risk Attitude (# safe choices)
1	**Lottery A:** 1/10 of 80 , 2/10 of 40 , 3/10 of 20 , 4/10 of 10.	5	21	-4
2		10	16	-3
3		15	11	-2
4		20	6	-1
5		25	1	0
6		30	-4	1
7		35	-9	2
8		40	-14	3
9		45	-19	4
10		50	-24	5

Notes: All payoffs are in ECUs. -5 = extremely risk-loving, -4 = highly risk-loving, -3 = very risk-loving, -2 = risk-loving, -1 = slightly risk-loving, 0 = risk-neutral, 1 = slightly risk-averse, 2 = risk-averse, 3 = very risk-averse, 4 = highly risk-averse, 5 = stay in bed.
Market/subject mean = 0.427, market maximum (minimum) = 1.500 (-1.167), subject maximum (minimum) = 5 (-4). Spearman's rank correlation coefficient between the average risk attitude in one market and the market price in the 1st period: ρ = 0.1205, p = 0.5111 (negative relationship expected).

Table A. 4: Ex-post Questionnaire Question - Attitude Toward Risk

Question: Are you generally willing to take risks, or do you try to avoid risks?										
Highly risk-averse (0)	----	---	--	-	(5)	+	++	+++	++++	Highly risk-loving (10)

Notes: Market/subject mean = 4.646, market maximum (minimum) = 6.667 (2.667), subject maximum (minimum) = 10 (0). Spearman's rank correlation coefficient between the average risk attitude in one market and the market price in the 1st period: ρ = 0.0956, p = 0.6029 (positive relationship expected).

Trading Behavior of Insiders and Outsiders

Table A. 5: First-period Comparisons of Insiders and Outsiders

	Insider w/ Bayes (1st Per.)			Insider w/o Bayes (1st Per.)		
	+	-	p-value[a]	+	-	p-value[a]
p^D	338.9	147.4	**.0397**	524.3	340.0	**.0235**
p^S	609.8	301.0	**.0541**	761.0	607.5	**.0279**
q^D	12.6	13.5	.7116	12.4	5.3	**.0262**
q^S	4.4	6.2	.2245	8.6	4.4	**.0626**
	Outsider w/ Bayes (1st Per.)			Outsider w/o Bayes (1st Per.)		
	+	-	p-value[b]	+	-	p-value[b]
p^D	361.6	446.4	.1257	290.7	355.7	.3250
p^S	581.8	609.5	.6807	517.1	602.8	.6921
q^D	10.7	10.6	.9293	13.3	8.8	.4297
q^S	5.0	6.6	.2744	6.1	5.6	.6287
	w/ Bayes+ (1st Per.)			w/ Bayes- (1st Per.)		
	Insider	Outsider	p-value[c]	Insider	Outsider	p-value[c]
p^D	338.9	361.6	.6968	147.4	446.4	**.0013**
p^S	609.8	581.8	.6100	301.0	609.5	**.0386**
q^D	12.6	10.7	.7947	13.5	10.6	.8083
q^S	4.4	5.0	.6733	6.2	6.6	.9159
	w/o Bayes+ (1st Per.)			w/o Bayes- (1st Per.)		
	Insider	Outsider	p-value[c]	Insider	Outsider	p-value[c]
p^D	524.3	290.7	**.0180**	340.0	355.7	.7830
p^S	761.0	517.1	.1896	607.5	602.8	.3560
q^D	12.4	13.3	.5238	5.3	8.8	.4484
q^S	8.6	6.1	**.0871**	4.4	5.6	.4296

Notes: Mann-Whitney U test, two-sided: [a] *N* = 16 (8/8), [b] *N* = 32 (16/16), [c] *N* = 24 (8/16).

Table A. 6: Profits and Prediction Earnings of Insiders and Outsiders

	Insider+			Insider-		
	w/ Bayes	w/o Bayes	p-value	w/ Bayes	w/o Bayes	p-value
Profit[a]	7568	8962	**.0929**	4369	4483	.6744
Pred. Earnings[a]	133.1	172.9	**.0460**	137.3	136.3	.4005
	Outsider+			Outsider-		
	w/ Bayes	w/o Bayes	p-value	w/ Bayes	w/o Bayes	p-value
Profit[b]	7183	6527	.2582	4315	4235	.6242
Pred. Earnings[b]	100.3	121.5	.4397	131.3	108.2	.5216
	w/ Bayes+			w/ Bayes-		
	Insider	Outsider	p-value	Insider	Outsider	p-value
Profit[c]	7568	7183	.3913	4369	4315	.9025
Pred. Earnings[c]	133.1	100.3	.3272	137.3	131.3	.8303
	w/o Bayes+			w/o Bayes-		
	Insider	Outsider	p-value	Insider	Outsider	p-value
Profit[c]	8962	6527	**.0059**	4483	4235	.3913
Pred. Earnings[c]	172.9	121.5	.1500	136.3	108.2	.2439

Notes: Mann-Whitney U test, two-sided: [a] N =16 (8/8), [b] N = 32 (16/16), [c] N = 24 (8/16).

Limit Buy and Sell Prices

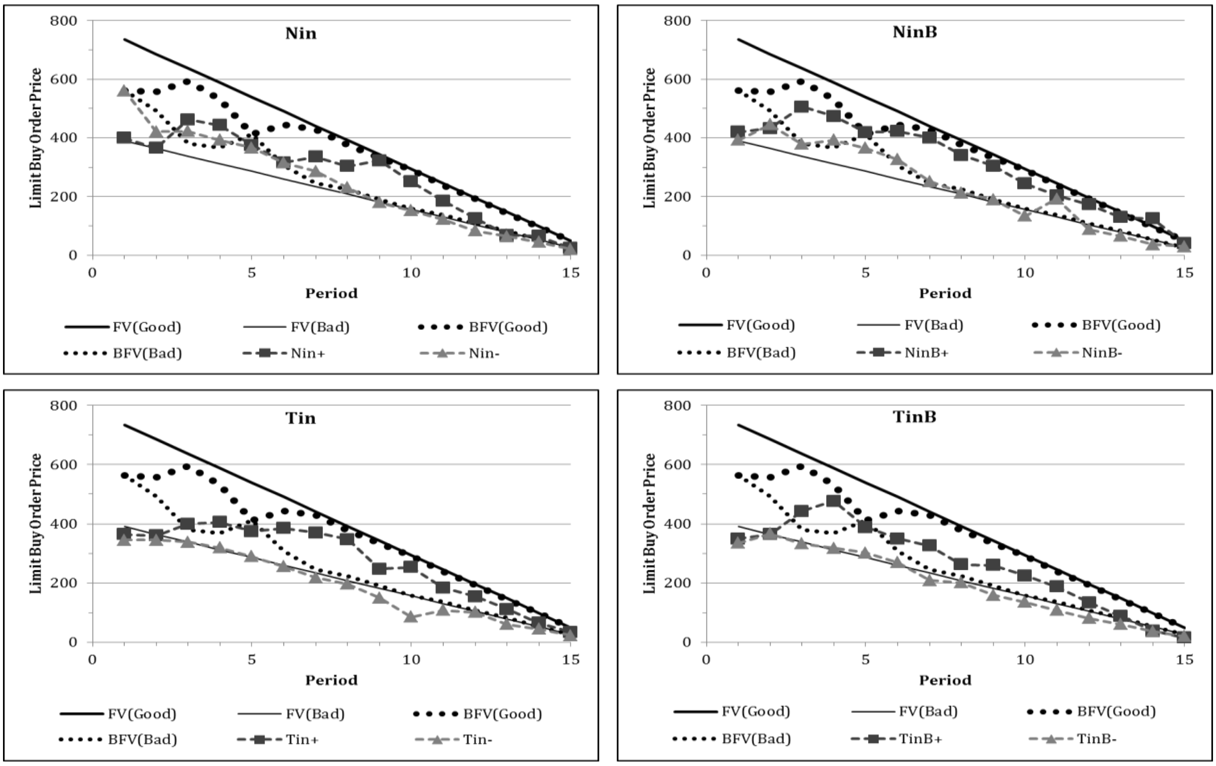

Figure A. 1: Average Limit Buy Order Prices

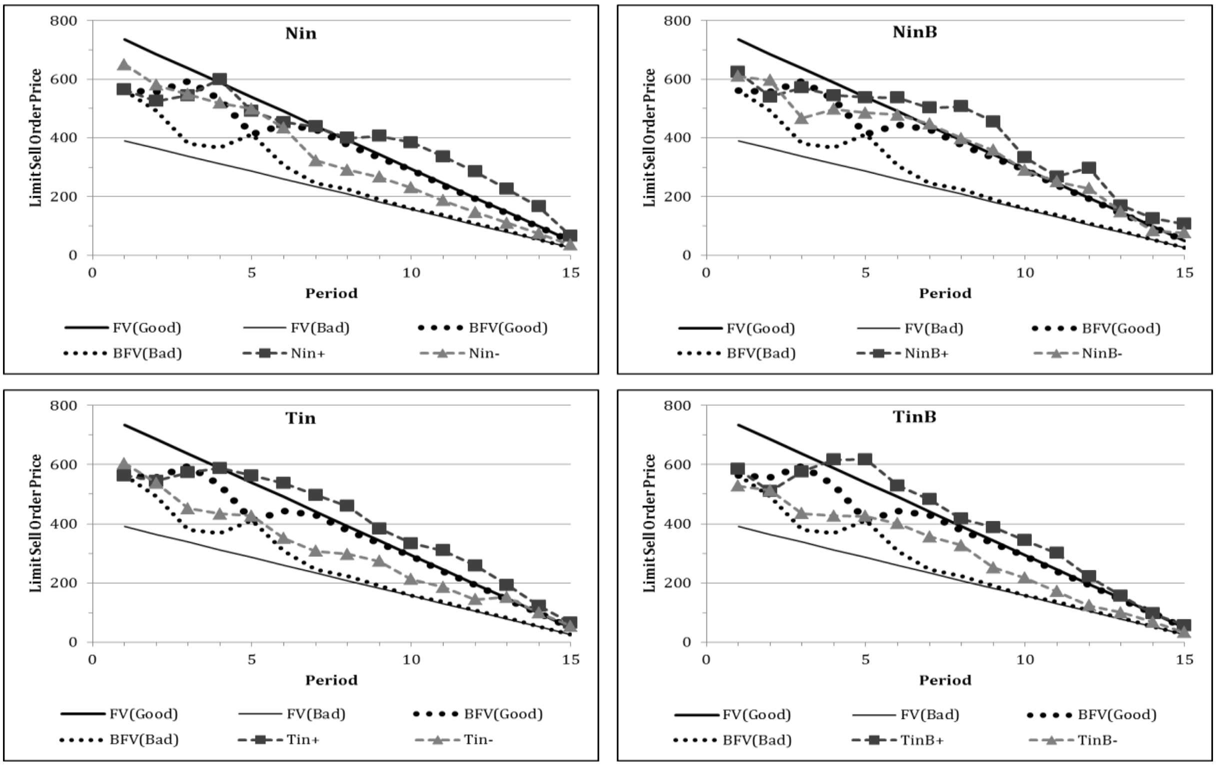

Figure A. 2: Average Limit Sell Order Prices

Beliefs

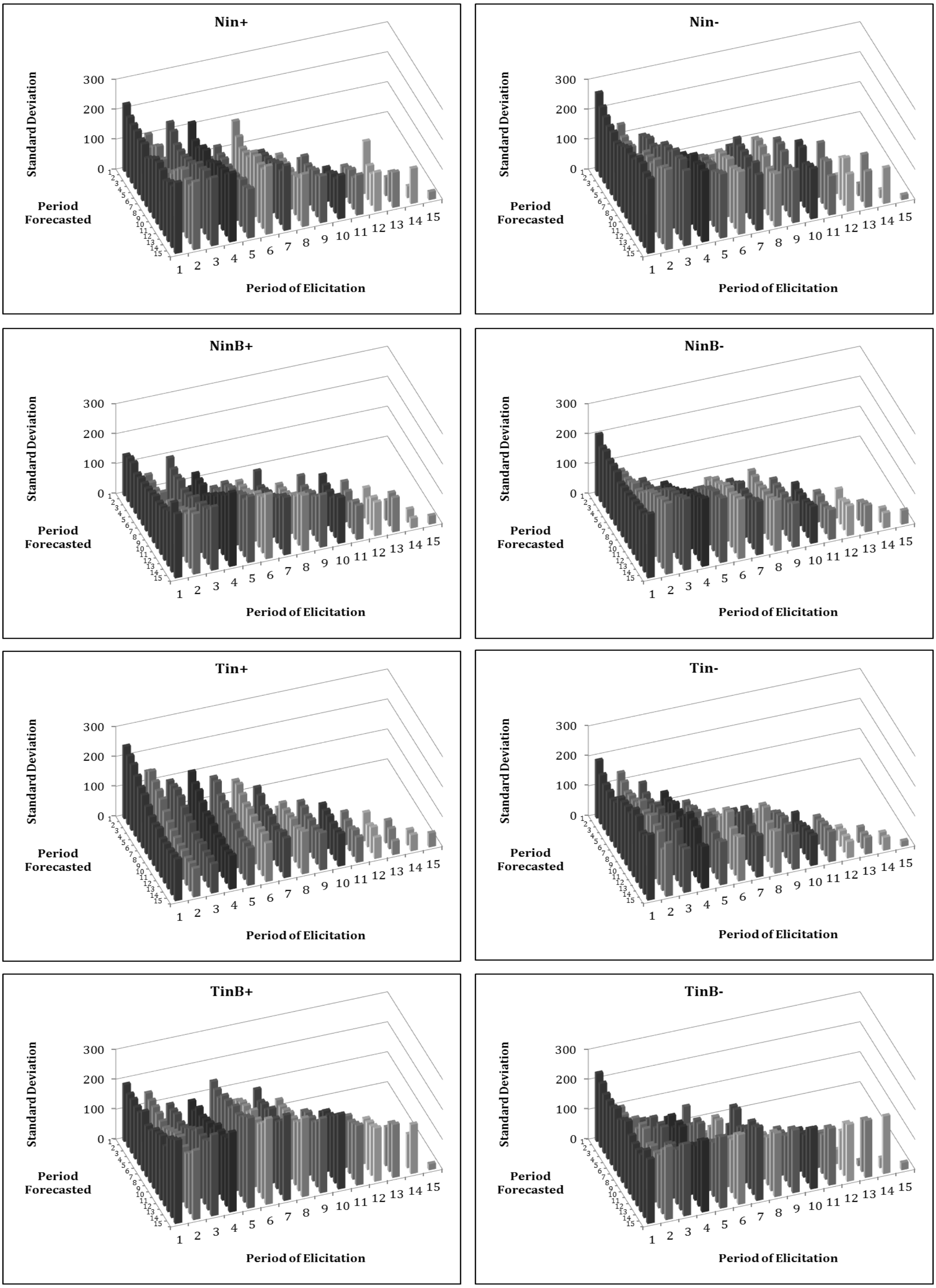

Figure A. 3: Average Standard Deviations of Predicted Market Prices

Appendix B

Results of Additional Experiments with Known Fundamentals (SSW)

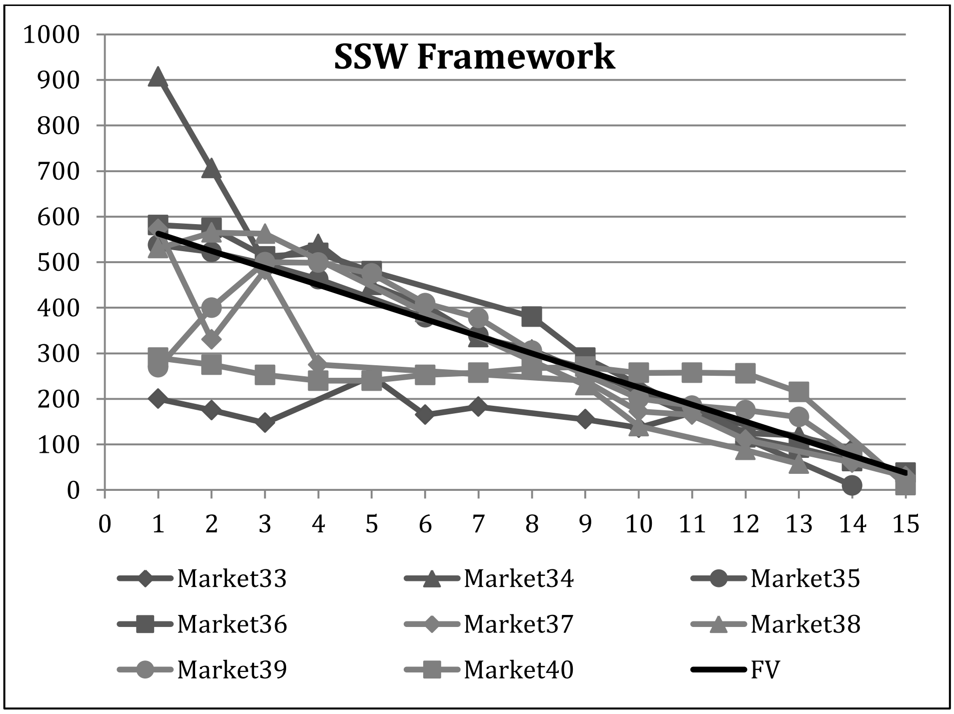

Figure B. 1: Individual Market Prices in the SSW Framework

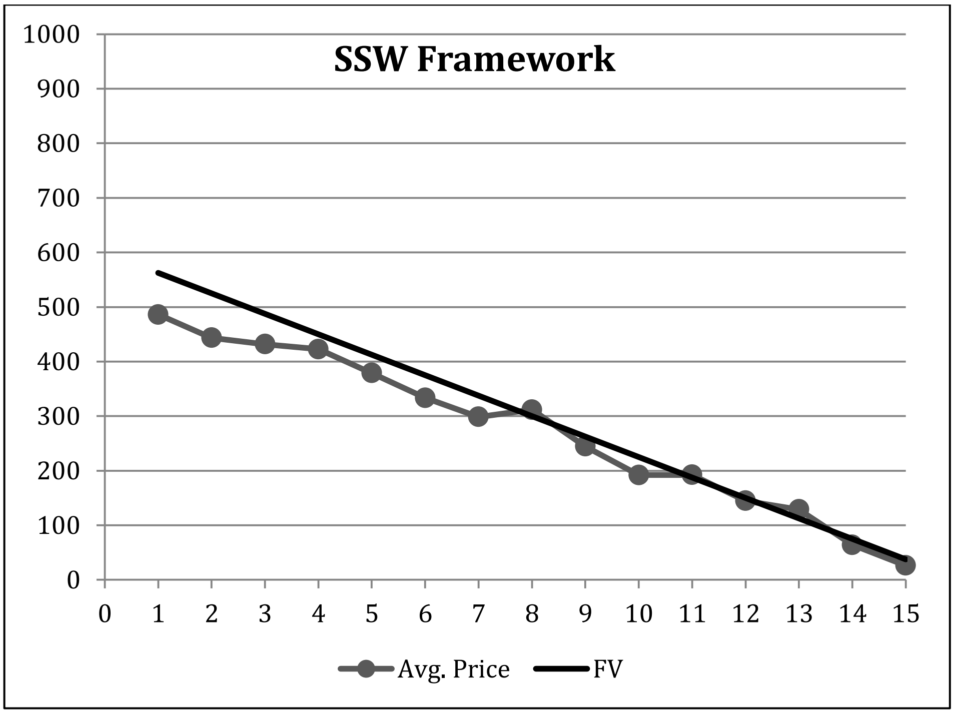

Figure B. 2: Average Market Price in the SSW Framework

Appendix C

Experimental Instructions (Risk Tests)

Welcome! You participate in an experiment that consists of two parts. In Part I of the experiment, you first take part in a decision experiment in which you can earn money. How much you earn depends, in Part I, only on your personal decisions. In Part II, your earnings will also depend on the choices of others. Each participant makes its decisions in isolation from the others on her/his computer. We ask you not to talk to other participants.

PART I

Part I of the experiment consists of three tasks. In Task 1 you have to make 10 decisions, first. In each you must choose between two options, lottery X or lottery Y. Each lottery involves two payments, for which there are different probabilities of occurrence, in each case. The payoffs are given in a fictitious currency ECU (experimental currency units). At the end of Part I, the computer will select among your 10 decisions randomly one, for which you are paid according to your selected option. The resulting ECUs are converted according to a fixed exchange rate in €.

In Task 2A and 2B, you have to make 10 decisions each, choosing between a lottery and a safe payment (in ECU). At the end of Part I, the computer will select from among these choices randomly one, each, for which you are paid in € according to your selected option, taking into account the exchange rate.

AVAILABLE INFORMATION

A calculator is available at the right side of each decision screen which you can open via a small calculator icon. Once you have made your decisions in all three tasks, you will receive your results on the screen including your payment in € for Part I of the experiment.

PAYMENT

Your proceeds (in ECU) from the three tasks of Part I are converted into €, whereat each ECU is worth €0.005. You will also receive a compensation for your appearance. The payout is conducted individually and anonymously at the end of the experiment.

In order to start the experiment, you need to click on the <Next> button. After completion of Part I, we ask you to stay at your place in the cabin and wait for further instructions for Part II of the experiment.

Experimental Instructions (TinB)

In Part II, the main part of the experiment, you will participate in a market experiment in which you can still earn money. How much you earn depends, in this part, on your decisions and, unlike in Part I, also on the decisions of other participants. Each participant makes its decisions in isolation from the others on her/his computer. We ask you not to talk to other participants.

PART II

You now participate in a market which runs 15 trading periods. At the beginning you will be randomly matched with five other persons to build a group of six, in which you remain throughout the 15 trading periods. You will not know the identity of your group members at any time, though.

In this part, you assume the role of a trader on a stock market for assets of a single type. On this market, you have the opportunity to submit a buy and / or a sell offer in each of the 15 trading periods. However, you are not obliged to.

At the beginning of the 15 periods, each group member is endowed with 10 assets and an initial trading capital of 10,000 ECU. This initial trading capital has to be repaid at the end of the experiment in full, again!

THE VALUE OF AN ASSET

Each asset has a lifespan of 15 trading periods. The so-called fundamental value of an asset is determined in each of the 15 periods as the sum of the, for all assets identical, dividends to be accrued in the future. After the last dividend payment at the end of the last period the asset is worthless. The dividend for an asset is randomly determined in each period by the computer and can take a value of 10 ECU, 20 ECU, 40 ECU or 80 ECU.

There are two possible "states" with respect to the asset, State 1 ("good" state) and State 2 ("bad" state). Each state has the same probability of 50%. Given these probabilities, the computer randomly selects one of the two states before the first trading period. This state (State 1 or State 2) withstands for the total market duration of 15 trading periods.

Two randomly selected participants per group of six participants, whose identity remains secret, will be informed at the beginning of the market which state has actually been chosen and applies to all participants during the entire duration of the market. The other participants receive no information about the actually chosen state. The randomly drawn state determines the probabilities with which each of the possible values of the dividends of 10 ECU, 20 ECU, 40 ECU or 80 ECU are drawn. These probabilities and the expected dividend of one asset are presented in Table 1 for the two states.

Since, in the two states, the probabilities of the possible dividend values and thus the expected dividend per period of an asset are different, also the fundamentals of an asset will develop in different ways over the course of the market. Table 2 shows the computation of the fundamental values in the periods 1 to 15 for the two possible states.

Table 1

	State 1 ("good") [50%]	**State 2 ("bad") [50%]**
Possible Dividends [Probabilities]	10 ECU [10%]	10 ECU [40%]
	20 ECU [20%]	20 ECU [30%]
	40 ECU [30%]	40 ECU [20%]
	80 ECU [40%]	80 ECU [10%]
Expected Dividend of an Asset per Period	49 ECU	26 ECU

Table 2

Fundamental Values (in ECU)					
Period	**State 1 ("good") [50%]**	Cond. Prob. for State 1	**State 2 ("bad") [50%]**	Cond. Prob. for State 1	**Expected Value according to Bayes**
1	735 (=15×49)	0.5	390 (=15×26)	0.5	562.5 (=0.5×735+0.5×390)
2	686 (=14×49)	$p_{1,2}$	364 (=14×26)	$p_{2,2}$	$p_{1,2}$×686+$p_{2,2}$×364
3	637 (=13×49)	$p_{1,3}$	338 (=13×26)	$p_{2,3}$	$p_{1,3}$×637+$p_{2,3}$×338
4	588 (=12×49)	$p_{1,4}$	312 (=12×26)	$p_{2,4}$	$p_{1,4}$×588+$p_{2,4}$×312
5	539 (=11×49)	$p_{1,5}$	286 (=11×26)	$p_{2,5}$	$p_{1,5}$×539+$p_{2,5}$×286
6	490 (=10×49)	$p_{1,6}$	260 (=10×26)	$p_{2,6}$	$p_{1,6}$×490+$p_{2,6}$×260
7	441 (=9×49)	$p_{1,7}$	234 (=9×26)	$p_{2,7}$	$p_{1,7}$×441+$p_{2,7}$×234
8	392 (=8×49)	$p_{1,8}$	208 (=8×26)	$p_{2,8}$	$p_{1,8}$×392+$p_{2,8}$×208
9	343 (=7×49)	$p_{1,9}$	182 (=7×26)	$p_{2,9}$	$p_{1,9}$×343+$p_{2,8}$×182
10	294 (=6×49)	$p_{1,10}$	156 (=6×26)	$p_{2,10}$	$p_{1,10}$×294+$p_{2,10}$×156
11	245 (=5×49)	$p_{1,11}$	130 (=5×26)	$p_{2,11}$	$p_{1,11}$×245+$p_{2,11}$×130
12	196 (=4×49)	$p_{1,12}$	104 (=4×26)	$p_{2,12}$	$p_{1,12}$×196+$p_{2,12}$×104
13	147 (=3×49)	$p_{1,13}$	78 (=3×26)	$p_{2,13}$	$p_{1,13}$×147+$p_{2,13}$×78
14	98 (=2×49)	$p_{1,14}$	52 (=2×26)	$p_{2,14}$	$p_{1,14}$×98+$p_{2,14}$×52
15	49 (=1×49)	$p_{1,15}$	26 (=1×26)	$p_{2,15}$	$p_{1,15}$×49+$p_{2,15}$×26

Since, in the game, you are not necessarily informed about which state has actually been drawn, you may only know the initial probability of 50% for each state, you are provided at the beginning of each period with recalculated probabilities for the two states according to the so-called Bayesian method. These so-called conditional probabilities for the states take into account the, up to that time, randomly drawn dividends. Because the conditional probabilities cannot be specified in advance, they are denoted in Table 2 with $p_{i,j}$. Thereby, $i \in \{1, 2\}$ denotes the state and $j \in \{2, \ldots, 15\}$ denotes the period. In addition to the recalculated conditional probabilities you are provided, at the beginning of each period, with a fundamental value which is adapted to these conditional probabilities (fundamental value according to Bayes) on your screen.

DECISIONS

Before you can submit your buy and sell offers for the assets in each trading period, you are asked to forecast the resulting asset price in the market for all future periods. This market price is determined and announced to you at the end of each period. In particular, you enter in each period $t \in \{1, \ldots, 15\}$ a total of $(16 - t)$ forecasts for the future periods. Because you can rethink your forecasts in each period, you have to submit for each period t a total of t forecasts in the course of the market. Depending on the forecast accuracy of your forecasts you receive a payment (in ECU) after each period. Table 3 gives an overview of the payments depending on the quality of forecasts. These payments can be received for each period t a maximum of t times. With the <Tabulator> button you can switch the entry fields for your decisions. All entries are completed by clicking on the <Submit Forecasts!> button.

Table 3

Accuracy of the Forecast	Payment for each Correct Forecast
Within ± 10% of the actual market price	5 ECU
Within ± 10-20% of the actual market price	2 ECU
Within ± 20-30% of the actual market price	1 ECU

Trading in each period takes place as follows. Each trading period lasts a maximum of 240 seconds. In the first 120 seconds, you first have the opportunity to submit an offer to buy by entering a "limit buy price" and the corresponding "limit buy quantity" in the appropriate fields on the screen.

The limit buy price is the price you are willing to pay at most per asset. This means you buy at this or any lower price which is established on the market. Please enter in addition to your limit buy price your corresponding limit purchase quantity of assets you want to buy at a price lower than or equal to your limit buy price. If only a smaller amount of assets is available on the market for you, you get this smaller amount. In extreme cases, it is also possible that you get no assets. If you do not want to buy at any price but just want to keep your asset inventory, leave the entry fields empty.

Please confirm your entries by clicking on the button <Confirm Buying Decision!>. Subsequently you switch to the screen for the submission of your selling offer.

In the second 120 seconds you have the opportunity to submit an offer to sell, by entering a "limit sell price" and the corresponding "limit sell quantity" in the appropriate fields on the screen.

The limit sell price is the price you want to have at least per asset. This means you sell at this or any higher price which is established on the market. Please enter in addition to your limit sell price your corresponding limit sell quantity of assets you want to sell at a price higher than or equal to your limit sell price. If there is only a lower demand for your assets on the market, you sell this smaller amount. In extreme cases, it is also possible that you sell no assets. If you do not want to sell at any price but just want to keep your asset inventory, leave the entry fields empty.

Please confirm your entries by clicking on the button <Confirm Selling Decision!>. When all participants have completed their decision to sell, the experiment continues. All buy and sell offers are aggregated, respectively. Out of this, the market price and the corresponding trading volume (the total quantity traded) are determined. All individual transactions that are possible under these conditions are conducted. If no transactions can take place, there is no market price. In this case, we denote the market price with 0.

Transactions take place as long as there are traders who want to sell at a lower or the same price than traders are willing to pay. For the determination of the market price and trading volume all bids are aggregated, from the highest to the lowest bid, into a falling demand curve in price, and all selling offers are aggregated, from the lowest to the highest selling offer, into an increasing supply curve in price. The intersection of these two curves determines the (maximum possible) trading volume. The market price is determined as the average of the smallest limit buy price and the highest limit sell price for which a transaction just comes about.

Please note that your inventory of assets and trading capital changes through trade after each period. The selling of assets reduces the asset and increases the trading capital inventory. The buying of assets increases the asset and reduces the trading capital inventory. In addition, the dividend income, of the assets held by you at the end of each period, increases the trading capital.

When choosing your buying and selling offers, you must ensure that they are permissible. If you trade, you firstly can never sell more assets than you have in your own asset inventory in this period, secondly never buy more assets as is permitted by the available sum of the asset holdings of the other market participants in your group, and thirdly never buy more assets at a certain price as is permitted by your trading capital in this period. Fourthly, you must note that your limit sell price, at which you wish to sell assets, must be higher than your limit buy price, at which you wish to buy assets. Possible prices that may be entered are all integer numbers between 1 and 1500, as long as none of the rules above is violated. If you make an entry that violates these rules, this will be automatically indicated on the screen and you have to revise your input. However, in this case, you also have the opportunity to continue without entering an offer by leaving the entry fields empty.

If you do not verify your buying and/or selling decision during the respective 120 seconds, the (possibly) entered decisions are not taken into account, i.e., you would not buy or sell anything in the respective decision stage!

AVAILABLE INFORMATION

A calculator is available at the right side of each decision screen, which you can open via a small calculator icon. Additionally, you are provided in each period, in all decision stages, with all relevant information via a summary table on the screen. Just click on the button <Show Results of Previous Periods> which is located in the middle at the bottom of the screen. To return from this summary screen back into the respective decision stage, you have to click on the button <Back to…>, respectively. Furthermore, an overview of the results of the current period is displayed after each period on the screen.

PAYMENT

Your relevant income for the payout (in ECU) in Part II of the experiment is determined by your trading capital at the end of the last period minus the initial trading capital. The relevant income for the payout is calculated alternatively as the sum of your individual period profits. The period profit is calculated as follows:

Period profit	=	Your asset holdings at the end of the period × Dividend per asset in this period (= dividend income)
	+	Proceeds from the disposal of assets in this period
	–	Expenditures for purchased assets in this period
	+	Remuneration for the forecast(s) of the market price in this period

Your relevant income for the payout (in ECU) from Part II is converted into €, whereat each ECU is worth €0.003. In addition, you will receive your payout from Part I and a show-up fee of €3. If your trading capital at the end of the last period of part II is not sufficient for the repayment of the initial trading capital, your relevant income for the payout in Part II is negative. This negative payment is deducted from your payout from Part I and your show-up fee. However, you cannot suffer a real loss, i.e., your minimum payout is zero. The payout is conducted individually and anonymously at the end of the experiment.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. Then you will be provided with a number of questions regarding these instructions on your screen. If you have any questions, please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

III

SOCIAL COSTS OF INEQUALITY – HETEROGENEOUS ENDOWMENTS IN PUBLIC-GOOD EXPERIMENTS

with Claudia Keser, Martin Schmidt and Cornelius Schnitzler

Abstract: We compare voluntary contributions to the financing of a public good in a symmetric setting to those in asymmetric settings, in which four players have different, randomly allocated endowments. We observe that a weak asymmetry in the endowment distribution leads to the same contribution level as symmetry. Players tend to contribute the same proportion of their respective endowment. In a strongly asymmetric setting, where one player has a higher endowment than the three other players together, we observe significantly lower group contributions than in the other settings. The super-rich player does not contribute significantly more than what the others contribute on average and thus a much lower proportion of the endowment.

JEL-Classification: C92, D63, H41

Keywords: Experimental economics, linear public good, income heterogeneity

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Download: http://wwwuser.gwdg.de/~cege/Diskussionspapiere/DP217

1. Introduction

In international relations the provision of global public goods plays an extensive role. The reduction of greenhouse gas emissions, cross-border crime prevention and disease control are well-known examples. Since it is difficult to exclude non-contributing parties from the consumption of a public good, there exist incentives to free ride on the contributions of others, which lead to inefficiently low provision levels (Olson, 1965). The relatively small number of parties typically involved in the decision making on the provision of global public goods is marked by their heterogeneity in interests and resources. The interaction of industrialized, emerging and development countries, evidently involves a strong inequality in wealth. Besides these international interactions, wealth heterogeneity is also omnipresent on national scales. Income inequalities are on the rise in many, even highly developed, countries. Income inequality measured by the Gini coefficient, a standard measure that ranges from 0 (when everybody has the same income) to 1 (when all income belongs to one person), has on average risen by almost 10 percent from the mid-1980s to the late 2000s in the OECD countries, latterly averaging 0.316. Inequality lies, for example, in Germany with 0.295 slightly below and in the United States with 0.378 above the average (OECD, 2011). The general question is how these international and national inequalities affect outcomes in situations that involve cooperation and consensus among heterogeneous parties. Our study contributes to answering this question and asks whether wealth heterogeneity is likely to affect outcomes related to the provision of public goods in an experimental-economics setting that involves wealth distributions that approximate the reported OECD average.

From a theoretical point of view, Warr's (1983) neutrality theorem states that the provision of a single public good is unaffected by a redistribution of wealth. Bergstrom et al. (1986) elaborate on this theorem, confirming that small redistributions will not change the equilibrium supply of a public good. However, this is true only as long as the set of contributors remains unchanged. They argue that large redistributions will change the set of contributors and thus the supply of a public good. Maurice et al. (2013) present a laboratory experiment on a (non-linear) Voluntary-Contributions Mechanism (VCM), investigating the effect of un-equalizing or equalizing redistributions of endowments. They observe no significant effect on the contribution level and interpret this result as an indication for the validity of Warr's theorem.

In the extensive literature on VCM experiments it has mostly been neglected that (the degree of) asymmetry in the endowments and/or interests in the provision of a public good could impact the voluntary contribution level. The bulk of experiments is based on the simple linear game introduced by Marwell and Ames (1979) and Isaac et al. (1984) and uses a symmetric parameterization, implying that each of the players has the same endowment and the same marginal return from the public good. Even though each player's dominant strategy is to make zero contribution to the public good, experiment participants typically contribute between 40 and 60 percent of their endowment (Ledyard, 1995). Many studies examine to what extent the actual contribution level depends on various factors, including, for example, the marginal per-capita return (MPCR) from the public good (i.e., the individual value of one unit contributed to the public good relative to the value of its private consumption), the group size, or the interaction of both (e.g., Isaac and Walker, 1988; Weimann et al., 2014). However there has been little attention to asymmetry.

To fill this gap in the literature, our study investigates whether and how inequalities in endowments affect contribution levels, without making reference to redistribution as in Maurice et al. (2013). We present a (linear) VCM experiment, in which we compare, in a between-subject design, contributions under a symmetric, weakly asymmetric and strongly asymmetric allocation of endowments among four players with respective initial Gini coefficients of 0.000, 0.125, and 0.350. We assume that, independent of their endowments, all players in the public-good game have the same profit function, which implies the same return from the public good. The novelty in our setting is that in the strongly asymmetric situation, one player has no interest in achieving the social optimum, in which the sum of profits is maximized. This player's equilibrium profit is higher than the individual profit in the social optimum.

In our experiment, we observe that a weak asymmetry in the endowment distribution (with a Gini coefficient of 0.125) has no effect on the overall public-good provision and leads to the same contribution level as in the case of symmetry. In this weakly asymmetrical setting players tend to contribute the same proportion of their respective endowment. In contrast, in the strongly asymmetric setting (with a Gini coefficient of 0.350), where the super-rich player has a higher endowment than the three other players together, we observe significantly lower group contributions than in the other settings. The super-rich player does not contribute significantly more than what the others contribute on average and thus a much lower proportion of the endowment. We interpret the difference in the behavioral patterns between the weakly and strongly asymmetric settings as a shift in the contribution norm from relative to absolute equality of contributions.

This paper is structured as follows. In Section 2 we embed our study into the related literature. Section 3 presents the model and experimental design. In Section 4 we show the results. Section 5 concludes this paper with a discussion.

2. Related Literature

Keser (2002) hypothesizes that cooperation is easier to achieve in the case of symmetry than asymmetry among the players: assuming that reciprocity is used as an instrument to achieve cooperation, the cooperative goal is most easily determined in the symmetric case, where equal contribution is an obvious requirement. It is not so clear, though, where and how players in an asymmetric situation are supposed to cooperate. This relates to an observation made by Selten et al. (1997). In a strategy experiment on an asymmetric duopoly, they identify decisions guided by ideal points defined in conflicting ways. It thus comes as no surprise that, applying similar settings, Mason et al. (1992) and Keser (2000) observe more cooperative outcomes in symmetric than in asymmetric oligopolies.

There are only few studies investigating asymmetries in public-good experiments and their results are mixed. Fisher et al. (1995) conduct linear VCM experiments with heterogeneous demand for public goods. They observe that the contribution level in groups with two players with a high MPCR and two players with a low MPCR lies between the levels of homogeneous groups, in which all players either have a low or a high MPCR. They find a strong effect of an individual's own MPCR on the contribution: even in heterogeneous groups, low-MPCR types contribute less than high-MPCR types.

Investigating endowment heterogeneity in a linear VCM game, Hofmeyer et al. (2007) find that endowment heterogeneity does not have any significant impact on the group-contribution level. Similarly, Sadrieh and Verbon (2006) observe that the contribution level is neither affected by the degree nor the skew of endowment inequality in a dynamic public-good game, where each round's earnings are added to a player's available endowment in the following round. In contrast, Cherry et al. (2005) observe that endowment heterogeneity in a one-shot linear VCM game decreases the contribution level relative to homogeneous endowments. Their experiment, though, is less controlled than the experiments in Hofmeyer et al. and in our study in that it does not keep constant the sum of endowments across the homogeneous and heterogeneous treatments.

Hofmeyer et al. observe that low and high endowment players contribute the same fraction of their endowment. They call this the "fair-share rule". In contrast, Buckley and Croson (2006) observe in their linear VCM experiment with heterogeneous endowments that the players less wealthy in endowment give the same absolute amount and thus more as a percentage of their endowment as the more wealthy players. They demonstrate that this result is contradicting the assumptions of inequity aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and altruism (Becker, 1974). Inequity aversion would predict (in addition to full free riding and full contribution) a higher proportion of endowment contributed to the public good by the wealthier participants. Inequity aversion is thus contradicted also by the experiments by Hofmeyer et al. and by us. Altruism would simply predict higher absolute contributions by the wealthier participants; the results by Hofmeyer et al. and our study are in accordance with this.

Van Dijk and Wilke (1994) observe in a one-shot public-good experiment with heterogeneous endowments that the more endowment participants possess, the more they contribute and interpret it as "noblesse oblige". They observe, however, that it plays a role whether endowments have been randomly allocated or the difference in endowments has been justified by (making the subjects believe in) the requirement to spend an unequal time in the experiment: the difference between the contributions of low-endowment and high-endowment players is larger in former than the latter case.

The asymmetry in our experiment is based on a random allocation of heterogeneous endowments. We are aware that it can make a difference, whether endowments are randomly allocated or have to be earned in a laboratory task, although Cherry et al. (2005) observe that the origin of heterogeneous endowments does not have a significant effect on voluntary contributions in a one-shot public-good game. In bargaining and dictator games, earned endowments tend to lead to more inequitable outcomes than randomly allocated endowments (e.g., Hoffman and Spitzer, 1985; Loomes and Burrows, 1994; Cherry et al., 2002). Nonetheless, we needed to make a choice for this study and have opted for random allocation of endowments, in order to maintain maximum control over their distribution. In a real-effort pregame, we could only have achieved this control through a tournament element, which might impact behavior in the public-good game in an uncontrolled way.

The provision of public goods and the appropriation of common pool resources are two related instances of collective action. Cardenas and Carpenter (2008) report field experiments on common pool resources, where the players are heterogeneous in their real-life status: Cardenas (2003) shows how the mixing of economic classes affects play in a CPR game. Groups composed of mostly poor people conserve common property better than groups that are mixed between poor people and more affluent local property owners. Likewise, Cardenas and Carpenter (2004) show that mixed groups of students from different countries perform noticeably worse than homogenous groups in a CPR game. These results suggest that the lower level of contributions that we observe in the strongly asymmetric setting of this study is likely to have some external validity.

3. The Experiment

3.1 The Game

In our public-good game n players form a group. Each player i ($i = 1, \ldots, n$) is endowed with a fixed number of tokens, e_i, which have to be allocated between two possible types of investment, a *private* and a *public* investment. The amount allocated to the private investment is denoted as x_i, with $0 \leq x_i \leq e_i$, and the amount allocated to the public investment is denoted as y_i, with $0 \leq y_i \leq e_i$. Since the entire endowment has to be allocated, $x_i + y_i = e_i$ has to be satisfied.

The profit of each player i depends on his individual private investment and the sum of all public investments. Each token that he allocates to the private investment yields him an individual return of α, while each token that he allocates to the public investment yields himself and any other group member a return of β, with $\alpha > \beta$ and $n\beta > \alpha$. The profit function of player i can thus be written as:

$$\Pi_i\left(x_i, \sum_{j=1}^{n} y_j\right) = \alpha x_i + \beta \sum_{j=1}^{n} y_j \tag{1}$$

The game-theoretical solution of this game is straightforward. Due to the linear form of the profit function and a player's individual return on private investment being larger than on the public investment ($\alpha > \beta$), the game has an equilibrium in dominant strategies, where each player contributes the entire endowment to the private and nothing to the public investment ($x_i^* = e_i, y_i^* = 0$). If this game is played over a finite number of T periods, the subgame-perfect equilibrium solution prescribes, based on backward induction, that in each period t ($t = 1, \ldots, T$) each player contributes the entire endowment to the private and nothing to the public investment ($x_{i,t}^* = e_i, y_{i,t}^* = 0$).

Due to $n\beta > \alpha$, the sum of profits of all n players is maximized if all tokens are allocated to the public investment. The group optimum in a repeated game is thus found, where all players allocate in each round their entire endowments to the public investment. The game-theoretical solution (subgame-perfect equilibrium) is thus collectively inefficient.

3.2 Experimental Design

We conducted the computerized experiment in the *Göttingen Laboratory of Behavioral Economics* at the Georg-August-Universität Göttingen, Germany, between December 2009 and March 2010. The lab consists of 24 computers in isolated booths, such that vision of someone else's computer screen or verbal communication with other participants is impossible. In total, 108 students from various disciplines participated in the experiment. They were randomly selected from a subject pool of students who volunteered for participation in experiments on decision making, in which they can earn money. On average, a roughly equal number of female and male students participated in the experiment. According to subject availability, we conducted sessions with 12 or 16 participants each. This implies that we collected three or four independent observations per session. The experiment software was based on z-Tree (Fischbacher, 2007).

The procedure was as follows. Before the experiment, the participants get together with the experimenter in a meeting room, where the experimenter distributes written instructions and reads them aloud to all participants. From this moment on, participants are neither allowed to communicate with each other nor to ask questions regarding the instructions in front of everybody else. Each of the participants gets randomly assigned a participation number, which corresponds to a computer terminal in the laboratory.

After the reading of the instructions, the participants get seated at their respective computer terminals. First they have to go through a computerized questionnaire regarding the instructions. They have the opportunity to individually clarify with the experimenter any open questions they might have. Only when all participants have correctly answered to all questions of comprehension the experiment begins.

The participants are randomly assigned to groups of four to play a four-player public-good game (with $n = 4$). The group compositions stay unmodified during the entire experiment session, i.e., we use a so-called *partners* design (Andreoni, 1988). Subjects do not know the identity of the other participants with whom they interact.

The parameters of the profit function are $\alpha = 2$ and $\beta = 1$. This implies that the marginal per-capita return (MPCR)[1] of the investment in the public account is constant and amounts to 0.5.

The game is to be played for $T = 25$ rounds, which is known to each participant. Each player in a group is assigned a player number from one to four, which is communicated to each player in private in the beginning of the experiment. In each round, each participant has to make an allocation decision in integers, i.e., only entire tokens can be allocated to the private or public investment. At the end of each round, each participant is informed of the contribution to the public investment made by each of the three other

[1] The MPCR is defined as the ratio of the private value of one token invested into the public account to the private value of one token invested into the private account.

players in the group, identified by their player numbers but otherwise anonymous. The record of all previous rounds is also displayed on the screen.

The participants are informed in the instructions that the total profit gained during the experiment and measured in Experimental Currency Unit (ECU) will be multiplied by a conversion factor of 0.01 € per ECU and anonymously paid after the experiment. The conversion factor is the same for each player.

Table 1 presents the treatment design. We consider three different treatments: (1) homogeneous endowments of 15 (*Sym* treatment), (2) heterogeneous endowments of 10, 15, 15, 20 (*AsymWeak* treatment) and (3) heterogeneous endowments of 8, 8, 8, 36 (*AsymStrong* treatment). In all three treatments the total endowment of the four players is equal to 60. The AsymStrong treatment is specific in that player 4 has an endowment that is larger than the sum of the endowments of the three other players. Player 4 thus has no interest in achieving the group optimum, where the sum of profits is maximized.

Table 1: Treatments

Treatment	Endowment					# of
	Player 1	Player 2	Player 3	Player 4	Total	Observations
Sym	15	15	15	15	60	7
AsymWeak	10	15	15	20	60	10
AsymStrong	8	8	8	36	60	10

An experiment session lasted about 60 to 90 minutes, including the reading of the instructions, the questionnaire to make sure that every participant has understood the rules of the game, the experiment, an ex-post questionnaire and the pay-out. In addition to the money gained in the experiment, we paid a show-up fee of 3 €. The average payoff earned was 14.25 €.

4. Experimental Results

To analyze our data, we use non-parametric statistics based on seven independent observations for the Sym and ten observations, each, for the AsymWeak and AsymStrong treatments. The analysis is based on the Stata Statistical Software, Release 10. We denote the Wilcoxon-Mann-Whitney U test (also called rank-sum test) simply as *U test* and the Wilcoxon matched-pairs signed-rank test as *signed-rank* test. All tests are two-sided.

The analysis will be geared at the testing of four hypotheses.

Hypothesis 1: *The overall contribution level is independent of the endowment distribution.*

Hypothesis 2: *All player types contribute the same proportion of their respective endowment ("fair-share rule").*

The first two hypotheses are based on the respective results by Hofmeyer et al. (2007), whose experiment is very similar to ours.

Hypothesis 3: *Players use the reciprocity principle.*

Keser and van Winden (2000) interpret behavior in the public-good experiment in terms of "*conditional cooperation, which is characterized by both forward-looking and reactive behavior*". In other words, they observe participants to use reciprocity as an instrument to achieve a cooperation goal. Forward-looking behavior shows, among others, in the so-called end-game effect (i.e., the break-down of cooperation toward the end of the game).

Hypothesis 4: *In the case of endowment heterogeneity, public-good provision leads to a reduction in the inequity of wealth.*

Van Dijk and Wilke (1994) point out that the provision of a public good is an indirect opportunity to reallocate wealth. In the extreme, if all players contribute all of their endowments to the public investment, they end up equally wealthy, independent of the distribution of their initial endowments. In that respect, any inequity in the endowments can be reduced by the provision of a public good. At the same time, if players make different contributions to the public investment, some differences in wealth will be created. This un-equalizing effect will necessarily be visible in the case of equal endowments, but it might be overcompensated by the equalizing effect due to the public good provided in the case of endowment heterogeneity. Since we expect significantly positive contributions in all treatments and thus important equalizing effects, we hypothesize that in the treatments with endowment heterogeneity, the inequality in final wealth will be smaller than the inequality in the endowments.

These four hypotheses are to be addressed in the four subsections.

4.1 Group Contributions

Figure 1 exhibits, for each of the three treatments, the average group contribution to the public investment in each of the 25 rounds. The contribution level in the AsymStrong treatment lies in each period clearly below the contribution levels in the other two treatments. On average over all 25 rounds, we observe a group contribution of 34.48 in Sym, 33.05 in AsymWeak and 22.02 in AsymStrong. The Kruskal-Wallis test indicates that there is a statistically significant difference between the three treatments ($p = 0.0012$). Pair-wise comparisons (U tests) show that the group contribution in AsymWeak is not significantly different from the one in Sym ($p = 0.7694$). However, the group contribution in AsymStrong is significantly below the one in Sym ($p = 0.0034$) and in AsymWeak ($p = 0.0011$). Similarly, a comparison of the median values of individual contributions to the public investment (10 in Sym, 8 in AsymWeak, and 6 in AsymStrong) shows no statistically significant difference between Sym and AsymWeak ($p = 0.3756$). However, we observe statistically significant differences between Sym and AsymStrong ($p = 0.0291$) and between AsymWeak and AsymStrong ($p = 0.0998$). We conclude that the average and median contributions in the AsymStrong treatment are significantly lower than in the two other treatments.

The standard deviations of group contributions (averages over the standard deviations of the independent groups) are 13.24 in Sym, 12.39 in AsymWeak and 10.39 in AsymStrong, implying variation coefficients of 38 percent (in Sym and Asymweak) and 47 percent (in AsymStrong). Neither the Kruskal-Wallis test nor pairwise comparisons based on the U test show statistically significant differences, requiring significance at the 10-percent level in two-sided testing (Kruskal-Wallis test: $p = 0.2515$; Sym vs. AsymWeak: $p = 0.5582$; Sym vs. AsymStrong: $p = 0.1719$; AsymWeak vs. AsymStrong: $p = 0.1736$).

Regarding the dynamics in the game, Figure 1 exhibits, in all three treatments, a decline of the group contribution over time, including a relatively sharp decline in the final rounds—the so-called *end-game effect* (Selten and Stoecker, 1986). Comparing the average group contribution in periods 1-10 to the one in periods 11-20, we observe a statistically significant decline in the Sym treatment, but none in the others.[2] From periods 11-20 to the final periods 21-25, we observe no difference in the Sym treatment but a significant decline in the average group contribution in the AsymWeak and AsymStrong treatments.[3]

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[2] The p-values of the signed-rank tests are 0.0180, 0.1688, and 0.1394 in Sym, AsymWeak and AsymStrong, respectively.

[3] The p-values of the signed-rank tests are 0.1282, 0.0051, and 0.0051 in Sym, AsymWeak and AsymStrong, respectively. The lack of significance for the end-game effect in the Sym treatment is due to one outlier out of seven.

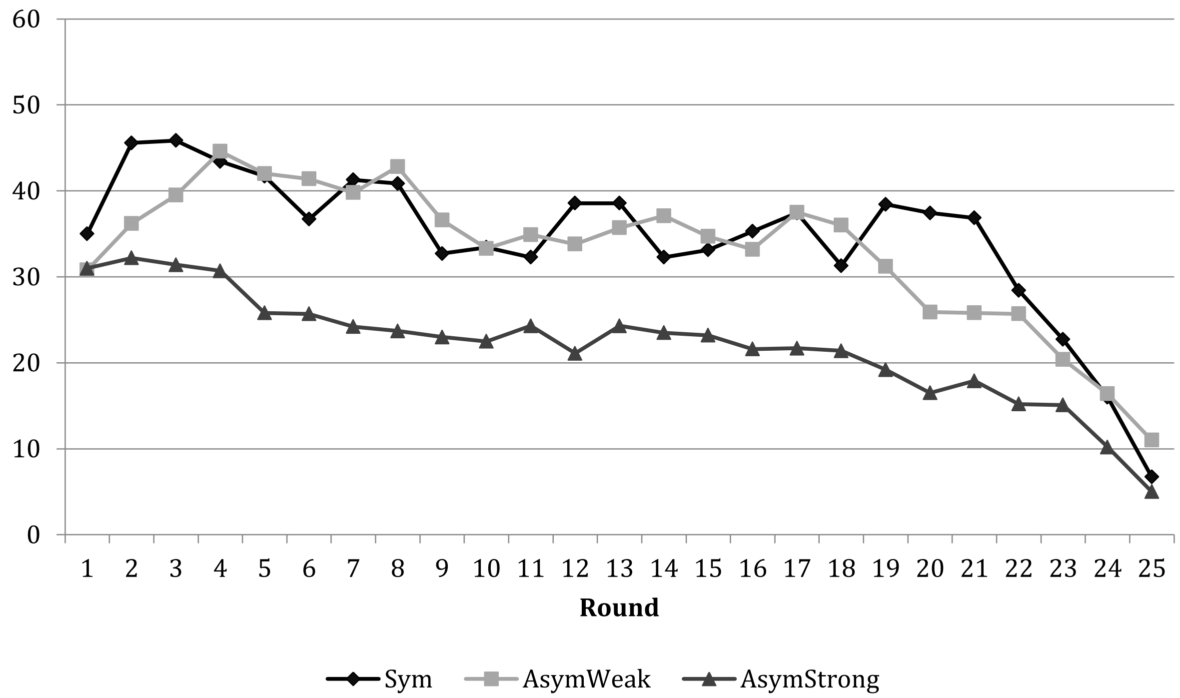

Figure 1: Group Contributions to the Public Investment

In none of the three treatments do we observe a significant change in the standard deviation of the group contributions over time, when we compare (1) periods 1-10 with 11-20 and (2) periods 11-20 with 21-25, requiring significance at the 10-percent level.[4]

Result 1: *There is no significant difference in the contribution level between the Sym and the AsymWeak treatments – a result consistent with Hypothesis 1 and the similar experiment by Hofmeyer et al. (2007). However, in the AsymStrong treatment we do observe a significantly lower contribution level than in the two other treatments.*

The lower contribution level in AsymStrong than in Sym could potentially be considered as a confirmation of the result by Cherry et al. (2005). However, to compare their one-shot game in an adequate way with our repeated game, we consider either the very first period or the last period of the game. In neither period, considered individually, do we observe a significant difference among the three treatments.[5]

[4] Signed-rank tests. Sym: $p^{(1)} = 0.8658$ and $p^{(2)} = 0.4990$; AsymWeak: $p^{(1)} = 0.0926$ and $p^{(2)} = 0.7213$; AsymStrong: $p^{(1)} = 0.4446$ and $p^{(2)} = 0.6465$.

[5] First round: Kruskal-Wallis test p = 0.6912. Pairwise comparisons based on U tests, Sym and AsymWeak p = 0.4344, Sym and AsymStrong p = 0.4639, AsymWeak and AsymStrong p = 1.0000.
Last round: Kruskal-Wallis test p = 0.3575. Pairwise comparisons based on U tests, Sym and AsymWeak p = 0.4902, Sym and AsymStrong p = 0.6175, AsymWeak and AsymStrong p = 0.1438.

4.2 Contributions by Player Types

For a better understanding of what is going on in the asymmetric treatments, we analyze the contributions by the various player types, as defined by their endowments. We proceed with an examination of the AsymWeak treatment, first, and the AsymStrong treatment, second.

In the AsymWeak treatment, we denote the player with an endowment of 10 as *poor*, the players with an endowment of 15 as *wealthy* and the player with an endowment of 20 as *rich*. The average contribution levels of the poor, wealthy and rich are, 6.31, 7.65 and 11.44, respectively. This corresponds to a percentage of the endowment of 63.1, 51.0 and 57.1, respectively for the poor, wealthy and rich (see also Figure 2 for the development over time).

Comparing poor and wealthy group members, we observe no statistically significant difference, neither in the average contribution nor in the contribution as a share of the endowment (signed-rank tests, p-values of 0.2842 and 0.2411, respectively).

Comparing poor and rich group members, we observe a significantly different (higher) contribution level of the rich (signed-rank test, $p = 0.0218$) but no significant difference in the contribution as a share of the endowment (signed-rank test, $p = 0.6098$).

Comparing wealthy and rich group members, we observe a significantly different (higher) contribution level of the rich (signed-rank test, $p = 0.0051$) but no significant difference in the contribution as a share of the endowment (signed-rank test, $p = 0.1386$).

Result 2a: *In the AsymWeak treatment, the poor, wealthy and rich tend to contribute the same proportion of their respective endowment. This confirms Hypothesis 2 (fair-share rule) and replicates the result by Hofmeyer et al. (2007).*

In the AsymStrong treatment, we denote the players with an endowment of 8 as *poor* and the player with an endowment of 36 as *rich*. The average contribution levels of poor and rich players are 4.79 and 7.63, respectively. This corresponds to 59.9 and 21.2 percent of the corresponding endowment (see also Figure 3 for the development over time). We observe that the contribution levels are not significantly different, requiring significance at the 10-percent level (signed-rank test, $p = 0.1141$). However, the poor contribute a significantly different (higher) percentage of their endowment than the rich ($p = 0.0069$).

Result 2b*: In the AsymStrong treatment, the rich player tends to contribute the same amount as the poor players and thus a much lower percentage of the individual endowment. This contradicts Hypothesis 2 (fair-share rule).*

We provide the following interpretation of this result, which would need confirmation in further studies. The AsymStrong treatment is based on a parameterization that exhibits a special characteristic, which is not typical in public-good experiments: the rich player has no interest in achieving the group optimum as defined by the maximum of the sum of profits. The rich player's Nash equilibrium profit is higher than the individual profit in the group optimum. Thus, the contribution of the same proportion of endowment seems not to be considered as "fair" any more. However, there exists another potential cooperative goal that appears to define fair contributions in the AsymStrong treatment: the group optimum under the constraint that each player contributes the same amount. We call this the "constrained optimum". In the AsymStrong treatment the constrained optimum makes all players, including the rich player, better off than in the Nash equilibrium.

This interpretation finds support in the observation that we can assign the independent AsymStrong groups to two, equally large categories. The first category comprises groups, in which the rich player starts with a high contribution (far above the endowment of a poor player) but drops the contribution, after a few periods, to the endowment level of a poor player and then stays there. The reason appears to be anger about the poor players not contributing their entire endowments. The second category comprises groups, in which, from the beginning, the rich player does not contribute more than the maximum amount that a poor player may contribute.

The above results related to Hypothesis 2 find confirmation in random-effects regressions on the proportion of the endowment contributed to the public investment in AsymWeak (Model 1) and AsymStrong (Model 2). The regression results are presented in Table 2. In Asymweak, neither the dummy variable for the rich player (Rich) nor for the poor player (Poor) show a significantly positive or negative coefficient. In AsymStrong, the dummy variable for the rich player (Rich) shows a significantly negative coefficient. In both models, we observe a significantly negative end-game effect (Last5Periods) and a significantly negative overall time trend (Period).

With respect to the individual contribution decisions, we recall that in linear public-good experiments their distribution typically has peaks at both zero and the contribution of one's entire endowment. Table 3 exhibits the relative frequencies of individual contributions at these peaks in the three treatments. In the Sym treatment, 20 percent of the individual contributions are at zero and 30 percent at full contribution, roughly. This also holds for the wealthy players in AsymWeak having the same endowment as the players in Sym. The poor players in AsymWeak and AsymStrong show higher relative frequencies of full contribution, around 40 percent, while the rich players in AsymStrong hardly ever contribute their entire endowment to the public good.

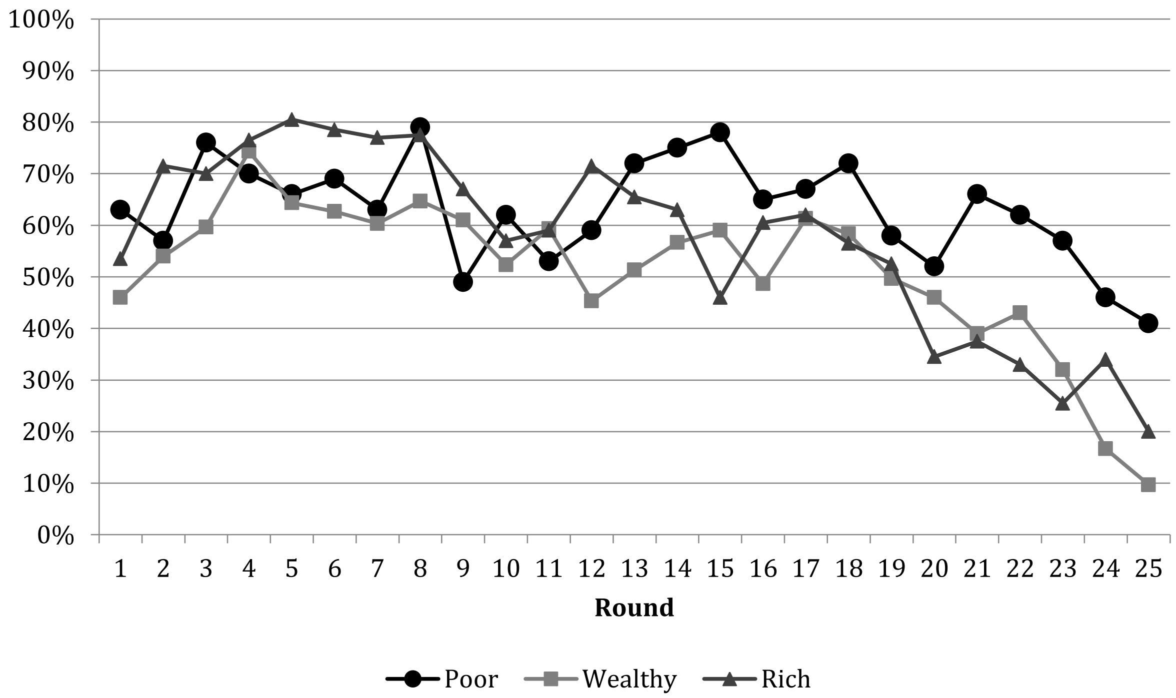

Figure 2: Proportion of Endowment Contributed in AsymWeak

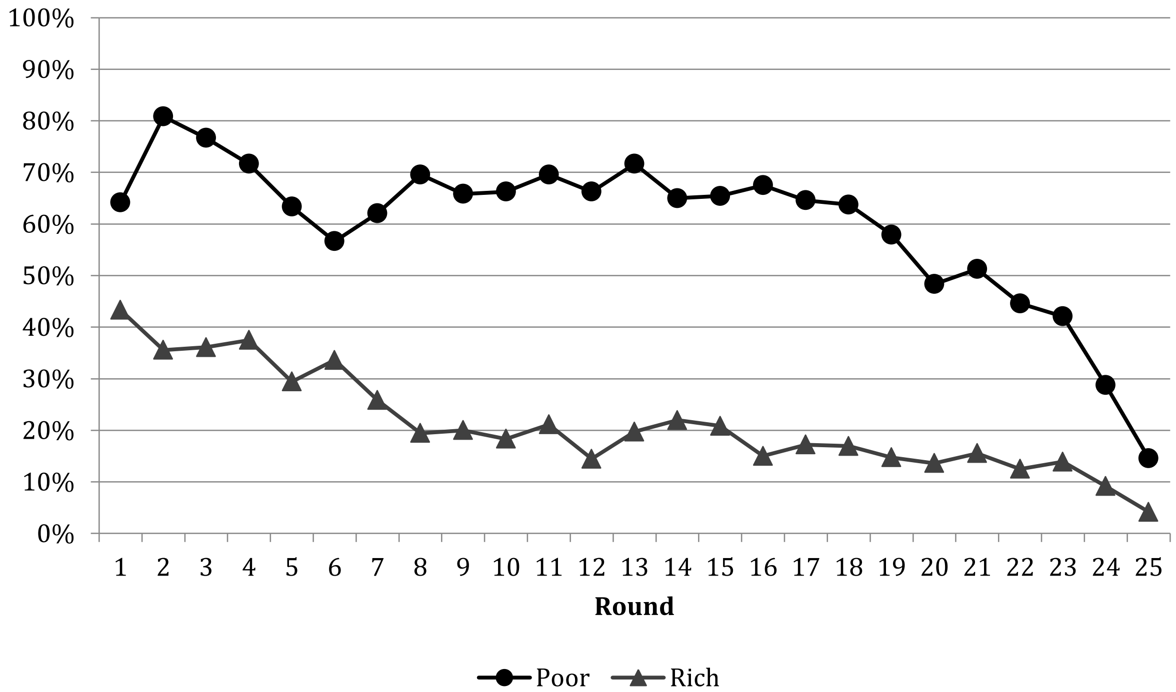

Figure 3: Proportion of Endowment Contributed in AsymStrong

Table 2: Proportion of the Endowment Contributed to the Public Investment

	Model 1 AsymWeak	Model 2 AsymStrong
Period	-0.0067***	-0.0089***
Last5Periods	-0.1717***	-0.1422***
Rich	0.6919	-0.3873***
Poor	0.1207	
Intercept	0.6317***	0.7438***
σ_u	0.223	0.123
σ_e	0.300	0.324
R^2	0.095	0.254
N	1000	1000

Notes: Random-effects regressions. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Relative Frequency of Individual Decisions, which were either Zero or Full Contribution to the Public Investment

	Zero Contribution (in percent)	Full contribution (in percent)
Sym	18.1	29.4
AsymWeak – Poor	18.0	**41.2**
AsymWeak – Wealthy	21.2	28.6
AsymWeak – Rich	18.0	28.4
AsymStrong – Poor	20.7	**37.9**
AsymStrong – Rich	23.6	**1.6**

4.3 Reciprocity

Keser and van Winden (2000) define reciprocity in a qualitative way: *"If a subject intends to change his decision from one period to the next, he changes it in the direction of the other group members' average contribution in the previous period. This means that he increases (decreases) his contribution if it was below (above) the average of the others."* (p. 33). In the case of heterogeneous endowments, we need to distinguish between the considerations of absolute or relative contribution levels. We determine for each independent group of the same player type whether or not it reacts in the majority of cases in the predicted direction. Since almost all (groups of) players of type Sym, AsymWeak-poor, AsymWeak-wealthy, AsymWeak-rich, and AsymStrong-poor do react as predicted, we conclude that we have significant evidence of reciprocity both with respect to absolute and relative contributions. For the AsymStrong-rich player, however, we find significant evidence of reciprocity only with respect to absolute values.

Since this is a very conservative way of testing, we examine reciprocity in OLS regressions on the difference between the proportion of one's endowment contributed in the current and in the previous period (Model 3 for AsymWeak and Model 4 for Asymstrong). The results are presented in Table 4. $LaggedDeviation$ measures the lagged difference of one's own proportion of the endowment contributed and the average proportion of endowment contributed by the others. The estimated coefficient of this variable is significantly negative in both treatments, which indicates the type of reciprocity defined above: ceteris paribus, if I have contributed a higher percentage than the others, I tend to decrease my contribution relative to the endowment, and vice versa. The estimates of Model 3 (AsymWeak) suggest, ceteris paribus, neither an increase nor a decrease in the percentage of endowment contributed by wealthy and rich players, but a significant increase by the poor players. Similarly, the estimates of Model 4 (AsymStrong) suggest, ceteris paribus, an increase for the poor players, but a decrease for the rich ones.

Result 3: *In keeping with Hypothesis 3, we do observe reciprocity for all player types in our experiment.*

Table 4: Changes in the Proportion of One's Endowment Contributed to the Public Investment

	Model 3 AsymWeak	Model 4 AsymStrong
Period	-0.0044**	-0.0014
Last5Periods	0.0143	-0.0472
LaggedDeviation	-0.3975***	-0.5456***
Rich	0.0345	-0.3642***
Poor	0.0618**	
Intercept	0.0205	0.1582***
adjusted R^2	0.204	0.284
N	960	960

Notes: OLS regressions. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.4 Profits and Gini Indices

Table 5 exhibits the average profits realized per period. The Kruskal-Wallis test shows a significant difference between the average sum of profits per period in the three treatments (p = 0.0012). The comparison between Sym and AsymWeak shows no significant difference (U test, p = 0.7694). The comparisons between Sym and AsymStrong (p = 0.0034) and between AsymWeak and AsymStrong (p = 0.0011) show significant differences based on two-sided U tests. We conclude that the average sum of profits per period is significantly lower in AsymStrong than in the other two treatments. This directly relates to the differences in the group contribution levels observed above.

The comparison of the average profit per period realized in Sym (where all group members are "wealthy" with an endowment of 15) and by the wealthy type in AsymWeak shows no significant difference (U test, p = 0.2828).

The comparison of the endowment types within the AsymWeak treatment based on two-sided signed rank tests shows a significant difference between the poor and the wealthy (p = 0.0125), a significant difference between the poor and the rich (p = 0.0166) and a weakly significant difference between the wealthy and the rich (p = 0.0827). Also the comparison of the endowment types within the AsymStrong treatment shows a strongly significant difference between the poor and the rich (p = 0.0051).

The two Asym treatments start with an inequality in wealth, i.e., an inequality in the endowments. After each decision round, the distribution of wealth might have changed, i.e., the distribution of profits might be different from the distribution of initial endowments. To analyze the change in the inequality in wealth from the initial endowment distribution to the end of the experiment, we calculate Gini coefficients.[6]

Table 6 presents the average Gini coefficients for the distribution of the players' initial endowments and for the final distribution of players' total profits accumulated over the 25 rounds of the game within each group. For the sake of completeness, we do this for all three treatments. For the Sym treatment the initial-endowment Gini coefficient is zero and thus the coefficient may only stay the same or increase for the distribution of the final wealth. As discussed above, differences in the individual contributions may render the distribution of wealth less equal. The Gini coefficients for the initial endowment distributions in AsymWeak and AsymStrong might seem surprising given the numbers reported in the UN Human Development Report 2011 (UNDP, 2011). It provides Gini coefficients of 0.283 for Germany, or 0.585 for Colombia.

We observe that, based on the Gini coefficients, the inequality decreases by 51 percent in the AsymWeak and by 31 percent in the AsymStrong treatment. These reductions in inequality are statistically significant (signed-rank tests, $p = 0.0051$). The reduction is significantly more important in AsymWeak than in AsymStrong (U test, $p = 0.0696$). Note that in the extreme, i.e., the provision of the public good at the social optimum, the Gini coefficient would be zero. In contrast, the equilibrium outcome of zero contribution would leave the initial Gini coefficient unchanged. In the Asym treatments, an increase of the Gini coefficient through public-good provision would be technically feasible.

Result 4: *In accordance with Hypothesis 4, we do observe a significant reduction in inequality in the experiments with heterogeneous endowments. The reduction is significantly more important under AsymWeak than under AsymStrong.*

[6] The Gini coefficient is a measure of statistical dispersion and it is commonly used as a measure of inequality of income or wealth. It is usually defined mathematically based on the Lorenz curve. It can be thought of as the ratio of the area that lies between the line of equality and the Lorenz curve and the total area under the line of equality. The Gini coefficient can range from 0 to 1. A low Gini coefficient indicates a more equal distribution, with 0 corresponding to complete equality, while higher Gini coefficients indicate more unequal distributions, with 1 corresponding to complete inequality.

Table 5: Average Period Profits

	Sym	AsymWeak	AsymStrong
Average Sum of Profits	188.96 (120; 240; 240)	186.10 (120; 240;200)	164.03 (120; 240; 182)
Average Profit – Poor	---	40.44 (20; 60; 40)	28.42 (16; 60; 32)
Average Profit – Wealthy	47.24 (30; 60; 60)	47.75 (30; 60; 50)	---
Average Profit – Rich	---	50.17 (40; 60; 60)	78.75 (72; 60; 88)

Note: Figures in parentheses are the per-period profits in equilibrium, the social optimum, and in the constrained optimum.

Table 6: Gini Coefficients

Treatment	Gini Coefficients (for initial endowments)	Gini Coefficient (for final total profits)	Reduction (in percent)
Sym	0.0000	0.0449	-
AsymWeak	0.1250	0.0639	51.11
AsymStrong	0.3500	0.2422	30.79*

5. Conclusion

In the case of weak asymmetry in the distribution of players' endowments in a public-good game, we observe that the overall contribution level remains unchanged relative to a similar situation with a symmetric distribution of the same sum of endowments. Our experiment thus replicates the neutrality result by Hofmeyer et al. (2007), which gives hope for its robustness. However, our experiment also shows that a strong asymmetry in endowments may lead to significantly lower contributions. The asymmetry in our AsymStrong treatment is so important that this treatment differs from the typical VCM experiments in one crucial aspect: there exists a super-rich player that is not interested in achieving the social optimum.

Our experimental results of the AsymWeak treatment confirm the observation by Hofmeyer et al. (2007) that cooperation is largely based on a "fair-share rule", i.e., the principle that players contribute the same proportion of their respective endowment to the public investment. This is not what we observe in the strongly asymmetric treatment, though. The super-rich player tends to contribute an amount that is not significantly different from the average contribution of the poor players.

This difference in the behavioral patterns between the AsymWeak and AsymStrong treatments indicates a potential norm shift that can be interpreted as follows. In the weakly asymmetric treatment, full contribution defines the ultimate cooperative goal for each of the three player types. We observe reciprocating behavior, in which contributing the same proportion of one's endowment appears to play a larger role than contributing the same absolute amount. This suggests that there exists a behavioral norm based on the fair-share rule. However, in our strongly asymmetric treatment, the super-rich player has no interest in achieving the full-contribution social optimum, where the sum of all players' profits would be maximized. The social optimum would imply equal profit for all players, and for the rich player a profit far below the Nash-equilibrium profit. While public-good provision in the case of heterogeneous endowments generally enhances social efficiency and involves an equalizing redistribution aspect, this aspect becomes—at some critical level of public-good provision below the social optimum—unfavorable to the super-rich player in the AsymStrong treatment. The critical level of public-good provision can be identified by a "constrained social optimum", i.e., the socially optimal solution under the restriction that everybody contributes the same amount. This implies that everybody contributes an amount equal to the poorest player's endowment, which imposes an upper limit on the absolute contribution of the richer players. It is in every individual player's interest to reach this constrained optimum. Thus, the behavioral norm in the AsymStrong treatment requires that everybody contributes the same absolute amount.

Our result could surely be taken into account in the discussions and evaluations of global and national endeavors on public-good provision and can potentially partly explain why negotiations and other social interactions do not lead to the desired cooperative outcomes. In the light of rising asymmetries within countries our research findings clearly convey a warning against this trend. Inequality has its price: In the case of strong asymmetries in the financial resources of the parties involved, the voluntary contributions mechanism might lead to outcomes that are far from being socially efficient.

References

Andreoni, J., 1988. Why free ride?: Strategies and Learning in Public Goods Experiments. Journal of Public Economics 37, 291-304.

Becker, G.S., 1974. A Theory of Social Interactions. The Journal of Political Economy 82, 1063-1093.

Bergstrom, T., Blume, L., Varian, H., 1986. On the Private Provision of Public Goods. Journal of Public Economics 29, 25-49.

Bolton, G.E., Ockenfels, A., 2000. ERC: A Theory of Equity, Reciprocity, and Competition. The American Economic Review 90, 166-193.

Buckley, E., Croson, R., 2006. Income and Wealth Heterogeneity in the Voluntary Provision of Linear Public Goods. Journal of Public Economics 90, 935-955.

Cardenas, J.C., 2003. Real Wealth and Experimental Cooperation: Evidence from Field Experiments. Journal of Development Economics 70, 263-289.

Cardenas, J.C., Carpenter, J., 2004. An Inter-Cultural Examination of Cooperation in the Commons. Working Paper, Department of Economics, Middlebury College.

Cardenas, J.C., Carpenter, J., 2008. Behavioral Development Economics: Lessons from Field Labs in the Developing World, Journal of Development Studies 44, 311-338.

Cherry, T.L., Kroll, S., Shogren, J.F., 2005. The Impact of Endowment Heterogeneity and Origin on Public Good Contributions: Evidence from the Lab. Journal of Economic Behavior & Organization 57, 357–365.

Cherry, T.L., Frykblom, P., Shogren, J.F., 2002. Hardnose the Dictator. American Economic Review, 92, 1218-1221.

Fehr, E., Schmidt, K.M., 1999. A Theory of Fairness, Competition, and Cooperation. The Quarterly Journal of Economics 114, 817-868.

Fisher J., Isaac, R.M., Schatzberg J. W., Walker, J.M., 1995. Heterogeneous Demand for Public Goods: Behavior in the Voluntary Contributions Mechanism. Public Choice 85, 249-266.

Hoffman, E., Spitzer, M., 1985. Entitlements, Rights, and Fairness: An Experimental Examination of Subjects' Concepts of Distributive Justice. Journal of Legal Studies 15, 254–297.

Fischbacher, U., 2007. z-Tree: Zurich Toolbox for Ready-made Economic Experiments. Experimental Economics 10, 171-178.

Hofmeyer, A., Burns, J., Visser, M., 2007. Income Inequality, Reciprocity and Public Good Provision: An Experimental Analysis. South African Journal of Economics 75, 508-520.

Isaac, R.M., Walker, J. M., Thomas, S. H., 1984. Divergent Evidence on Free Riding: An Experimental Examination of Possible Explanations. Public Choice 43, 113-149.

Isaac, R.M., Walker, J. M., 1988. Group Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism. Quarterly Journal of Economics 103, 179–199.

Keser, C., 2000. Cooperation in Symmetric Duopolies with Demand Inertia. International Journal of Industrial Organization 18, 23-38.

Keser, C., 2002. Cooperation in Public Goods Experiments. In: Bolle F., Lehmann-Waffenschmidt M. (Eds.), Surveys in Experimental Economics: Bargaining, Cooperation, and Election Stock Markets. Physica-Verlag, Heidelberg.

Keser, C., van Winden, F., 2000. Conditional Cooperation and Voluntary Contributions to Public Goods. Scandinavian Journal of Economics 102, 23-39.

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

Loomes, G., Burrows, P., 1994. The Impact of Fairness on Bargaining Behaviour, Empirical Economics 19, 201-221.

Marwell, G., Ames, R.E., 1979. Experiments on the Provision of Public Goods. I. Resources, Interest, Group Size, and the Free-Rider Problem. The American Journal of Sociology 84, 1335-1360.

Mason, C.F., Phillips, O.R., Nowell, C., 1992. Duopoly Behavior in Asymmetric Markets: An Experimental Evaluation. Review of Economics and Statistics 74, 662-669.

Maurice, J., Rouaix, A., Willinger, M., 2013. Income Redistribution and Public Good Provision: An Experiment. International Economic Review 54, 957-975.

OECD, 2011. Divided We Stand: Why Inequality Keeps Rising. OECD Publishing. http://dx.doi.org/10.1787/9789264119536-en.

Olson, M., 1965. The Logic of Collective Action: Public Goods and the Theory of Groups, Cambridge, MA: Harvard University Press.

Ostrom, E., Gardner, R., Walker, J., 1994. Rules, Games, and Common-Pool Resources. The University of Michigan Press.

Sadrieh, A., Verbon, H.A.A., 2006. Inequality, Trust, and Growth: An Experimental Study. European Economic Review 50, 1197-1222.

Selten, R., Mitzkewitz, M., Uhlich, G.R., 1997. Duopoly Strategies Programmed by Experienced Players. Econometrica 65, 517-555.

Selten, R., Stoecker, R., 1986. End Behavior in Sequences of Finite Prisoner's Dilemma Supergames: A Learning Theory Approach, Journal of Economic Behavior & Organization 7, 47-70.

UNDP, 2011. Human Development Report 2011: Sustainability and Equity: A Better Future for All. New York: Palgrave Macmillan. (http://hdr.undp.org/en/media/HDR_2011_EN _Complete.pdf)

Van Dijk, E., Wilke, H., 1994. Asymmetry of Wealth and Public Good Provision. Social Psychology Quarterly 57, 352-359.

Warr, P. G., 1983. The Private Provision of a Public Good is Independent of the Distribution of Income. Economics Letters 13, 207-211.

Weimann, J., Brosig-Koch, J., Heinrich, T., Hennig-Schmidt, H., Keser, C, Stahr, C., 2014. An Explanation of (First Round) Contributions in Public-Good Experiments. CESifo Working Paper No. 5039, October 2014.

Appendix A

Additional Data Tables

Table A. 1: Average Group Contribution in Rounds 1-10, 11-20 and 21-25

Treatment	Rounds 1-10		Rounds 11-20		Rounds 21-25	
	Average	Std.	Average	Std.	Average	Std.
Sym	39.66	9.37	35.47	9.47	22.14	12.49
AsymWeak	38.70	7.41	34.00	9.48	19.86	10.74
AsymStrong	27.02	12.67	21.68	8.51	12.68	8.77

Table A. 2: Average Individual Contributions in Sym

Group	Player e = 15		
	Mean	% e	Median
Sym1	7.53	50.2	10
Sym2	7.27	48.5	5
Sym3	13.77	91.8	15
Sym4	9.82	65.5	15
Sym5	7.35	49.0	8.5
Sym6	7.35	49.0	9.5
Sym7	7.25	48.3	5
Average	8.62	57.5	9.71

Table A. 3: Average Individual Contributions by Player Type in AsymWeak

Group	Player type *e* = 10			Player type *e* = 15			Player type *e* = 20		
	Mean	% e	Median	Mean	% e	Median	Mean	% e	Median
AsymWeak1	4.00	40.0	3	6.12	40.8	5	9.36	46.8	0
AsymWeak2	9.80	98.0	10	14.24	94.9	15	19.08	95.4	20
AsymWeak3	5.72	57.2	5	6.90	46.0	5	11.48	57.4	12
AsymWeak4	8.40	84.0	10	8.12	54.1	5	9.60	48.0	10
AsymWeak5	1.44	14.4	0	5.00	33.3	4	14.16	70.8	17
AsymWeak6	4.56	45.6	5	10.24	68.3	10	12.8	64.0	14
AsymWeak7	9.32	93.2	10	4.58	30.5	5	7.24	36.2	8
AsymWeak8	8.16	81.6	10	5.32	35.5	5	6.60	29.1	8
AsymWeak9	6.88	68.8	8	6.76	45.1	6.5	9.84	43.3	10
AsymWeak10	4.80	48.0	5	9.24	61.6	10	14.24	37.0	20
Average	6.31	63.1	6.6	7.65	51.0	7.1	11.44	52.8	11.9

Table A. 4: Average Individual Contributions by Player Type in AsymStrong

Group	Player e = 8			Player e = 36		
	Mean	% e	Median	Mean	% e	Median
AsymStrong1	4.67	58.3	5	6.88	19.1	2
AsymStrong2	6.08	76	8	2.24	6.2	0
AsymStrong3	5.61	70.2	8	8	22.2	8
AsymStrong4	5.63	70.3	8	3.6	10	4
AsymStrong5	4.29	53.7	5	5.48	15.2	6
AsymStrong6	4.89	61.2	5	19.88	55.2	20
AsymStrong7	3.63	45.3	4	7.56	21	3
AsymStrong8	4.09	51.2	4	5.88	16.3	6
AsymStrong9	4.04	50.5	4	11.92	33.1	8
AsymStrong10	5.01	62.7	6	4.88	13.5	6
Average	4.79	59.9	5.7	7.63	21.2	6.3

Appendix B

Experimental Instructions (AsymWeak)

You participate in an economic decision experiment, in which you can earn money. How much each of you will earn depends on your personal decisions and those of other participants in the experiment. Each participant makes his decisions at a computer, isolated from the others. We ask you not to talk to other participants.

The experiment consists of 25 rounds. In the beginning of the experiment you will be randomly matched with three other persons to build a group of four. You will remain in this group during the entire experiment. You will not know the identity of your group members at any time, though.

Each group member is endowed in each round with a certain amount of tokens. Player 1 is endowed with 10 tokens per round. Players 2 and 3 are endowed with an amount of 15 tokens each. Player 4 is endowed with 20 tokens per round. The individual player numbers (and thus the individual endowments) will be randomly assigned and announced at the beginning of the experiment.

DECISIONS

In each of the 25 rounds, each group member has to decide on how to allocate her/his tokens between two alternatives, called X and Y. The return of a token, in experimental currency units (ECU), is different for the two alternatives. The return of the allocation decision is determined as follows:

Each token that you contribute to X yields a return of 2 ECU. If you contribute nothing to X, your return from X is zero.

Each token that you contribute to Y, yields to you and to each of the other group members a return of 1 ECU. You may thus have a positive return from Y even if you don't contribute anything to Y.

Group Member	Endowment (tokens)
Player 1	10
Player 2	15
Player 3	15
Player 4	20

You may allocate your tokens to X or to Y only, but you may also allocate them among both alternatives. However, only entire tokens may be contributed. In the decision box on your screen you need to enter, for each alternative, the number of tokens that you want to allocate. If you do not want to contribute anything to X or Y, you need to type in a zero. The sum of the tokens contributed to X and Y must be always equal to your endowment of tokens. This means that the entire endowment has to be allocated among X and Y. With the <Tab> key you can switch among the entry fields. The entries have to be confirmed by clicking on <OK>.

Your individual return per round is the sum of your returns from X and Y and is calculated as follows:

Return = 2 × (your contribution to X) + (sum of tokens contributed to Y in your group).

PAYMENT

At the end of the experiment, you will be paid based on your individual total profit over all 25 rounds. Your individual total profit in ECU will be converted into € (1 ECU = 0.01 €) and paid to you in cash. You are paid at the end of the experiment. The payment is carried out individually and anonymously.

AVAILABLE INFORMATION

In each round, you will see an overview table on your screen which provides you with the results of all previous rounds that you have played. The results include the following information for each round:

Your endowment, your mandatory minimum contribution to Y, your contribution to X, your contribution to Y, the individual contributions to Y of each of the other group members, your return from X, your return from Y, your round profit, and your total profit.

If you want to see the results of earlier rounds, which are no longer visible in the table, please use the scroll function on the right side of the table.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. You then will be given on your screen a number of questions regarding these instructions. If you have any questions please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

IV

MANDATORY MINIMUM CONTRIBUTIONS, HETEROGENEOUS ENDOWMENTS, AND VOLUNTARY PUBLIC-GOOD PROVISION

with Claudia Keser and Martin Schmidt

Abstract: In a public-good experiment with heterogeneous endowments, we investigate if and how the contribution level as well as the previously observed "fair-share" rule of equal contributions relative to one's endowment (Hofmeyr et al., 2007; Keser et al., 2014) may be influenced by minimum-contribution requirements. We consider three different schedules: FixMin, requiring the same absolute contributions, RelMin, requiring the same relative contributions, and ProgMin, requiring minimum contributions that progressively increase with the endowment. We find that minimum contributions exert norm-giving character and may lead to an increase in average group contributions. This is especially true for the progressive schedule. On the individual level, this schedule leads to higher relative contributions by the wealthier players and thus violates the "fair-share" norm. On the group level, it leads to the highest contribution level and the lowest inequality in total profits as measured by the Gini index.

JEL-Classification: C92, D63, H41

Keywords: Experimental economics, public goods, heterogeneous endowments, mandatory minimum contributions, norms

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1. Introduction

When it comes to their funding, several public institutions, such as, for example, museums, theaters, and operas, rely on a two-tier model. They apply mandatory admission charges that may be voluntarily supplemented by charitable donations. Given that these institutions provide merit goods, their two-tier funding situation may be modeled in a public-good game, where mandatory levies are requested and additional contributions are possible. Such a model has been introduced by James Andreoni (1993) to investigate crowding-out effects of public intervention in a laboratory experiment. He observes that voluntary contributions are partially crowded out by a lump-sum “tax”. It still remains an open question, though, how such mandatory levies should be designed to maximize the revenues of public institutions, taking into account that agents possess unequal economic possibilities (wealth) and differ in their willingness to pay.

An extensive experimental literature on the voluntary contribution mechanism (VCM) finds that behavior in public-good games cannot solely be explained by standard economic preferences. Contributions, though declining over time, are generally higher than the Nash-equilibrium prediction. This is true whether the dominant strategy is to contribute nothing (e.g., Marwell and Ames, 1979, 1980) or whether it lies in the interior of the strategy space (e.g., Keser, 1996). Survey studies suggest that, when the dominant strategy is to contribute nothing and participants are equally endowed, initial contributions typically lie between 40 and 60 percent of the endowment but decay over time. In the last round about 70 percent of subjects contribute nothing (e.g., Davis and Holt, 1993; Dawes and Thaler, 1988; Ledyard, 1995; Ostrom, 2000). Although contributions are higher than theoretically predicted, they are at a considerable distance from the social optimum. There is ample evidence that subjects tend to coordinate their contributions by conditional cooperation, i.e., they begin cooperatively and reciprocate depending on the actions of others (e.g., Keser and van Winden, 2000; Fischbacher et al., 2001). How such cooperation is affected by an inequality in endowments (wealth) is, however, not yet well understood. John Ledyard’s conjecture that homogeneity in endowments has a positive effect on group contributions, or in other words, that heterogeneity has negative effects (Ledyard, 1995), has only partly been confirmed in the recent literature. Group contributions in weakly asymmetric environments tend to be equal to those in symmetric settings, where the same total endowment is allocated evenly over all group members. Thereby, players tend to follow a “fair-share” rule, where they coordinate on equal relative contributions of the endowment (Hofmeyr et al., 2007; Keser et al., 2014; Keser and Schmidt, 2014). The “fair-share” rule has its limitations, though. When the asymmetry in the endowments becomes so large that one of the players loses interest in the group optimum, the norm shifts from equal relative to equal absolute contributions and the group contribution level declines significantly (Keser et al., 2014).

In this study, we consider an environment with heterogeneous endowments where the “fair-share” norm applies (the AsymWeak treatment of Keser et al. (2014)) and investigate if and how this norm as well as the group contribution level may be influenced by minimum contribution requirements similar to the "taxes" in Andreoni (1993). In our experiment, we implement various minimum-contribution schedules (MCS) charging subjects with different endowments with different levies. These levies are compulsory minimum contributions. The staggering of our MCS is motivated by common tax structures to be found in real-life settings. We consider a treatment with a lump-sum "tax" (FixMin), requiring the same absolute minimum contributions from all players, a treatment with a flat "tax" rate (RelMin) that requires the same minimum contribution relative to their respective levels of endowment from all players, and a treatment with a progressive "tax" schedule (ProgMin), where the more wealthy players are requested to provide a higher minimum contribution relative to their endowment than the less wealthy ones. The AsymWeak treatment of Keser et al. (2014) serves as the baseline treatment (NoMin) without any minimum-contribution requirement.[1] We do not see the mandatory levies in our study as taxes in the strict sense. Tax burdens impose tax levels, which are not intended to be overspent by taxpayers. Our minimum-contribution schedules more closely resemble the mandatory admission charges mentioned above. We consider them as a policy tool to potentially impose norms.

Despite the fact that in our experimental game there are no "standard economic" incentives for contributions above the compulsory minimum values, we expect our different minimum contribution schemes to exert "expressive power" (e.g., Cooter, 1998; Galbiati and Vertova, 2008), while driving contributions beyond the enforced minima due to incomplete crowding-out (Andreoni, 1993). Thereby, we anticipate that the miscellaneous schedules differently affect the sense of justice and the willingness to contribute among the group members. To investigate this, we define a measure of motivational crowding-out for our experimental setup. This measure relates to the classic crowding-out in the analysis of public policy (Andreoni, 1993; Andreoni and Payne, 2011) but it is different in that it considers the percentage of the freely disposable endowment that is contributed, rather than the absolute amount contributed. The motivational crowding-out measure indicates zero crowding-out if subjects that contribute, for example, 50 percent of their endowment in the absence of mandatory minimum contribution requirements will still contribute 50 percent of their freely disposable endowment (endowment beyond the mandatory contribution) in the presence of such requirements. Full motivational crowding-out implies contributions equal to the mandatory contribution levels.

In the choice of the different minimum-contribution schedules, we pay attention to two features. Firstly, the total amount of minimum contributions is constant across all treatments. Secondly, minimum contributions for the individual player types are lower than the respective average contributions in the baseline treatment (without mandatory minimum contributions) and thus sum up to less than the (unenforced) average total

[1] The differentiation of mandatory contribution levels in the treatments with the relative and the progressive MCS can be seen as a kind of third degree price discrimination, where the levies vary by wealth status.

group contribution in the baseline treatment.[2] This is necessary, since we are not interested in increasing contributions to the public good by mandatory contributions that are high enough to exceed the amount that people would contribute voluntarily, anyway. We strive to investigate if and how different distributions of a given total mandatory levy may change individual and group contribution patterns.

As discussed above, our study relates to two literature strands. The first one deals with the "expressive power" of law and is thus particularly relevant to the part of our study that deals with the impact of the various minimum contribution schemes on contribution norms. Law can be defined as an obligation, and, according to the expressive-power hypothesis, it might have psychological effects on individual preferences. In other words, actors might view an obligation as an internal value. Law can thus create a focal point by creating values (e.g., Cooter, 1998; Galbiati and Vertova, 2008). The second literature strand deals with the impact of external interventions on intrinsic motivation with respect to crowding-out or crowding-in (e.g., Deci et al., 1999). Given the finding of incomplete crowding-out of voluntary contributions by minimum-contribution requirements (Andreoni, 1993; Chan et al., 2002), we expect our tax systems to increase group contributions. Both literature strands are presented in more detail in Section 2.

The main findings of our experiments can be summarized as follows. We find that mandatory minimum contributions do have a norm-giving character (expressive power). Group contribution levels are significantly higher in ProgMin than in NoMin and FixMin. On the individual level, we observe in all treatments that individuals with higher endowments make on average higher contributions than those with lower endowments. Furthermore, in RelMin, we replicate the "fair-share" rule observed in NoMin (Keser et al., 2014). In FixMin, we find relative contributions to be higher for the less than for the more wealthy players, but we observe the opposite in ProgMin. This suggests that the contribution norm can indeed be influenced through a deliberate intervention like a minimum contribution requirement. As a consequence, the progressive contribution schedule leads to a significant increase in average group contributions relative to the baseline treatment without minimum contribution requirements. While we observe motivational crowding-out in FixMin, we have no evidence for motivational crowding-out in ProgMin and RelMin.

The remainder of this paper is structured as follows. Section 2 gives a short overview over the related literature. Section 3 presents the experimental design and derives testable hypotheses. Section 4 reviews these hypotheses in the face of the experimental results. Section 5 provides a summary and conclusions.

[2] To investigate crowding-out, Andreoni (1993) chooses a "tax" below the interior solution of the non-linear public-good game. Our linear public good game does not have an interior Nash equilibrium but has a dominant strategy solution to contribute nothing. The outcome of the baseline treatment, however, lies in the interior of the strategy space and can be presented as a quantal response equilibrium under the assumption of altruism and error making (Anderson et al., 1998).

2. Related Literature

We consider two ways how mandatory minimum contributions schedules could impact voluntary contributions to a public good. The first is derived from the literature on expressive law that hypothesizes that obligations have a potential to influence behavior. They may create focal points or norms, which channel individuals' beliefs about the behavior of others and act as coordination devices (Cooter, 1998; Galbiati and Vertova, 2008; McAdams and Nadler, 2005). Rational individuals internalize a norm (i.e., change their behavior) when commitment promises an advantage (Cooter, 1998). A norm set by the mandatory minimum contribution levels that is perceived as appropriate to enhance one's profit is hence potentially able to increase individual and group contributions.

Galbiati and Vertova (2008), for example, study expressive law with weakly incentivized non-binding obligations in a public-good game. These obligations are presented as minimum contributions that are not mandatory and thus leave the players' decision spaces unaffected. However, participants know that they will be probabilistically audited and penalized or rewarded if they have under- or over-fulfilled their obligations. In a repeated linear public-good game with groups of six equally endowed subjects, Galbiati and Vertova test whether different obligation levels imply different levels of cooperation. They find that obligations in repeated interactions significantly affect the average level of individual contributions and the rate of decrease in cooperation over time. Higher obligations reduce the pace of the decline in average contributions. Unexpected changes in the level of minimum contributions have asymmetric effects on the level of cooperation: "*a reduction does not alter the pattern of deterioration of cooperation over time, whereas an increase triggers a re-start in cooperation*" (p. 148). In a follow-up study, Galbiati and Vertova (2014) disentangle the effects of obligations and incentives. They consider non-binding incentives (such that zero contribution to the public good still remains the dominant strategy for risk-neutral players) with a low and a high probability of an audit. They find obligations and non-binding incentives to be complementary, jointly supporting high levels of contribution. Incentives alone do not significantly increase contributions, while high obligations in the form of recommendations moderately increase them.

In a similar study, using a repeated public-good game with groups of two identically endowed subjects, Riedel and Schildberg-Hörisch (2013) find that obligations increase contributions in the first rounds. Contributions toward the end of the game, however, are not statistically distinguishable to the case without obligations. Individual contributions are affected by the own obligation but independently from the partners obligation. For a given obligation, behavior is not significantly different between symmetric and asymmetric obligation treatments. However, the fraction of non-compliers is higher for subjects with higher inflicted obligation. Given that the decline in contributions is only significant for individuals with high obligations, subjects seem to incur non-monetary costs while disobeying obligations. People are not more likely to violate an obligation if it is perceived unfair.

The three studies above differ from our study in that the therein employed obligations, i.e., minimum contributions, are not binding. That means that in these studies participants face the same decision space whether obligations are imposed or not, i.e., under- or over-fulfillment of the obligation is possible. In our study the decision space is reduced by the minimum contribution requirements in the MCS treatments such that only over-fulfillment of the obligation is possible.

The second potential impact channel of minimum contributions relates to the literature on the impact of external interventions on intrinsic motivation. According to Ryan and Deci (2000) "*[i]ntrinsic motivation is defined as the doing of an activity for its inherent satisfaction rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards*" (p. 56). It is argued that, given a task that is performed voluntarily or for the sake of its own, any form of outside interference may affect the intrinsic motivation on which the initial action is based and thus change the amount of effort exerted in the task. Crowding-out of intrinsic motivation is reinforced, when the external intervention is perceived as controlling (Falk and Kosfeld, 2006) or when it has a negative effect on people's feeling of self-determination, competence and self-esteem (Deci, 1971; Nyborg and Rege, 2003; Rotter, 1966).

Titmuss (1970) was the first to establish the hypothesis that monetary rewards may crowd out intrinsic motivation. He came up with the example of blood donations, where present donors may reduce donations, if they perceive that their intrinsic motivation is not appreciated, when monetary incentives for their donations are offered. The result is what Condry and Chambers (1978) call "hidden costs of reward" as rewards tend to distract attention from the process of the task activity itself to the goal of getting a reward. This hypothesis was confirmed by Uptom (1973). Since Titmuss (1970) a large body of literature found indication for his hypothesis in a variety of other circumstances[3]. Note, however, that in contrast to the said, interventions, might also be perceived as supportive and promote self-esteem. If this is the case, they might even crowd in intrinsic motivation (Frey and Jegen, 2001).

In the case of the funding of a public good, a specific additional factor could play a crucial role: the perception of one's moral responsibility for the provision of the good. If the government enforces minimum contribution levels, individuals may perceive a decay of their responsibility for the provision, leading to a crowding-out of (additional) voluntary contributions. If however, the intervention is able to communicate morally ideal contribution levels, which are perceived as symbolic, even a crowding-in is possible (Brekke et al., 2003; Nyborg and Rege, 2003).

Theoretical models on government intervention in the provision of public goods, for models with an interior equilibrium, predict complete crowding-out of private voluntary

[3] See, for example, Deci (1971, 1972), Deci et al. (1999), Frey (1993, 1994, 1997a, 1997b), Frey et al. (1996), Frey and Oberholzer-Gee (1997), Frey and Goette (1999), Frey and Jegen (2001), Gneezy and Rustichini (2000a, 2000b), and Lepper et al. (1973).

by public contributions (e.g., Warr, 1982, 1983; Roberts, 1984, 1987; Bergstrom et al., 1986; Bernheim, 1986). Indeed, crowding-out of voluntary public-good provision by governmental provision is found in several empirical studies. In the context of charitable giving Abrams and Schmitz (1978, 1984) find crowding-out of about 30 percent and that in addition to governmental charitable payments the need of the recipients plays a crucial role in the decision for private charitable donations. Payne (1998) observes crowding-out of about 50 percent of private donations to non-profit organizations (NGOs) with increased government funding. In a laboratory experiment, based on a public-good game with an interior equilibrium, Andreoni (1993) finds crowding-out of about 70 percent by mandatory contributions. In a similar study Chan et al. (2002) also find that crowding-out is incomplete and that enforced contributions significantly increase total contributions to the public good.

3. The Experiment

3.1 The Game

In our public-good game n players form a group. Each player i ($i = 1, \dots, n$) is endowed with a number of tokens, e_i, which have to be allocated between a private and a public investment. Let x_i denote the amount allocated to the private investment and y_i the amount allocated to the public investment by player i, with $x_i, y_i \geq 0$. The investments have to be in entire tokens and have to add up to the endowment. Furthermore, there is a minimum contribution requirement to the public investment c_i, with $c_i \geq 0$. Thus, $0 \leq x_i \leq e_i - c_i$, $c_i \leq y_i \leq e_i$, and $x_i + y_i = e_i$. The profit of each player i depends on his individual private investment and the sum of all public investments in his group. Each token that he allocates to the private investment yields him an individual return of α, while each token that he allocates to the public investment yields him and each other group member a return of β, with $\alpha > \beta$ and $n\beta > \alpha$. The profit function of player i can thus be written as:

$$\pi_i\left(x_i, \sum_{i=1}^{n} y_i\right) = \alpha x_i + \beta \sum_{i=1}^{n} y_i \qquad (1)$$

Since a player's individual return in the private investment is larger than in the public investment ($\alpha > \beta$), the game has an equilibrium in dominant strategies, where each player contributes the required minimum to the public investment and all remaining tokens to his private investment ($x_i^* = e_i - c_i,\ y_i^* = c_i$). If this game is played over a finite number of T rounds, the subgame perfect equilibrium solution prescribes, based on backward induction, that in each round $t \in (1, \dots, T)$ each player contributes the required minimum to the public investment and all remaining tokens to his private investment ($x_{it}^* = e_i - c_i,\ y_{it}^* = c_i$).

Given that $n\beta > \alpha$, the sum of profits of all n players is maximized if all tokens are allocated to the public investment. Hence, in the social optimum all players allocate in each round their entire endowment to the public investment. The game-theoretical solution (subgame-perfect equilibrium) is thus collectively inefficient.

Given the evidence from earlier experiments on this kind of linear public-good game, where contributions, significantly deviate from the Nash equilibrium solution, also other equilibrium concepts are conceivable. For example, the so-called quantal response equilibrium, which is based on the assumption that subjects' decisions are determined by altruism and decision-error, can explain why mean contributions deviate from the Nash equilibrium (Anderson et al., 1998). Based on the quantal response equilibrium concept, the crowding-out measure by Andreoni (1993), which is based on the assumption that the Nash equilibrium (before and after taxation) lies in the interior of the decision space and that the lump-sum tax is smaller than the equilibrium contribution, can also be used in the context of our study to evaluate the impact of our minimum contribution schedules on individual and group contributions.

3.2 Procedure

We conducted the computerized experiment in the *Göttingen Laboratory of Behavioral Economics* at the University of Göttingen, Germany, based on the z-tree software package (Fischbacher, 2007).[4] Participants were 160 bachelor and master students from various disciplines (mostly economics and business administration). Recruited via ORSEE (Greiner, 2004), they had previously volunteered to participate in decision-making experiments. On average, a roughly equal number of female and male students participated in the experiments; the number of women and men approximately balanced during all sessions. According to subject availability, we conducted sessions with three to four groups each, implying three to four independent observations per session. In total 40 independent observations were collected in four different treatments.

The procedure of the experiment was as follows. Upon arrival in the meeting room each participant got a randomly assigned participation number corresponding to a computer terminal in the lab. As soon as the required number of participants had shown up, the experimenter distributed written instructions (a translation of these is provided in Appendix B) and read them aloud to all participants.

Participants were informed that they would be randomly assigned to groups which remain unchanged during the entire experimental session (partners design). Participants, however, did not get to know the identity of the participants with whom they interacted. Each player in a group was randomly assigned a player number from one to four, which was individually communicated at the beginning of the experiment and remained unchanged. Each player number was associated with a certain fixed endowment and minimum contribution requirement per round. At the end of each round, participants were informed about the contributions to the public investment by each of the other players in the group (identified by their player number but otherwise anonymous), the total group contribution, the profit for the current round, and the total profit so far. Moreover, all participants were provided with a history of all previous rounds, containing the same information, on the screen.

After the reading of the instructions participants were seated at their respective computer terminals. Before the experiment started, we used computerized control questions with regard to the understanding of the instructions. The experiment did not start until all participants had provided correct answers to all questions.

The participants were informed in the instructions that the profits gained in the course of the experiment were measured in Experimental Currency Unit (ECU) and that these profits were to be multiplied by a conversion factor of 0.01 € per ECU (which is the same for all players) for the final payment, in addition to a show-up fee of 3 €. The cash payment was conducted anonymously after the experiment.

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[4] The lab consists of 24 computers in isolated booths, such that vision of someone else's computer screen or verbal communication with other participants is highly restricted.

An experimental session lasted on average around 75 minutes. The average payoff earned was about 15.50 € (including a 3 € show-up fee).

3.3 Parameters and Treatments

Participants are assigned to groups of four ($n = 4$), the game is played for 25 rounds ($T = 25$), and the parameters of the profit function are $\alpha = 2$ and $\beta = 1$ (which implies a constant marginal per capita return (MPCR[5]) of 0.5 for the investment in the public account). Furthermore, participants are informed that Player 1 (Type 10) is endowed with 10 ECU, Players 2 and 3 (Type 15) are endowed with 15 ECU, each, and that Player 4 (Type 20) is endowed with 20 ECU. In each round, each participant has to make an allocation decision, conditioned on his minimum contribution requirement to the public good (c_i). Minimum contribution requirements of all player types are common knowledge.

Table 1 presents the individual minimum contribution requirements (c_i) for the three player types in our four treatments: (1) NoMin, (2) FixMin, (3) RelMin, and (4) ProgMin. Under NoMin no participant is forced to contribute a mandatory levy; under FixMin every participant is forced to contribute a mandatory levy of 6 ECU; under RelMin each participant is forced to contribute a mandatory levy of 40 percent of her/his endowment; and under ProgMin each Type 10 player has to contribute 2 ECU, each Type 15 player has to contribute 6 ECU, and each Type 20 player has to contribute 10 ECU. The amounts of 2 ECU, 6 ECU, and 10 ECU in ProgMin correspond to progressive MCS rates of 20, 40, and 50 percent, for the three player types. The FixMin treatment is in principle a regressive MCS system, in that poorer individuals have to contribute relatively more of their endowment. The amounts of 6 ECU correspond to a regressive MCS regime with rates of 60, 40, and 30 percent for the three player types, respectively. In all treatments the total endowment of the four players is equal to 60 and in all MCS treatments the total mandatory levy is equal to 24.

[5] The MPCR is defined as the ratio of the private value of one token invested into the public investment to the private value of one token invested into the private investment.

Table 1: Treatments

Treatment No.	Label	Minimum Contributions (c_i) Type 10				$\sum_{i=1}^{4} c_i$	# Obs.
		Type 10	Type 15		Type 20		
		Player 1	Player 2	Player 3	Player 4		
1	NoMin	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	10
2	FixMin	6 (60%)	6 (40%)	6 (40%)	6 (30%)	24	10
3	RelMin	4 (40%)	6 (40%)	6 (40%)	8 (40%)	24	10
4	ProgMin	2 (20%)	6 (40%)	6 (40%)	10 (50%)	24	10

3.4 Hypotheses

To facilitate the illustration of the results in the following section our analysis focuses on two hypotheses.

Hypothesis 1: *Minimum contribution requirements incompletely crowd out voluntary contributions implying that we observe higher group contributions in the MCS treatments than in NoMin.*

Andreoni (1993) and Chan et al. (2002) measure crowding-out by $(\bar{Y}_0 + C - \bar{Y}_C)/C$, where $\bar{Y}_0$ is the average group contribution to the public good in NoMin, C is the sum of minimum contributions of all group members, and $\bar{Y}_C$ is the average group contribution to the public good in the respective MCS treatment. Thus, crowding-out is 0 percent if $\bar{Y}_C = \bar{Y}_0 + C$ and it is 100 percent if $\bar{Y}_0 = \bar{Y}_C$. Based on this measure, they find that crowding-out is incomplete and, thus, that their public policy interventions by enforced minimum contributions significantly increase total contributions to the public good. Therefore, we expect that the three minimum contribution schedules increase group contributions above the level of NoMin, but not by the full amount of the contribution requirements.

Hypothesis 2: *Players follow a simple "fair-share" rule of equal relative contributions of the endowment in RelMin but not in FixMin and ProgMin.*

Keser et al. (2014) have shown that players in NoMin tend to coordinate their contributions by using the simple "fair-share" rule, where they contribute equal amounts relative to the endowment. Since in RelMin mandatory contributions are staggered relative to the endowment, we expect contributions to follow this rule as well. However, we expect that Type 10 players contribute a higher (lower) share of their endowment than both other types in FixMin (ProgMin), and that Type 20 players contribute a higher (lower) share of their endowment than both other types in ProgMin (FixMin). In other words, we expect the proportional mandatory contributions in

RelMin, the regressive mandatory contributions in FixMin, and the progressive mandatory contributions in ProgMin, respectively, to exert their "intended" influence by pushing individual contributions in the direction in which the minimum contribution requirements are staggered. We derive support for this conjecture from the literature on expressive law. This literature suggests that mandatory minimum contributions schedules may exert "expressive power" through the imposed obligations by expressing certain levels of "fair contribution" (Galbiati and Vertova, 2008; Riedel and Schildberg-Hörisch, 2013).

4. Experimental Results

Beyond the analysis of group contributions in Subsection 4.1 (Hypothesis 1) and individual contributions in subsection 4.2 (Hypothesis 2), we shall investigate reciprocity in Subsection 4.3 and profits in Subsection 4.4. All nonparametric tests presented in the following subsections are two-sided. We shall denote the Mann-Whitney U test as U test and the Wilcoxon matched-pairs signed-rank test as signed-rank test.

4.1 Group Contributions

Figure 1 presents the development of the average group contributions to the public investment ($\bar{Y}_t$) in the four treatments over the 25 rounds. As can be seen, the ProgMin treatment exhibits the highest contributions.[6] Due to the large end-game effect in NoMin (in approximately the last five rounds), which is impeded by the minimum contribution requirements in the MCS treatments, we report only figures for rounds 1 to 20 in the forthcoming analysis. For this game interval, average group contributions are 36.4 in NoMin, 38.7 in FixMin, 40.2 in RelMin, and 44.7 in ProgMin.[7] This indicates that the mandatory contributions only partially crowd out voluntary contributions. Following Andreoni (1993), crowding-out is 90.2 percent in FixMin, 83.8 percent in RelMin and as little as 65.0 percent in ProgMin. Pairwise treatment comparisons, based on U tests, show that average group contributions in ProgMin are significantly higher than those in NoMin ($p = .0343$) and FixMin ($p = .0963$); no other pairwise comparison shows a statistically significant difference.

It is important to mention that group contributions in ProgMin do not start from the beginning on a higher level than in the other two MCS treatments. They rather rise during the first rounds of the game and then remain nearly constant until the end-game. In the first round, we find that average group contributions do not differ between the MCS treatments, with respective figures of 39.0, 36.5, and 38.5 in FixMin, RelMin, and ProgMin. The average first-round contribution in NoMin is 30.8; it is significantly lower than in FixMin ($p = .0884$) and in ProgMin ($p = .0487$), when compared by U tests.[8]

Result 1: *Group contribution levels are significantly higher in ProgMin than in NoMin and FixMin. For ProgMin, this confirms Hypothesis 1 that crowding-out is incomplete.*

[6] Over rounds 1-25, the mean group contributions are 43.5 in ProgMin compared to 33.1 in NoMin, 37.7 in FixMin, and 39.8 in RelMin. The respective average standard deviations are 7.5, 12.4, 5.9, and 6.1.

[7] Average standard deviations of total group contributions for rounds 1-20 are 9.9, 5.3, 5.4, and 6.8 for NoMin, FixMin, RelMin, and ProgMin respectively.

[8] Average standard deviations of total group contributions for round 1 are 9.0, 7.4, 6.9, and 7.9 for NoMin, FixMin, RelMin, and ProgMin respectively.

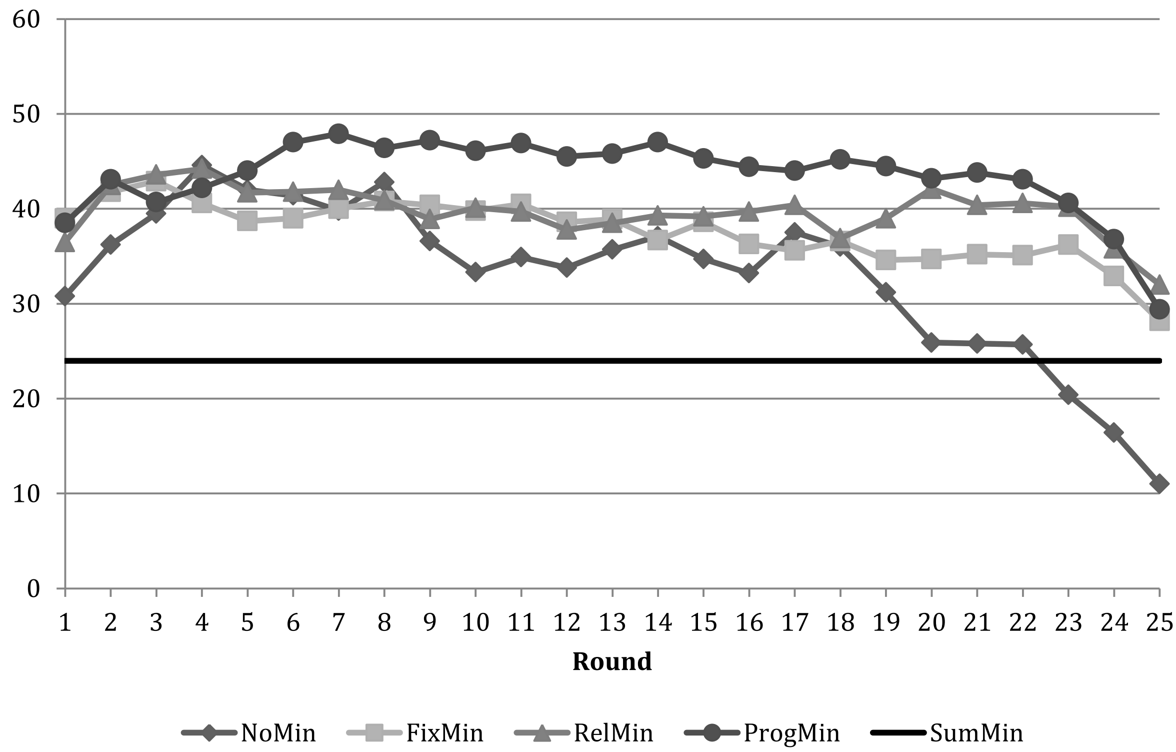

Figure 1: Average Group Contributions per Round (by Treatment)

Net relative group contributions and motivational crowding-out: To compare voluntary contributions in the NoMin treatment to the contributions in the MCS treatments, while taking into account the different sizes of strategy sets in these two kinds of treatments, we calculate for each round t the *net relative group contribution*:

$$Y_t^{Net} = \frac{\sum_{i=1}^{4} y_{it} - \sum_{i=1}^{4} c_i}{\sum_{i=1}^{4} e_{it} - \sum_{i=1}^{4} c_i} = \begin{cases} \frac{Y_t}{60} & \text{for NoMin} \\ \frac{Y_t - 24}{36} & \text{otherwise} \end{cases} \tag{2}$$

Y_t^{Net} captures, for round t, the group contribution above the sum of mandatory contributions (group contribution minus sum of mandatory contributions) relative to the net endowment of the group (group endowment minus sum of mandatory contributions). This measure ranges from zero to one. It is zero, when only the mandatory levies are contributed (which are zero in the case of NoMin) and one, when the entire net endowment is contributed.

This measure allows a more flawless comparison of the treatments in our study since it takes into account that players with different endowments and different minimum contribution requirements have different strategy sets. Based on this measure we define a "*motivational crowding-out* or *crowding-in*" of voluntary contributions, which is different from the classic definition of crowding-out by public policy (Andreoni, 1993). If we observe that in a MCS treatment groups contribute a lower (higher) percentage of their freely disposable endowments (net endowments) than the groups in the NoMin treatment, we interpret this observation as motivational crowding-out (crowding-in) of contributions by the minimum contribution requirements. Motivational crowding-out is, in contrast to the classic crowding-out, not measured token by token but in percent of the endowment that is at free disposal. While we define that net relative group contributions at the same level as in the NoMin treatment imply zero motivational crowding-out, full motivational crowding-out is defined by zero net relative group contributions. Both definitions are different from the classic definitions in Andreoni (1993).

Figure 2 shows the development of the average net relative group contributions in the four treatments. Visual inspection suggests two distinct contribution levels over rounds 1 to 20: NoMin and ProgMin show average contributions of 60.6 percent and 57.6 percent, respectively, while FixMin and RelMin show average contributions of 40.8 percent and 45.1 percent, respectively.[9, 10] Pairwise comparisons, based on U tests, indicate significant differences between NoMin and FixMin as well as ProgMin and FixMin ($p = .0963$, for both comparisons). Thus, we find on average small and statistically insignificant motivational crowding-out of 4.9 percent in ProgMin and higher but still statistically insignificant motivational crowding-out of 25.5 percent in RelMin. Only the motivational crowding-out of 32.6 percent in FixMin is statistically significant.

Result 2: *Motivational crowding-out of group contribution is statistically significant in FixMin. There is no significant motivational crowding-out in ProgMin and RelMin.*

[9] The corresponding average standard deviations of Y_t^{Net} for rounds 1-20 are .1645, .1478, .1503, and .1885, for NoMin, FixMin, RelMin, and ProgMin respectively.

[10] The overall negative time trend is moderate and seems to be, except for the first periods, not different between the treatments.

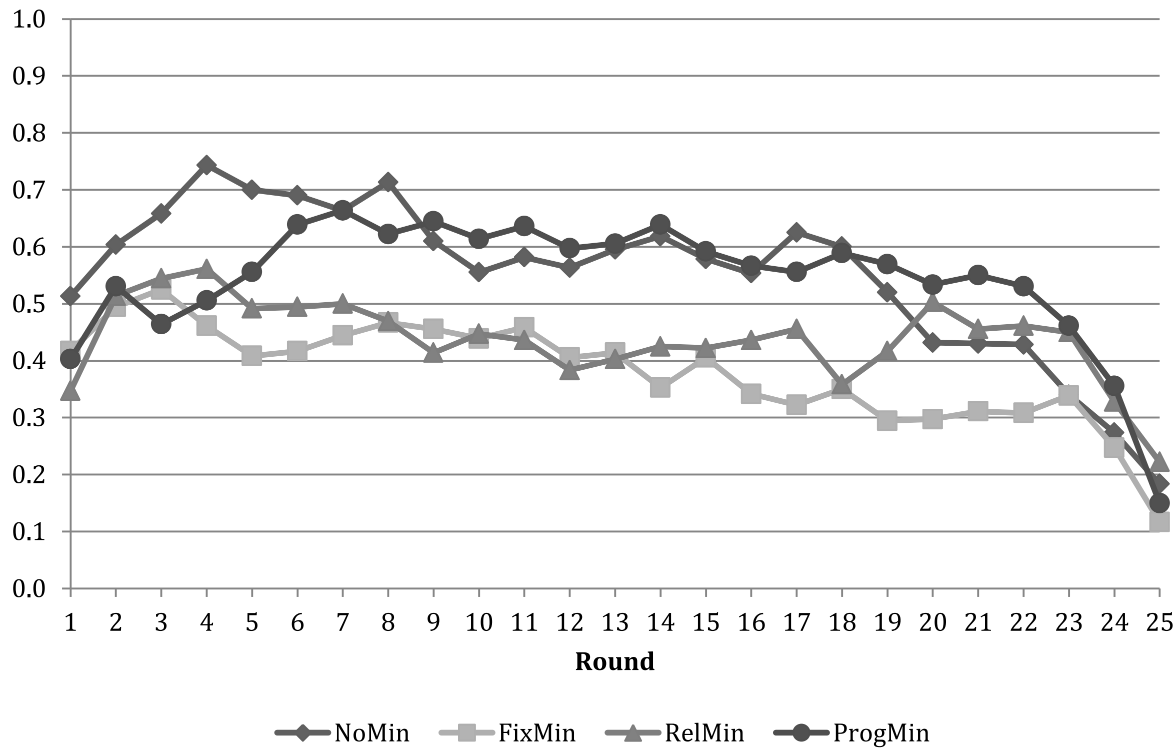

Figure 2: Average Net Group Contributions (by Treatment)

4.2 Contributions by Player Types

4.2.1 Comparison within Treatments

To compare the contributions of the different player types within each treatment, differences in the end-game effects for the player types play a minor role. We thus consider averages over rounds 1 to 25 in this analysis.

Figure A.1 in Appendix A presents the development of average contributions of the three player types (Type 10, Type 15, and Type 20) in the four treatments over the 25 rounds.[11] We find the non-surprising tendency for more abundantly endowed players to contribute more in absolute terms. Table A. 1 in Appendix A shows that, with the exception of two comparisons, all pairwise comparisons, based on signed-rank tests, show significant differences with $p \leq .0593$.

Given the asymmetry in endowments, we consider two "relative contribution measures" to compare the contributions of the poor (Type 10), wealthy (Type15), and rich (Type 20) players. The first measure goes back to the fair-share rule in Hofmeyr et al. (2007) and Keser et al. (2014); it measures the absolute contributions of the player types relative to their individual endowment (relative contribution). Figure A. 2 in Appendix A presents the development of average relative contributions for the three player types in

[11] For Type 10 (player 1) and Type 20 (player 4) the averages are based on ten players for each average, each. For Type 15 (players 2 and 3), the averages are based on twenty players.

the four treatments. As can be seen, there are no significant differences in the average relative contributions between the player types both in NoMin (AsymWeak treatment of Keser et al. (2014)) and RelMin. For RelMin, where the mandatory contributions push contributions toward the "fair-share" rule with equal relative contributions, this result is highly plausible. In FixMin average relative contributions significantly differ between the player types such that relative contributions to the public good decrease with the endowment level. For ProgMin, on the other hand, the contribution hierarchy is reversed such that the wealthier players contribute relatively more. Table A. 2 in Appendix A provides the p-values of the pairwise comparisons of contributions by player type in the four treatments (signed-rank tests). These widely confirm the previous statement: all differences in NoMin and RelMin are insignificant, and (almost) all differences in FixMin and ProgMin are significant ($p \leq .0745$, the unique exception is the difference between Types 15 and 20 in ProgMin that is not statistically significant). We may conclude that the proportional mandatory contributions in RelMin, the regressive mandatory contributions in FixMin, and the progressive mandatory contributions in ProgMin, respectively, exert their "intended" influence. RelMin leads to equal relative contributions, FixMin to higher relative contributions by the less wealthy players, and ProgMin to higher relative contributions by the more wealthy players.

Result 3: *In RelMin players follow the simple "fair-share" rule of equal relative contributions of the endowment. However, this rule does not apply in FixMin and ProgMin: average relative contributions are higher for the less wealthy players in the regressive FixMin treatment and higher for the more wealthy players in the progressive ProgMin treatment. These results confirm Hypothesis 2.*

The second relative-contribution measure, y_{it}^{Net}, essentially calculates Y_t^{Net} on an "individual" basis for each player type $i \in \{Type\ 10, Type\ 15, Type\ 20\}$:

$$y_{it}^{Net} = \frac{y_i - c_i}{e_i - c_i}, \tag{3}$$

where c_i is treatment dependent. It captures for each player type i the average individual contribution net of the mandatory contribution (absolute contribution minus mandatory contribution) relative to the net endowment (individual endowment minus mandatory contribution).

Figure A. 3 in Appendix A presents the development of average y_{it}^{Net} for the three player types in the four treatments. Table A. 3 in Appendix A shows the p-values of the pairwise comparisons based on signed-rank tests. As can be seen, there is only one difference that is statistically significant ($p = .0745$, Type 10 players contribute significantly more than Type 20 players in FixMin). None of the remaining comparisons yields statistical significance. We conclude that players tend to follow a modified "net fair-share" rule of equal relative contributions of the disposable endowment in FixMin and ProgMin. The "net fair-share" rule also applies in NoMin and RelMin, since it coincides with the original "fair-share" rule.

Result 4: *Players follow in all treatments a "net fair-share" rule of equal contributions relative to the decision space.*

4.2.2 Comparison between Treatments

So far, we have focused our analysis on the differences between the player types within each of the four treatments. For a deeper understanding of the mechanics that might be at work in the various treatments, i.e., how the norms might be set by the different MCS regimes, we compare the behavior of each player type across the four treatments. If we observe differences in behavior, these differences could ultimately lead to differences in group contributions between the treatments. Due to the strong end-game effect in NoMin, which is impeded by the minimum contribution requirements in the MCS treatments, we again report only averages over rounds 1 to 20 in this analysis.

Figure 3 depicts that, on average, relative contributions (and thus also absolute contributions) of Type 10 are highest in FixMin, where also the mandatory minimum contribution relative to the endowment is highest for this player type. The trajectories in the other treatments are not clearly distinguishable. Contributions of Type 15 are clearly highest in ProgMin and lowest in NoMin; the trajectories in FixMin and RelMin lie in between. Contributions of Type 20 are highest in ProgMin and lowest in FixMin. NoMin shows a clear decline that, toward the end of the game, even undercuts the level of FixMin. Contributions in RelMin lie between those in FixMin and ProgMin.

Considering contributions in the first round, we find that, on average, Type 10 players contribute 6.3, 7.2, 6.4, and 5.7; Type 15 players 6.9, 9.4, 9.3, and 9.7; and Type 20 players 10.7, 13, 11.6, and 13.5 in NoMin, FixMin, RelMin, and ProgMin, respectively. For Types 10 and 20, the differences between the treatments are never statistically significant. For Type 15, differences are significant between NoMin and all three MCS treatments ($p \leq .0698$, U tests); comparisons between the MCS treatments yield no significant differences.

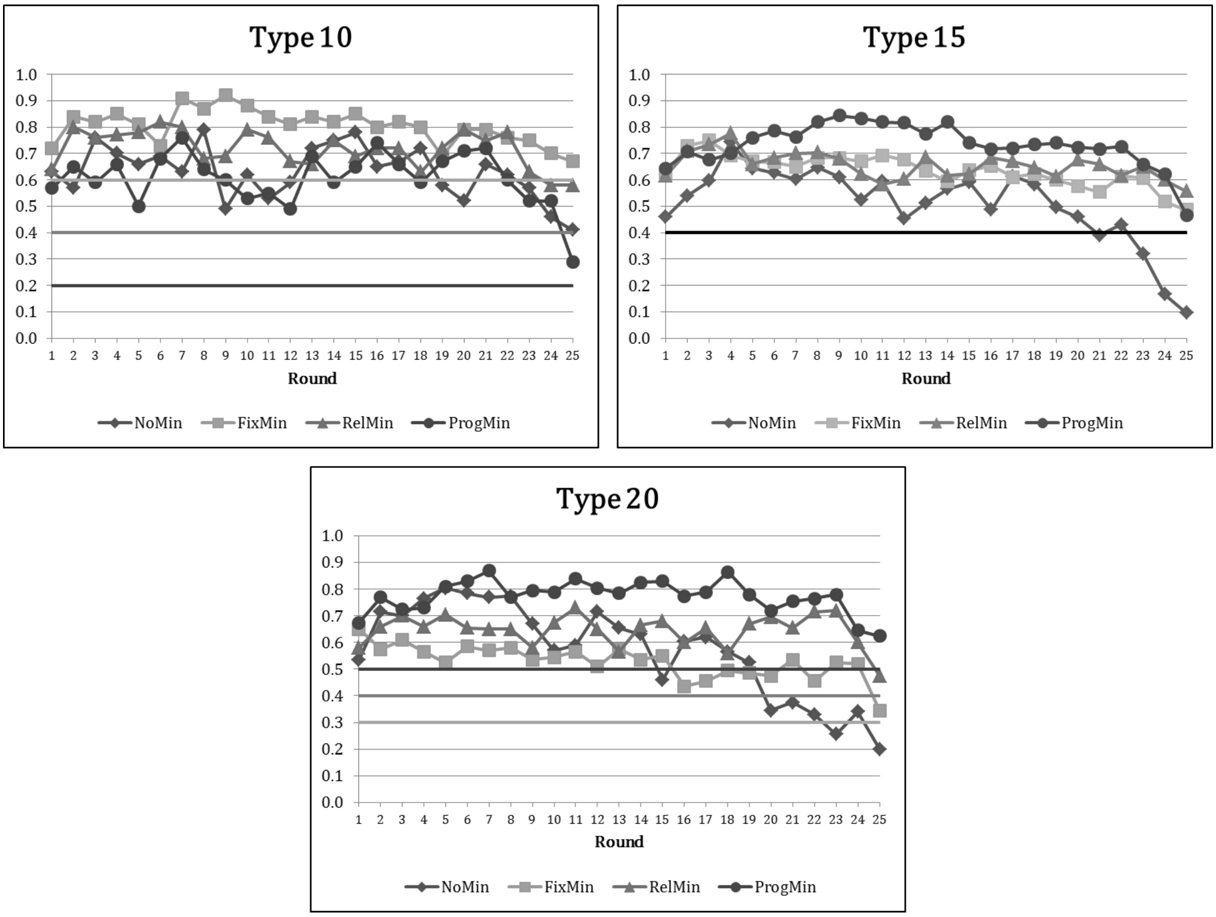

Figure 3: Average Relative Contributions (by Treatment)

For contributions in rounds 1 to 20, Table A. 4 in Appendix A shows the p-values of the pairwise comparisons of average absolute [and net] contributions for the three player types (U tests). As can be seen, Type 10 players contribute on average most in FixMin and least in ProgMin and NoMin; contributions in RelMin lie in between. However, only the difference between ProgMin and FixMin is statistically significant (p = .0257). Type 15 players contribute in all MCS treatments on average more than in NoMin but only the difference between ProgMin and NoMin is significant (p = .0232). Although differences between the MCS treatments are not significant, the average figures indicate that contributions are highest in ProgMin, followed by RelMin, and then FixMin. Type 20 players contribute on average least in FixMin and most in ProgMin; contributions in NoMin and RelMin lie in between. Contributions in ProgMin are thereby significantly higher than in all other treatments (p ≤ .0696), between which there is no statistically significant difference. For Type 20 we observe motivational crowding-out in FixMin and RelMin (p ≤ .0696, for both). For no other player type do we observe motivational crowding-out. To conclude, for player types 15 and 20 but not for player type 10, ProgMin leads to the highest contributions to the public good. Given that Type 10 players have a lower leverage on group contributions than Type 15 and Type 20 players, this explains why we observe the highest group contribution level in ProgMin, which is significantly higher than in NoMin.

Result 5: *Type 10 and Type 20 players contribute most, when they are facing relatively high mandatory contributions (FixMin and ProgMin, respectively) and contribute least, when they are facing relatively low mandatory contributions (ProgMin and FixMin, respectively). Type 15 players contribute most in ProgMin and least in NoMin.*

One might argue that contributions in the MCS treatments increase merely due to the enforced increase in the contributions of uncooperative subjects, while the cooperative subjects' contributions might have remained the same. To test for this eventuality, we use a simple approach. For each player type and treatment, we order average contributions from the lowest to the highest, and divide this ordering by half. We can thus distinguish between more and less cooperative subjects and compare the behavior of the more cooperative subjects' in the various treatments. The average contributions are presented in Table A. 5 in Appendix A. Tests for differences across the treatments, based on U tests, confirm for both Type 15 and 20 players that the increase in contributions in ProgMin is not solely driven by the higher contributions of uncooperative subjects.[12]

Additionally, we find that in ProgMin lower-bound contributions of Type 15 players ($y_i = c_i = 6$), for which mandatory contributions are equal in all MCS treatments, exhibit with 19.8 percent the lowest proportion of all MCS treatments ($p \leq .0030$, U tests). In NoMin, we observe 38.3 percent of contributions of six or below. Furthermore, we also find that in ProgMin Type 15 and 20 players display the highest proportion of full contributions ($y_i = e_i = 15$ and $y_i = e_i = 20$, respectively) compared to all other treatments ($p \leq .0225$, U tests); for Type 10 players differences in the proportions of full contributions between the treatments are insignificant. The respective figures for lower-bound and full contributions are presented in Table A. 6 in Appendix A.

The results concerning contributions by cooperative players and concerning lower bound and full contributions indicate that the ProgMin treatment leads to a norm shift, not just to higher group contributions due to a higher constraint for the wealthier players.

[12] Cooperative Type 15 players significantly contribute more in ProgMin than in RelMin and FixMin ($p \leq .0413$); all other differences are not significant. Cooperative Type 20 players contribute significantly more in ProgMin than in NoMin and FixMin ($p = .0413$, for both comparisons); all other differences are not significant. For Type 10 players, contributions of cooperative players are not significantly different between all treatments.

4.3 Reciprocity

As known from the literature (e.g., Keser and van Winden, 2000; Fischbacher et al., 2001), subjects behave reciprocally and make contributions that depend on the actions of others. Keser and van Winden (2000) argue that players, if they change their contribution from one round to the next, tend to increase (decrease) their contribution, if in the previous round their contribution was below (above) the average of the group. Given the different endowments of player types in our experiment, we examine reciprocity in terms of changes in relative contributions. In other words, we examine how players react if their own relative contribution has been lower (higher) than the average of the relative contributions of the other group members in the previous round.

Table 2 presents the results of a regression on the reaction of the individual relative contribution to the average relative contribution of the other group members in the previous round. The dependent variable is the individual change of the relative contribution to the public investment from the previous to the current round (Δy_{it}^{Rel}). The major explanatory variable is the lagged difference between the relative contribution of the player and the average relative contribution of the other group members ($L.Diff2MeanOthers$). Additionally, we control for player-type and treatment effects by using dummy variables (and interactions), considering Type 10 and NoMin as the respective reference group.

Table 2 indicates that $L.Diff2MeanOthers$ is significantly negative and thus provides clear evidence for reciprocity. Another important finding concerns the ProgMin treatment and potentially explains why it shows the highest group contribution level. On the one hand, we observe that Type 10 players behave most reciprocally (the interaction term *ProgMin × L.Diff2MeanOthers* is significantly negative) and, on the other hand, that Type 15 and Type 20 players behave least reciprocally (the interaction terms *Type 15 × ProgMin × L.Diff2MeanOthers* and *Type 20 × ProgMin × L.Diff2MeanOthers* are significantly positive). These findings are consistent with our previous results. As it seems, Type 15 and Type 20 players choose their contributions in this treatment "irrespective" of the contributions by Type 10 players. The two wealthier types seem to accept the low contributions by Type 10 players and "simply follow" the contribution norms set by the ProgMin schedule. This may, at least partially, explain why contributions of both player types in ProgMin are highest in this treatment, despite the fact that Type 10 players exhibit their lowest contributions of all treatments. Additionally, we find that the change in relative contributions is becoming more negative during the course of the game ($Round$ is significantly negative).

Result 6: *Players generally behave reciprocally. In ProgMin, Type 10 players behave more and Type 15 and 20 players less reciprocally.*

Table 2: Regression for Comparisons of Reciprocity

Dependent variable:	Δy_{it}^{Rel}	
Constant	.0378	(.0251)
L.Diff2MeanOthers	-.3268***	(.0552)
Round	-.0021***	(.0007)
Type 15	-.0390	(.0291)
Type 20	-.0043	(.0295)
FixMin	.0437	(.0288)
RelMin	.0201	(.0294)
ProgMin	-.0855**	(.0340)
Type 15 × FixMin	-.0267	(.0343)
Type 15 × RelMin	-.0001	(.0352)
Type 15 × ProgMin	.1312***	(.0389)
Type 20 × FixMin	-.1372***	(.0387)
Type 20 × RelMin	-.0417	(.0367)
Type 20 × ProgMin	.0981**	(.0398)
Type 15 × L.Diff2MeanOthers	-.1285*	(.0703)
Type 20 × L.Diff2MeanOthers	-.0313	(.0823)
FixMin × L.Diff2MeanOthers	.0601	(.0765)
RelMin × L.Diff2MeanOthers	-.0355	(.0800)
ProgMin × L.Diff2MeanOthers	-.2083**	(.0849)
Type 15 × FixMin × L.Diff2MeanOthers	.0072	(.0991)
Type 15 × RelMin × L.Diff2MeanOthers	-.0576	(.1030)
Type 15 × ProgMin × L.Diff2MeanOthers	.1995*	(.1078)
Type 20 × FixMin × L.Diff2MeanOthers	-.1446	(.1244)
Type 20 × RelMin × L.Diff2MeanOthers	-.0840	(.1183)
Type 20 × ProgMin × L.Diff2MeanOthers	.3226***	(.1151)
R^2	.2346	
N	3040	

Notes: OLS-regressions with robust variance estimates. Standard errors in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

4.4 Profits and Gini Indices

Table 3 illustrates the average profits per round over rounds 1 to 20 for the three player types and the resulting average group profits in the four treatments. Pairwise comparisons, using U tests, show that solely the differences in average group profits between ProgMin and NoMin (p = .0343), and ProgMin and FixMin (p = .0963) are significant.

Table 3: Average Profits per Round

	NoMin	FixMin	RelMin	ProgMin
Type 10	43.30	42.30	45.60	52.23
Type 15	49.33	49.03	50.31	52.04
Type 20	50.75	57.07	54.27	53.19
Group profit	192.70	197.41	200.48	209.49

Notes: Averages for rounds 1 to 20. Social optimum sum of profits per round = 240. Equilibrium sum of profits per round = 120, 168, 168, 168. Equilibrium profit per round for Type 1 = 20, 32, 36, 40; equilibrium profit per round for Type 2 = 30, 42, 42, 42; equilibrium profit per round for Type 3 = 40, 52, 48, 44 (NoMin, FixMin, RelMin, ProgMin). Social optimum profit per round = 60 (for all types).

Comparisons for the player types between treatments based on U tests show that Type 10 players earn on average significantly more in ProgMin than in all other treatments, between which there are no significant differences ($p \leq .0343$). For Type 15 players, profits in ProgMin are significantly higher than in NoMin ($p = .0989$) and FixMin ($p = .0498$); for the other differences, we cannot reject the null hypothesis of no significant difference. For Type 20 players, profits in FixMin are significantly higher than in NoMin and ProgMin ($p \leq .0172$); all other differences are statistically insignificant.

Given that players in all four treatments start with different endowments, and that contributions to the public investment tend to result in an equalization of total profits through a redistribution of wealth, we analyze, based on the Gini index, the differences in inequality between the initial distribution of endowments, the distribution of total profits in equilibrium, and the actual distribution of total profits over rounds 1 to 20 in the four treatments. Table 4 displays the respective figures.

Average total profit Gini indices are smaller than Nash-equilibrium Gini indices for NoMin ($p = .0051$) and FixMin ($p = .0284$), using MPSR tests; for RelMin the difference is almost significant ($p = .1141$). For ProgMin, on the other hand, total profit Gini indices are significantly higher than Gini indices in equilibrium ($p = .0218$).

Furthermore, the comparison of average total profit Gini indices discloses that ProgMin exhibits significantly smaller Gini indices than all other treatments. Based on U tests, we find significant differences between NoMin and ProgMin, and FixMin and RelMin ($p = .0284$, respectively), and also between FixMin and ProgMin, and RelMin and ProgMin ($p = .0065$, respectively).

Table 4: Gini indices

Treatment	Gini index for endowments [net of MCs] (1)	Gini index in Nash equillibrium (2)	Gini index for total profits (3)	Differences in percent (3)-(1)/ (2)-(1)/(3)-(2)
NoMin	.1250 [.1250]	.1250	.0561	-55.1/-0.0/-55.1
FixMin	.1250 [.2083]	.0893	.0674	-46.1/-28.6/-24.5
RelMin	.1250 [.1250]	.0536	.0471	-62.3/-57.1/-12.1
ProgMin	.1250 [.0417]	.0179	.0279	-77.7/-85.7/+55.9

Notes: Gini indices for total profits over rounds 1 to 20.

Result 7: *ProgMin leads to the lowest inequality in total profits of all treatments. Although, the inequality in total profits is larger than in equilibrium, the average group profit in ProgMin is the highest of all treatments.*

5. Conclusion

We investigate whether and how cooperation and the previously observed “fair-share” norm in public-good experiments with asymmetrically endowed players are influenced by enforced minimum-contribution schedules. We consider schedules, where all players face the same absolute minimum contribution irrespective of their endowment (FixMin), where all players face the same minimum contribution relative to the endowment (RelMin), and where a player with a higher endowment faces a higher minimum contribution relative to the endowment than a player with a lower endowment (ProgMin). Our mandatory minimum-contribution schedules relate to the literature on tax fairness or “vertical equity”. In taxpayer surveys, Gerbing (1988) and Roberts and Hite (1994) find evidence of a preference for progressive tax rates. For upper-income taxpayers, however, Gerbing finds that they perceive flat tax rates as more fair. In the context of a public-good game, where participants can vote for several minimum contribution schemes, which are intended to provide a jointly agreed minimum group provision level, Gallier et al. (2014) find that the scheme which equalizes payoffs (similar to ProgMin) is mostly chosen by less wealthy players, while rich players mostly chose the scheme which equalizes contributions (similar to FixMin). Given this evidence and the pervasive calls for fairer tax systems implying tax breaks for lower and middle income classes together with tax increases for upper income classes, it is possible that an as fairer perceived distribution of mandatory minimum contributions (as, for example, in ProgMin) exerts a positive effect on individual and consequently total group contributions.

The results of our experiment suggest the potential of mandatory minimum contributions to exert expressive power. We observe them to exert a norm-giving character. They seem to communicate relations of fair contributions by the different player types and thus might increase group contributions relative to the situation without minimum-contribution requirements. It turns out that this is particularly true for our ProgMin treatment, which is likely perceived as the most fair among all mandatory contribution systems considered. ProgMin is the only treatment, where the crowding-out of voluntary contributions to the public good by mandatory contributions is significantly incomplete, when we use the measure by Andreoni (1993). For RelMin and FixMin the crowding-out is close to complete. When we consider motivational crowding-out as defined in this paper, it is statistically significant only in FixMin. ProgMin exhibits hardly any motivational crowding-out.

On the individual level, we find support for the “fair-share” rule in RelMin. This rule cannot be detected in FixMin and ProgMin due to the norms set through the (inverted) progressivity in both treatments. In the regressive FixMin treatment average relative contributions are higher for less wealthy players and in ProgMin average relative contributions are higher for more wealthy players. As we see, the “fair-share” norm can be eroded through a deliberate intervention. In particular, in ProgMin, the norm of what is a player’s fair share is adapted in the “intended” direction. Players in FixMin and

ProgMin seem to coordinate on a modified fair-share rule of equal contributions relative to the decision space, which we call the "net fair-share" rule. Average relative contributions to the available decision space are equal for all player types in FixMin and ProgMin.

Type 15 players, for which mandatory contributions are the same in all three MCS treatments, contribute most in ProgMin and least in NoMin. The other two player types contribute more, when they are facing relatively high mandatory contributions (FixMin for Type 10 and ProgMin for Type 20) and contribute less, when they are facing relatively low mandatory contributions (ProgMin for Type 10 and FixMin for Type 20). We also find Type 10 players to behave most and Type 15 and Type 20 players to behave least reciprocally in ProgMin. As it seems, Type 15 and Type 20 players choose their contributions in this treatment "irrespective" of the lower contributions by Type 10 players. This may, at least partially, explain why contributions of both player types in ProgMin are the highest of all treatments, despite the fact that Type 10 players exhibit their lowest contributions of all treatments. Thus, the observation that group contributions are significantly higher in ProgMin than in the other three treatments can potentially be explained by the acceptance of the norm of progressive contributions among the Type 15 and Type 20 players in this treatment, rendering their contributions unconditional on the contributions by Type 10 players. Furthermore, we find that ProgMin exhibits the lowest inequality in total profits of all our treatments in terms of the Gini index.

In spite of these strong results, we advise caution generalizing our findings, in particular with respect to public policy. The response of contributions in a public-good game with heterogeneous endowments to mandatory minimum contributions may not be the same as the response of real economic factors as, for example, labor supply on an intervention in this sphere (Lindsey, 1987). In our experiment, heterogeneous endowments were randomly allocated to all participants in a group. Thus, participants neither had to supply their endowments by themselves nor to work for them. Even though neither Clark (2002) nor Cherry et al. (2005) find that these origins of the endowments, compared to cases where participants are provided with windfall endowments, have an effect in their public-good experiments, we believe that at least some caution is advised concerning possible effects of the endowment origin. This might be particularly true, when the asymmetry in the endowment distribution becomes more important. For example, Cherry et al. (2002) find an effect of endowment origin on behavior in a dictator-game setting. If endowments had to be earned, our mandatory contributions could likely exert similar effects as taxes and lead to a decline in the work effort, which would be in keeping with the Laffer curve hypothesis. Note, however, that for almost all types (with the exception of Type 10 in FixMin and Type 20 in ProgMin) our tax rates are well below the empirically observed tax-revenue-maximizing rates of 50 to 60 percent (e.g., Sutter and Weck-Hannemann, 2003). Although our study is able to show that the progressive minimum-contribution schedule performed best in our public-good setting in terms of overall contribution rates, we are not able to predict, which degree of progression would work best in a public-good environment, where endowments must be earned.

With respect to our initial example of public institutions, which rely on two-tier financing models based on mandatory admission charges plus voluntarily charitable donations and/or employ third degree price discrimination by setting admission fees that vary by status (e.g., regular tickets and reduced tickets for children, students, retirees, unemployed etc.), the increase in average group contributions in ProgMin compared to NoMin and FixMin suggests that progressive tariff structures can indeed be used to improve the financing of such institutions.

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References

Abrams, B.A., Schmitz, M.D., 1978. The 'Crowding-out' Effect of Governmental Transfers on Private Charitable Contributions. Public Choice 33 (1), 29-39.

Abrams, B.A., Schmitz, M.D., 1984. The Crowding-out Effect of Governmental Transfers on Private Charitable Contributions: Cross-Section Evidence. National Tax Journal 37 (4), 563–568.

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 (2), 297–323.

Andreoni, J., 1993. An Experimental Test of the Public-Goods Crowding-Out Hypothesis. The American Economic Review 83 (5), 1317–1327.

Andreoni, J., Payne, A.A., 2011. Is Crowding Out Due Entirely to Fundraising? Evidence from a Panel of Charities. Journal of Public Economics (Charitable Giving and Fundraising Special Issue) 95 (5–6), 334–343.

Bergstrom, T., Blume, L., Varian, H.R., 1986. On the private provision of public goods. Journal of Public Economics 29 (1), 25–49.

Bernheim, B.D., 1986. On the Voluntary and Involuntary Provision of Public Goods. The American Economic Review 76 (4), 789–793.

Brekke, K.A., Kverndokk, S., Nyborg, K., 2003. An Economic Model of Moral Motivation. Journal of Public Economics 87 (9–10), 1967–1983.

Chan, K.S., Godby, R., Mestelman, S., Muller, R.A., 2002. Crowding-out Voluntary Contributions to Public Goods. Journal of Economic Behavior & Organization 48 (3), 305–317.

Cherry, T.L., Frykblom, P., Jason F. Shogren, 2002. Hardnose the Dictator. The American Economic Review 92 (4), 1218–1221.

Cherry, T.L., Kroll, S., Shogren, J.F., 2005. The Impact of Endowment Heterogeneity and Origin on Public Good Contributions: Evidence from the Lab. Journal of Economic Behavior & Organization 57 (3), 357–365.

Clark, J., 2002. House Money Effects in Public Good Experiments. Experimental Economics 5 (3), 223-231.

Condry, J., Chambers, J., 1978. Intrinsic Motivation and the Process of Learning, in: Lepper, M.R., Greene, D.((Eds.), The Hidden Costs of Reward: New Perspectives on the Psychology of Human Motivation. John Wiley, New York, pp. 61–84.

Cooter, R., 1998. Expressive Law And Economics. The Journal of Legal Studies 27 (S2), 585–607.

Davis, D.D., Holt, C.A., 1993. Experimental Economics. Princeton University Press, Princeton, New Jersey.

Dawes, R.M., Thaler, R.H., 1988. Anomalies: Cooperation. The Journal of Economic Perspectives 2 (3), 187–197.

Deci, E.L., 1971. Effects of Externally Mediated Rewards on Intrinsic Motivation. Journal of Personality and Social Psychology 18 (1), 105–115.

Deci, E.L., 1972. Intrinsic Motivation, Extrinsic Reinforcement, and Inequity. Journal of Personality and Social Psychology 22 (1), 113–120. 10.1037/h0032355.

Deci, E.L., Koestner, R., Ryan, R.M., 1999. A Meta-Analytic Review of Experiments Examining the Effects of Extrinsic Rewards on Intrinsic Motivation. Psychological Bulletin 125 (6), 627–668.

Falk, A., Kosfeld, M., 2006. The Hidden Costs of Control. The American Economic Review 96 (5), 1611–1630.

Fischbacher, U., Gächter, S., Fehr, E., 2001. Are People Conditionally Cooperative? Evidence from a Public Goods Experiment. Economics Letters 71 (3), 397–404.

Fischbacher, U., 2007. z-Tree: Zurich Toolbox for Ready-made Economic Experiments. Experimental Economics 10 (2), 171–178.

Frey, B.S., 1993. Does Monitoring Increase Work Effort? The Rivalry with Trust and Loyalty. Economic Inquiry 31 (4), 663–670.

Frey, B.S., 1994. How Intrinsic Motivation is Crowded Out and In. Rationality and Society 6 (3), 334–352.

Frey, B.S., Oberholzer-Gee, F., Eichenberger, R., 1996. The Old Lady Visits Your Backyard: A Tale of Morals and Markets. Journal of Political Economy 104 (6), 1297–1313.

Frey, B.S., 1997a. A Constitution for Knaves Crowds out Civic Virtues. The Economic Journal 107 (443), 1043–1053.

Frey, B.S., 1997b. Not Just for the Money: An Economic Theory of Personal Motivation. Edward Elgar Publishing, Cheltenham, UK and Brookfield, USA.

Frey, B.S., Goette, L., 1999. Does Pay Motivate Volunteers? Working Paper Series No. 7. Institute for Empirical Research in Economics, University of Zurich.

Frey, B.S., Jegen, R., 2001. Motivation Crowding Theory. Journal of Economic Surveys 15 (5), 589–611.

Frey, B.S., Oberholzer-Gee, F., 1997. The Cost of Price Incentives: An Empirical Analysis of Motivation Crowding- Out. The American Economic Review 87 (4), 746–755.

Galbiati, R., Vertova, P., 2008. Obligations and Cooperative Behaviour in Public Good Games. Games and Economic Behavior 64 (1), 146–170.

Galbiati, R., Vertova, P., 2014. How Laws Affect Behavior: Obligations, Incentives and Cooperative Behavior. International Review of Law and Economics 38, 48–57.

Gallier, C., Kesternich, M., Sturm, B., 2014. Voting for Burden Sharing Rules in Public Goods Games. ZEW Discussion Paper No. 14-056.

Gerbing, M.D., 1988. An Empirical Study of Taxpayer Perceptions of Fairness. Unpublished PhD Thesis, University of Texas, Austin, USA.

Gneezy, U., Rustichini, A., 2000a. A Fine Is a Price. The Journal of Legal Studies 29, 1–17.

Gneezy, U., Rustichini, A., 2000b. Pay Enough or Don't Pay at All. Quarterly Journal of Economics 115 (3), 791–810.

Greiner, B., 2004. The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics. University of Cologne, Working Paper Series in Economics 10 (23), 63–104.

Hofmeyr, A., Burns, J., Visser, M., 2007. Income Inequality, Reciprocity and Public Good Provision: An Experimental Analysis. South African Journal of Economics 75 (3), 508–520.

Keser, C., 1996. Voluntary Contributions to a Public Good when Partial Contribution is a Dominant Strategy. Economics Letters 50 (3), 359–366.

Keser, C., Markstädter, A., Schmidt, M., Schnitzler, C., 2014. Social Costs of Inequality - Heterogeneous Endowments in Public-Good Experiments. cege Discussion Paper 217, University of Göttingen.

Keser, C., Schmidt, M., 2014. Cooperation and Punishment among Heterogeneous Agents. Working Paper, University of Göttingen.

Keser, C., van Winden, F., 2000. Conditional Cooperation and Voluntary Contributions to Public Goods. The Scandinavian Journal of Economics 102 (1), 23–39.

Ledyard, J.O., 1995. Public Goods: A Survey of Experimental Research, in: Kagel, J.H., Roth, A.E. (Eds.), The Handbook of Experimental Economics. Princeton University Press, New Jersey.

Lepper, M.R., Greene, D., Nisbett, R.E., 1973. Undermining Children's Intrinsic Interest with Extrinsic Reward: A Test of the "Overjustification" Hypothesis. Journal of Personality and Social Psychology 28 (1), 129–137.

Lindsey, L.B., 1987. Individual Taxpayer Response to Tax Cuts: 1982–1984: With Implications for the Revenue Maximizing Tax Rate. Journal of Public Economics 33 (2), 173–206.

Marwell, G., Ames, R.E., 1979. Experiments on the Provision of Public Goods. I. Resources, Interest, Group Size, and the Free-rider Problem. American Journal of Sociology, 1335–1360.

Marwell, G., Ames, R.E., 1980. Experiments on the Provision of Public Goods. II. Provision Points, Stakes, Experience, and the Free-rider Problem. American Journal of Sociology, 926–937.

McAdams, R.H., Nadler, J., 2005. Testing the Focal Point Theory of Legal Compliance: The Effect of Third-Party Expression in an Experimental Hawk/Dove Game. Journal of Empirical Legal Studies 2 (1), 87–123.

Nyborg, K., Rege, M., 2003. Does Public Policy Crowd Out Private Contributions to Public Goods. Public Choice 115 (3-4), 397-418.

Ostrom, E., 2000. Collective Action and the Evolution of Social Norms. The Journal of Economic Perspectives 14 (3), 137–158.

Payne, A.A., 1998. Does the Government Crowd-out Private Donations? New Evidence from a Sample of Non-Profit Firms. Journal of Public Economics 69 (3), 323–345.

Riedel, N., Schildberg-Hörisch, H., 2013. Asymmetric Obligations. Journal of Economic Psychology 35, 67–80.

Roberts, M.L., Hite, P.A., 1994. Progressive Taxation, Fairness, and Compliance. Law & Policy 16 (1), 27–48.

Roberts, R.D., 1984. A Positive Model of Private Charity and Public Transfers. The Journal of Political Economy, 136–148.

Roberts, R.D., 1987. Financing Public Goods. Journal of Political Economy 95 (2), 420–437.

Rotter, J.B., 1966. Generalized Expectancies for Internal versus External Control of Reinforcement. Psychological Monographs: General and Applied 80 (1), 1–28 (whole No. 609).

Ryan, R.M., Deci, E.L., 2000. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. Contemporary Educational Psychology 25 (1), 54–67.

Sutter, M., Weck-Hannemann, H., 2003. Taxation and the Veil of Ignorance - A Real Effort Experiment on the Laffer Curve. Public Choice 115 (1-2), 217-240.

Titmuss, R.M., 1970. The Gift Relationship: From Human Blood to Social Policy. Allen & Unwin (London), London.

Uptom, W.E., 1973. Altruism, Attribution, and Intrinsic Motivation in the Recruitment of Blood Donors, Cornell University.

Warr, P.G., 1982. Pareto Optimal Redistribution and Private Charity. Journal of Public Economics 19 (1), 131–138.

Warr, P.G., 1983. The Private Provision of a Public Good is Independent of the Distribution of Income. Economics Letters 13 (2–3), 207–211.

Appendix A

Additional Tables and Figures

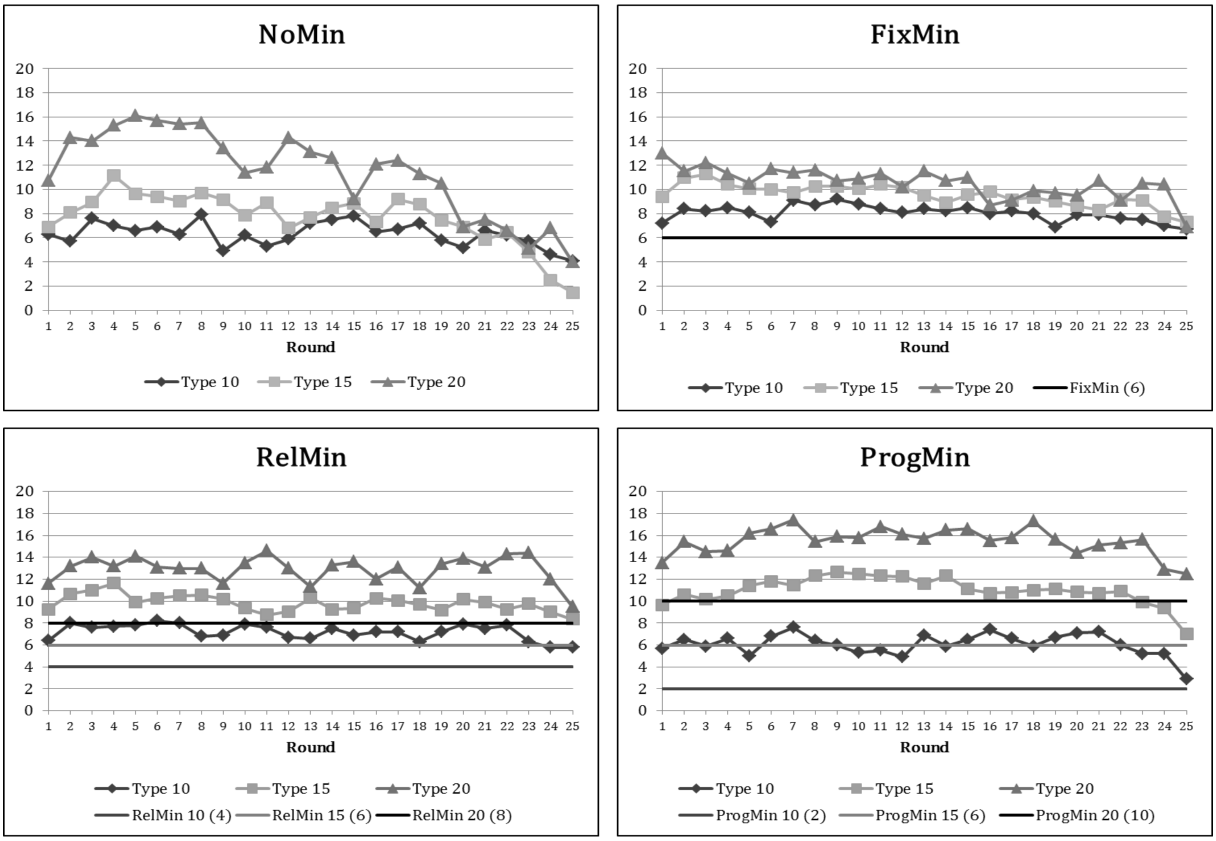

Figure A. 1: Average Absolute Contributions by Player Type

Table A. 1: Comparisons of Average Absolute Contributions between Player Types (p-values of two-sided signed-rank tests)

	NoMin				**FixMin**		
	Type 10 (6.31)	Type 15 (7.65)	Type 20 (11.44)		Type 10 (8.03)	Type 15 (9.54)	Type 20 (10.56)
Type 10 (6.31)	-	.2845	**.0218**	Type 10 (8.03)	-	**.0593**	**.0284**
Type 15 (7.65)	-	-	**.0051**	Type 15 (9.54)	-	-	.2411
Type 20 (11.44)	-	-	-	Type 20 (10.56)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (7.18)	Type 15 (9.82)	Type 20 (12.92)		Type 10 (6.07)	Type 15 (11.00)	Type 20 (15.48)
Type 10 (7.18)	-	**.0166**	**.0069**	Type 10 (6.07)	-	**.0051**	**.0051**
Type 15 (9.82)	-	-	**.0069**	Type 15 (11.00)	-	-	**.0051**
Type 20 (12.92)	-	-	-	Type 20 (15.48)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player types are given in parentheses.

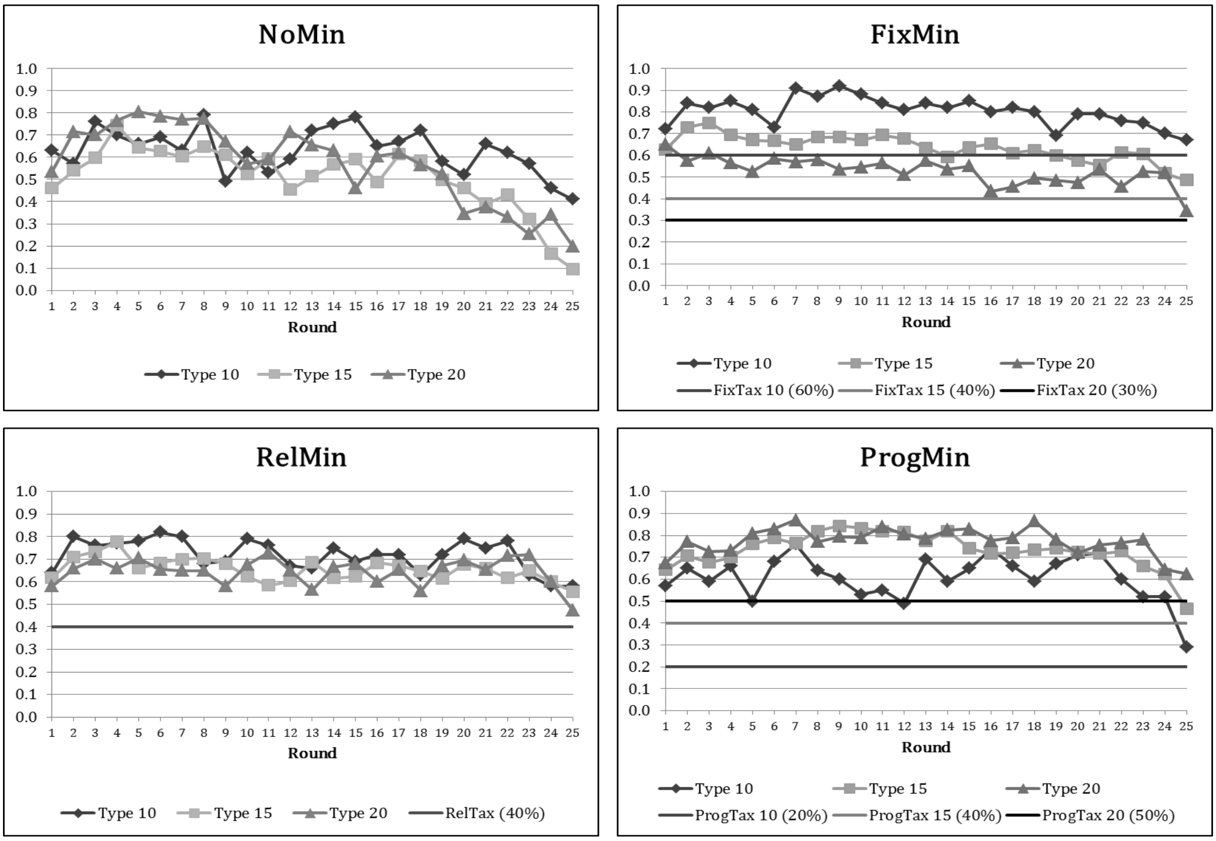

Figure A. 2: Average Relative Contributions by Player Type

Table A. 2: Comparisons of Average Relative Contributions between Player Types (p-values of two-sided signed-rank tests)

	NoMin				FixMin		
	Type 10 (.6308)	Type 15 (.5101)	Type 20 (.5720)		Type 10 (.8032)	Type 15 (.6359)	Type 20 (.5280)
Type 10 (.6308)	-	.2411	.6465	Type 10 (.8032)	-	**.0166**	**.0093**
Type 15 (.5101)	-	-	.1394	Type 15 (.6359)	-	-	**.0593**
Type 20 (.5720)	-	-	-	Type 20 (.5280)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (.7184)	Type 15 (.6549)	Type 20 (.6460)		Type 10 (.6068)	Type 15 (.7332)	Type 20 (.7740)
Type 10 (.7184)	-	.1394	.2845	Type 10 (.6068)	-	**.0593**	**.0745**
Type 15 (.6549)	-	-	.2411	Type 15 (.7332)	-	-	.3329
Type 20 (.6460)	-	-	-	Type 20 (.7740)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player types are given in parentheses.

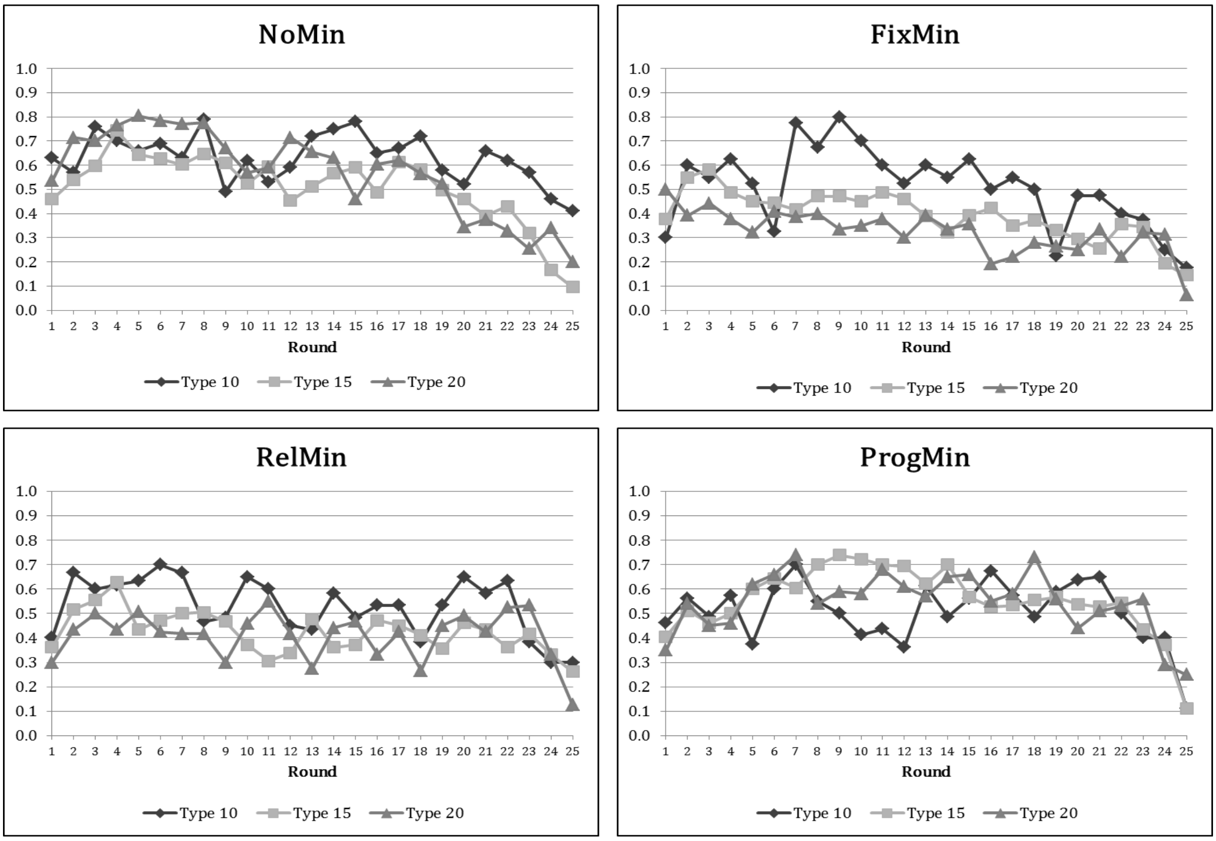

Figure A. 3: Average Net Contributions by Player Type

Table A. 3: Comparisons of Average Net Contributions between Player Types (p-values of two-sided signed-rank tests)

	NoMin				FixMin		
	Type 10 (.6308)	Type 15 (.5101)	Type 20 (.5720)		Type 10 (.5080)	Type 15 (.3931)	Type 20 (.3257)
Type 10 (.6308)	-	.2411	.6465	Type 10 (.5080)	-	.1394	**.0745**
Type 15 (.5101)	-	-	.1394	Type 15 (.3931)	-	-	.5076
Type 20 (.5720)	-	-	-	Type 20 (.3257)	-	-	-
	RelMin				**ProgMin**		
	Type 10 (.5307)	Type 15 (.4249)	Type 20 (.4100)		Type 10 (.5085)	Type 15 (.5553)	Type 20 (.5480)
Type 10 (.5307)	-	.1394	.2845	Type 10 (.5085)	-	.5076	.7213
Type 15 (.4249)	-	-	.2411	Type 15 (.5553)	-	-	.9594
Type 20 (.4100)	-	-	-	Type 20 (.5480)	-	-	-

Notes: Comparisons and average contributions involve rounds 1 to 25. Averages for the player types are given in parentheses.

Table A. 4: By Type: Comparisons of Average Absolute [and Average Net] Contributions between Treatments (p-values of two-sided U tests)

Type 10				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.1211 [.5453]	.5453 [.4963]	.7624 [.4057]
FixMin	-	-	.3445 [1.000]	**.0257** [.8205]
RelMin	-	-	-	.2725 [.9097]
ProgMin	-	-	-	-
Type 15				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.1617 [.1988	.1508 [.2265]	**.0232** [.8798]
FixMin	-	-	.8798 [.8798]	.1304 [.1306]
RelMin	-	-	-	.1123 [.1124]
ProgMin	-	-	-	-
Type 20				
	NoMin	FixMin	RelMin	ProgMin
NoMin	-	.2265 [**.0191**]	.9698 [**.0696**]	**.0639** [.5706]
FixMin	-	-	.1509 [.4057]	**.0082** [**.0963**]
RelMin	-	-	-	**.0696** [.1988]
ProgMin	-	-	-	-

Note: Average contributions over rounds 1 to 20 in NoMin, FixMin, RelMin, ProgMin: Type10: $\bar{y}_i$: 6.53, 8.21, 7.32, 6.26; $\bar{y}_i^{Net}$: .6525, .5513, .5533, .5325. Type 15: $\bar{y}_i$: 8.51, 9.84, 9.97, 11.35; $\bar{y}_i^{Net}$: .5675, .4267, .4408, .5947. Type 20: $\bar{y}_i$: 12.80, 10.82, 12.99, 15.78; $\bar{y}_i^{Net}$: .6400, .3443, .4154, .5780.

Table A. 5: Comparisons of Contributions by Cooperative and Uncooperative Players within Treatments

		NoMin	FixMin	RelMin	ProgMin
Type 10	U	4.4	7.4	6.0	4.6
	C	8.6	9.0	8.7	7.9
Type 15	U	5.6	7.7	8.1	9.5
	C	11.4	12.0	11.8	13.2
Type 20	U	10.0	7.7	10.3	13.5
	C	15.6	13.9	15.6	18.1

Notes: Average contribution figures involve rounds 1 to 20. U = Uncooperative players, C = Cooperative players. For Type 10 and 20 there are per definition respectively 5 U and 5 C players per treatment and for Type 15 respectively 10 U and 10 C players per treatment.

Table A. 6: Relative Frequency of Individual Decisions at the Lower-Bound or Full Contribution to the Public Investment

	Lower-bound contributions (in percent)	Full contributions (in percent)
NoMin – Type 10	15.0 [39.5; 25.0; 17.5]	41.5
NoMin – Type 15	14.3 [38.3; 38.3; 38.3]	32.3
NoMin – Type 20	10.0 [19.0; 23.0; 27.0]	32.0
FixMin – Type 10	32.0	44.0
FixMin – Type 15	33.3	24.8
FixMin – Type 20	28.0	17.5
RelMin – Type 10	20.5	37.0
RelMin – Type 15	28.8	18.8
RelMin – Type 20	18.0	17.5
ProgMin – Type 10	25.5	36.5
ProgMin – Type 15	19.8	40.0
ProgMin – Type 20	25.0	43.5

Notes: All figures involve rounds 1 to 20. Lower bound contributions are 0 in NoMin for all player types; 6 in FixMin for all player types; 4, 6, and 8 in RelMin; and 2, 6, and 10 in ProgMin for Type 10, Type 15, and Type 20 players, respectively. Figures in [] respectively show the percentage of contributions that were below the minimum contributions in FixMin, RelMin, and ProgMin for the three player types.

Appendix B

Experimental Instructions (ProgMin)

You participate in an economic decision experiment, in which you can earn money. How much each of you will earn depends on your personal decisions and those of other participants in the experiment. Each participant makes his decisions at a computer, isolated from the others. We ask you not to talk to other participants.

The experiment consists of 25 rounds. In the beginning of the experiment you will be randomly matched with three other persons to build a group of four. You will remain in this group during the entire experiment. You will not know the identity of your group members at any time, though.

Each group member is endowed in each round with a certain amount of tokens. Player 1 is endowed with 10 tokens per round. Players 2 and 3 are endowed with an amount of 15 tokens each. Player 4 is endowed with 20 tokens per round. The individual player numbers (and thus the individual endowments) will be randomly assigned and announced at the beginning of the experiment.

DECISIONS

In each of the 25 rounds, each group member has to decide on how to allocate her/his tokens between two alternatives, called X and Y. The return of a token, in experimental currency units (ECU), is different for the two alternatives. The return of the allocation decision is determined as follows:

Each token that you contribute to X yields a return of 2 ECU. If you contribute nothing to X, your return from X is zero.

Each token that you contribute to Y, yields to you and to each of the other group members a return of 1 ECU. You may thus have a positive return from Y even if you don't contribute anything to Y.

During the allocation of your tokens, you must note that you are required to contribute a minimum contribution to Y. This minimum contribution is 2 tokens for Player 1, 6 tokens for Players 2 and 3 each, and 10 tokens for Player 4.

Group Member	Endowment (tokens)	Mandatory Contribution to Y
Player 1	10	2
Player 2	15	6
Player 3	15	6
Player 4	20	10

You may allocate your tokens, above the minimum contribution to Y, to X or to Y only, but you may also allocate them among both alternatives. However, only entire tokens may be contributed. In the decision box on your screen you need to enter, for each alternative, the number of tokens that you want to allocate. If you do not want to contribute anything to X, you need to type in a zero. The sum of the tokens contributed to X and Y must be always equal to your endowment. This means that the entire token endowment has to be allocated among X and Y. With the <Tab> key you can switch among the entry fields. The entries have to be confirmed by clicking on <OK>.

Your individual return per round is the sum of your returns from X and Y and is calculated as follows:

Return = 2 × (your contribution to X) + (sum of tokens contributed to Y in your group).

PAYMENT

At the end of the experiment, you will be paid based on your individual total profit over all 25 rounds. Your individual total profit in ECU will be converted into € (1 ECU = 0.01 €) and paid to you in cash. You are paid at the end of the experiment. The payment is carried out individually and anonymously.

AVAILABLE INFORMATION

In each round, you will see an overview table on your screen which provides you with the results of all previous rounds that you have played. The results include the following information for each round:

Your endowment, your mandatory minimum contribution to Y, your contribution to X, your contribution to Y, the individual contributions to Y of each of the other group members, your return from X, your return from Y, your round profit, and your total profit.

If you want to see the results of earlier rounds, which are no longer visible in the table, please use the scroll function on the right side of the table.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. You then will be given on your screen a number of questions regarding these instructions. If you have any questions please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

V

RECOMMENDED MINIMUM CONTRIBUTIONS IN A PUBLIC-GOOD GAME WITH HETEROGENEOUS ENDOWMENTS

with Claudia Keser

Abstract: We investigate whether the recommendation of minimum contributions in a public-good experiment with heterogeneous endowments impacts behavior in the same way as mandatory minimum contributions. Keser et al. (2014b) have observed that the latter, when they are progressive, (1) increase group contributions to a level significantly above the contributions in a baseline treatment without minimum contributions and (2) modify the "fair-share" norm of equal relative contributions. Similar progressive minimum contributions presented as recommendations in our experiment do not show the same effect.

JEL-Classification: C92, D63, H41

Keywords: Experimental economics, public goods, heterogeneous endowments, recommended minimum contributions, norms

1. Introduction

In a linear public-good experiment with an asymmetric distribution of endowments, Keser et al. (2014b) demonstrate that mandatory minimum contributions may be used to increase group contributions to the public good.[1] A progressive minimum-contribution schedule, which imposes higher obligations on players with higher endowments, is found to be particularly effective. It shows a norm-giving character, inducing the rich players to give a higher share of their endowment than the poor players.

Similarly, in symmetric linear public-good experiments, Galbiati and Vertova (2008) and Riedel and Schildberg-Hörisch (2013) show that "weakly incentivized" obligations prescribing minimum contributions (of 20 or 80 percent of the endowment) are effective in influencing individual contribution decisions. Riedel and Schildberg-Hörisch (2013) show that this is true even for asymmetric obligations. The argument provided by the authors of both studies is that obligations have an expressive function (see, e.g., Kahan, 1997; Cooter, 1998; McAdams, 2000; McAdams and Nadler, 2005), which attaches an emotional cost of disobeying the own obligation (see, e.g., Bénabou and Tirole, 2011). Thus, obligations can affect individual behavior even if they are backed by weak monetary incentives only. In both studies, incentives are provided by a probabilistic penalty (reward) if an individual contributes less (more) than the minimum requested. They are considered as non-binding since, assuming risk-neutrality, they are too small to make contributing to the public good profitable.

Such weakly incentivized non-binding obligations are a less stringent policy tool than mandatory minimum contributions and they seem to work effectively in symmetric linear public-good settings. Furthermore, Galbiati and Vertova (2014) suggest that obligations (recommendations to contribute at least 80 percent of the endowment) even work without monetary incentives. Based on this promising evidence of "expressive law", the question that we address in this paper is whether, in the setting with heterogeneous endowments (Keser et al., 2014a; 2014b), simply recommending minimum contributions is sufficient to impact the contribution norm. We focus on the most promising, progressive minimum-contribution schedule and test whether, presented as a pure recommendation, it is similarly able to impact the norm among heterogeneously endowed agents and increase average group contributions, as does the mandatory progressive minimum-contribution schedule in Keser et al. (2014b).

Evidence in support of our conjecture can be found in Dale and Morgan (2010). In a public-good experiment with equally endowed subjects, they find that a moderate recommendation significantly increases group contributions, while suggesting the

[1] The minimum contributions are for all player types lower than average voluntary contributions to the public good in the baseline treatment without enforced minimum contributions. Consequently, they sum up to less than the observed average group contribution in the baseline treatment, where zero contribution is the dominant strategy for all players. This guarantees that the dominant strategy solution with mandatory minimum contributions does not imply an increase in the contribution level per se.

contribution of the entire endowment does not. Similarly, a "moral message", in the middle of an experiment with strangers re-matching, may lead to a temporary increase in contributions (Dal Bó and Dal Bó, 2014). In step-level public-good experiments, Marks et al. (1999) and Croson and Marks (2001) find that recommended contributions facilitate coordination and thus significantly increase the relative frequency of successful provisions of the public good, when valuations of the public good are heterogeneous. For the homogeneous case, however, recommendations make no difference. In real-life charitable projects, moderate recommendations can positively impact the frequency of donations (Cialdini and Schroeder, 1976; Brockner et al., 1984; Weyant and Smith, 1987; Fraser et al., 1988), whereas high recommendations can increase the average size of contributions (Doob and McLaughlin, 1989).

The explanation given by the "expressive law" literature for the potential impact on behavior is that obligations create focal points or norms, which channel individuals' beliefs about the behavior of others and act as coordination devices. Similarly, Dal Bó and Dal Bó (2014) provide a twofold explanation for the (temporary) effect of moral messages. The first is a "preference effect", which states that moral messages influence the level or relationship of contributions deemed to be morally right. The second is an "expectation effect", which states that moral messages affect players' expectations about the contributions of others in an optimistically fashion. These explanations give hope that, in our setting, progressive recommendations on minimum contributions are conceivably able to increase group contributions by setting a norm of fair contributions among heterogeneously endowed players, implying that the richer players contribute a higher share of the endowment than the poorer players.

The remainder of this paper is organized as follows. Section 2 presents the experimental design and procedures. Section 3 provides the experimental results. Section 4 gives a summary and concludes.

2. The Experiment

2.1 The Game

Our baseline public-good game has been introduced in Keser et al. (2014a) as the *AsymWeak* treatment. Each of four players ($i = 1, \dots, 4$) is endowed with an exogenously given number of tokens e_i, with $e_1 = 10,\ e_2 = e_3 = 15,\ e_4 = 20$. The four players decide independently on the allocation of their individual token endowment between a private and a public investment. Let x_i denote the amount allocated to the private investment and y_i the amount allocated to the public investment by player i, with $x_i, y_i \geq 0$. The investments have to be in entire tokens and to add up to the individual endowment. Thus, $0 \leq x_i \leq e_i$, $0 \leq\ y_i \leq e_i$, and $x_i + y_i = e_i$.

The profit π_i of each player i depends on this player's private investment and the sum of public investments in the group. Each token that a player allocates to the private investment yields an individual return of 2 *Experimental Currency Units* (ECU), while each token allocated to the public investment yields a return of 1 ECU to each of the four group members. The profit of player i is thus given by

$$\pi_i = 2x_i + \sum_{i=1}^{n} y_i \qquad (1)$$

Since each player's individual return of a token invested in the private investment is larger than in the public investment, the game has an equilibrium in dominant strategies, where each player contributes the entire endowment to the private investment ($x_i^* = e_i; y_i^* = 0$).

The game is played over 25 rounds. The subgame-perfect equilibrium solution prescribes, based on backward induction, that in each round each player plays the dominant strategy and contributes zero to the public investment.

However, the subgame-perfect equilibrium is collectively inefficient. Given that the group return of a token allocated to the public investment is 4 ECU and thus larger than the individual return of 2 ECU of the same token allocated to the private investment, the group optimum would request all players to allocate in each round all of their endowments to the public investment.

In the following we call this baseline game the *NoMin/Rec* treatment and consider two additional treatments. In *ProgMin*, we impose mandatory minimum contributions ($c_i > 0$) to the public investment; specifically, $c_1 = 2,\ c_2 = c_3 = 6,\ c_4 = 10$. This treatment corresponds to the progressive minimum-contribution schedule in Keser et al. (2014b). Since the minimum contributions are mandatory, they constrain the individual allocation decisions for each player i by $0 \leq x_i \leq e_i - c_i$, $c_i \leq\ y_i \leq e_i$, and $x_i + y_i = e_i$. The dominant strategy solution thus prescribes, for each player i, to contribute the required minimum contribution to the public investment and allocate all remaining tokens to the private investment ($x_i^* = e_i - c_i; y_i^* = c_i$).

ProgRec is our novel treatment. In *ProgRec*, we make minimum-contribution recommendations ($r_i > 0$). Similarly to ProgMin, they are $r_1 = 2$, $r_2 = r_3 = 6$, $r_4 = 10$. In this treatment the minimum contributions are not mandatory and thus leave the strategy space as well as the equilibrium prediction of the baseline treatment unaffected.

In all three treatments, all of the above information, including the minimum-contribution requirements or recommendations of all player types, is common knowledge. Table 1 summarizes the treatments. We distinguish between Type 10 (*poor*), Type 15 (*wealthy*) and Type 20 (*rich*) players, corresponding to their respective endowment. The amounts of the minimum contributions, mandatory or recommended, are progressive and correspond to rates of 20 percent for the *poor*, 40 percent for the *wealthy*, and 50 percent for the *rich* players. No explicit rationale is given to explain the amounts of minimum contributions to the participants. In *ProgRec*, however, we mention that the recommended values account for the fact that players with a higher endowment potentially can contribute more to the public investment. To amplify the moral substance of the recommendation, we additionally include a philosophical saying of the Chinese philosopher and poet Lao-tze: *"He who knows he has enough is rich"*.

Table 1: Treatment Overview

Treatment	Minimum Contributions (mandatory or recommended)				# Obs.
	Type 10	Type 15		Type 20	
	Player 1	Player 2	Player 3	Player 4	
NoMin/Rec	0	0	0	0	10
ProgMin	2 (20%)	6 (40%)	6 (40%)	10 (50%)	10
ProgRec	2 (20%)	6 (40%)	6 (40%)	10 (50%)	10

2.2 The Procedures

We conducted the computerized experiment in the Göttingen Laboratory of Behavioral Economics at the University of Göttingen, Germany, based on the z-Tree software package (Fischbacher, 2007).[2] In total, 120 bachelor and master students from various disciplines (mostly economics and business administration) participated in the three treatments of this study. The *NoMin/Rec* treatment corresponds to the *AsymWeak* treatment in Keser et al. (2014a) and the *ProgMin* treatment corresponds to the treatment with the same label in Keser et al. (2014b). Participants were student volunteers recruited for a decision-making experiment via ORSEE (Greiner, 2004). A roughly equal number of female and male students participated in all sessions. According to subject availability, we conducted sessions with three to five groups each, implying three to five independent observations per session. We collected 10 independent observations of each treatment, 30 in total.

The procedure of the experiment was as follows. The experimenter distributed written instructions (a translation of these is provided in the Appendix) and read them aloud to all participants. Participants were informed that they are randomly assigned to groups of four that remained unchanged during the entire experimental session (partners design). Participants, however, did not get to know the identity of the participants with whom they interacted. Each player in a group was randomly assigned a player number from one to four, which was individually communicated at the beginning of the experiment and remained unchanged. Each player number was associated with an endowment and, if applicable, with a minimum-contribution requirement or recommendation (see Table 1 above). At the end of each round, participants were informed about the individual contribution to the public investment by each of the three other players in the group (identified solely by their player number).

After the reading of the instructions, participants had to answer to a number of questions controlling for the understanding of the instructions. The experiment did not start until all participants had correctly answered to all questions.

The participants were informed in the instructions that the profits gained in the course of the experiment are measured in Experimental Currency Units (ECU) and that these will be multiplied by a conversion factor of 0.01 € per ECU for the final payment, in addition to a show-up fee of 3 €. The cash payment was conducted anonymously after the experiment. An experimental session lasted on average around 75 minutes. The average payoff earned was about 15.00 € (including the 3 € show-up fee).

[2] The lab consists of 24 computers in isolated booths, such that vision of someone else's computer screen and verbal communication with other participants is highly restricted.

3. Experimental Results

All nonparametric tests presented below are two-sided. We require significance at the 10-percent level. We denote the Mann-Whitney U test as U test and the Wilcoxon matched-pairs signed-rank test as signed-rank test.

3.1 Group Contributions

Figure 1 presents, for each of the three treatments, the development of the average group contributions to the public investment over the 25 rounds. As can be seen, with a mean of 43.5, *ProgMin* exhibits the highest group contributions, while contributions in *NoMin/Rec* and *ProgRec*, with respective means of 33.1 and 31.1, proceed close to each other on a lower level.[3] Pairwise treatment comparisons of average group contributions over all 25 rounds, based on U tests, show that contributions in *ProgMin* are significantly larger than in *NoMin/Rec* (p = .0101) and *ProgRec* (p = .0233). Group contributions in *NoMin/Rec* and *ProgRec* are statistically indistinguishable.

Result 1: *The recommendations in ProgRec are not able to increase the group contribution level.*

3.1 Contributions by Player Types

3.1.1 Comparison within Treatments

Considering average absolute contributions, we know from Keser et al. (2014b), that in *NoMin/Rec* and *ProgMin* the richer players contribute significantly more than the poorer ones. We find that this is also true in *ProgRec* ($p \leq .0469$, signed-rank tests).

Keser et al. (2014b) also show that average relative contributions, i.e., contributions relative to the endowment, are equal for all three player types in *NoMin/Rec* ("fair-share" norm), but significantly higher for richer players in *ProgMin* such that the "fair-share" norm is breached. In *ProgRec*, we observe Type 10 players to contribute on average a significantly lower share of the endowment than Type 15 players (p = .0593); all other differences are insignificant, though. The "fair-share" norm thus seems to be not significantly affected by the recommendations in *ProgRec*. In contrast to *ProgMin*, individual relative contributions in *ProgRec* still follow the simple "fair-share" norm as in *NoMin/Rec*.

[3] Average standard deviations of total group contributions for rounds 1-25 are 12.4, 7.5, and 8.5 for NoMin/Rec, ProgMin, and ProgRec respectively.

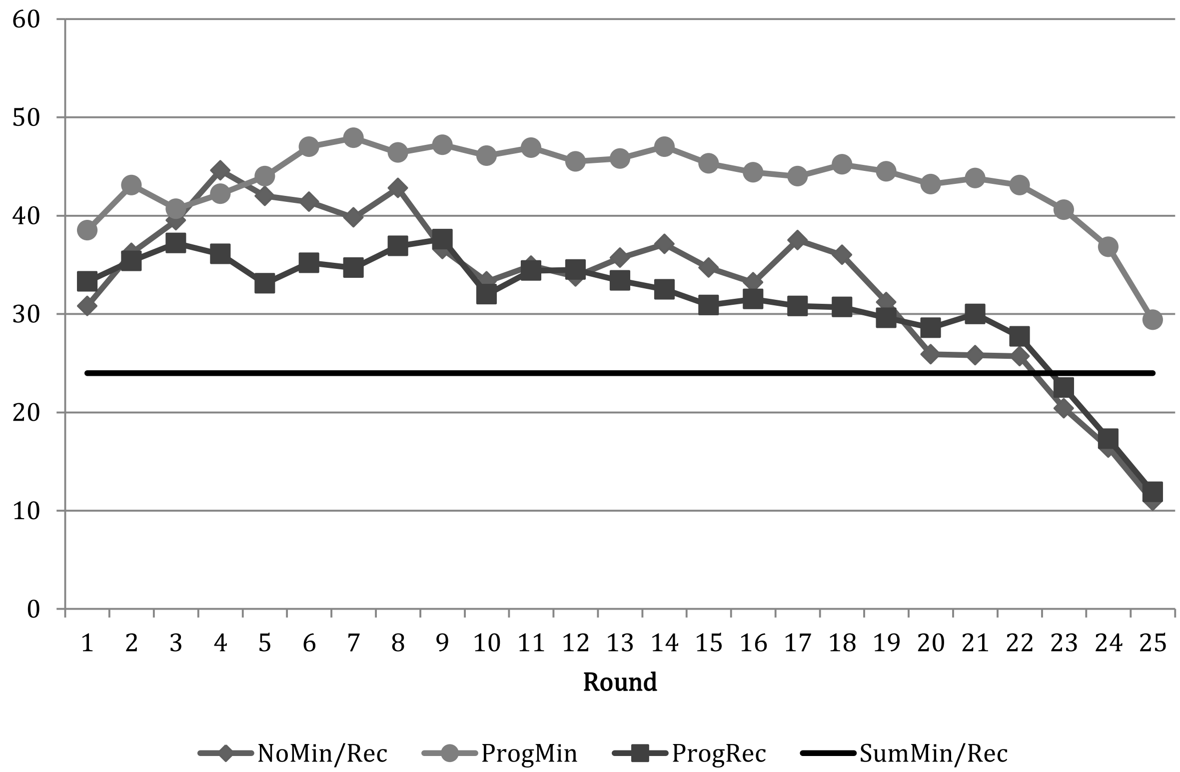

Figure 1: Average Group Contributions per Round (by Treatment)

Result 2: *The recommendations in ProgRec do not impact the relative contribution pattern; the "fair-share" norm is not breached. This indicates that the recommendations do not exert norm-giving character.*

3.1.2 Comparison between Treatments

Figure 2 shows, by player type, the relative contributions in the three treatments. As can be seen, (relative) contributions of Type 10 players are on average lower in *ProgRec* than in the two other treatments; however, only the difference from *NoMin/Rec* is statistically significant ($p = .0963$, U test). This suggests that the previously observed, significantly lower average group contribution in *ProgRec* than in *ProgMin* must be primarily caused by lower contributions of Type 15 and Type 20 players.

This presumption finds support in Figure 2. Contributions of Type 15 and Type 20 players follow similar trajectories in *NoMin/Rec* and *ProgRec* which, however, are both lower on average than in *ProgMin*. Average contributions of both player types are indeed significantly lower in *NoMin/Rec* and *ProgRec* than in *ProgMin* ($p \leq .0413$, U tests). The recommendations in *ProgRec* have, relative to *NoMin/Rec*, only insignificant effects on the contributions of Type 15 and Type 20 players.

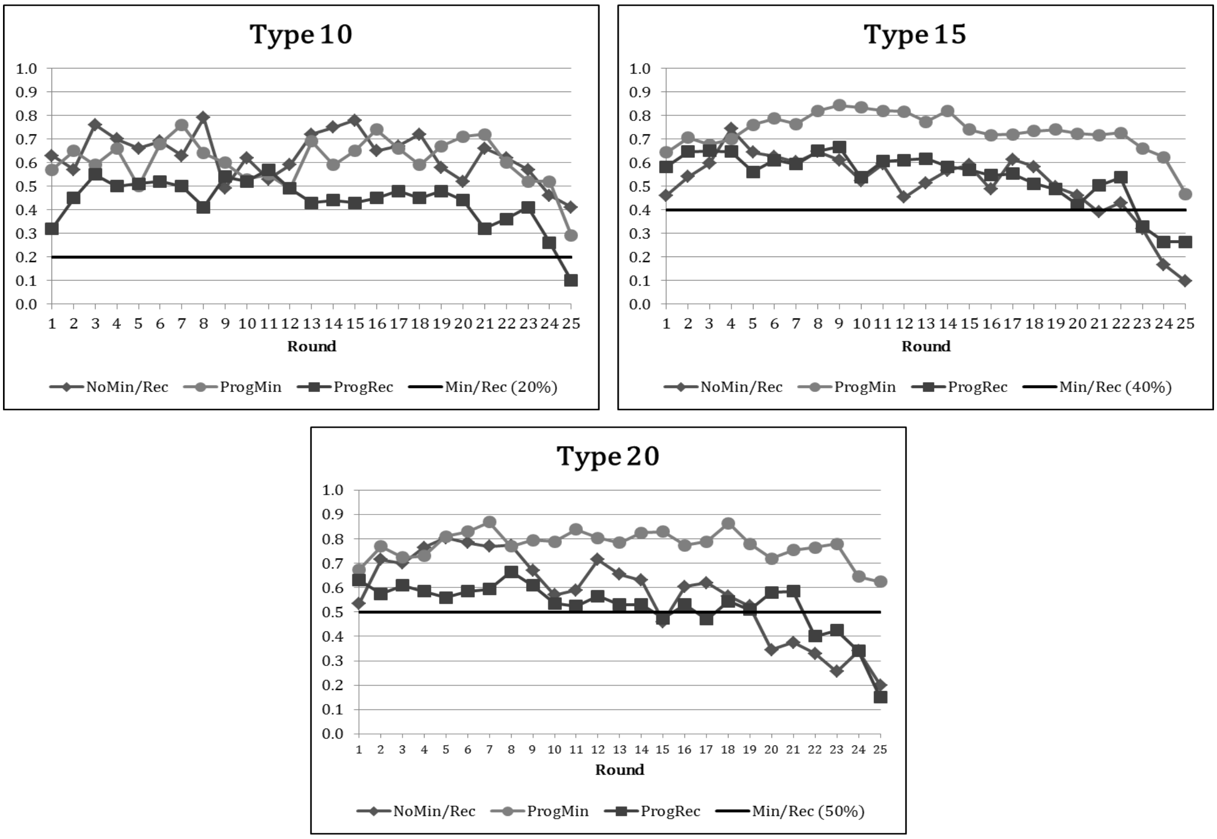

Figure 2: Average Relative Contributions by Treatment and Player Type

Result 3: *The recommended minimum contributions in ProgRec do not increase contributions of the richer players (Type 15 and Type 20) above the level observed in NoMin/Rec, as do the mandatory minimum contributions in ProgMin.*

To identify probable effects of recommended minimum contributions on contributions at the margin, we compare zero and full contributions of all player types between *NoMin/Rec* and *ProgRec*. The respective figures are shown in Table 2. We find that zero contributions are significantly more frequent in *NoMin/Rec* than in *ProgRec* for Type 10 and Type 15 players ($p \leq .0001$, U tests); for Type 20 players this is almost significant ($p = .1076$, U test). However, we also find that full contributions are significantly more seldom in *ProgRec* compared to *NoMin/Rec* for all three player types ($p \leq .0987$, U tests).

Result 4: *On the one hand, recommendations exert a positive effect in reducing zero contributions in comparison to NoMin/Rec but, on the other hand, they exert a negative effect on full contributions.*

Table 2: Relative Frequency of Individual Decisions which were either Zero or Full Contribution to the Public Investment

	Zero Contributions (in percent)	Full Contributions (in percent)
NoMin/Rec – Type 10	18.0	41.2
NoMin/Rec – Type 15	21.2	28.6
NoMin/Rec – Type 20	18.0	28.4
ProgRec – Type 10	6.8	22.4
ProgRec – Type 15	9.2	24.0
ProgRec – Type 20	12.8	14.0

4. Conclusion

Recommendations in our experiment do not exert norm-giving power. Group contributions are not statistically different from those observed in the baseline treatment but significantly smaller than in the treatment with mandatory minimum contributions. In contrast to the latter, recommendations have no impact on the "fair-share" norm: the different player types tend to contribute, on average, the same portion of their endowment to the public good. Additionally, for none of the three player types do the recommendations show a positive impact on the contribution level. In contrast, the poor players contribute significantly less than in the baseline treatment. It follows that, for all player types, contributions are significantly lower than those in the treatment with mandatory minimum contributions. Furthermore, recommendations, on the one hand, exert a positive effect in reducing zero contributions in comparison to the baseline treatment, but, on the other hand, they exert a negative effect on full contributions.

Our results suggest that mere recommendations might not be an adequate policy tool for influencing the contribution norm and/or increasing the overall contribution level in heterogeneous public-good settings. It appears that some incentives are necessary. More research is needed in this direction.

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References

Bénabou, R., Tirole, J., 2011. Laws and Norms 17579. National Bureau of Economic Research.

Brockner, J., Guzzi, B., Kane, J., Levine, E., Shaplen, K., 1984. Organizational Fundraising: Further Evidence on the Effect of Legitimizing Small Donations. Journal of Consumer Research 11 (1), 611–614.

Cialdini, R.B., Schroeder, D.A., 1976. Increasing Compliance by Legitimizing Paltry Contributions: When Even a Penny Helps. Journal of Personality and Social Psychology 34 (4), 599–604.

Cooter, R., 1998. Expressive Law and Economics. The Journal of Legal Studies 27 (S2), 585–607.

Croson, R., Marks, M., 2001. The Effect of Recommended Contributions in the Voluntary Provision of Public Goods. Economic Inquiry 39 (2), 238–249.

Dal Bó, E., Dal Bó, P., 2014. "Do the Right Thing:" The Effects of Moral Suasion on Cooperation. Journal of Public Economics 117, 28–38.

Dale, D.J., Morgan, J., 2010. Silence is golden: Suggested Donations in Voluntary Contribution Games, University of California, Berkeley, USA.

Doob, A.N., McLaughlin, D.S., 1989. Ask and You Shall be Given: Request Size and Donations to a Good Cause. Journal of Applied Social Psychology 19 (12), 1049–1056.

Fischbacher, U., 2007. z-Tree: Zurich Toolbox for Ready-made Economic Experiments. Experimental Economics 10 (2), 171–178.

Fraser, C., Hite, R.E., Sauer, P.L., 1988. Increasing Contributions in Solicitation Campaigns: The Use of Large and Small Anchorpoints. Journal of Consumer Research 15 (2), 284–287.

Galbiati, R., Vertova, P., 2008. Obligations and Cooperative Behaviour in Public Good Games. Games and Economic Behavior 64 (1), 146–170.

Galbiati, R., Vertova, P., 2014. How Laws Affect Behavior: Obligations, Incentives and Cooperative Behavior. International Review of Law and Economics 38, 48–57.

Greiner, B., 2004. The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics. University of Cologne, Working Paper Series in Economics 10 (23), 63–104.

Kahan, D.M., 1997. Between Economics and Sociology: The New Path of Deterrence. Michigan Law Review 95, 2477–2497.

Keser, C., Markstädter, A., Schmidt, M., 2014b. Mandatory Minimum Contributions, Heterogenous Endowments and Voluntary Public-Good Provision. cege Discussion Paper 224, University of Göttingen.

Keser, C., Markstädter, A., Schmidt, M., Schnitzler, C., 2014a. Social Costs of Inequality - Heterogeneous Endowments in Public-Good Experiments. cege Discussion Paper 217, University of Göttingen.

Marks, M.B., Schansberg, D. Eric, Croson, Rachel T. A., 1999. Using Suggested Contributions in Fundraising for Public Good. Nonprofit Management and Leadership 9 (4), 369–384.

McAdams, R.H., 2000. A Focal Point Theory of Expressive Law. Virginia Law Review 86 (8), 1649–1729.

McAdams, R.H., Nadler, J., 2005. Testing the Focal Point Theory of Legal Compliance: The Effect of Third-Party Expression in an Experimental Hawk/Dove Game. Journal of Empirical Legal Studies 2 (1), 87–123.

Riedel, N., Schildberg-Hörisch, H., 2013. Asymmetric Obligations. Journal of Economic Psychology 35, 67–80.

Weyant, J.M., Smith, S.L., 1987. Getting More by Asking for Less: The Effects of Request Size on Donations of Charity. Journal of Applied Social Psychology 17 (4), 392–400.

Appendix

Experimental Instructions (ProgRec)

You participate in an economic decision experiment, in which you can earn money. How much each of you will earn depends on your personal decisions and those of other participants in the experiment. Each participant makes his decisions at a computer, isolated from the others. We ask you not to talk to other participants.

The experiment consists of 25 rounds. In the beginning of the experiment you will be randomly matched with three other persons to build a group of four. You will remain in this group during the entire experiment. You will not know the identity of your group members at any time, though.

Each group member is endowed in each round with a certain amount of tokens. Player 1 is endowed with 10 tokens per round. Players 2 and 3 are endowed with an amount of 15 tokens each. Player 4 is endowed with 20 tokens per round. The individual player numbers (and thus the individual endowments) will be randomly assigned and announced at the beginning of the experiment.

DECISIONS

In each of the 25 rounds, each group member has to decide on how to allocate her/his tokens between two alternatives, called X and Y. The return of a token, in experimental currency units (ECU), is different for the two alternatives. The return of the allocation decision is determined as follows:

Each token that you contribute to X yields a return of 2 ECU. If you contribute nothing to X, your return from X is zero.

Each token that you contribute to Y, yields to you and to each of the other group members a return of 1 ECU. You may thus have a positive return from Y even if you don't contribute anything to Y.

For the allocation of your tokens, we provide you, depending on your endowment, with recommended values for the contribution to Y which, however, are not binding. The recommended values account for the fact that players with a higher endowment can potentially contribute more to the alternative Y. The recommended minimum contribution is two tokens for Player 1, six tokens for Players 2 and 3, respectively, and ten tokens for Player 4. Please adhere to the recommended minimum contributions.

Group Member	Endowment (ECU)	Recommended Minimum Contribution to Y
Player 1	10	2
Player 2	15	6
Player 3	15	6
Player 4	20	10

You may allocate your tokens, above the minimum contribution to Y, to X or to Y only, but you may also allocate them among both alternatives. However, only entire tokens may be contributed. In the decision box on your screen you need to enter, for each alternative, the number of tokens that you want to allocate. If you do not want to contribute anything to X or Y, you need to type in a zero. The sum of the tokens contributed to X and Y must be always equal to your endowment. This means that the entire token endowment has to be allocated among X and Y. With the <Tab> key you can switch among the entry fields. The entries have to be confirmed by clicking on <OK>.

Your individual return per round is the sum of your returns from X and Y and is calculated as follows:

Return = 2 × (your contribution to X) + (sum of tokens contributed to Y in your group).

PAYMENT

At the end of the experiment, you will be paid based on your individual total profit over all 25 rounds. Your individual total profit in ECU will be converted into € (1 ECU=0.01 €) and paid to you in cash. You are paid at the end of the experiment. The payment is carried out individually and anonymously.

AVAILABLE INFORMATION

In each round, you will see an overview table on your screen which provides you with the results of all previous rounds that you have played. The results include the following information for each round:

Your endowment, your recommended minimum contribution to Y, your contribution to X, your contribution to Y, the individual contributions to Y of each of the other group members, your return from X, your return from Y, your round profit, and your total profit.

If you want to see the results of earlier rounds, which are no longer visible in the table, please use the scroll function on the right side of the table.

We ask you now to go to the computer with your participation number. There you have to click on <Continue>. You then will be given on your screen a number of questions regarding these instructions. If you have any questions please address yourself to the experimenter. Only when all participants have correctly answered all questions, the experiment starts.

He who knows he has enough is rich. (Lao-tze)