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ATTITUDES TOWARDS RISK: AN EXPERIMENT

Jürgen Eichberger, Werner Güth and Wieland Müller*
Ruprecht Karls University Heidelberg, Max Planck Institute for Research into Economic Systems, and Humboldt University Berlin

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ABSTRACT

The evaluations of a repeated lottery with and without the option to sell the second-stage lottery are compared theoretically and experimentally. Comparing individuals' risk attitudes, we find that risk attitudes differ depending on the measure of risk attitude applied. We also find that subjects show low or no risk aversion, but put very high value on the opportunity to sell the lottery in the second stage of the decision problem. These findings cast doubts on the suitability of the random price mechanism for truthful revelation of willingness to pay in sequential decision problems.

1. INTRODUCTION

Since von Neumann and Morgenstern (1947) provided an axiomatic treatment of the expected utility hypothesis there have been discussions about the interpretation of the theory. Was it meant to be a descriptive tool for the analysis of actual behaviour? Or should it be viewed as a blueprint for how to make 'rational' decisions in the face of risk? Shortly after this seminal work experimental and empirical studies began. Camerer (1995) offers a survey over this large literature. In economic applications, expected utility theory became the dominant model of decision-making under risk because it offered a clear distinction between the evaluation of outcomes (the von

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Neumann–Morgenstern utility function) and the evaluation of risk (the probability distribution over outcomes).

With this clear distinction between risk and risk preferences, risk attitudes could be conveniently defined in terms of curvature properties of the von Neumann–Morgenstern utility function. Moreover, as Rothschild and Stiglitz (1970) showed, all natural notions of behaviour towards risk lead to the same classification of individuals according to the curvature of their von Neumann–Morgenstern utility function. Despite the large number of experimental studies recorded by Camerer (1995), there seems to be no attempt to test these alternative definitions of risk attitudes directly in experiments. This is even more surprising since some of the more recent non-expected utility theories, like the rank-dependent expected utility model of Quiggin (1982) or the cumulative prospect theory of Tverski and Kahneman (1992), yield alternative conclusions about the consistency of the various concepts of risk attitude.[1]

In this paper we report about an experiment which tests different notions of risk attitude directly. The random price mechanism (Becker et al. (1964)) was chosen in order to provide monetary incentives for revealing the valuation of lotteries. This experimental design is commonly used to provide incentives for the truthful revelation of valuations. Our experiment highlights some features of the mechanism, however, which, at least to our knowledge, are not widely known.

Our experiment studies decision-makers' evaluations of lotteries with one or two chance moves. In a third (dynamic) treatment participants have the option to trade the second-stage lottery after the first-stage lottery has been resolved. With this design, we hope to gain insights about

- whether subjects understand the diversification effect of a repeated lottery,
- how they react to information revealed conditional on whether they are allowed to act on this information or not, and
- how they value the option to sell the second stage of a lottery in the light of the first-stage results.

In the light of the literature on preferences for the early or late resolution of uncertainty, the diversification effect of a repeated task could also be viewed as a preference for gradual resolution of uncertainty. This interpretation appears rather tenuous, however, since both chance moves are performed in quick succession.

[1] Chateauneuf and Cohen (2000) provide a survey of these results.

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The question of how decision-makers view and evaluate successive choices is also relevant for the design of experiments itself. When accounting for experimental results (see Camerer (1995) for a survey), one almost always applies the model of risky decision-making to the basic decision task and not to the repeated situation, although repeating the same risky choices may weaken the effects of different risk attitudes. In our study the crucial stochastic event occurs either once or twice and it is explicitly taken into account how optimal behaviour depends on risk attitude. By repeating the task once without prior announcement we test whether the smaller variance of the final payoffs in the repeated lottery influences actual behaviour as predicted by theory.

In a brief summary, our experimental design can be described as follows. In a first treatment, treatment A, participants are endowed with a lottery $\mathcal{L}$ which pays with equal probability a high premium $2 \cdot \overline{p}$ and a low premium $2 \cdot \underline{p}$ where $\overline{p} > \underline{p} > 0$. Subjects have to choose the limit price b_1 above which they are willing to sell the lottery. A price p is randomly drawn. If this price p for $\mathcal{L}$ exceeds b_1, the participant is paid the price p in exchange for the lottery $\mathcal{L}$. Otherwise, the lottery is played and the participant receives its prize. Clearly, the only dominant strategy is to bid the price at which one is indifferent between selling and not selling the lottery (see Becker *et al.* (1964)). In essence, we apply the incentive-compatible random price mechanism to elicit the willingness to accept for the basic lottery $\mathcal{L}$. The limit price b_1 is the only decision of a participant.

In treatment B, the only decision is again the limit price b_2 for which one is willing to sell the repeated lottery. Here the lottery yields the sum of the returns from two successive and independent draws of the prizes $\overline{p}$ and $\underline{p}$. The return from the repeated lottery is now $2 \cdot \overline{p}$ and $2 \cdot \underline{p}$, each with probability $\frac{1}{4}$, and $\overline{p} + \underline{p}$ with probability $\frac{1}{2}$.

Treatment C has also two chance moves but a participant is free to sell the lottery in the first *and* the second stage. More specifically, participants first choose a limit price b_3 for which they would be willing to sell the repeated lottery. If the random price is such that no sale occurs, then the first lottery drawing is carried out. Knowing the payoff from this first stage, $\overline{p}$ or $\underline{p}$, participants choose a second limit price $b_3(\cdot)$ for which they would be willing to sell the final stage of the lottery.

Thus, the basic decision in treatment A elicits the certainty equivalent for the basic lottery and hence the risk premium of the risky investment. Treatment B determines the certainty equivalent for the once repeated lottery. Finally, treatment C elicits the certainty equivalents of the second-stage

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lottery and the willingness to accept for the two-stage lottery with this additional sales option.[2]

The experiment used both a *between-subjects design* where each group of participants encounters only a single treatment and a *within-subjects design* where participants confront the choice situations of all three treatments.

In the following section, we recall the most common preference-based concepts of risk attitudes. Section 3 derives the optimal decisions under the expected utility hypothesis for all three treatments. Section 4 contains the details of our experimental procedure. The main results are described and discussed in section 5. We conclude by summarizing our results and comparing them to some previous experimental studies.

2. ATTITUDES TOWARDS RISK

The literature offers several concepts for how to measure decision-makers' attitudes towards risk. For a brief survey, Chateauneuf and Cohen (2000) can be consulted. Rothschild and Stiglitz (1970) show that the following two notions of risk aversion are equivalent in the context of an expected utility maximizing individual.

Consider a preference relation $\succeq$ on the set of lotteries $\mathcal{L}$ with a typical element $X = (x_1, p_1; \ldots, x_n, p_n)$ where x_s denotes the outcome s which occurs with probability p_s. Denote by $\mathcal{E}X$ the expected value of a lottery X. Probably the best known definition compares the lottery with its certainty equivalent. Following Chateauneuf and Cohen (2000), we refer to this risk attitude notion as *weakly risk averse*, *weakly risk neutral* and *weakly risk loving*.

Definition 1: A decision-maker is

- weakly risk averse if $(\mathcal{E}X, 1) \succ X$
- weakly risk neutral if $(\mathcal{E}X, 1) \sim X$
- weakly risk loving if $(\mathcal{E}X, 1) \prec X$

for all $X \in \mathcal{L}$.

[2] One may argue that 'willingness to accept' studies underestimate risk aversion due to the robust findings of endowment or status quo effects revealing on average lower willingness to pay than willingness to accept. Here this is not important since we are more interested in the differences between treatments rather in the absolute evaluations of lotteries.

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A much stronger criterion to distinguish attitudes towards risk uses lotteries with the same mean value which can be ordered according to their spread. Denote by $F_X(t) := \Sigma_{x_i \leq t} p_i$ the probability distribution function of lottery X. We say lottery Y is a *mean-preserving spread* of lottery X if

(i) $\int_{-\infty}^{\infty} F_X(t)\mathrm{dt} = \int_{-\infty}^{\infty} F_Y(t)\,\mathrm{dt}$,
(ii) $\int_{-\infty}^{x} F_X(t)\mathrm{dt} \leq \int_{-\infty}^{x} F_Y(t)\,\mathrm{dt}$ for all x.

Denote by MPS(X) a lottery which is a mean-preserving spread of lottery X.

Definition 2: A decision-maker is

- strongly risk averse if $X \succ \mathrm{MPS}(X)$
- strongly risk neutral if $X \sim \mathrm{MPS}(X)$
- strongly risk loving if $X \prec \mathrm{MPS}(X)$

for all $X \in \mathcal{L}$.

Because any lottery X is a mean-preserving spread of the lottery ($\mathcal{E}X$, 1), it is clear that every strongly risk-averse individual is also weakly risk averse. However, the reverse implication is not true in general. For individuals with expected utility preferences, however, the concepts of definitions 1 and 2 are equivalent and are characterized by curvature properties of the von Neumann–Morgenstern utility function. Chateauneuf and Cohen (1994) also investigate the implications of concepts for measuring risk attitudes in the context of non-expected utility theories.

3. OPTIMAL DECISIONS

The experiment elicits the value of the lottery by using the random price mechanism (Becker *et al.* (1964)) for which it is a dominant strategy to reveal the certainty equivalent of a lottery. In each treatment, subjects were endowed with a lottery and asked to name a price above which they would sell the lottery. A randomly selected price then determined whether a subject could sell the lottery.

Three treatments are considered. Treatment A assesses the subject's attitude towards risk. Treatment B is similar to treatment A but allows us to check whether participants understand the diversification effect of a repeated lottery and whether they are influenced by decision-irrelevant information.

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Table 1. The structure of the three treatments

		Chance moves take place Once	Twice
Decisions take place	*Once*	Treatment A	Treatment B
	Twice	—	Treatment C

Treatment C studies the value of the additional option to sell the lottery after partial resolution of uncertainty.

The basic payoff of a lottery is

- $\overline{p} = 5$ with probability 0.5,
- $\underline{p} = 1$ with probability 0.5.

This lottery is repeated once in treatments B and C. Outcomes are doubled in treatment A where the basic lottery is played only once. Treatment C allows players to trade the second-stage lottery after the outcome of stage 1 has been observed. Table 1 summarizes the structure of the three treatments.

In order to contrast the experimental results with theoretical predictions, we determine the behaviour of an expected utility maximizer in the three treatments. The formal derivation of optimal bids is relegated to appendix A.

3.1 Treatment A

In treatment A, subjects are endowed with the following lottery:

$$X_1 = \begin{cases} 2 \cdot \overline{p} = 10 & \text{with probability } \frac{1}{2} \\ 2 \cdot \underline{p} = 2 & \text{with probability } \frac{1}{2} \end{cases}$$

The mean and standard deviation of lottery X_1 are

$$\mu_1 = 6 \qquad \sigma_1 = 4$$

Subjects are asked to quote a price $b_1 \in [1, 10]$ for which they are willing to sell lottery X_1. A price $p \in [1, 10]$ is then randomly drawn from a uniform distribution. For $p > b_1$, the lottery X_1 is sold and the payoff of the subject

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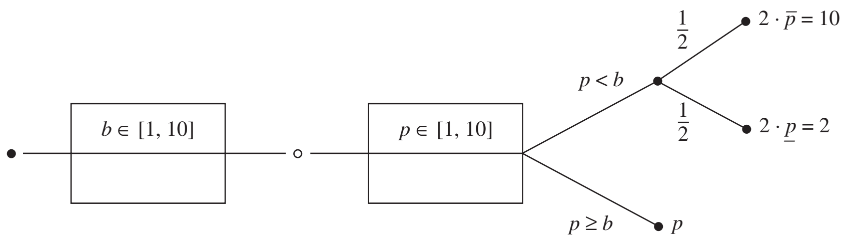

Figure 1. Treatment A.

is p. For $p \leq b_1$, the lottery X_1 is played and the subject receives the lottery payout. Figure 1 illustrates the sequence of moves.

The expected utility from quoting a sales price b is easily computed as

$$V_1(b) := \frac{u(2 \cdot \underline{p}) + u(2 \cdot \overline{p})}{2} \frac{b-1}{9} + \frac{1}{9} \int_b^{10} u(p)\, \mathrm{d}p$$

It is optimal for the decision-maker to offer the certainty equivalent of the lottery as limit price for which the lottery will be sold:

$$b_1^* = u^{-1}\left(\frac{u(2) + \underline{u}(10)}{2} \right)$$

It is worth noting that the expected utility of the lottery plus sales option exceeds the expected value of the basic lottery. For $u(x) = x$ (risk neutrality) we obtain $b_1^* = 6$ and $V_1(b_1^*) = 6\frac{8}{9}$ which is higher than the lottery's expected value of 6 due to the additional expected gains from random prices larger than 6. It is, of course, questionable whether, in view of the minor stakes in usual classroom experiments, deviations from risk neutrality make sense. As shown by Rabin (2000) substantial deviations from risk neutrality in such experiments would imply absurd degrees of risk aversion or risk loving over large stakes.

3.2 Treatment B

In treatment B, lottery X_1 is once repeated:

$$X_2 = \begin{cases} 2 \cdot \overline{p} = 10 & \text{with probability } \frac{1}{4} \\ \overline{p} + \underline{p} = 6 & \text{with probability } \frac{1}{2} \\ 2 \cdot \underline{p} = 2 & \text{with probability } \frac{1}{4} \end{cases}$$

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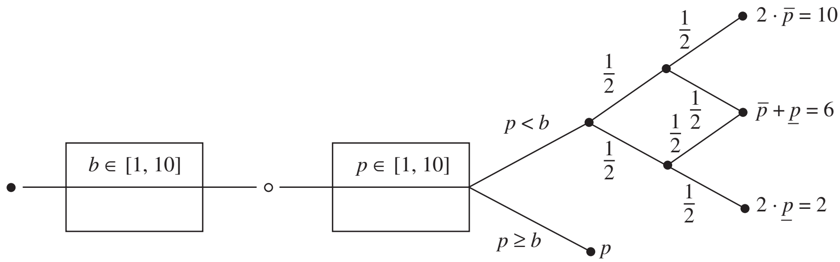

Figure 2. Treatment B.

As mean and standard deviation of the compound lottery X_2 we obtain

$$\mu_2 = 6(=\mu_1) \qquad \sigma_2 = \sqrt{8}\left(=\sigma_1/\sqrt{2}\right)$$

Note that lottery X_1 is a mean-preserving spread of lottery X_2.

As in treatment A, subjects are asked to quote a price $b_2 \in [1, 10]$ for which they would be willing to sell the lottery X_2. The price $p \in [1, 10]$ is randomly drawn from a uniform distribution. For $p > b_2$, the lottery X_2 is sold and the payoff of the subject is p. For $p \leq b_2$, the lottery X_2 is played and the subject receives the lottery payout. Figure 2 illustrates this scenario.

Maintaining the assumption that decision-makers are expected utility maximizers, the expected utility from a bid b is easily computed:

$$V_2(b) := \frac{1}{4}\left[u(2\cdot\overline{p}) + 2\cdot u\left(\overline{p}+\underline{p}\right) + u\left(2\cdot\underline{p}\right)\right]\frac{b-1}{9} + \frac{1}{9}\int_b^{10} u(p)\,\mathrm{d}p$$

and the optimal bid b_2^* is

$$b_2^* = u^{-1}\frac{1}{4}[u(10) + 2\cdot u(6) + u(2)]$$

which is again equal to the certainty equivalent of lottery X_2.

Comparing the optimal bids in treatments A and B, it is not difficult to check the following properties.

- For *risk-averse* decision-makers, $u(\cdot)$ strictly concave,

  $$6 > b_2^* > b_1^* \qquad \text{and} \qquad V_2\left(b_2^*\right) > V_1\left(b_1^*\right)$$

  follows, since X_1 is a mean-preserving spread of X_2.

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- In the case of *risk-neutral* decision-makers, $u(x) = x$, we obtain

$$6 = b_2^* = b_1^* \quad \text{and} \quad V_2\left(b_2^*\right) = V_1\left(b_1^*\right) = 6\frac{8}{9}$$

- For *risk-loving* agents, $u(\cdot)$ strictly convex, we have

$$6 < b_2^* < b_1^* \quad \text{and} \quad V_2\left(b_2^*\right) < V_1\left(b_1^*\right)$$

3.3 Treatment C

In treatment C, subjects face a repeated lottery with the same payoffs as in X_2. In addition, the participants have an opportunity to sell the lottery after the first stage. The endowment of participants is the lottery

$$X_3 = \begin{cases} 2 \cdot \overline{p} = 10 & \text{with probability } \frac{1}{4} \\ \overline{p} + \underline{p} = 6 & \text{with probability } \frac{1}{2} \\ 2 \cdot \underline{p} = 2 & \text{with probability } \frac{1}{4} \end{cases}$$

with mean $\mu_3 = \mu_2 = \mu_1$ and standard deviation $\sigma_3 \sigma_2 = \sigma_1/\sqrt{2}$

In stage 1, the subjects quote a price $b_3 \in [1, 10]$ for which they are willing to sell the lottery. A price $p \in [1, 10]$ is then randomly drawn from a uniform distribution. For $p > b_3$, the lottery X_3 is sold and the payoff of the subject is p. For $p \leq b_3$, the first stage of the lottery X_3 is played.

After observing the outcome of the first stage, $\underline{p} = 1$ or $\overline{p} = 5$, respectively, owners of the lottery who have not sold the lottery in stage 1 can make a second sales offer at prices $\underline{b}_3 := b_3(\underline{p})$ or $\overline{b}_3 := b_3(\overline{p})$, respectively. Again a price $p' \in [1, 10]$ is drawn from a uniform distribution. For $p' \geq \underline{b}_3$ ($p' \geq \overline{b}_3$), the lottery is sold and the payoff of the subject is p'. For $p' < \underline{b}_3$ ($p' < \overline{b}_3$), the second draw of the lottery X_3 takes place and the respective payoffs are realized. Figure 3 illustrates this choice situation.

One can determine the optimal limit prices working backwards. Suppose the lottery was not sold in stage 1. In stage 2, the expected utility from quoting a price $b_3(x)$, which may depend on the previously realized result x, i.e. $\overline{p}$ or $\underline{p}$, is

$$V_3[b(x) \mid x] := \frac{1}{2}\left[u(x + p) + u\left(x + \underline{p}\right)\right]\frac{b(x) - 1}{9} + \frac{1}{9}\int_{b(x)}^{10} u(x + p)\, \mathrm{d}p$$

Choosing $b(x)$ optimally we obtain the limit price $b_3^*(x)$

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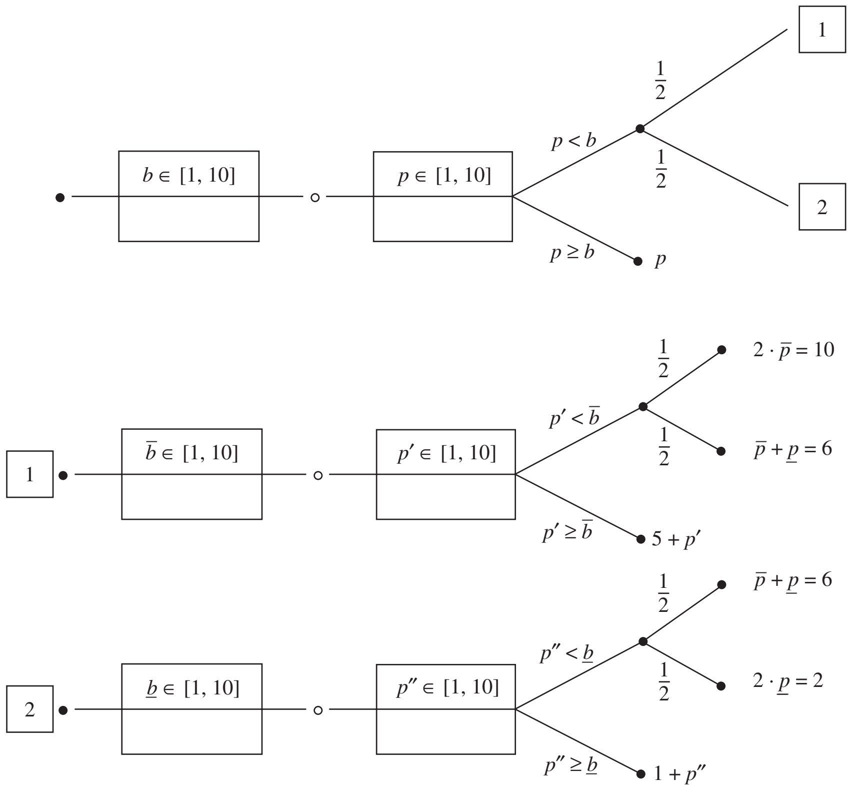

Figure 3. Treatment C.

$$b_3^*(x) = u^{-1}\left(\frac{1}{2}[u(x+1)+u(x+5)]-x\right)$$

and the maximal expected utility attainable with it

$$V_3^*(x) := V_3\left[b_3^*(x) \mid x\right]$$
$$= \frac{1}{2}[u(x+1)+u(x+5)]\frac{b_3^*(x)-1}{9}+\frac{1}{9}\int_{b_{3(x)}^*}^{10} u(x+p)\,\mathrm{d}p$$

For a risk-neutral participant with $u(x) = x$, $V_3^*(x) = x + 5\frac{13}{18}$ and the optimal bid $b_3^*(x) = 3$ is independent of x. Due to the sales option, the second-

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stage lottery yields an additional value of $5\frac{13}{18}$ which is much higher than the expected value of 3 from the second-stage lottery alone.

In stage 1, an expected utility maximizer will choose the limit price such that

$$V_3(b) := \frac{1}{2}\left[V_3^*(\underline{p}) + V_3^*(\overline{p})\right]\frac{b-1}{9} + \frac{1}{9}\int_b^{10} u(p)\,\mathrm{d}p$$

is maximized,

$$b_3^* = u^{-1}\left(\frac{1}{2}\left[V_3^*(\underline{p}) + V_3^*(\overline{p})\right]\right)$$

It is possible not to sell the second-stage lottery by bidding sufficiently high. Hence, the two-stage lottery X_2 is a choice option of the decision-maker. Consequently, $b_3^* \geq b_2^*$ must be true. For a risk-neutral decision-maker with $u(x) = x$, for example, the optimal bid $b_3^* = 8\frac{13}{18}$ exceeds $b_2^* = 6$ and also lottery X_3's certainty equivalent of 6. In fact, one can show that $b_3^* > b_2^*$. This extra value of lottery X_3 is a consequence of the additional sales option in stage 2. The following proposition summarizes the comparison of bids. The proof is straightforward and omitted.

Proposition 1: Suppose decision-makers' preferences satisfy the expected utility hypothesis.

1. If decision-makers are
   - risk averse, then $6 > b_2^* > b_1^*$,
   - risk neutral, then $6 = b_2^* = b_1^*$,
   - risk loving, then $6 < b_2^* < b_1^*$.
2. For any attitude towards risk,

$$b_3^* > b_2^*$$

The higher bids in treatment C reflect the chances of extra profits from the sales mechanism with randomly chosen prices. Decision-makers of any risk attitude will like these extra chances.

3.4 Hypotheses

Based on the assumption that decision-makers are expected utility maximizers with uniform curvature of the von Neumann–Morgenstern

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utility index $u(\cdot)$, our theoretical analysis leads us to propose the following hypotheses.

1. *Expected utility:*
   - either $6 > b_2^* > b_1^*$ (risk aversion),
   - or $6 = b_2^* = b_1^*$ (risk neutrality),
   - or $6 < b_2^* < b_1^*$ (risk preference).
2. *Risk attitudes:* risk attitudes do not depend on whether they are measured by
   - the difference between certainty equivalent and expected value, $b_1^* - 6 \gtreqless 0$, or
   - preferences over mean-preserving spreads, $b_1^* - b_2^* \gtreqless 0$.
3. *Value of the random price mechanism:* individuals do realize that the random price mechanism has an intrinsic value.

Our experimental design should allow us to check these hypotheses. In contrast to non-expected utility theories, expected utility implies that risk-averse individuals have a certainty equivalent below the expected value of the lottery *and* a preference for less dispersed distributions in the sense of mean-preserving spreads. It will be interesting to see whether participants of the experiment will value the extra chances inherent in the random price mechanism as highly as the theory predicts.

4. EXPERIMENTAL PROCEDURE

The experimental sessions were carried out at the Humboldt University in Berlin. Participants were students of economics from a large first-year microeconomics course.[3] For each session, a group of 40 students was recruited. In addition to performing the experimental task, participants were asked to fill in a questionnaire assessing their understanding of the experimental procedure. An English translation of the German instructions is given in appendix B. In order to control for effects due to the novelty of the situation, each treatment was repeated a second time without prior announcement. By this we have tried to exclude the further diversification effect of repeating an experimental decision task involving uncertainty.

Three groups of students participated only in a single treatment. We refer to these groups as between-subjects experiments. A fourth group of students

[3] At this time, the course had not yet introduced concepts of decision-making under risk.

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made decisions on all three treatments. We refer to this group as within-subjects experiments. The between-subjects design confronts different people with different decision tasks. When comparing the different tasks one relies on the homogeneity of these groups. One can control for group homogeneity by asking participants to answer a questionnaire on their characteristics. The within-subjects design avoids such homogeneity problems but may overburden participants and induce less situation-specific behaviour. The within-subjects group offers the opportunity to study consistency of risk attitudes and behaviour across treatments.

A group of 40 students was confronted with the one-stage lottery (treatment A). A second group of 39 students attended the experiment of treatment B. A third group of 38 students was subjected to treatment C.

The group of 40 participants in the within-subjects experiment was split into two subgroups of 20 participants. For the first group of 20, earnings of all three treatments were actually paid. For the second group, the threefold earnings of one randomly selected treatment was paid out. This distinction was made in order to check whether the widespread practice of paying out only one randomly selected outcome would affect the participants' behaviour (see Cubitt *et al*. (1998b)).

5. RESULTS

Two types of results will be distinguished in this section. First, we will deal with the question of whether the observed behaviour is consistent with theoretical predictions based on expected utility theory. These theoretical predictions were derived and formulated in three hypotheses in section 2. In a separate subsection, we will reconsider our results as to their implications for the design of decision-making experiments. The complete data set is given in appendix C.

5.1 Risk attitudes and valuation of the resale option

5.1.1 Risk attitudes

Risk attitudes of expected utility maximizers can be tested either

- by comparing the certainty equivalent of a lottery with its expected value or
- by studying their preference over mean-preserving spreads.

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Table 2. Preference pattern

Risk attitude	Certainty equivalent		Mean-preserving spread
Risk averse	$\mu > b(X(\mu))$	and	$b(X(\mu)) > b(X'(\mu))$
Risk neutral	$\mu = b(X(\mu))$	and	$b(X(\mu)) = b(X'(\mu))$
Risk loving	$\mu < b(X(\mu))$	and	$b(X(\mu)) < b(X'(\mu))$

Table 3. First-round results for initial bids

Method	*Treatment*	*Mean*	*Median*	*Mode*	*Standard deviation*	*Min*	*Max*	*N*
Between	A	6.17	6.0	6.0	1.61	1.0	10.0	40
subjects	B	6.10	6.0	6.0	1.24	2.9	10.0	39
	C	7.31	7.5	6.0	1.35	5.0	9.9	38
Within	A	6.38	6.0	6.0	1.51	2.5	10.0	40
subjects	B	6.60	6.3	6.0	1.67	1.0	10.0	40
	C	7.74	8.0	6.0	1.60	4.7	10.0	40

Denote by $b(X)$ the certainty equivalent of lottery X, and by $X'(\mu)$ a mean-preserving spread of lottery $X(\mu)$. If a decision-maker's preferences satisfy the expected utility hypothesis,[4] then the preference pattern given in table 2 must hold.

Moreover, $\mu > b(X(\mu)) > b(X'(\mu))$ for risk-averse participants, while the reverse inequalities must hold for risk-loving decision-makers.

Examining the average bids for the one-stage lottery in treatment A, we find values of 6.17 and 6.38 in the first round (table 3) and 6.32 and 6.34 in the second round (table 4). At first sight, this suggests that the participants were risk neutral with a slight tendency towards risk-loving behaviour.[5] This overall risk neutrality is confirmed by the results for the mode and median in this treatment. The average bids for the lotteries with a reduced variance in treatment B, their modes and medians also support this picture. Risk neutrality would predict a bid of exactly 6 in both treatments A and B. The null hypothesis of equal bid distributions for treatments A and B in first-round

[4] Note that these two indicators for risk attitude no longer lead to the same classification if the decision-maker's preferences do not satisfy the expected utility hypothesis.

[5] Since we elicit the willingness to accept rather than the one to pay, the fact that average bids are sightly larger than the monetary expectation of the lottery could be caused by an endowment or status quo effect (see Samuelson and Zeckhauser (1988)).

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Table 4. Second-round results for initial bids

Method	*Treatment*	*Mean*	*Median*	*Mode*	*Standard deviation*	*Min*	*Max*	*N*
Between subjects	A	6.32	6.0	6.0	1.87	2.7	10.0	40
	B	6.00	6.0	6.0	1.56	1.0	10.0	39
	C	7.44	7.7	8.0	1.58	3.5	10.0	38
Within subjects	A	6.34	6.0	6.0	1.58	3.0	10.0	40
	B	6.28	6.0	6.0	1.40	1.0	10.0	40
	C	7.37	7.25	6.0	1.60	4.0	10.0	40

bids of the between-subjects design cannot be rejected in a two-tailed Mann–Whitney U test ($p = 0.917$).

This picture of a risk-neutral population of participants is put into question by the comparison of the mean bids in treatments A and B. Except for the first round of the within-subjects case, average bids are slightly higher for the more dispersed lottery in treatment A. This indicates risk-loving behaviour. Though the exceptional within-subjects case may be viewed as suggesting a risk-averse preference for a smaller variance, a one-tailed Wilcoxon test of the null hypothesis that the bid distribution in treatment A is concentrated on lower bids than in treatment B in the first round can be rejected at the 10% level ($p = 0.074$). The comparison of treatments A and B supports the view of a slightly risk-loving population of participants.

The conflicting assessment of the participants' risk attitudes, depending on whether the risk attitude is measured by divergence of the certainty-equivalent bid from the expected value of the lottery or by the preferences over mean-preserving spreads, suggests a closer look at the risk attitudes displayed in the choices of treatments A and B.

5.1.2 Consistency of risk attitudes

As argued in section 2, whether measured by the preference for the expected value of a lottery or by the disliking of mean-preserving spreads, individuals with expected utility preferences should be classified according to their risk attitudes consistently. For individuals with non-expected utility preferences such consistency is not necessary. Since any lottery can be viewed as a mean-preserving spread of its mean, the strong measure of risk attitude of definition 2 will imply the weak notion of definition 1. Since risk attitudes

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are a characteristic of an individual, comparing the bids in treatments A and B of our within-subjects experiments should shed some light on this question.

We classify the risk attitude of participants in the within-subjects design according to the certainty-equivalent bid *and* according to their preferences over mean-preserving spreads. When investigating how many participants were consistent in their risk attitudes, we do not want to rely on small numerical variations in the bids but on rather broad classifications. We will classify a decision-maker as risk neutral if the bid in treatment A, $b(A)$, falls into an interval $[\mu - 0.5, \mu + 0.5]$. Similarly, a subject submitting a bid in treatment B, $b(B)$, in the interval of 0.5 around $b(A)$, $[b(A) - 0.5, b(A) + 0.5]$, will be classified as risk neutral. The deviation of ±0.5 corresponds to approximately 6% of the total variation of payoffs. Table 5 summarizes this classification.

A cross-tabulation according to this classification for both groups of participants in the within-subjects treatments is given in tables 6 and 7. Table 6 tests the consistency of the measurement of risk attitudes in the first round of the within-subjects case.

Most striking is the fact that only a quarter of the participants (11 subjects) were ranked consistently by the two measures. This observation certainly casts doubt on the validity of the assumption that these individuals are expected utility maximizers. Since risk neutrality is a borderline case, we had to construct intervals around the critical values. As a consequence there is necessarily some imprecision of measurement in the neighbourhood of risk neutrality.

Disregarding the middle row and column, there remains a surprisingly large number of subjects (nine participants) who had a certainty-equivalent bid below the expected value of the lottery but did strictly prefer the riskier lottery in treatment A. According to our classification in section 2 these individuals are weakly risk averse but not strongly risk averse. Such behaviour is perfectly acceptable for non-expected utility maximizers.[6]

Table 5. Classification of attitudes towards risk

Risk averse	*Risk neutral*	*Risk loving*
$b(A) < 5.5$	$5.5 \leq b(A) \leq 6.5$	$6.5 < b(A)$
$b(A) + 0.5 < b(B)$	$b(A) - 0.5 \leq b(B) \leq b(A) + 0.5$	$b(B) < b(A) - 0.5$

[6] For example, with the rank-dependent expected utility model one can explain such behaviour easily if the von Neumann–Morgenstern utility function is concave and the probability transformation function is convex. We would like to thank Michelle Cohen for pointing this out to us.

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Table 6. Cross-tabulation of risk attitude classifications: first round

		Preferences for diversification			
		Risk averse	*Risk neutral*	*Risk loving*	*N*
Certainty-	*Risk averse*	0	3	9	12
equivalent	*Risk neutral*	1	10	2	13
based	*Risk loving*	4	10	1	15
	N	5	23	12	40

Table 7. Cross-tabulation of risk attitude classifications: second round

		Preferences for diversification			
		Risk averse	*Risk neutral*	*Risk loving*	*N*
Certainty-	*Risk averse*	5	5	1	11
equivalent	*Risk neutral*	2	12	1	15
based	*Risk loving*	0	10	4	14
	N	7	27	6	40

The four subjects who were ranked as risk loving according to the certainty equivalent and risk averse because of their dislike of mean-preserving spreads are not consistent with the concepts of weak and strong attitudes towards risk. They dislike mean-preserving spreads sometimes but not always.

Table 6 confirms the previous observation that subjects tended to be risk neutral or risk loving. In general, the preference for the more risky lottery was stronger than the ranking according to the certainty-equivalent bid would suggest.

Table 7 cross-tabulates the classification of risk preferences according to preference for diversification and according to the certainty equivalent for the second round of the within-subjects treatment.

The second round shows a more consistent picture. Over 50% of the group (21 subjects) are now ranked the same way by the two measures. Moreover, the extremely inconsistent behaviour of risk-averse subjects according to the certainty-equivalent bid preferring the riskier lottery has nearly disappeared. This could be interpreted as if subjects would need some experience with the treatment before understanding completely the implications of the scenario.

The effect of experience is also reflected in significantly lower bids in the repetition of treatments B and C for the pooled data of the within-subjects

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Table 8. Cross-tabulation of risk attitude in treatment A: first versus second round

		Second round Risk averse	Risk neutral	Risk loving	N
First round	*Risk averse*	5	3	3	11
	Risk neutral	5	8	2	15
	Risk loving	1	2	11	14
	N	11	13	16	40

Table 9. Cross-tabulation of risk attitude in treatment B: first versus second round

		Second round Risk averse	Risk neutral	Risk loving	N
First round	*Risk averse*	6	0	1	7
	Risk neutral	2	19	3	24
	Risk loving	0	2	6	8
	N	8	21	10	39

design ($p = 0.049$ for treatment B and $p = 0.0295$ for first-stage bids in treatment C in a one-tailed Wilcoxon test).

Consistency of the two measures for attitudes toward risk requires some understanding of the concept of a mean-preserving spread. Consistency over the two rounds in terms of certainty-equivalent bids does not rely on such skills. This consistency can also be tested for the between-subjects treatments.

Consider first the between-subjects results of treatment A (see table 8). In this case, 60% of the participants (24 subjects) are consistent in their attitudes towards risk. The dominant risk attitude appears to be risk-loving behaviour. In treatment B, the degree of consistency is even greater. In contrast to treatment A, however, 50% of the participants can be ranked as risk neutral (see table 9).

5.1.3 Preference for resale option

In treatment C, decision-makers could sell the second stage of their lottery if they had not sold the whole lottery in stage 1. Though this lottery resem-

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bles the one in treatment B, the experimental results show a completely different picture. Due to the second sale option after stage 1, decision-makers could profit twice from randomly chosen prices. Our theoretical considerations in section 2 suggest that decision-makers will value highly the extra option to sell in the random price mechanism. The analysis of optimal behaviour in section 3 suggests that, for all types of risk preferences, the first bid in treatment C should exceed the bid in treatment B. In the case of risk neutrality, the first bid should be as high as 8.7.

Indeed, the experimental results show high first-stage bids in treatment C. While the average bid was close to 6 in treatments A and B, it was between 7.31 and 7.74 in treatment C (table 3). The median was similarly upward biased, while the mode remained at the expected value $\mu = 6$. This suggests a strong positive valuation for the additional sales option.

These observations are confirmed by statistical tests of the null hypothesis of higher bids in treatment C. In the first round of treatment C, the distribution of first-stage bids is significantly more concentrated on higher bids than in the first rounds of treatments A and B. Using a one-tailed Mann–Whitney U test for the between-subjects data yields $p = 0.0005$ for treatment C versus treatment A and $p < 0.001$ for treatment C versus treatment B. For the within-subjects data, a one-tailed Wilcoxon test resulted also in $p < 0.001$ both for treatment C versus treatment A and for treatment C versus Treatment B.

Though, in the first round of treatment C, bids clearly exceeded the bids in the other treatments, they did not reach the level 8.72 predicted for a risk-neutral expected utility maximizer in section 3. This more cautious behaviour stands in stark contrast to the risk-loving tendencies in treatments A and B. Obviously, subjects realized the potential to gain from the random price mechanism as our hypothesis in section 4 predicted; however, the exuberance in the face of risk seems to be greatly diminished. It is possible that the participants took this part of the experiment as a more serious task than the pure choices of lotteries.

Probably the most surprising feature of the results, however, is the bids in the second stage of treatment C. Table 10 shows mean bids ranging from 4.14 to 5.97. In the second-stage lottery the expected value equals 3 and the maximum payout from the lottery was 5. The summary statistics in table 10 suggest an extreme risk-liking behaviour. The frequency distributions show bids up to 10, double the maximum outcome of the lottery. Such behaviour is inconsistent with expected utility theory, in fact with any decision theory which is purely consequentialist. In order to explain bids which exceed the maximum payoff of a lottery, a decision-maker has to have an intrinsic preference for gambling.

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Table 10. Second-stage bids in treatment C

Round	*Method*	*Type of bid*	*Mean*	*Median*	*Mode*	*Standard deviation*	*Min*	*Max*	*N*
First	*Between*	$\bar{b}_3$	4.14	4.7	5.0	1.33	1.0	6.0	14
	subjects	$\underline{b}_3$	4.74	4.9	3.0	1.52	2.5	7.5	15
	Within	$\bar{b}_3$	5.56	5.0	4.0	2.05	3.0	10.0	16
	subjects	$\underline{b}_3$	4.75	5.0	5.0	1.65	1.0	8.2	24
Second	*Between*	$\bar{b}_3$	3.94	4.0	3.0	1.54	1.1	6.6	16
	subjects	$\underline{b}_3$	3.86	4.0	5.0	1.21	2.4	5.0	8
	Within	$\bar{b}_3$	4.89	5.0	5.0	1.83	1.0	7.49	14
	subjects	$\underline{b}_3$	5.97	5.5	5.0	1.99	3.0	10.0	12

Of course, participants who did not sell in stage 1 were those with the highest bids in period 1. Thus, there is a selection bias towards more risk-loving participants. Hence, it should not be surprising to find more risk-loving behaviour in the group of second-stage bidders. Yet, bidding more than the maximum amount that could be obtained in the second-stage lottery cannot be reconciled with standard decision theories which insist on valuing only the outcomes of the lottery.[7]

In assessing this extreme overbidding in the second round as inconsistent with any purely consequentialist decision theory, we implicitly assume that participants were not influenced by the random price mechanism itself. In theory the maximum price of the range of random prices should not matter for the incentive to bid the true valuation of the lottery. Hence there was no reason to adjust the price range of the random price mechanism for the second-stage bid where the maximum gain from the lottery was 5. The highest possible random price of 10 was chosen to match the highest price of the compound lottery and maintained for the second-stage bid. In a different context, Bohm *et al*. (1997) report bidding behaviour in the random price mechanism which is sensitive to the range of random prices.

In the light of the observations by Bohm *et al*. (1997), one cannot exclude the possibility that many participants of our experiment were induced by the high price of 10 in the random price mechanism to bid more than 5 when

[7] This argument would, of course, also question the interpretation of average bids b_1 and b_2 exceeding $\mu = 6$ as risk-loving behaviour. The columns 'Max' in tables 3 and 4 show that some participants always preferred to keep the lottery, which would imply extremely risk-loving attitudes.

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Table 11. Competence of participants as measured by the answers to control questions

	Competence level								
	4	3	2	1	0	–1	–2	–3	–4
Treatment A	1	—	0.7	0	0.43	1	0.4	—	0
Treatment B	0.84	—	0.8	0.75	1	1	0.8	0.5	0
Treatment C	—	0.75	1	0.93	1	1	1	0.5	—

selling the second-stage lottery with the maximum prize of 5. The highest price of the random price mechanism may have become the focal point for determining the bid. Thus, some participants may have confused the value of the random price mechanism with the value of the lottery, not understanding the role of the bid as a way to insure against random prices below their valuation of the lottery. These observations suggest that the random price mechanism should be subjected to a severe experimental test of its robustness with regard to the range of random prices.

Finally, the results of table 10 reveal no clear wealth effect. A one-sided Wilcoxon test of the null hypothesis of a higher bid distribution after a low payoff $\underline{p}$ is not supported by the data. There is also no hint of the 'gambler's effect' of an increased expectation of a high outcome as a consequence of a low outcome in stage 1.

5.1.4 Competence of participants

The discrepancies in the risk preferences of participants when measured by certainty equivalents or preferences over mean-preserving spreads suggest that the answers to the questionnaires should be checked to see whether participants did understand the implications of the different lotteries. The questionnaire posed four questions related to the outcome of the lottery and the payoff obtainable from a bid for two results of the draws in the lottery and from the price distribution. Competence of the participant was measured by the sum of the scores of the four questions, where a correct answer was given a mark of 1, a false answer a mark of –1, and no answer was given 0.

Table 11 shows the relationship between competence levels ranging from 4, all answers were correct, to –4, no answer was correct, and the share of subjects within the same competence group who were consistent in their risk attitudes across rounds. The table shows only a slight positive relationship

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between the degree of understanding of the lotteries and of the sales mechanism and the degree of consistency in risk attitudes. We conclude from this that incompetence about the lotteries and the sales mechanism cannot account for the observed inconsistencies in the classification of risk attitudes.

5.2 Methodological issues

Several implications for the design of experiments can be drawn from our observations.

5.2.1 Between- versus within-subjects data

Do participants react significantly to 'method', i.e. to being confronted with only one task (A, B or C) or to all three tasks? When testing this hypothesis we rely on the pooled data of the within-subjects design. At the 1% level homogeneity of the between-subjects and the within-subjects distributions cannot be rejected for treatments A, B and (first-stage bids) C. At the 5% level the (on average negative) difference of first-round bids in treatment B when comparing between- with within-subjects data is significant. In our view, such weak confirmation for one of the altogether six comparisons should not be overrated. Whatever can be learned from our data is supported by both the between-subjects and the within-subjects data.

5.2.2 Effect of random payout

In the within-subjects experiments, half of the 40 participants (group 1) were paid for all three tasks whereas the other half were paid only for one randomly selected task A, B or C. To provide similar monetary incentives for these groups, the randomly selected payoff was tripled.

Comparing the bid distributions of first- and second-round bids in the case of treatment A reveals only one weak ($p = 0.049$) effect in the case of first-stage bids in the first round of treatment C. In our view, such a weak effect for one of altogether eight comparisons (we have pooled the second-period bids $\overline{b}_3$ and $\underline{b}_3$ in treatment C) does not question our former analysis which disregarded the different payment regimes in the case of treatment C and the within-subjects design (see Cubitt *et al.* (1998a), who report positive effects of deterministic versus stochastic payment for a different but related task).

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5.2.3 The random price mechanism for eliciting certainty equivalents

In a recent study, Bohm *et al.* (1997) found that the random price mechanism is sensitive to the support of the price distribution. In particular, the maximum price possible appears to be important for the results of the mechanism. To avoid such effects in our experiment, the random price p' in stage 2 of treatment C was selected from the same interval [1, 10] as the price p in stage 1. The extreme overbidding observed in stage 2 of treatment C may be an unintended consequence of this design choice. Retrospectively, it appears possible that the fact that a price of 10 was possible in stage 2 may have biased upward the bids of the participants. Such a bias may, of course, have influenced also bids in the other treatments.

6. CONCLUDING REMARKS

We can summarize our main findings by the following effects.

1. Subjects show risk neutrality or risk-loving behaviour.
2. Consistency in risk attitudes across repetitions and for different measures of risk attitudes is limited.
3. Subjects are aware of the value of the resale option due to the random price mechanism.
4. Subjects bid unreasonably high in second sale.

A noticeable result of our experiment is the observation that, in this simple lottery context, the behaviour of a large number of participants appears to be consistent with expected utility theory and risk-loving or risk-neutral preferences. The large group of subjects who were classified as weakly risk averse but strongly risk loving in the within-subjects experiments suggests, however, that at least a substantial proportion of subjects may be better characterized by non-expected utility theories.

It is also consistent with expected utility theory that bids in stage 1 of treatment C were significantly higher than bids in treatment B. In these respects expected utility theory appears to be sufficiently flexible to explain these observations. Other results of our experiment are harder to reconcile with well-known theories of behaviour under risk. The overbidding in stage 2 of treatment C is incompatible not only with expected utility theory but with any purely consequentialist explanation.

There are, of course, competing explanations for some of our observations. The risk-loving behaviour could also be explained by an endowment effect

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(see footnote 5). Inconsistency in the risk preferences across treatments could be due to people who are variety seeking not only in consumption but also in risk taking. The unreasonable high bids in stage 2 of treatment C may be a consequence of the sensitivity of the random price mechanism to the maximum price in the random price distribution.

Despite these additional considerations, our study leaves us with two lessons which point out new routes for further research.

1. On the one hand, our experimental results cast some doubts on the robustness of various theoretically well-established measures of risk attitudes as a stable feature of an individual's preferences. When we designed our experiment we did not expect that risk attitudes would be a critical aspect in our setup. The two-stage lottery design offered the opportunity to test the two commonly used notions of risk aversion. Such a direct test had not been performed before and we expected behaviour consistent with both the expected-value-based measure and the mean-preserving-spread-based measure as predicted by expected utility theory. Though we observed more consistent behaviour in the repetition of our experiment, there are sufficient doubts to warrant further research. In particular, our experiment suggests use of the classification of individuals' preferences according to the two concepts of risk aversion to test whether individ-uals' preferences are better represented by the expected utility hypothesis or by non-expected utility theories. Only expected utility requires both concepts to coincide. Rank-dependent theories predict only strongly risk-averse individuals to be weakly risk averse. This distinction suggests new experiments testing risk attitudes directly.
2. On the other hand, our experiments question the random price mechanism as an appropriate tool to elicit true valuations, in particular in sequential decisions. The mechanism assumes that individuals who face the lottery of the random price mechanism realize that the value of the object which they offer to sell serves as a hedge against low prices. In particular, a bid does not compromise their chances for obtaining high prices. Hence, the upper limit of the mechanism's price range should not matter for their bid. Yet there is no doubt that the mechanism has a value which is clearly recognized by the subjects in their bidding behaviour. Moreover, as the extreme overbidding of the second-stage valuation of the lottery indicates, people may confuse the values of the lottery and the mechanism. In any case, as a widely used mechanism for the truthful elicitation of valuations, the random price mechanism deserves further scrutiny. One

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must carefully test its suitability for the evaluation of lotteries and in sequential decision scenarios.

APPENDIX A: OPTIMAL BIDS

Optimal behaviour in treatment A

Straightforward calculation shows that $V_1(b)$ is a concave function if the von Neumann–Morgenstern utility index u is a strictly increasing function.

In this treatment, subjects face the decision problem

choose $b \in [1, 10]$ such that $V_1(b)$ is maximized

Differentiating $V_1(b)$ yields the following first-order condition which is also sufficient because $V_1(b)$ is concave:

$$\frac{u(2 \cdot \underline{p}) + u(2 \cdot \overline{p})}{2} - u\left(b_1^*\right) = 0$$

It is optimal for the decision-maker to offer the certainty equivalent of the lottery as limit price for which the lottery will be sold. Solving for b_1^* yields the optimal quote for the sales price:

$$b_1^* = u^{-1}\left(\frac{u(2 \cdot \underline{p}) + u(2 \cdot \overline{p})}{2}\right) = u^{-1}\left(\frac{u(2) + u(10)}{2}\right)$$

Optimal behaviour in treatment B

$V_2(b)$ is concave if u is a strictly increasing function. The first-order conditions of the problem

choose $b \in [1, 10]$ such that $V_2(b)$ is maximized

are necessary and sufficient:

$$\frac{1}{4}\left[u(2 \cdot \overline{p}) + 2 \cdot u\left(\overline{p} + \underline{p}\right) + u(2 \cdot \underline{p})\right] - u\left(b_2^*\right) = 0$$

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One obtains again a limit price equal to the certainty equivalent of lottery X_2,

$$b_2^* = u^{-1}\left(\frac{1}{4}\left[u(2\cdot\overline{p}) + 2\cdot u(\overline{p}+\underline{p}) + u(2\cdot\underline{p})\right]\right)$$
$$= u^{-1}\left(\frac{1}{4}[u(10) + 2\cdot u(6) + u(2)]\right)$$

Optimal behaviour in treatment C

One can determine the optimal limit prices working backwards. Suppose the lottery was not sold in stage 1. In stage 2 a limit price $b_3^*(x)$ will be determined which may depend on the previously realized result x, i.e. $\overline{p}$ or $\underline{p}$. The expected utility from quoting a price $b_3(x)$ is

$$V_3[b(x)\,|\,x] := \frac{1}{2}\left[u(x+\underline{p}) + u(x+\overline{p})\right]\frac{b(x)-1}{9} + \frac{1}{9}\int_{b(x)}^{10} u(x+p)\,\mathrm{d}p$$

The optimization problem

choose $b \in [1,10]$ such that $V_3[b(x)|x]$ is maximized

yields the first-order condition

$$\frac{1}{2}\left[u(x+\underline{p}) + u(x+\overline{p})\right] - u\left[x + b_3^*(x)\right] = 0$$

Hence,

$$b_3^*(x) = u^{-1}\left(\frac{1}{2}\left[u(x+\underline{p}) + u(x+\overline{p})\right] - x\right)$$
$$= u^{-1}\left(\frac{1}{2}[u(x+1) + u(x+5)] - x\right)$$

and

$$V_3^*(x) := V_3\left[b_3^*(x)\,|\,x\right]$$
$$= \frac{1}{2}\left[u(x+\underline{p}) + u(x+\overline{p})\right]\frac{b_3^*(x)-1}{9} + \frac{1}{9}\int_{b_3^*(x)}^{10} u(x+p)\mathrm{d}p$$
$$= \frac{1}{2}[u(x+1) + u(x+5)]\frac{b_3^*(x)-1}{9} + \frac{1}{9}\int_{b_3^*(x)}^{10} u(x+p)\mathrm{d}p$$

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In stage 1, an expected utility maximizer will choose the limit price such that

$$V_3(b) := \frac{1}{2}\left[V_3^*(\underline{p}) + V_3^*(\overline{p})\right]\frac{b-1}{9} + \frac{1}{9}\int_b^{10} u(p)\mathrm{d}p$$

is maximized. From the first-order condition

$$\frac{1}{2}\left[V_3^*(\underline{p}) + V_3^*(\overline{p})\right] - u\left(b_3^*\right) = 0$$

we compute

$$b_3^* = u^{-1}\left(\frac{1}{2}\left[V_3^*(\underline{p}) + V_3^*(\overline{p})\right]\right)$$

APPENDIX B: INSTRUCTIONS (ENGLISH TRANSLATION)

Treatment A [B]

Welcome to our experiment! Please read these instructions carefully! Do not talk to your neighbours and keep quiet during the entire experiment. If you have a question, give notice. We will then come to you.

In this experiment you will have to make a few decisions. How much money you will finally earn depends on your own decisions as well as on chance moves.

You have the opportunity to participate in a lottery which pays in periods 1 and 2 either DM5.00 or DM1.00. How is it decided which of the payoffs the lottery generates in the two periods?

You will throw a die once [twice].

- You win in period 1 and 2 DM5.00 if the die shows an even number. [You win DM5.00 each time the die shows an even number.]
- You win in period 1 and 2 DM1.00 if the die shows an odd number. [You win DM1.00 each time the die shows an odd number.]

You can now keep the lottery and participate in it or you can sell it to us (the experimenters).

How can you sell the lottery, in case you want to?

For this purpose you have to determine a lower price limit *b* (*b* has to lie between DM1.00 and DM10.00). You will sell the lottery at a randomly

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chosen price p, if p is larger than your price limit b. Otherwise you will keep the lottery and participate in it. The price p will be randomly selected from the set of all prices:

$$\text{DM}1.10, \text{DM}1.20, \ldots, \text{DM}9.90, \text{DM}10.00 \tag{*}$$

Please note that your price limit b does not determine the price at which you sell the lottery but the interval ($b < p \leq$ DM10.00) of prices p for which you are willing to sell the lottery. Therefore, the price limit optimal for you is the price p at which selling and not selling the lottery appears equally favourable.

Please note further that by choosing $b =$ DM10.00 you can ensure keeping the lottery independent of the randomly drawn price. In contrast to this you can ensure to sell the lottery in any case by the choice of $b =$ DM1.00.

For a better understanding of the rules the sequence of events is listed again.

1. You determine your lower price limit b. (As explained above, this is the price limit above which you are willing to sell the lottery to us.)
2. The price p is randomly selected. (For this purpose, somebody will reach into a bowl with chips. The chips carry the prices listed in (*).
3. If $p > b$, you will sell the lottery to us. In this case your payoff will be DM p.
4. If $p \leq b$, you will keep the lottery and participate in it. It will be played by you by throwing the die once [twice]. In this case you will receive the payoff of the lottery as described above.

The decision is made on a separate form, which we will soon hand out to all participants.

You will receive a code-number to keep your anonymity towards us. Please keep your code-card carefully, because you will later receive your payment only when presenting it.

Treatment C

Welcome to our experiment! Please read these instructions carefully! Do not talk to your neighbours and keep quiet during the entire experiment. If you have a question, give notice. We will then come to you.

In this experiment you will have to make a few decisions. How much money you will finally earn depends on your own decisions as well as on chance moves.

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You have the opportunity to participate in a lottery which pays in periods 1 and 2 either DM5.00 or DM1.00. How is it decided which of the payoffs the lottery generates in the two periods?

You will throw a die twice.

- You win DM5.00 each time the die shows an even number.
- You win DM1.00 each time the die shows an odd number.

You can now keep the lottery and participate in it or you can sell it to us (the experimenters).

How can you sell the lottery, in case you want to?

In the first place you can sell the lottery as a whole. To do this you have to determine a lower price limit b (b has to lie between DM1.00 and DM10.00). You will sell the entire lottery at a randomly chosen price p, if p is larger than your price limit b. Otherwise you will keep the lottery and participate in it by throwing the die once. The price p will be randomly selected from the set of all prices:

$$\text{DM}1.10, \text{DM}1.20, \ldots, \text{DM}9.90, \text{DM}10.00 \tag{*}$$

If you have not sold the entire lottery, you can again sell your payoff claims from the second throw of the die. This follows according to the same procedure as above.

Please note that your price limit b does not determine the price at which you sell the entire lottery (respectively your payoff claims from the second throw of the die), but the interval ($b < p \leq \text{DM}10.00$) of prices p, for which you are willing to sell the entire lottery (respectively your payoff claims from the second throw of the die). Therefore, the price limit optimal for you is the price p at which selling and not selling the lottery appears equally favourable.

Please note further that by choosing $b = \text{DM}10.00$ you can ensure keeping your payoff claims from each throw of the die independent of the randomly drawn price. In contrast to this you can ensure to sell the entire lottery (respectively your payoff claims from the second throw of the die) in any case by the choice of $b = \text{DM}1.00$.

For a better understanding of the rules the sequence of events is listed again.

1. You determine your lower price limit b for the entire lottery. (As explained above, this is the price limit above which you are willing to sell the entire lottery to us.)

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2. The price p is randomly selected. (For this purpose, somebody will reach into a bowl with chips. The chips carry the prices listed in (*).)
3. If $p > b$, you will sell the entire lottery to us. In this case your payoff will be DM p and the experiment ends.
4. If $p \leq b$, you will keep the lottery and participate in it and the experiment will be continued. The first period of the lottery will be played by you by throwing the die once. The respective payoff is your profit of the first period.
5. You can now sell your payoff claims from the second throw of the die by again determining a lower price limit b.
6. A second price p is randomly determined.
7. If $p > b$ you will sell your payoff claims from the second throw of the die. In this case your payment is DM p plus your profits from the first period.
8. If $p \leq b$ you will keep your payoff claims from the second throw of the die. The second period of the lottery is then played by you throwing the die again. Your payment is then the sum of the respective profits from the first and the second throw of the die.

The decision(s) are made on a separate form, which we will soon hand out to all participants. You will receive a code-number to keep your anonymity towards us. Please keep your code-card carefully, because you will later receive your payment only when presenting it.

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APPENDIX C: DATA

1. Between-subjects treatments

	Treatment A			*Treactment B*	
Subject	*First-round bid*	*Second-round bid*	*Subject*	*First-round bid*	*Second-round bid*
a-1	5.00	6.00	b-1	10.00	10.00
a-2	8.00	6.00	b-2	5.00	5.00
a-3	7.90	7.50	b-4	6.00	6.00
a-4	5.50	5.50	b-5	6.50	7.00
a-5	6.00	6.00	b-6	6.00	6.00
a-6	5.40	6.80	b-7	6.00	6.00
a-7	7.99	7.99	b-8	6.00	6.00
a-8	4.90	10.00	b-9	6.00	5.00
a-9	5.00	5.00	b-10	4.00	4.50
a-10	4.00	3.00	b-11	4.90	1.00
a-11	1.00	10.00	b-12	8.00	6.00
a-12	7.50	7.50	b-13	6.00	6.00
a-13	8.00	8.00	b-14	6.10	6.10
a-14	6.00	6.00	b-15	8.00	6.00
a-15	7.00	5.00	b-16	5.99	5.99
a-16	5.50	4.50	b-17	6.00	6.00
a-17	8.00	8.00	b-18	2.90	3.00
a-18	6.90	6.90	b-19	6.00	6.00
a-19	6.00	5.00	b-20	6.00	6.00
a-20	4.50	3.20	b-21	6.00	6.00
a-21	7.00	5.60	b-22	5.90	5.90
a-22	5.50	5.00	b-23	6.00	6.00
a-23	6.00	6.00	b-24	7.00	7.00
a-24	6.50	7.50	b-25	6.10	3.90
a-25	3.50	6.30	b-26	4.00	4.00
a-26	5.50	5.50	b-27	6.00	6.00
a-27	6.00	2.70	b-28	6.00	10.00
a-28	6.00	9.50	b-29	8.00	8.00
a-29	9.00	8.00	b-30	6.70	7.20
a-30	7.49	7.40	b-31	5.10	7.00
a-31	5.00	6.00	b-32	5.50	5.50
a-32	5.90	5.90	b-33	5.00	5.00
a-33	5.00	4.00	b-34	5.90	5.90
a-34	5.00	5.00	b-35	5.90	5.90

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	Treatment A			*Treactment B*	
Subject	*First-round bid*	*Second-round bid*	*Subject*	*First-round bid*	*Second-round bid*
a-35	6.80	7.20	b-36	6.00	6.00
a-36	6.00	6.00	b-37	5.90	6.00
a-37	6.40	6.40	b-38	8.40	7.50
a-38	8.00	8.00	b-39	6.00	7.00
a-39	10.00	10.00	b-40	7.00	6.70
a-40	6.00	3.00			

Treatment C

	First round				*Second round*			
Subject	*Bid 1*	*Prize 1*	*Bid 2*	*Prize 2*	*Bid 1*	*Prize 1*	*Bid 2*	*Prize 2*
c-1	6.10	—	—	—	6.10	—	—	—
c-2	7.00	—	—	—	7.90	—	—	—
c-4	5.90	—	—	—	8.90	—	—	—
c-5	6.91	—	—	—	7.39	—	—	—
c-6	8.50	$\underline{p}$	7.49	$\underline{p}$	8.50	—	—	—
c-7	6.90	—	—	—	8.00	—	—	—
c-8	6.00	—	—	—	6.00	—	—	—
c-9	6.00	—	—	—	5.00	—	—	—
c-10	9.00	$\bar{p}$	5.00	$\bar{p}$	7.00	—	—	—
c-11	9.90	$\bar{p}$	1.00	—	9.90	$\bar{p}$	1.80	—
c-12	6.00	—	—	—	6.50	—	—	—
c-13	8.00	$\bar{p}$	4.00	$\underline{p}$	8.00	—	—	—
c-14	8.00	$\bar{p}$	5.00	$\bar{p}$	8.00	—	—	—
c-15	8.50	$\bar{p}$	5.00	$\underline{p}$	7.50	—	—	—
c-16	6.00	—	—	—	6.00	—	—	—
c-17	8.00	$\underline{p}$	4.40	$\underline{p}$	10.00	$\underline{p}$	2.40	$\bar{p}$
c-18	6.00	$\underline{p}$	3.00	—	6.00	$\underline{p}$	3.00	$\bar{p}$
c-19	8.60	$\underline{p}$	4.50	$\underline{p}$	7.50	$\bar{p}$	6.60	$\bar{p}$
c-20	8.00	$\bar{p}$	4.00	$\bar{p}$	8.00	$\bar{p}$	4.00	$\bar{p}$
c-21	8.50	$\bar{p}$	4.50	$\underline{p}$	8.50	$\bar{p}$	5.00	$\bar{p}$
c-22	6.00	$\underline{p}$	3.00	—	6.00	$\bar{p}$	3.00	$\bar{p}$
c-23	7.50	$\underline{p}$	7.50	$\bar{p}$	7.50	$\bar{p}$	4.00	$\bar{p}$
c-24	5.00	$\bar{p}$	5.00	$\underline{p}$	5.00	$\underline{p}$	5.00	$\underline{p}$
c-25	5.10	$\bar{p}$	4.90	$\underline{p}$	5.20	$\bar{p}$	1.10	—
c-26	7.50	$\bar{p}$	2.50	—	7.00	$\bar{p}$	3.00	—
c-27	7.50	$\underline{p}$	6.00	—	9.00	$\bar{p}$	2.50	—

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Treatment C

	First round				*Second round*			
Subject	*Bid 1*	*Prize 1*	*Bid 2*	*Prize 2*	*Bid 1*	*Prize 1*	*Bid 2*	*Prize 2*
c-28	5.90	$\underline{p}$	3.00	—	5.90	$\underline{p}$	4.90	—
c-29	8.00	$\underline{p}$	4.00	—	9.00	$\overline{p}$	3.70	—
c-30	6.00	$\underline{p}$	2.50	—	6.00	$\underline{p}$	2.50	—
c-31	5.90	$\underline{p}$	4.90	—	8.90	$\overline{p}$	4.00	—
c-32	6.00	$\overline{p}$	3.00	—	6.00	$\overline{p}$	3.00	—
c-33	7.00	$\overline{p}$	6.00	—	8.00	$\overline{p}$	5.00	—
c-34	9.90	$\underline{p}$	5.90	—	10.00	$\underline{p}$	5.00	—
c-35	9.00	$\underline{p}$	3.10	—	9.00	$\underline{p}$	3.10	—
c-36	7.80	$\underline{p}$	5.00	—	8.00	$\underline{p}$	5.00	—
c-37	8.00	$\underline{p}$	5.00	—	3.50	$\overline{p}$	6.50	—
c-38	8.00	$\overline{p}$	5.00	—	8.00	$\overline{p}$	5.00	—
c-39	9.90	$\underline{p}$	4.90	—	9.90	$\overline{p}$	4.90	—

2. Within-subjects treatments

Group 1 (earnings of all three treatments were actually paid)
First round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
1	5.00	5.00	9.00	$\overline{p}$	5.00	—
2	5.00	6.00	9.00	$\overline{p}$	4.00	—
3	5.10	6.10	6.10	$\overline{p}$	3.20	—
4	8.40	7.60	8.90	$\underline{p}$	4.00	—
5	6.50	6.00	10.00	$\underline{p}$	4.00	—
6	6.00	7.00	8.00	$\underline{p}$	4.90	—
7	6.00	6.80	6.00	$\underline{p}$	2.60	—
8	5.00	10.00	10.00	$\underline{p}$	5.00	—
9	7.50	7.00	9.80	$\overline{p}$	5.50	—
10	5.00	10.00	7.50	$\overline{p}$	7.50	—
11	5.00	9.80	9.80	$\underline{p}$	8.20	—
12	5.00	7.00	9.90	$\underline{p}$	4.90	—
13	6.00	6.00	9.00	$\underline{p}$	3.00	—
14	2.50	5.00	6.00	$\underline{p}$	5.00	—
15	5.00	6.00	10.00	$\overline{p}$	5.00	—
16	8.00	8.00	9.00	$\underline{p}$	8.00	$\overline{p}$

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First round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
17	10.00	1.00	8.50	$\underline{p}$	5.00	—
18	5.10	5.90	8.50	$\bar{p}$	6.00	—
19	8.00	8.00	7.00	$\bar{p}$	5.00	—
20	9.00	6.00	6.00	$\bar{p}$	4.00	—

Second round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
1	3.00	1.00	6.00	$\underline{p}$	5.00	$\underline{p}$
2	10.00	6.00	6.00	$\bar{p}$	5.00	$\underline{p}$
3	4.00	4.00	6.00	$\bar{p}$	3.00	—
4	6.00	6.00	8.00	$\bar{p}$	6.00	$\bar{p}$
5	5.00	6.00	9.00	$\bar{p}$	3.00	—
6	6.00	7.00	8.00	$\underline{p}$	4.90	—
7	5.80	6.80	6.50	$\bar{p}$	2.90	—
8	10.00	4.80	6.70	$\bar{p}$	5.70	$\bar{p}$
9	6.00	6.00	9.50	$\underline{p}$	6.50	$\bar{p}$
10	5.00	7.00	6.20	$\bar{p}$	6.80	$\bar{p}$
11	6.90	7.40	8.40	$\underline{p}$	8.40	$\bar{p}$
12	7.00	6.50	9.90	$\underline{p}$	5.00	$\bar{p}$
13	6.00	6.00	9.00	$\underline{p}$	3.00	$\bar{p}$
14	5.50	6.00	6.50	—	—	—
15	5.00	6.00	10.00	$\bar{p}$	5.00	$\bar{p}$
16	8.00	8.00	9.00	$\bar{p}$	7.00	$\underline{p}$
17	7.50	8.00	8.50	$\underline{p}$	6.00	$\bar{p}$
18	5.10	5.60	8.20	$\bar{p}$	5.60	$\bar{p}$
19	6.00	6.00	8.00	$\bar{p}$	5.00	$\bar{p}$
20	5.00	5.00	5.00	—	—	—

Group 2 (one randomly selected treatment was paid out)
First round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
1	6.00	6.00	6.00	$\underline{p}$	3.00	—
2	6.00	6.00	6.00	$\underline{p}$	3.00	—
3	8.00	8.00	8.00	$\bar{p}$	8.00	—
4	6.50	6.80	8.00	$\bar{p}$	4.00	—
5	6.00	6.00	10.00	$\underline{p}$	6.00	—

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First round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
6	10.00	10.00	10.00	$\bar{p}$	10.00	$\bar{p}$
7	6.80	6.80	7.20	$\bar{p}$	7.20	—
8	5.10	5.10	5.00	$\bar{p}$	4.00	—
9	7.00	7.00	7.00	$\bar{p}$	3.00	—
10	6.00	6.00	6.00	$\underline{p}$	6.00	—
11	6.00	6.00	8.00	$\underline{p}$	6.00	—
12	5.90	5.00	5.90	$\underline{p}$	5.00	—
13	7.50	7.50	7.00	$\bar{p}$	3.50	—
14	6.59	7.99	7.99	$\bar{p}$	7.99	—
15	7.00	7.00	8.00	$\underline{p}$	1.00	—
16	6.50	6.50	6.50	$\underline{p}$	6.00	—
17	5.50	6.00	6.90	$\underline{p}$	3.30	—
18	7.81	4.71	9.80	$\underline{p}$	6.11	—
19	4.90	4.70	4.70	$\underline{p}$	5.00	—
20	6.80	6.80	6.80	$\underline{p}$	5.00	—

Second round

Subject	*Bid A*	*Bid B*	*Bid C1*	*Prize 1*	*Bid C2*	*Prize 2*
1	6.00	6.00	6.00	—	—	—
2	6.00	6.00	6.00	—	—	—
3	8.00	8.00	8.00	$\underline{p}$	8.00	$\underline{p}$
4	5.00	8.00	8.00	$\underline{p}$	4.00	—
5	6.00	6.00	10.00	$\underline{p}$	6.00	—
6	10.00	10.00	10.00	$\underline{p}$	10.00	$\underline{p}$
7	6.90	7.20	7.50	$\underline{p}$	4.80	—
8	5.10	5.10	5.10	—	—	—
9	7.00	7.00	7.00	—	—	—
10	6.00	6.00	6.00	—	—	—
11	6.00	6.00	8.00	$\underline{p}$	5.00	—
12	5.80	5.00	5.90	—	—	—
13	6.00	6.00	6.50	—	—	—
14	4.99	7.99	7.99	$\bar{p}$	7.49	$\bar{p}$
15	7.00	7.00	10.00	$\bar{p}$	1.00	—
16	6.50	6.50	6.50	—	—	—
17	6.90	6.00	4.00	—	—	—
18	10.00	6.61	6.21	—	—	—
19	5.00	5.00	5.00	—	—	—
20	6.80	6.80	6.80	—	—	—

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Jürgen Eichberger
Department of Economics
Ruprecht Karls University Heidelberg
Economic Theory I
Alfred Weber Institut
Grabengasse 14
69117 Heidelberg
Germany
E-mail: juergen.eichberger@awi.uni-heidelberg.de

Werner Güth
Max Planck Institute for Research into Economic Systems
Kahlaische Strasse 10
07745 Jena
Germany
E-mail: gueth@mpiew-jena.mpg.de

Wieland Müller
Department of Economics
Humboldt University Berlin
Spandauer Strasse 1
10178 Berlin
Germany
E-mail: wmueller@wiwi.hu-berlin.de

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