The Incentive Effects of Uncertainty in Tournaments

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Abstract

Employees are exposed to different sources of uncertainty when competing in tournaments. First, they face the outcome risk of winning or losing. Second, they face prize risk in promotion tournaments due to the stochastic option value of future promotion possibilities. In addition, employees face strategic uncertainty, since they compete against a performance standard that is endogenously determined by the effort of their opponent. This paper investigates empirically whether and how these sources of uncertainty affect incentives to provide effort. In the absence of strategic uncertainty, we find that outcome risk strongly increases average effort, while prize risk does not affect effort on average. Averages hide substantial variation in individual responses to outcome and prize risk that depend on gender as well as on second- and third-order risk attitudes. We also find that agents reduce effort in response to strategic uncertainty, particularly in the presence of outcome or prize risk.

JEL codes: C72, C91, D81, D83, J33, M12, M51, M52

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1 Introduction

Tournament contracts that are based on relative rather than absolute performance measures are frequently used for the provision of incentives in firms and organizations. Even though contracts of this type are not generally superior to alternative pay-for-performance schemes (Lazear and Rosen, 1981; Green and Stockey, 1983; Nalebuff and Stiglitz, 1983), they have several desirable features. In particular, tournament contracts are well suited to deal with indivisible rewards, they help to reduce monitoring costs due to the fact that ordinal rankings are sufficient, and they eliminate uncertainty resulting from common productivity shocks (O'Keefe et al., 1984).

The incentive properties of tournaments have generally been studied extensively both theoretically and empirically.[1] Surprisingly little is known about the reaction of competitors to the specific uncertainty they are exposed to in tournaments, however. Existing contributions have focused on the reaction of risk averse agents to uncertainty on the *extensive* margin. The respective literature has convincingly shown that risk averse agents self-select into fixed wage schemes to avoid the uncertainty inherent in pay for performance schemes if they have a choice (Cadsby et al., 2007; Dohmen and Falk, 2011).[2] Risk averse employees are most likely unable to avoid tournaments by occupational sorting, however. Tournaments are prevalent both in occupations for high-skilled employees as well as in less skill intensive environments – think of bonus tournament for bankers and fund managers, or of 'employee of the week/month' tournaments in retail chains, for example. Moreover, even if current income is not tied to individual performance measures, the prospect of being promoted to a better-paid job generates tournament incentives in any organization with a pyramidal organizational structure that does not exclusively rely on external hiring policies. Consequently, occupations where (promotion) tournament incentives are entirely absent are likely to be the exception rather than the rule.

This paper investigates empirically how agents react on the *intensive* margin to the uncertainty they are exposed to in tournaments. In particular, we consider three different sources of uncertainty that employees are typically exposed to in promotion tournaments. First, the outcome distribution in tournaments is binary, i.e., employees face the 'outcome risk' of winning or losing, respectively. Second, promotion prizes typically entail a stochastic component, namely the option value of participation in later stages of the promotion tournament (Rosen, 1986). The stochastic option value often accounts for a large share of promotion prizes and is particularly important for incentives if the wage structure across hierarchy levels is convex, suggesting that employees are typically ex-

[1] McLaughlin (1988) surveys theoretical contributions. Empirical contributions based on personnel data include Knoeber and Thurman (1994), Eriksson (1999), and Bognanno (2001). For evidence from laboratory experiments see Bull et al. (1987), Schotter and Weigelt (1992), Harbring and Irlenbusch (2003), Altmann et al. (2012), and the references cited therein.

[2] See also Bonin et al. (2007), Bellemare and Shearer (2010), or Grund and Sliwka (2010).

posed to 'prize risk' in promotion tournaments. In addition, employees arguably face 'strategic uncertainty'.[3] They compete against a performance standard that is endogenously determined by the effort choice of their opponent, and the effort choice of the opponent is ultimately determined by individual characteristics that are often unobservable.

From a theoretical perspective, the reaction of risk averse agents to outcome risk depends on the expected effort choice of the opponent (McGuire et al., 1991). In particular, risk averse agents are predicted to respond to outcome risk by providing more (less) effort than risk neutral agents if they expect low (high) effort by the opponent.[4] The impact of outcome risk on Nash equilibrium effort provision of risk averse agents in homogeneous tournaments depends on third-order risk attitudes, as recently shown by Treich (2010). In particular, risk averse agents provide less (more) effort than risk neutral agents in equilibrium if they are prudent (imprudent). Outcome risk should not affect behavior of risk neutral agents, however. Theory also predicts that prize risk leaves effort choices of risk neutral agents unaffected. Risk averse agents, instead, are predicted to provide less effort than risk neutral agents for any given level of effort provided by the opponent (Guigou et al., 2017).

While theory predicts that only risk averse employees react to outcome risk and prize risk, respectively, strategic uncertainty might affect effort choices of any employee, independent of risk attitudes. It is a well-established finding that the variance of effort choices in tournaments is high (Bull et al., 1987; van Dijk et al., 2001), which implies that tournament participants are typically exposed to strategic uncertainty regarding the effort provided by the opponent.[5] Generally speaking, the optimal response to strategic uncertainty is often hard to assess. We consider a setting that allows us to test whether agents account for strategic uncertainty when choosing their own effort or not, however. In particular, agents who *know* that their opponent chooses equilibrium effort should provide more effort in the setting we consider than agents who only *expect* equilibrium effort by their opponent if they take strategic uncertainty into account.[6]

We use controlled variation in laboratory experiments to identify the reaction of participants to outcome risk, prize risk and strategic uncertainty in pairwise interactions. The experiment is designed such that the aforementioned sources of risk and uncertainty are switched on and off

[3] We use the term 'risk' if the probability distribution of outcomes is objectively known, as in case of 'outcome risk' and 'prize risk', respectively. Instead, we use the term 'uncertainty' if the probability distributions of outcomes is based on subjective expectations and beliefs, as in case of 'strategic uncertainty'.

[4] Intuitively, chances to win the tournament prize are ceteris paribus decreasing in the effort provided by the opponent. Therefore, risk averse agents are willing to pay a premium in terms of effort costs to 'insure' themselves against the downside risk of losing if effort by the opponent is low and they are likely to win. In contrast, risk averse agents are unwilling to 'gamble' if effort by the opponent is high and they are thus likely to lose.

[5] In theoretical models, it is common to assume common knowledge of types. This assumption eliminates strategic uncertainty, since agents compute best-responses and implement Nash equilibrium efforts. Common knowledge of all individual characteristics that determine the effort choice of the opponent is unrealistic in real-life tournaments, however.

[6] Importantly, this theoretical prediction on the response to strategic uncertainty depends only on the expected response by the opponent and can thus be tested with elicited point beliefs. Information on the shape of the subjective probability distribution regarding effort provided by the opponent over the entire strategy space is not necessary due to the inverted U-shape of the best-response function.

within subjects in different parts of an experimental session. In a first step, we elicit the entire best-response function of all participants in the baseline condition (BL) where agents compete for shares of a deterministic tournament prize. In addition, we elicit the best-response function of participants in the outcome risk condition (OR) and the prize risk condition (PR). The only difference between BL and OR is that participants are exposed to outcome risk in the latter, but not in the former. In particular, agents compete for shares of a divisible tournament prize in BL, while the winner receives the entire indivisible tournament prize in OR. Similarly, the only difference between BL and PR is that participants are exposed to prize risk in the latter, but not in the former. The stochastic tournament prize in PR has the same expected value as the deterministic prize in BL, but a higher variance. To infer the impact of outcome and prize risk on equilibrium effort provision in tournaments with homogeneous agents, we compare effort at the intersection of the elicited best-response function with the 45-degree line across conditions.

Best-response functions define optimal effort for any given effort choice of the opponent, such that they cannot be affected by strategic uncertainty. This implies that the previously described comparison of best-response functions across conditions isolates the effects of outcome risk and prize risk in the absence of strategic uncertainty. To investigate whether strategic uncertainty affects behavior in tournaments, we additionally elicit the unconditional effort choice of each participant and the expected response by the opponent in conditions BL, OR, and PR. Arguably, agents face strategic uncertainty when choosing effort unconditionally, since the expected effort and the effort actually implemented by the opponent do not necessarily coincide. We can then investigate (within subject) whether participants respond differently to a given level of effort provided by the opponent if opponent effort is either based on subjective expectations, or if opponent effort is instead deterministic as in best-response functions. Moreover, we can test whether the reaction to strategic uncertainty depends on the presence of other sources of risk by comparing the impact of strategic uncertainty on effort choices across conditions BL, OR, and PR.

Our results show that outcome risk significantly increases average effort provision. In particular, average equilibrium effort is roughly 15% higher in OR than in BL when comparing effort choices across conditions within subjects. The positive impact of outcome risk on effort provision is particularly pronounced when restricting attention to subjects classified as being risk neutral, even though these participants should not react to outcome risk according to theoretical predictions. A potential explanation for this finding could be that the reaction of risk neutral participants to outcome risk is driven by the possibility to outperform others and the resulting 'thrill of victory' (Coffey and Maloney, 2010). In line with this conjecture, we find that the positive (average) effect of outcome risk on equilibrium effort is entirely driven by male participants who are typically assumed to be more competitive (Niederle and Vesterlund, 2007). Moreover, evidence from a strategically equivalent control treatment where subjects interact with the computer (and not with human opponents) indicates that both the positive impact of outcome risk on equilibrium effort and the gender effect observed in our main treatments disappears in the absence of clearly defined ‘winners’ and ‘losers’. Finally, we find that second- and third-order risk attitudes affect the response to outcome risk in our main treatments. In particular, our results show that outcome risk reduces equilibrium effort ceteris paribus for participants classified as being risk averse, in particular if these participants are also prudent. In this sense, our analysis provides some evidence that higher-order risk attitudes (Deck and Schlesinger, 2014) affect the intensity of competition in tournaments.

Our results also show that prize risk leaves average effort provision unaffected. In particular, average equilibrium effort of participants does not differ across conditions `PR` and `BL`. The reaction to prize risk depends on elicited risk attitudes, however, as predicted by theory. Participants classified as being risk averse reduce their effort when being exposed to prize risk. Instead, equilibrium effort of risk neutral participants is not affected by prize risk, while risk loving participants even appear to weakly increase their effort in response to prize risk.

Regarding strategic uncertainty, our results show that agents take strategic uncertainty into account. In particular, we find that participants provide more effort in all conditions if they choose own effort conditionally and thus *know* that their opponent chooses equilibrium effort, than if they choose own effort unconditionally and only *expect* equilibrium effort by their opponent. The reaction to strategic uncertainty is more pronounced in conditions `OR` and `PR`, however, where the variance of implemented effort choices is high due to the presence of fundamental risk, than in condition `BL` where the variance of implemented effort choices is comparatively low. This indicates that participants correctly anticipate that the degree of strategic uncertainty they are exposed to is higher in conditions `OR` and `PR` than in `BL` and react accordingly. Interestingly, we also find that effort is negatively affected by strategic uncertainty only if participants expect equilibrium effort by their opponent, but not otherwise – which is also in line with theoretical predictions.

Our findings have several important managerial implications for organizations. First, our results indicate that risk due to the binary outcome distribution in tournaments is unlikely to reduce incentives to provide effort, even though the majority of agents both in our experimental sample and in the population at large is typically risk averse rather than risk neutral (Dohmen et al., 2011). In particular, we find that the positive incentive effect of the ‘thrill of victory’ dominates adverse incentive effects of outcome risk that affect effort choices through second- and third-order risk attitudes. This suggests that pay-for-performance schemes based on rankings and *ordinal* performance signals as in `OR` may not only help to reduce monitoring costs, but may also provide stronger performance incentives than pay-for-performance schemes based on *cardinal* differences of performance signals, as in `BL`.

Second, the finding that prize risk does not affect average equilibrium effort suggests that dynamic promotion incentives of stochastic option values in organizations with multiple hierarchy levels have incentive effects that are comparable to immediate wage increases. Convex wage structures in promotion tournaments, as suggested by Rosen (1986) in theory, are thus unlikely to be problematic in practice if employees are not too risk averse on average.

Third, we observe that risk averse and prudent participants provide less effort in the presence of prize risk or outcome risk than subjects classified as being risk neutral or risk loving, respectively. This implies more risk tolerant employees are ceteris paribus more likely to be promoted, such that managers and employees in higher ranks of organizations will be more risk tolerant than average employees. Even though sorting by risk attitudes across hierarchy levels might be unproblematic or even desirable in some settings, it is likely to cause problems in others. This holds in particular for occupations that are primarily concerned with risk management of organizations. Our results indicate that external hiring policies might dominate internal promotion schemes in such cases.

Finally, our results show that organizations should take strategic uncertainty into account when designing incentives, since strategic uncertainty affects incentives to provide effort. Moreover, the strength of the reaction to strategic uncertainty appears to be related to the variance of effort choices in a given environment. In particular, the adverse effect on incentives amounts to more than 20% of equilibrium effort in `OR` and `PR` where the variance of effort choices is comparatively high, compared to only 10% in `BL` where the variance of effort choices is much lower. In this sense, our results indicate that outcome and prize risk strongly affect effort choices through the uncertainty regarding opponent effort, even though we find no evidence that outcome risk and prize risk reduce average equilibrium effort in the absence of strategic uncertainty. Consequently, our findings suggest that the often observed high variance of effort choices is tournament can be problematic, even if organizations and principals are risk neutral as typically assumed.

The remainder of this paper is structured as follows. Section 2 introduces the formal model and derives theoretical predictions. The experimental design is explained in Section 3. Section 4 presents and discusses our main findings. Some additional findings are subsequently discussed in Section 5, and Section 6 concludes.

Related Literature. This paper contributes to the literature on tournaments, contests, and risk. First, we contribute to the empirical literature that investigates whether elicited risk attitudes affect behavior in pay for performance compensation schemes. Most contributions in this literature have focused on absolute rather than relative performance pay (Cadsby et al., 2009; Zubanov, 2015). There are only two contributions we are aware of that explicitly analyze how risk averse agents react to the risk that employees are exposed to in tournaments. In particular, Eriksson et al. (2009)

and Dohmen and Falk (2011) investigate how risk attitudes affect sorting into fixed wage, piece rate, or tournament schemes, i.e., these contributions focus on reactions on the extensive margin. To the best of our knowledge, our study is the first one that systematically analyzes whether elicited risk attitudes affect effort choices in tournaments on the intensive margin. Existing studies by Millner and Pratt (1991) and Shupp et al. (2013) that report correlations between elicited risk attitudes and individual effort choices in tournaments do not control for strategic uncertainty, even though the theoretically predicted reaction of risk averse agents to outcome risk is ambiguous (Konrad and Schlesinger, 1997) and depends on the expected effort choice by the opponent (McGuire et al., 1991).[7] We differ from this literature by explicitly taking uncertainty about the opponent's choices into account, as well as incorporating the possible effects of higher-order risk preferences, effectively allowing us to isolate the effects of different types of risk. Moreover, we are not aware of any empirical study that analyzes the incentive effect of prize risk in tournaments.

Second, our findings contribute to the literature that deals with strategic uncertainty. Existing contributions by Bull et al. (1987), Eriksson et al. (2009), or Sheremeta (2013) investigate how the often observed high variance of effort choices – which implies that tournament participants are exposed to strategic uncertainty – can be reduced. We analyze, however, whether and how agents react to the strategic uncertainty they are exposed to in tournaments. In particular, we test whether an exogenous variation in the degree of strategic uncertainty that participants are exposed to affects incentives to provide effort.

Third, we contribute to the recent literature that compares behavior across share and lottery contests. The contributions by Chowdhury et al. (2014) and Masiliunas et al. (2014) are designed to investigate whether and how the contest technology affects over-dissipation, not to analyze how outcome risk affects behavior of risk averse participants. We, in contrast, aim at isolating the different sources of risk to predict how risk preferences shape investment decisions. Our results show that the fact that there is a clear winner in a lottery contest, but not in a share contest, is likely to be responsible for often observed differences in behavior across share and lottery contests. In this sense, we also contribute to the literature that investigates reasons for over-dissipation in contest experiments – see Sheremeta (2015) and the references cited therein.

Finally, our findings are also relevant for the literature on self-protection models and insurance (Ehrlich and Becker, 1972). In particular, we provide evidence for the prediction by McGuire et al. (1991) that risk averse agents face a trade-off between insuring themselves against the bad outcome ('losing') and gambling for the good outcome ('winning') when choosing effort in the presence of

[7] In line with this theoretical prediction, our results indeed show that risk averse participants may respond to outcome risk by providing either more or less effort, depending on whether opponent effort is low or high, respectively. The only paper we are aware of that controls for the impact of strategic uncertainty is by Herrmann and Orzen (2008). While they elicit the entire best-response functions of participants as we do, they focus on the effect of social preferences on behavior in the presence of outcome risk.

outcome risk. As predicted by these models, we find that risk averse agents provide more effort in the presence than in the absence of outcome risk if opponent effort is low, such that the insurance motive dominates. Moreover, we find that risk averse agents react to outcome risk by providing less effort if opponent effort is high such that the gambling motive dominates.

2 Theoretical Predictions

2.1 Setup

Consider a tournament between two symmetric agents $i = \{1, 2\}$ with linear cost of effort who compete for the prize R. Agents are endowed with initial wealth ω and evaluate outcomes with the utility function $U(\cdot)$ that satisfies $U'(\cdot) > 0$. The prize R is a binary lottery with expected value $\tilde{R}$ that delivers either $\overline{R} = \tilde{R} + \zeta$ or $\underline{R} = \tilde{R} - \zeta$ with the same probability.

The prize may be divisible or not. The Tullock (1980) contest technology determines the *share* of the *divisible* prize R that agent i receives in the former, and the *probability* with which agent i receives the *indivisible* prize R in the latter case. The respective probability or share is increasing in own effort x_i, decreasing in the effort provided by the opponent, x_{-i}, and formally defined as follows:

$$\phi(x_i, x_{-i}) = \begin{cases} \frac{x_i}{x_i + x_{-i}} & \text{if} \quad x_i + x_{-i} > 0 \\ 0.5 & \text{if} \quad x_i + x_{-i} = 0 \end{cases}$$

This technology implies that the performance of agents is determined by effort x_i and a multiplicative error term ϵ_i. In particular, the share of the prize that agent i receives or the probability that agent i receives the entire prize, respectively, is defined as $\phi(x_i, x_{-i}) := \Pr(x_i \cdot \epsilon_i > x_{-i} \cdot \epsilon_{-i})$, where ϵ_i and ϵ_{-i} are independent draws from the exponential distribution with mean one.[8]

Condition 1: Baseline (BL). Agents compete for a deterministic prize of value $\tilde{R}$ ($\zeta = 0$) in the baseline condition. Moreover, the prize is divisible, such that agents compete for shares of this prize. Each agent i then faces the optimization problem

$$\max_{x_i \geq 0 | x_{-i}} U\left[\omega + \frac{x_i}{x_i + x_{-i}} \cdot \tilde{R} - x_i\right] , \tag{1}$$

i.e., each agent maximizes her utility by choosing own effort x_i while taking the effort x_{-i} invested by the opponent as given. The first-order optimality condition of agent i reads

$$\left(\frac{x_{-i}}{(x_i + x_{-i})^2}\tilde{R} - 1\right) \cdot U'\left[\omega + \frac{x_i}{x_i + x_{-i}} \cdot \tilde{R} - x_i\right] = 0$$

[8] For details on how to prove this equivalence, see Konrad (2009, p.52f).

and determines her best-response function $\mathrm{BR}_i^{\mathtt{BL}}(x_j)$. Given that agents face no uncertainty in the baseline condition, the best-response function is independent of risk attitudes and reads

$$\mathrm{BR}_i^{\mathtt{BL}}(x_j) = \sqrt{\tilde{R} \cdot x_j} - x_j \ . \tag{2}$$

Condition 2: Outcome Risk (OR). Agents compete for a deterministic prize of value $\tilde{R}$ in the outcome risk contion ($\zeta = 0$). The prize is indivisible, however, implying that the contest technology determines winning probabilities rather than shares. Each agent i then faces the optimization problem

$$\max_{x_i \geq 0 | x_{-i}} \left\{ \frac{x_i}{x_i + x_{-i}} \cdot U\left[\omega + \tilde{R} - x_i\right] + \left(1 - \frac{x_i}{x_i + x_{-i}}\right) \cdot U\left[\omega - x_i\right] \right\}, \tag{3}$$

i.e. each agent maximizes her expected utility by choosing own effort x_i while taking effort x_{-i} provided by the opponent as given. The stochastic nature of the contest technology implies, however, that the best-response function $\mathrm{BR}_i^{\mathtt{OR}}(x_j)$ depends on risk attitudes. It is implicitly defined by the first-order optimality condition

$$\frac{x_{-i}(U\left[\omega + \tilde{R} - x_i\right] - U\left[\omega - x_i\right])}{(x_i + x_{-i})^2} - \frac{x_i U'\left[\omega + \tilde{R} - x_i\right] + x_{-i} U'\left[\omega - x_i\right]}{x_i + x_{-i}} = 0. \tag{4}$$

Condition 3: Prize Risk (PR). Agents compete for a risky prize with expected value $\tilde{R}$ in the prize risk condition ($\zeta > 0$). The prize is divisible, however, implying that agents compete for shares of this prize. Each agent i then faces the optimization problem

$$\max_{x_i \geq 0 | x_{-i}} \left\{ \frac{1}{2} \cdot U\left[\omega + \frac{x_i}{x_i + x_{-i}} \cdot (\tilde{R} + \zeta) - x_i\right] + \frac{1}{2} \cdot U\left[\omega + \frac{x_i}{x_i + x_{-i}} \cdot (\tilde{R} - \zeta) - x_i\right] \right\} \ , \tag{5}$$

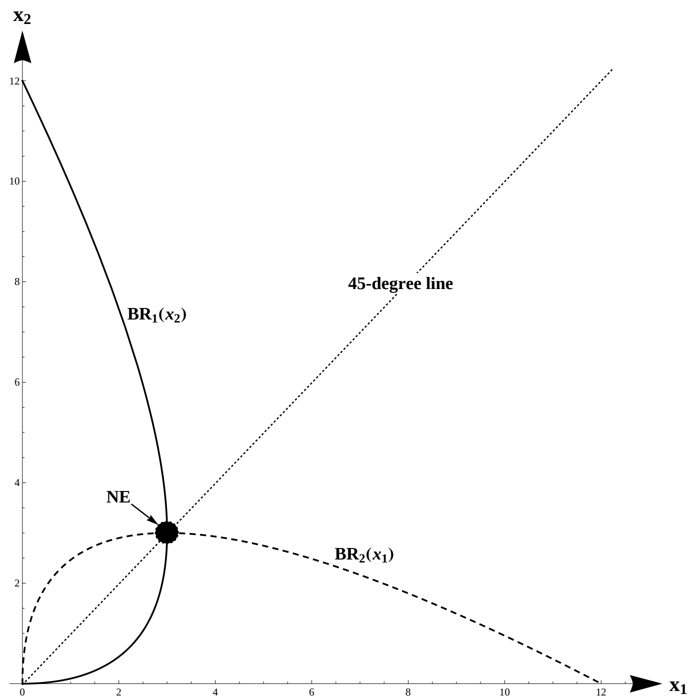
i.e. each agent maximizes her expected utility by choosing own effort x_i while taking effort x_{-i} provided by the opponent as given. The variance of the risky prize lottery implies that the best-response function $\mathrm{BR}_i^{\mathtt{PR}}(x_j)$ depends on second-order risk attitudes. It is implicitly defined by the first-order optimality condition

$$\left(\frac{x_{-i}(\tilde{R} + \zeta)}{(x_i + x_{-i})^2} - 1\right) U'\left[\omega + \frac{x_i(\tilde{R} + \zeta)}{x_i + x_{-i}} - x_i\right] + \left(\frac{x_{-i}(\tilde{R} - \zeta)}{(x_i + x_{-i})^2} - 1\right) U'\left[\omega + \frac{x_i(\tilde{R} - \zeta)}{x_i + x_{-i}} - x_i\right] = 0 \ . \tag{6}$$

2.2 Outcome and Prize Risk

Assume first that agents 1 and 2 are risk neutral ($U''(\cdot) = 0$), and that this is common knowledge. In this case, the first-order optimality conditions (4) and (6) in the outcome and prize risk condition, respectively, deliver the best-response function derived for the baseline condition in (2), i.e. $\mathrm{BR}_i(x_j) \equiv \mathrm{BR}_i^{\mathtt{BL}}(x_j) = \mathrm{BR}_i^{\mathtt{PR}}(x_j) = \mathrm{BR}_i^{\mathtt{OR}}(x_j)$. Intuitively, risk neutral agents are indifferent between the lotteries in PR or OR and their expected value in BL, implying that they do not react

Figure 1: Best-Response Function and the Symmetric Equilibrium



Note: The figure displays the best-response functions of two risk neutral agents 1 and 2 under the assumption that $E[R] = \tilde{R} = 12$.

to prize risk or outcome risk. Independent of the condition under consideration, the equilibrium is unique and symmetric (Perez-Castrillo and Verdier, 1992). It is either determined by the intersection of the best-response functions $\text{BR}_i(x_{-i})$ and $\text{BR}_{-i}(x_i)$, or by the point of intersection of any one best-response function with the 45-degree line. This is graphically illustrated in Figure 1.

Proposition 1. *Let* $x^*_{\text{RN}}(\mathtt{C})$ *denote equilibrium effort of risk neutral agents in condition* $\mathtt{C} = \{\mathtt{BL}, \mathtt{PR}, \mathtt{OR}\}$. *Then:*

$$\begin{array}{lrcl} \text{(a)} & x^*_{\text{RN}}(\mathtt{BL}) & = & x^*_{\text{RN}}(\mathtt{PR}) \quad . \\ \text{(b)} & x^*_{\text{RN}}(\mathtt{BL}) & = & x^*_{\text{RN}}(\mathtt{OR}) \quad . \end{array}$$

Proof. Follows immediately from the equivalence of best-response functions across conditions. □

Assume next that agents 1 and 2 are symmetric and risk averse ($U''(\cdot) < 0$), that this is common knowledge as before, and that the symmetric equilibrium is the unique equilibrium.[9] Outcome risk

[9] Guigou et al. (2017) and Cornes and Hartley (2012) prove existence and uniqueness of the symmetric equilibrium for most common classes of utility functions in PR and OR, respectively.

has non-monotonic effects on the best-response function of risk averse agents, and the effect of risk aversion on equilibrium effort choices is indeterminate (Konrad and Schlesinger, 1997). The reason is that effort choices in `OR` endogenously determine the probability of success or failure just as in self-protection models (Ehrlich and Becker, 1972). In this sense, agents face a trade-off between insuring themselves against the bad outcome ('losing') and gambling for the good outcome ('winning') when choosing their effort. McGuire et al. (1991) show that the insurance motive dominates if the winning probability of a risk neutral agent for given opponent investments is *above* a critical switching probability. Intuitively, the risk averse agents will then provide *more* effort than a risk neutral agents to further reduce the probability of losing. The same reasoning implies that risk averse agents will provide *less* effort than a risk neutral agent if the gambling motive dominates, i.e., if the winning probability of a risk neutral agent for given opponent effort is *below* a critical switching probability. Consequently, the best-response function of risk averse agents in `OR` will initially be *above* the one in `BL` when the winning probability is sufficiently high due to low effort provision of opponent. As opponent effort increases along the best-response function, the critical switching probability will eventually be reached, and subsequently the best-response function in `OR` will always be *below* the one in `BL`. Treich (2010) shows that the effect of risk aversion on effort in `OR` – and thus the critical switching probability – is determined by the third derivative of the utility function.

To investigate how prize risk affects the behavior of risk averse agents, note that the prize in `PR` is a mean preserving spread of the deterministic prize in `BL`. This implies that the prize risk condition is more risky than the baseline condition in the sense of Rothschild and Stiglitz (1970). Consequently, a risk averse agent i provides strictly less effort in `PR` than in `BL` for any given effort by the opponent x_{-i}, and – compared to `BL` – the entire best-response function is shifted downwards in `PR`. This implies that equilibrium effort of risk averse agents is lower in `PR` than in `BL` (Guigou et al., 2017).

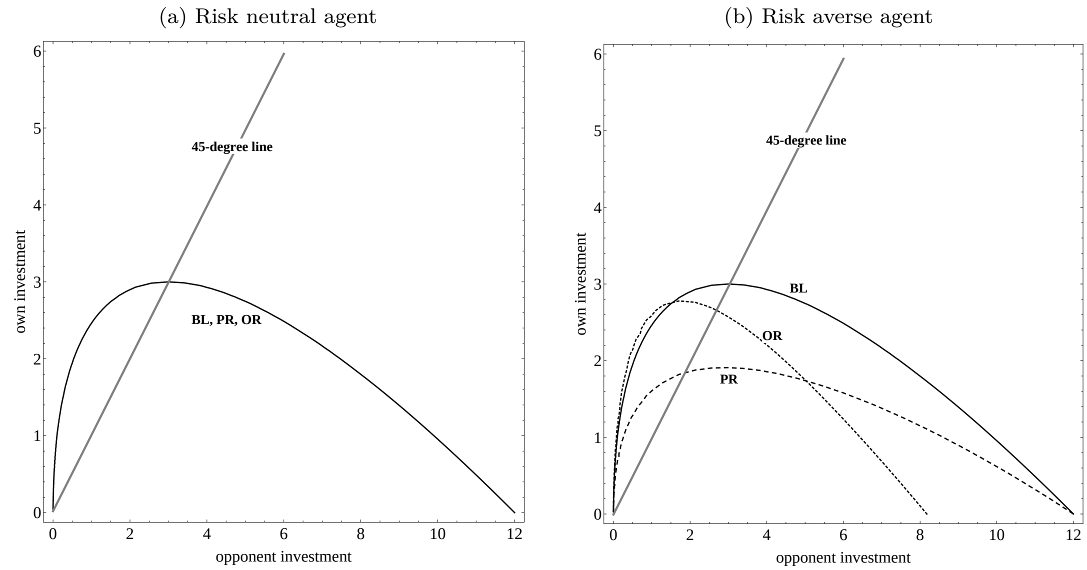
Proposition 2. *Let* $x^*_{\mathrm{RA}}(\mathtt{C})$ *denote equilibrium effort of risk averse agents in condition* $\mathtt{C} = \{\mathtt{BL}, \mathtt{PR}, \mathtt{OR}\}$. *Then:*

$$\text{(a)} \qquad x^*_{\mathrm{RA}}(\mathtt{BL}) \gtreqless x^*_{\mathrm{RA}}(\mathtt{OR}) \quad \Leftrightarrow \quad U'''(\cdot) \gtreqless 0 \; .$$

$$\text{(b)} \qquad x^*_{\mathrm{RA}}(\mathtt{BL}) > x^*_{\mathrm{RA}}(\mathtt{PR}) \; .$$

Proof. Part (a) follows from Proposition 2 and Corollary 1 in Treich (2010); part (b) follows from Proposition 3 in Guigou et al. (2017). □

Figure 2: Best-Response Functions, Risk Attitudes, and Strategic Uncertainty



Note: Panel (a) plots the best-response functions of a risk neutral agent in BL, OR, and PR; panel (b) plots the same best-response functions of a risk averse agent with CRRA preferences; parameters: $\lambda = 1.05$ (coefficient of relative risk aversion), $z = 12$ (opponent investment), and $E[R] = \tilde{R} = 12$.

2.3 Strategic Uncertainty

In the previous section, we assumed that agents are symmetric and that this is common knowledge. In reality, however, decision makers typically face 'strategic uncertainty' regarding the effort provision of the opponent. Likely candidates for the presence of 'strategic uncertainty' could be uncertainty regarding the opponent's type (e.g. in terms of risk attitudes), the anticipation of other-regarding preferences (e.g., Rabin, 1993; Fehr and Schmidt, 1999), or the expectation of mistakes in the sense of McKelvey and Palfrey (1995). Independent of its source, the presence of strategic uncertainty will not affect the best-response function that defines the optimal response for any *given* opponent effort. Strategic uncertainty may affect unconditional effort choices, however, if an agent attaches a strictly positive probability to the event that her opponent deviates from the symmetric equilibrium.

In contrast to McKelvey and Palfrey (1995) or Renou and Schlag (2010), we are not interested in the effect of strategic uncertainty on equilibrium outcomes. Instead, we investigate whether the best-response to a given opponent effort depends on the uncertainty that the opponent might potentially deviate from the expected effort choice. Said differently, we investigate whether one-sided strategic uncertainty affects effort choices, while previous contributions investigate whether equilibrium predictions change in the presence of two-sided strategic uncertainty. To illustrate what we have in mind, consider the best-response function of a risk neutral agent in BL, PR, or OR that is depicted in panel (a) of Figure 2. The figure reveals that the 45-degree line intersects with the best-response function at its maximum. Consequently, a decision maker who expects her opponent to provide equilibrium effort with certainty maximizes her own payoff by choosing effort equal to the maximum of her best-response function. Assume next that the decision maker is uncertain whether or not her opponent will indeed provide equilibrium effort. In particular, the decision maker is now assumed to attach a non-zero probability to the event that her opponent provides more or less than equilibrium effort. Given that the best-response to any effort choice other than the equilibrium prediction is strictly lower than the maximum of the best-response function, the decision maker should react to this strategic uncertainty by providing less effort. As illustrated in panel (b) of Figure 2, the same statement is not always true for risk averse decision makers. The reason is that the intersection between the 45-degree line and the best-response function of risk averse decision makers in `OR` and `PR` – that defines equlibrium effort – is not necessarily at the maximum of the best-response function. Whether equilibrium effort is located in the increasing range or decreasing range of the best-response function depends on the utility function and the source of risk (prize risk vs. outcome risk). Whenever the equilibrium effort choice is not located at the maximum of the best-response function, strategic risk can potentially increase rather than decrease equilibrium effort if strategic uncertainty induces decision makers to believe that effort by the opponent is closer to the maximum of her best-response function.

Proposition 3. *Assume that a decision maker believes her opponent to provide equilibrium effort, but faces strategic uncertainty. Due to strategic uncertainty, the decision maker assigns a strictly positive probability to above or below equilibrium effort by the opponent. Then:*

(a) The best-response effort is lower than the symmetric equilibrium prediction in `BL`*, independent of risk attitudes.*

(b) The best-response effort of risk-neutral decision makers is lower than the symmetric equilibrium prediction in `OR` *and* `PR`*.*

Proof. Follows directly from Figure 2. □

3 Experimental Design

3.1 Treatments and Parameters

We conducted an experiment with three different versions of a two player tournament. Subjects competed for shares of a divisible deterministic prize of value $\tilde{R} = 12.00$€ in the baseline condition (`BL`), for shares of a divisible risky prize with possible realizations $\underline{R} = 0.00$€ or $\overline{R} = 24.00$€

and expected value $\tilde{R} = 12.00$ € in the prize risk condition (PR), and for the probability to win an indivisible deterministic prize of value $\tilde{R} = 12.00$ € in the outcome risk condition (OR). Each subject participated in all three conditions, which allows for a within-subject comparison across conditions.

Subjects were paired in each of these conditions and could invest any integer amount between 0.00 € and 12.00 €. Using monetary investments rather than real-effort provision ensures that the cost of effort function is identical both across subjects and across conditions within an experimental session. One subject acted as type 1 with the respective investment being implemented, the other one as type 2. Independent of their type, subjects received a 12.00 € endowment to cover the cost of investment. The only difference between participants of type 1 and 2 was that the participant of type 1 made only one unconditional investment choice, while we elicited the entire best-response function for type 2 using the strategy-vector method. Payoffs in each condition were determined by the combination of the unconditional investment choice of type 1 and the corresponding conditional choice of type 2.

3.2 Implementation

Protocol of an Experimental Session. At the beginning of each session, participants received general instructions and were informed that the experiment encompassed three parts I, II, and III.[10] At the beginning of each of these parts, subjects received written instructions and learned whether the next part had several sub-parts (denoted by lower case characters). Whenever this was the case, it was made clear to participants that their earnings for the respective part were determined by a randomly chosen subpart. Subjects only received the instructions for the next subpart after they completed all previous parts, and these instructions were read out aloud by the experimenters to ensure common knowledge.

At the end of the experiment, we asked subjects to fill in a standard questionnaire, asking several demographic background variables. Subjects then learned their earnings from each part and were informed which sub-parts had been selected for payment. We added the earnings from parts I, II and III to a show up fee of 4 € and paid all subjects privately and in cash before dismissing them from the laboratory. We conducted six sessions in March, May and September 2015 at the laboratory of the University of Munich with 24 participants each. Recruitment was done using ORSEE (Greiner, 2015) and the experiment was programmed in zTree (Fischbacher, 2007). 144 subjects participated in the experiment, of which 70 were female. A session lasted approximately two hours and subjects earned on average 30.34 €.

[10] Since we are primarily interested in parts I and II subsequently, we relegate detailed information on part III to the appendix.

Elicitation of Risk Preferences. We elicited second- and third-order risk preferences in part I of the experiment before subjects were exposed to our main treatment in part II. First, we used a choice list similar to the one employed by Dohmen et al. (2011) to elicit second-order risk preferences in part Ia. Specifically, each subject was exposed to a series of binary choices between a cash gamble and a safe payoff. The cash gamble remained the same in all 20 binary choices – it always gave either 5.00 € or 1.00 €, each with 50 percent probability. The safe payoff increased in steps of 0.20 € from 1.20 € in the first to 5.00 € in the last row. We forced subjects to only switch at most once from the lottery to the fixed amount in order to calculate a unique switching point, and this switching point serves as our measure of risk attitude.Subsequently, subjects had to make five choices between two lotteries in part Ib of the experiment to measure subjects' third-order risk preferences, i.e. the extent of prudence.[11] The only difference between the two lotteries was that a zero-mean risk was either added to the high payoff state or to the low payoff state. We used lotteries `Prud1` to `Prud5` from Noussair et al. (2013), Table 1, but displayed the lotteries in reduced form as in Baillon (2016). After completion of all five lotteries, the computer randomly selected one lottery for payoff of this sub-part.

Main Treatment. Participants were exposed to our main treatments `BL`, `OR`, and `PR` in part II of the experiment. Subjects always started with the `BL` condition (part IIa), but parts IIb and IIc (`OR` or `PR`) were randomized across sessions to avoid order effects.[12] In each of the three conditions, all subjects first made one unconditional investment choice as type 1. Starting with session three, we additionally asked our subjects what they expected the corresponding type 2 to choose conditional on the investment choice they just made, incentivized by the use of a quadratic scoring rule.[13] Subsequently, participants were exposed to 13 conditional choices as type 2 on a separate screen. Subjects knew that the computer randomly assigned types to each player within a pair after all investment decisions were made by both subjects, and that only the decisions made by the randomly determined type would be implemented.

To make sure subjects fully understand the respective decision environment, we asked control questions before subjects made choices in part II and supplied subjects with calculators, payoff tables and a practice program for each condition.[14] The payoff tables only showed own payoffs and, where applicable, the payoff for each possible state together with the respective probability (in `OR` and `PR`). We abstained from indicating expected values or similar choice aides to not influence

[11] In sessions one and two, part Ib was a different task and the test for prudence only came as part IIIa. Details and rationale for all order variations and task substitutions can be found in Appendix A.

[12] The instructions are provided in Appendix B, and Table 8 in the appendix gives an overview of the sequence of tasks in each session.

[13] While a quadratic scoring rule might have some undesirable features (Manski, 2004), Trautmann and van de Kuilen (2015) show in a comparison with different elicitation mechanisms, that its performance is very similar to other heavily used incentivization rules. For the precise scoring rule, see the instructions in appendix B.

[14] The payoff tables can be found in Appendix C.

participants' choices. The practice program allowed subjects to enter ficticious investments for both player 1 and player 2 and to calculate the responding outcomes (and associated probabilities if applicable) as many times as they wished. Again, we avoided to give any information regarding expected value. When working on the practice program, subjects could take as much time as they needed and no clock was displayed.

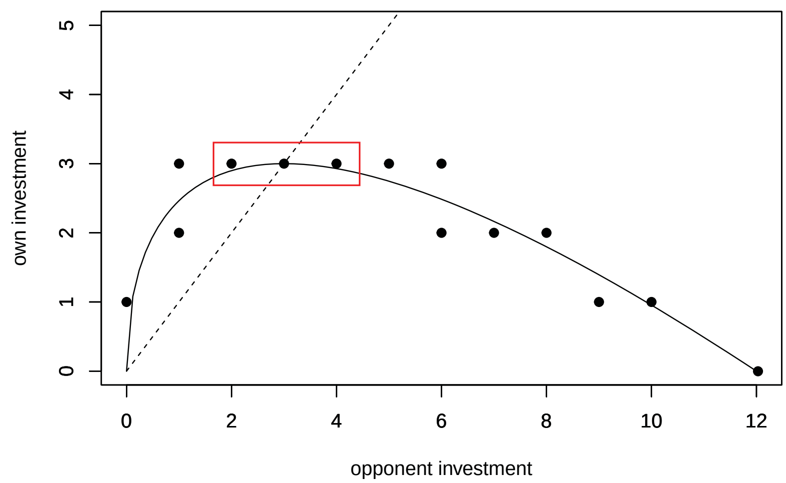
3.3 Testable Hypotheses

The experiment is designed such that it allows us to switch the different sources of risk and uncertainty on and off in a controlled way. The basic idea is that the within-subject comparison of best-response functions across conditions `BL` and `OR` for outcome risk, and across conditions `BL` and `PR` for prize risk identifies the individual reaction to these sources of fundamental risk for any given opponent investment choice, and thus in the absence of strategic uncertainty. Therefore, we are only interested in choices that participants make as type 2, since these choices determine the best-response function. We know from the discussion in section 2 that equilibrium effort choices are determined by the intersection of a 45-degree line with the best-response function in homogeneous interactions, i.e., in situations where both agents share the same utility function and where this is common knowledge. From a theoretical perspective, we should thus simply determine the point of intersection between the continuous best-response function and the 45-degree line for each individual and then compare the resulting amount across conditions. The best-response function elicited is however not continuous, but only defined for integer amounts. Therefore, we use the average of amounts invested for given opponent investments of 2.00 €, 3.00 €, and 4.00 € to approximate equilibrium investments.[15] This *hypothetical* equilibrium of two homogeneous players may very well differ from the *actual* equilibrium choices of the two actual (and potentially heterogeneous) matched players, as the former is independent of beliefs, risk preferences, or non-simultaneity of choices through use of the strategy vector method. Since we are not interested in the *actual* equilibrium, throughout our analysis, we will refer to the *hypothetical* equilibrium, where the aforementioned and other concerns do not play a role, simply as the equilibrium.

Figure 3 illustrates the difference between the step function elicited in the experiment and the continuous best-response function in the baseline condition. The figure shows the best-response to opponent investments of 2.00 €, 3.00 €, or 4.00 € is always equal to 3.00 € due to the discrete grid for risk neutral decision makers and thus exactly equal to the intersection of the 45-degree line and the best-response function. This does not necessary hold for risk averse agents, however, who might decide to invest less for some or for all of these given opponent investments in `PR`, and

[15] All our main findings continue to hold if we consider different somewhat stricter or less strict measures for equilibrium investments. Details available upon request.

Figure 3: Continuous Best-Response Function and Implementation in the Experiment



Note: The figure displays the best-response functions of all agents in the baseline condition (BL) for $\tilde{R} = 12$, and of risk neutral agents in the prize risk (PR) and outcome risk (OR) condition.

more or less for some or for all of these given opponent investments in OR. In these cases, the average of amounts invested for given opponent investments of 2.00 €, 3.00 €, and 4.00 € allows us to smoothen elicited integer choices to better account for marginal differences regarding the position of the best-response function in the range that is likely to intersect with the 45-degree line. Using the aforementioned measure for equilibrium efforts, we can directly test Propositions 1 and 2 from section 2 in the absence of strategic uncertainty, which would not be possible only considering unconditional choices. Consider outcome risk and its effect on the effort of risk neutral and risk averse subjects first.

Hypothesis 1 (**Outcome Risk**). *Outcome risk does not affect equilibrium investments of risk neutral agents, and the effect on equilibrium investment of risk averse agents depends on third-order risk attitudes:*

$$\text{(a)} \qquad x^*_{\text{RN}}(\texttt{BL}) = x^*_{\text{RN}}(\texttt{OR}) \; .$$

$$\text{(b)} \qquad x^*_{\text{RA}}(\texttt{BL}) \gtreqqless x^*_{\text{RA}}(\texttt{OR}) \quad \Leftrightarrow \quad U'''(\cdot) \gtreqqless 0 \; .$$

Next, consider prize risk and its effect on investments of risk neutral and risk averse subjects:

Hypothesis 2 (**Prize Risk**). *Prize risk does not affect equilibrium investments of risk neutral agents, and reduces equilibrium investment of risk averse agents:*

$$\text{(a)} \qquad x^*_{\text{RN}}(\texttt{BL}) \;=\; x^*_{\text{RN}}(\texttt{PR}) \;.$$

$$\text{(b)} \qquad x^*_{\text{RA}}(\texttt{BL}) \;>\; x^*_{\text{RA}}(\texttt{PR}) \;.$$

Finally, we investigate whether strategic uncertainty affects investment choices by testing Proposition 3. Theory predicts that agents who *know* that their opponent invests the equilibrium amount should invest more than agents who only *expect* equilibrium investments by their opponent if they take strategic uncertainty into account. To identify the effect of strategic uncertainty on investment, we compare the unconditional investment choice of a type-1 participant who expects equilibrium investment by her opponent with the conditional choice that the same participant made as type 2 when knowing for sure that the opponent invests the equilibrium amount. Following the definition of equilibrium investment discussed above, we classify expected opponent investments as 'equilibrium investments' if participants expect their opponent to invest either 2.00 €, 3.00 €, or 4.00 €. To test whether strategic uncertainty affects investment, let $x_{1i}(\texttt{C}|z^{\text{exp}})$ be the unconditional investment choices of agent i in her role as type 1 in condition $\texttt{C} \in \{\texttt{BL,PR,OR}\}$ who believes that her opponent invests z^{exp}. Let $x_{2i}(\texttt{C}|z)$ be the conditional investment choice of the same agent i in her role as type 2 in condition $\texttt{C} = \{\texttt{BL,PR,OR}\}$ for given opponent investment $z = z^{\text{exp}}$. Then, the difference $x_{1i}(\texttt{C}|z^{\text{exp}}) - x_{2i}(\texttt{C}|z)$ captures the response of agent i to the uncertainty that true opponent investment might differ from expected investment z^{exp} in condition $\texttt{C} \in \{\texttt{BL,PR,OR}\}$.

Hypothesis 3 (**Strategic Uncertainty**). *If agents expect equilibrium investments by their opponent, the optimal investment level in the presence of strategic uncertainty is lower than the symmetric equilibrium prediction in* `BL`*,* `OR` *and* `PR`*:*

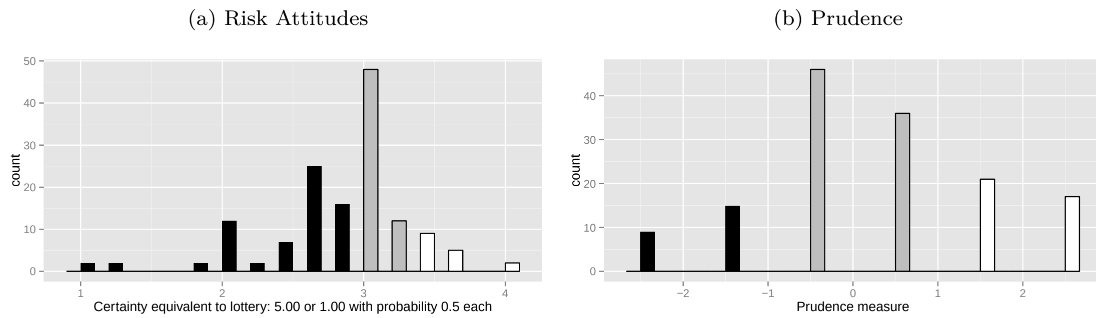
$$\text{(a)} \qquad x_{1i}(\texttt{BL}|z^{\text{exp}}) \;<\; x_{2i}(\texttt{BL}|x^*_{-i}) \quad \text{if} \;\; z^{\text{exp}} = x^*_{-i}(\texttt{BL}) \;.$$

$$\text{(b)} \qquad x_{1i}(\texttt{OR}|z^{\text{exp}}) \;<\; x_{2i}(\texttt{OR}|x^*_{-i}) \quad \text{if} \;\; z^{\text{exp}} = x^*_{-i}(\texttt{OR}) \;.$$

$$\text{(c)} \qquad x_{1i}(\texttt{PR}|z^{\text{exp}}) \;<\; x_{2i}(\texttt{PR}|x^*_{-i}) \quad \text{if} \;\; z^{\text{exp}} = x^*_{-i}(\texttt{PR}) \;.$$

Note that Hypothesis 3 abstracts from differences in the response to strategic uncertainty between risk neutral and risk averse subjects in conditions `OR` and `PR` previously discussed in section 2. If anything, this makes it harder to find effects of strategic uncertainty on investment in the data however.

Figure 4: Distribution of Risk and Prudence Attitudes



Note: Panel (a) displays the distribution of certainty equivalents in the experiment. The certainty equivalent is strictly below the the expected value of 3.00 € for risk averse subjects ($N = 68$, black bars), equal to the expected value for risk neutral subjects ($N = 60$, gray bars), and strictly higher than the expected value for risk loving subjects ($N = 16$, white bars). Panel (b) displays the distribution of the prudence measure. Most subjects are indifferent between the the two lottery options ($N = 82$, gray bars), and the number of prudent subjects ($N = 38$, white bars) is slightly higher than the number of imprudent subjects ($N = 24$, black bars).

4 Main Results

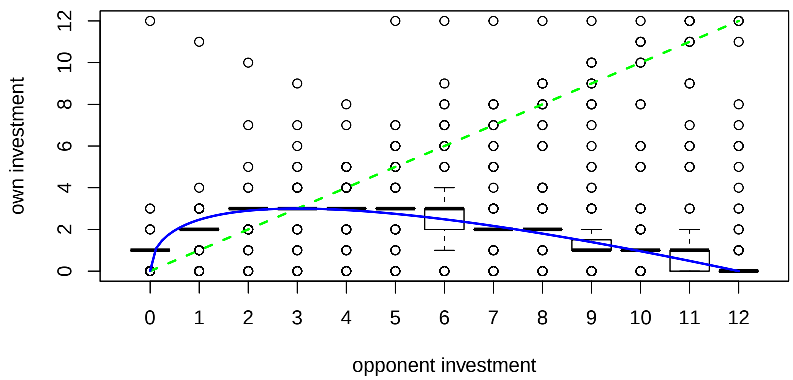
4.1 Preliminary Analsis

Before testing our hypothesis, we briefly describe some important features of our experimental data. Consider first the distribution of second- and third-order risk attitudes that is depicted in Figure 4. The histogram for second-order risk attitudes in panel (a) reveals that certainty equivalents strongly vary between subjects. Moreover, we find that most subjects are either risk neutral ($N = 60$, gray bars) or risk averse ($N = 68$, black bars), while the number of risk loving subjects is comparatively low ($N = 16$, white bars). According to panel (b), third-order risk preferences are typically less intense: Most subjects (82 out of 144) appear to be indifferent between the two lottery options (gray bars), and the number of prudent subjects is only slightly higher than the number of imprudent subjects.

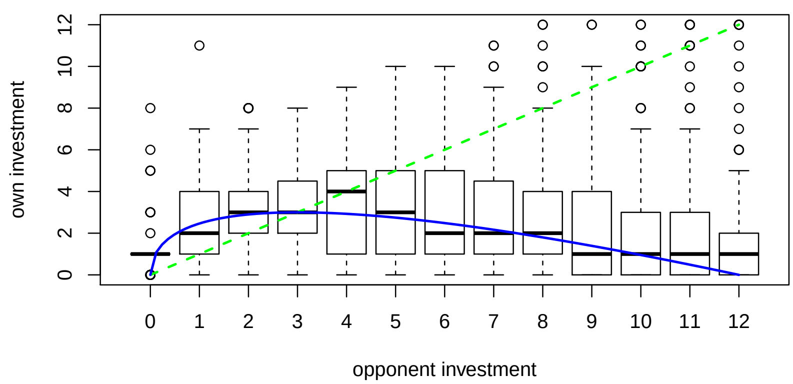
Consider next the box plot of conditional investment choices for given opponent investment in conditions `BL`, `PR`, and `OR` that is depicted in panels (a)-(c) of Figure 5. Independent of the condition, we find that median investment choices are first increasing and later decreasing in the amount invested by the opponent, i.e., we observe the theoretically predicted inverted U-shape.The figure also reveals that choices are concentrated around the theoretically predicted best-response function in `BL`, while the 95% confidence interval is much larger in `PR` and (even more so) in `OR`. The variance of investment choices in conditions `OR` and `PR` might be higher for several reasons. One might argue for example, that the decision environment is more complicated in conditions `PR` and `OR` (where subjects have to evaluate lotteries) than in condition `BL` (where subjects simply compare certain

Figure 5: Boxplot of Conditional Investment Choices by Condition (Type 2)

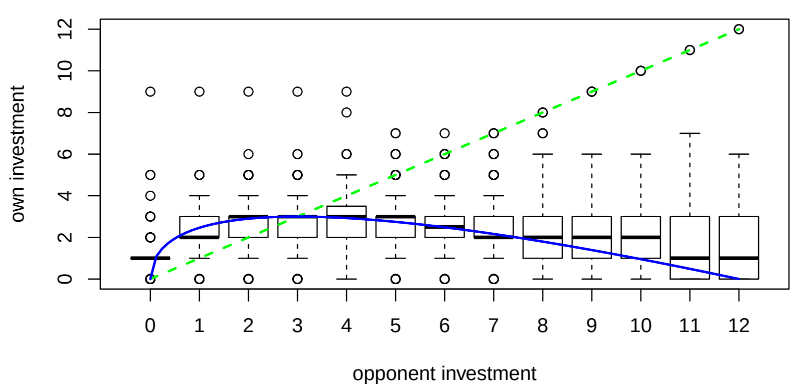
(a) Baseline



(b) Outcome Risk



(c) Prize Risk



Note: Panels (a)-(c) plot investment choices for given opponent investment levels by condition, as well as the theoretically predicted best-response function for risk neutral competitors (in blue) and the 45-degree line (in green).

Table 1: Baseline versus Outcome Risk

	x^*(BL)	x^*(OR)	$\Delta(x^*$(OR)-x^*(BL))	WSR-test
risk averse ($N = 68$)	2.809	3.025	0.216	$p = 0.291$
risk neutral ($N = 60$)	2.833	3.417	0.584	$p = 0.007$
risk loving ($N = 16$)	2.792	3.562	0.770	$p = 0.096$
all ($N = 144$)	2.817	3.248	0.431	$p = 0.002$

Note: The table provides mean equilibrium investment choices of participants by risk attitude in conditions BL and OR, using the the average of amounts invested for given opponent investments of 2.00 €, 3.00 €, and 4.00 € as a proxy for equilibrium investment choices. The reported p-values are obtained using a non-parametric Wilcoxon-signed rank (WSR) test.

payoffs), and that this additional complexity induces deviations from the theoretically predicted best-response function. Another reason could be that optimal investment choices and thus the best-response function depend on individual risk attitudes in conditions PR and OR, but not in BL. Given that (second-order) risk attitudes strongly vary between subjects – and that most subjects are risk averse rather than risk neutral – deviations from the theoretically predicted best-response function of risk neutral decision makers may be related to risk preferences. When restricting attention to the aforementioned proxy for equilibrium investment choices – the average of amounts invested for given opponent investments of 2.00 €, 3.00 €, and 4.00 € – we find that equilibrium investments are unrelated to risk attitudes in BL. At the same time, risk attitudes and equilibrium investment choices are strongly correlated in conditions PR and OR.[16] This between subjects correlation already suggests that risk attitudes affect investment choices. In what follows, we use a within-subject identification to investigate whether investment-choice differences across conditions are systematically related to elicited preference parameters.

4.2 Outcome Risk

Table 1 provides mean equilibrium investment choices of participants by risk attitude in conditions BL and OR. Visual inspection suggests that equilibrium investments are correlated with risk attitudes in OR, but not in BL. Using a non-parametric Wilcoxon-signed rank (WSR) test for inference, we find that risk neutral participants invest significantly more than the equilibrium prediction of 3.00 € in OR (WSR: $p = 0.054$), but not in BL (WSR: $p = 0.264$).

When focusing on within-subject comparisons across BL and OR to isolate the effect of outcome risk on investment choices, we find a pronounced positive effect of outcome risk on mean equilibrium

[16]The correlation coefficient equals 0.284 in PR (p-value= 0.001) and 0.214 in OR (p-value= 0.010), respectively.

investment. In particular, average investment increases from 2.817 units in `BL` to 3.248 units in `OR` across all participants, i.e., average investment is roughly 15% higher if competitors are exposed to outcome risk. The effect is not only sizeable, but also statistically significant at the 1%-level (WSR: $p = 0.002$). When dis-aggregating the data by elicited risk attitudes of participants, we find that risk averse participants respond to outcome risk by investing slightly more, but the difference across conditions is small and statistically insignificant (2.809 vs. 3.025, WSR: p-value= 0.291). Risk loving participants increase their investment choices in the outcome risk condition substantially, however, (2.792 vs. 3.562, WSR: p-value= 0.096), and the same holds for risk neutral subjects. They increase their equilibrium investment from 2.833 in `BL` to 3.417 in `OR` (WSR: $p = 0.007$).

From a theoretical perspective, the reaction of participants who are classified as being risk neutral is hard to explain. Risk neutral agents should be indifferent between deterministic outcomes in condition `BL` and the binary stochastic outcome distribution in condition `OR`, since expected values do not differ across conditions. This suggests that something unrelated to risk attitudes might be responsible for the observed differences in behavior across `BL` and `OR`. One potential explanation that comes to mind here is the 'thrill of victory' (Coffey and Maloney, 2010) that is also referred to as 'joy of winning' (Sheremeta, 2010). Intuitively, there is no clearly defined winner if prizes are shared between competitors as in `BL`. The presence of outcome risk in tournaments automatically implies, however, that the tournament determines a unique winner and a unique loser in condition `OR`. Said differently, condition `OR` ranks competitors by assigning the labels 'winner' and 'loser', which might affect investments of competitive participants who care about outperforming others.[17]

Two pieces of evidence suggest that the 'thrill of victory' is at least partly responsible for the observed increase of average equilibrium investment in `OR` relative to `BL`. First, we find that the positive effect of outcome risk on mean equilibrium investment is primarily driven by male participants. Males are typically more competitive than females (Niederle and Vesterlund, 2007; Gneezy et al., 2009), and thus likely to be more responsive to competitive pressure induced by the 'thrill of victory'. Second, we find that both the positive effect of outcome risk on average equilibrium investment and the gender effect disappear in a control treatment where the 'thrill of victory' is reduced, since participants compete with the computer rather than with a human opponent.

Both observations follow from the regression output provided in Table 2 and are subsequently discussed in more detail. Consider first columns (1) and (2) of Table 2 and the reaction to outcome risk in our regular sessions. The regression output shows how the average individual investment difference across conditions `OR` and `BL` is related to risk attitudes and gender. The measure of

[17] Even though we avoid value-laden terms such as 'winner' and 'loser' in the experimental instructions, participants will clearly understand that only one participant in each pair receives the entire prize in condition `OR`.

Table 2: The Effect of Outcome Risk on Equilibrium Investment – Regression Analysis

	Dependent variable: $\Delta[x^*(\texttt{OR}) - x^*(\texttt{BL})]$			
	`OR`		`OR comp`	
	(1)	(2)	(3)	(4)
Constant	0.614***	0.220	0.087	0.146
	(0.166)	(0.223)	(0.211)	(0.566)
risk attitude	0.593**	0.577**	0.550	0.561
	(0.278)	(0.272)	(0.791)	(0.811)
male		0.799***		−0.151
		(0.276)		(0.789)
Observations	144	144	24	24
R^2	0.031	0.085	0.022	0.023

Note: 'risk attitude' is a normalized version of the certainty equivalent elicited in part I of our experiment. In particular, we subtract the certainty equivalent of risk neutral decision makers to ensure that risk neutral participants are our base category. 'male' is a dummy variable that is equal to one for male participants and zero otherwise. *p<0.1; **p<0.05; ***p<0.01

risk attitudes is normalized such that the constant term captures the reaction to outcome risk by risk neutral participants. Consequently, column (1) shows that the within-subject treatment effect $\Delta[x^*(\texttt{OR}) - x^*(\texttt{BL})]$ is 0.614 for risk neutral participants, and that risk averse participant with a certainty equivalent that is 1.00 € below the expected value of the lottery in part 1 of our experiment respond to outcome risk by investing 0.593 units less than risk neutral participants. Controlling for gender by adding a dummy variable that equals one for male and zero for female participants does not affect the estimated coefficient of risk attitudes in column (2), but has a pronounced impact on the estimated constant term. In particular, the estimated constant is now close to zero and insignificant, which implies that risk neutral participants are less likely to respond to outcome risk if they are female. Male participants who are classified as being risk neutral respond to outcome risk by investing 1.019 units more, however. Consequently, the average response to outcome risk by risk neutral participants in column (1) follows from a close to zero reaction by female participants and a very pronounced reaction by male participants.

Consider next the reaction to outcome risk in our control treatment `comp`. Before we discuss the regression output in columns (3) and (4) of Table 2 in more detail, note that there is only one difference between our main treatment and the control treatment `comp`: participants do not compete with other subjects in `comp` as in our main treatment, but instead against the computer. Interestingly, the estimated coefficient for risk attitudes is almost identical across regular sessions and the control treatment.[18] The estimated constant term in column (3) is close to zero and insignificant, however, which indicates that risk neutral participants likely do not react to outcome risk when competing against the computer. Moreover, the estimates in column (4) suggest that there are no differences in the reaction to outcome risk between male and female participants in the control treatment. From a theoretical perspective, there is no reason why it should matter if the immediate opponent is human or computerized in the absence of a 'thrill of victory'. Participants in the `comp` session are exposed to the same outcome risk as in regular sessions, and they know that the computer implements real choices by humans from previous sessions.[19] In this sense, observed differences in behavior across regular sessions and the control treatment suggest that the 'thrill of victory' matters. Participants react differently to outcome risk if they can outperform a human competitor and if somebody else receives the prize in case they lose – as in our regular sessions – than if they compete against the computer.

Finally, we investigate whether the reaction to outcome risk is related to second- and third-order risk attitudes as predicted by the theoretical model. Table 3 displays the regression output when explaining differences in behavior across conditions `OR` and `BL` by second-order risk preferences ('*risk attitude*'), third-order risk preferences ('*prudence*'), gender ('*male*'), and different sets of additional control variables. As in Table 2 above, we observe pronounced differences in the reaction to outcome risk between male and female participants. We are primarily interested in the estimated coefficients for second- and third-order risk attitudes in column (1)-(3) that do not depend on gender, however.[20] First, we find that the estimated coefficient for third-order risk attitudes ('*prudence*') has the theoretically predicted sign and is weakly significant in column (1). The effect becomes stronger and highly significant when we control for additional factors in columns (2) and (3). The coefficient estimates suggest that more prudent subjects who indicate a preference for upside rather than downside zero-mean risk in one additional lottery pair reduce equilibrium investments by roughly 0.25 units. Second, we find that second-order risk attitudes ('*risk*') matter even after controlling for third-order risk attitudes. The estimated coefficients in columns (1)-(3) are statistically significant at the 5%-level and suggest that a reduction of the certainty equivalent by 1.00 € in the risk elicitation task reduces equilibrium investment choices by roughly 0.60 units. According to these estimates, a risk averse subject that is indifferent between a lottery that delivers 1.00 € and 5.00 € with probability 0.5 each or a sure payoff of 2.00 € – equivalent to a CRRA coefficient of roughly 1.35 – would respond to outcome risk by investing 0.60 less. This finding suggests that second-order

[18]The coefficient is not significantly different from zero in the control treatment, however, potentially due to the comparatively low number of independent observations.

[19]We use the best-response function of type 2 players as in our regular sessions to determine equilibrium investment choices. These choices are made conditional on given opponent investment choices, implying that differences in beliefs would not matter per se.

[20]Interaction terms of second- and third-order risk attitudes with the male dummy are close to zero and insignificant if we control for them in the regression. Details available upon request.

Table 3: Second-Order and Third-Order Risk Attitudes in `OR` – Regression Analysis

	Dependent variable: $\Delta[x^*(\mathtt{OR}) - x^*(\mathtt{BL})]$		
	(1)	(2)	(3)
Constant	0.199	0.198	0.134
	(0.210)	(0.209)	(0.221)
risk attitude	0.604**	0.562**	0.631**
	(0.270)	(0.270)	(0.272)
prudence	−0.184*	−0.273**	−0.255**
	(0.106)	(0.118)	(0.118)
risk attittude × prudence		−0.313	−0.264
		(0.190)	(0.191)
math grade			0.210
			(0.133)
misunderstood			0.394
			(0.388)
male	0.923***	0.923***	0.974***
	(0.283)	(0.282)	(0.282)
Observations	144	144	144
R^2	0.105	0.122	0.144

Note: 'risk attitude' is a normalized version of the certainty equivalent elicited in part I of our experiment. In particular, we subtract the certainty equivalent of risk neutral decision makers to ensure that risk neutral participants are our base category. 'prudence' is an elicited prudence measure in which participants whose third-derivative of their utility function is zero are the base category. 'risk attitude × prudence' is the interaction of elicited second- and third-order risk attitudes. 'math grade' is a de-meaned version of the last math grade in high school (self-reported). 'misunderstood' is a dummy that is equal to one if participants indicated that they had problems to understand the instruction in `BL`, `PR`, and/or `OR`. 'male' is a dummy variable that is equal to one for male participants and zero otherwise. *p<0.1; **p<0.05; ***p<0.01

risk attitudes directly affect the reaction to outcome risk in our experimental data, and not only through third-order risk attitudes as theory suggests.[21] Finally, the regression output in columns (2) and (3) suggests that additional variables that control for the interaction of second- and third-order risk preferences, the math grade, or for self-reported misunderstanding of the instructions have no (statistically significant) effect on the reaction to outcome risk after controlling for second- and third-order risk preferences as well as for gender of participants.

[21] Interestingly, elicited second- and third-order risk attitudes are almost uncorrelated in our data – the Spearman's rank correlation coefficient equals −0.004 (p-value 0.966). This observation provides further evidence for the claim that second-order risk attitudes appear to have a direct and independent effect on the reaction to outcome risk.

Table 4: Baseline versus Prize Risk

	x^*(BL)	x^*(PR)	$\Delta[x^*(\texttt{PR}) - x^*(\texttt{BL})]$	WSR-test
risk averse ($N = 68$)	2.809	2.422	-0.387	$p = 0.045$
risk neutral ($N = 60$)	2.833	3.000	0.167	$p = 0.194$
risk loving ($N = 16$)	2.792	3.125	0.333	$p = 0.572$
all ($N = 144$)	2.817	2.741	0.076	$p = 0.603$

Note: The table provides mean equilibrium investment choices of participants by risk attitude in conditions BL and PR, using the the average of amounts invested for given opponent investments of 2.00 €, 3.00 €, and 4.00 € as a proxy for equilibrium investment choices. The reported p-values are obtained using a non-parametric Wilcoxon-signed rank (WSR) test.

Taken together, our findings suggest that outcome risk affects investment choices through a behavioral and a fundamental risk margin. First, we observe behavioral responses to the property that pairwise tournaments determine a unique winner and a unique loser in the presence of outcome risk, but not in the baseline condition. It appears that particularly male participants respond to the resulting 'thrill of victory' by investing more, independent of their second- and third-order risk attitudes. Second, we find that it is important to account both for second- and third-order risk attitudes to determine the response to the fundamental risk that participants are exposed to in the presence of outcome risk. In particular, our data indicate that risk averse participants invest less in the symmetric equilibrium, in particular if they are prudent – in line with Hypothesis 1. We summarize these findings as follows:

Result 1 (**Outcome Risk**). *Outcome risk has a pronounced positive impact on average equilibrium investment choices that appears to be related to the 'thrill of victory'. Third-order risk attitudes have the theoretically predicted impact on equilibrium investment, but we also find that second-order risk attitudes have an independent and direct effect on the ceteris paribus reaction to outcome risk.*

4.3 Prize Risk

Table 4 displays mean equilibrium investment choices of participants by risk attitude in conditions BL and PR. Visual inspection reveals that average equilibrium investments are decreasing in the degree of risk aversion in PR, but not in BL. When restricting attention to risk neutral participants, we find that observed choices are very close to equilibrium predictions; we cannot reject equilibrium play of risk neutral participants in either condition (WSR: $p = 0.264$ in BL; WSR: $p = 0.987$ in PR).

When focusing on within-subject comparisons across BL and PR to isolate the effect of prize risk on investment choices, we find almost no effect of prize risk on mean equilibrium investment across

Table 5: Prize Risk – Regression Analysis

	Dependent variable: $\Delta[x^*(\texttt{PR}) - x^*(\texttt{BL})]$	
	(1)	(2)
Constant	0.099	-0.047
	(0.136)	(0.190)
risk attitude	0.570^{**}	0.524^{**}
	(0.229)	(0.233)
male		0.208
		(0.236)
math grade		-0.130
		(0.114)
misunderstood		0.211
		(0.334)
Observations	144	144
R^2	0.042	0.059

Note: 'risk attitude' is a normalized version of the certainty equivalent elicited in part I of our experiment. In particular, we subtract the certainty equivalent of risk neutral decision makers to ensure that risk neutral participants are our base category. 'male' is a dummy variable that is equal to one for male participants and zero otherwise. 'math grade' is a de-meaned version of the last math grade in high school (self-reported). 'misunderstood' is a dummy that is equal to one if participants indicated that they had problems to understand the instruction in BL, PR, and/or OR. *p<0.1; **p<0.05; ***p<0.01

all subjects. In particular, average investment equals 2.817 units in BL, compared to 2.741 units in PR (WSR: $p = 0.603$). When dis-aggregating the data by elicited risk attitudes of participants, we find that risk averse participants respond to prize risk by investing less (WSR: p-value= 0.045), i.e., they reduce their investments from 2.809 in BL to 2.422 in PR. Risk neutral participants, however, invest almost the same amount in both conditions (WSR: p-value= 0.194). Finally, it is worth mentioning that risk loving subjects invest more in PR than in BL, even though this difference is not significant (WSR: $p = 0.572$), potentially due to the low number of observations.

Columns (1) and (2) of Table 5 show that these findings do not change when using regression analysis rather than non-parametric tests for inference. The regression output provided in column (1) reveals that the within-subject treatment effect $\Delta[x^*(\texttt{PR}) - x^*(\texttt{BL})]$ is close to zero for risk neutral participants, since the measure of risk attitudes used in these regressions equals zero for risk neutral subjects. Moreover, column (1) shows that the reaction to prize risk is systematically related to risk attitudes. In particular, we find that the estimated coefficient for risk attitudes is highly significant and implies that a reduction of the certainty equivalent by 1.00 € in the risk

Table 6: The Effect of Strategic Uncertainty for Expected Equilibrium Opponent Investment

$\mathbf{z}^{\text{exp}} = \mathbf{x}^*_{-\mathbf{i}}$	$x_{1i}(\texttt{C}\|z^{\text{exp}})$	$x_{2i}(\texttt{C}\|x^*_{-i})$	$\Delta[x_{1i}(\texttt{C}\|z^{\text{exp}}) - x_{2i}(\texttt{C}\|x^*_{-i})]$	WSR-test
Baseline ($N = 63$)	2.667	3.000	**-0.333**	$p = 0.030$
Outcome Risk ($N = 37$)	2.757	3.459	**-0.702**	$p = 0.004$
Prize Risk ($N = 66$)	2.258	2.924	**-0.666**	$p = 0.001$

Note: The table provides averages of unconditional choices participants made as type 1, as well as the averages of conditional choices participants made as type 2 when the given opponent investment equals the amount type 1 expects her opponent to invest. We restrict attention to session 3–6 where expected opponent investment choices are elicited (N=96). The reported p-values are obtained using a non-parametric Wilcoxon-signed rank (WSR) test.

elicitation task reduces equilibrium investments by 0.57 units, which amounts to 20% of predicted equilibrium investments under risk neutrality. Column (2) of Table 5 shows that these findings are robust to the inclusion of additional control variables. Overall, we find support for Hypothesis 2:

Result 2 (**Prize Risk**). *Prize risk does neither affect average equilibrium investment choices across all participants nor across participants classified as being risk neutral. Prize risk reduces equilibrium investment choices of risk averse participants, however.*

4.4 Strategic Uncertainty

Theory predicts that agents who *know* that their opponent invests the equilibrium amount should invest more than agents who only *expect* equilibrium investments by their opponent if they take strategic uncertainty into account. Importantly, this prediction does only hold if agents expect equilibrium investments by their opponent. In fact, type-1 participants may optimally respond to strategic uncertainty by increasing rather than decreasing their unconditional investments if they expect their opponent to invest an amount to which their best-response is much lower than the maximum of their best-response function. Therefore, we initially restrict attention to agents who expect equilibrium investment by their opponent, i.e., who expect that their opponent invests either 2.00 €, 3.00 €, or 4.00 €.

Table 6 displays the averages of conditional and unconditional investment choices of participants who expect equilibrium investment by their opponent in conditions `BL`, `OR` and `PR`, respectively. We subsequently compare the unconditional investment choice of a type-1 participant who expects equilibrium investment by the opponent, $x_{1i}(\texttt{C}|z^{\text{exp}})$, with the conditional choice $x_{2i}(\texttt{C}|x^*_{-i})$ that the same participant made as type 2 when knowing for sure that the opponent invests the equilibrium amount. The effect of strategic uncertainty $\Delta[x_{1i}(\texttt{C}|z^{\text{exp}}) - x_{2i}(\texttt{C}|x^*_{-i})]$ has the predicted negative sign in all conditions. Moreover, a non-parametric Wilcoxon signed-rank test (WSR-test) indicates

Table 7: The Effect of Strategic Uncertainty for Expected Off-Equilibrium Opponent Investment

$\mathbf{z}^{\text{exp}} = \mathbf{x_{-i}} \neq \mathbf{x^*_{-i}}$	$x_{1i}(\mathtt{C}\|z^{\text{exp}})$	$x_{2i}(\mathtt{C}\|x_{-i})$	$\Delta[x_{1i}(\mathtt{C}\|z^{\text{exp}}) - x_{2i}(\mathtt{C}\|x_{-i})]$	WSR-test
Baseline ($N = 33$)	2.303	1.909	**+0.394**	$p = 0.575$
Outcome Risk ($N = 59$)	2.932	2.695	**+0.237**	$p = 0.899$
Prize Risk ($N = 30$)	2.133	2.333	**-0.200**	$p = 0.492$

Note: The table provides averages of unconditional choices participants made as type 1, as well as the averages of conditional choices participants made as type 2 when the given opponent investment equals the amount type 1 expects her opponent to invest. We restrict attention to session 3–6 where expected opponent investment choices are elicited (N=96). The reported p-values are obtained using a non-parametric Wilcoxon-signed rank (WSR) test.

that the effect is also statistically significant in all conditions. In particular, subjects in `BL` who expect equilibrium investment of their opponent invest 0.333 units less when being exposed to strategic uncertainty than in the absence of strategic uncertainty, on average. The reaction to strategic uncertainty by subjects in `OR` and `PR` is even twice as high: They reduce own investment by 0.702 in `OR` and 0.666 in `PR` units, respectively, when being exposed to strategic uncertainty. When expressed in relative rather than absolute terms, our findings suggest that participants respond to strategic uncertainty by investing roughly 10% less than in the absence of strategic uncertainty in `BL`, and by investing more than 20% less than in the absence of strategic uncertainty in `OR` and in `PR`. The response to strategic uncertainty is not related to elicited risk attitudes. In particular, the reaction to strategic uncertainty is negative and significantly different from zero both for risk averse and risk neutral subjects.[22] Finally, it is worth mentioning that the reaction to strategic uncertainty is ordered in the same way as the standard deviation of equilibrium investment choices across conditions. The standard deviation of investment choices effectively determines the degree of strategic uncertainty that agents are exposed to when making unconditional choices.[23] Given that participants cannot observe the realized standard deviation of implemented investment choices, it thus appears that they correctly anticipate the variance of investment choices and the resulting degree of strategic uncertainty they are exposed to.

To further investigate if the observed investment difference across conditional and unconditional choices is related to strategic uncertainty, we subsequently consider the response to strategic uncertainty by participants who expect off equilibrium investment by their opponents. As previously discussed, these participants may optimally respond to strategic uncertainty by increasing rather than decreasing their unconditional investments, if the subjective probability mass assigned to equi-

[22]The p-value of the WSR-test is below 0.05 in all subgroups with one exception. The exception are participants classified as being risk neutral in `BL`. Even though they invest slightly less when being exposed to strategic uncertainty, the effect is not significant at conventional levels. Details available upon request from the authors.

[23]The standard deviation is lowest in `BL` (1.10), intermediate in `PR` (1.40), and highest in `OR` (1.87).

librium investment by the opponent is sufficiently high. Table 7 provides the averages of conditional and unconditional investment choices for subjects who expect off equilibrium investment by their opponent in conditions `BL`, `OR` and `PR`, respectively. Interestingly, the reaction of these subjects to the strategic uncertainty they are exposed to is remarkably different. We even find weak evidence that subjects who expect off-equilibrium investment by their opponent respond to strategic uncertainty by investing slightly more. In particular, the average response to strategic uncertainty is positive in conditions `BL` and `OR`, but not significantly different from zero. Subjects in `PR` respond to strategic uncertainty by investing slightly less on average, but the reaction is once again not significant at conventional levels. We summarize our findings as follows:

Result 3 (**Strategic Uncertainty**). *Participants who expect equilibrium investments by their opponent respond to strategic uncertainty by investing significantly less in all conditions. The reaction to strategic uncertainty is more pronounced in conditions `OR` and `PR` where participants are also exposed to fundamental risk.*

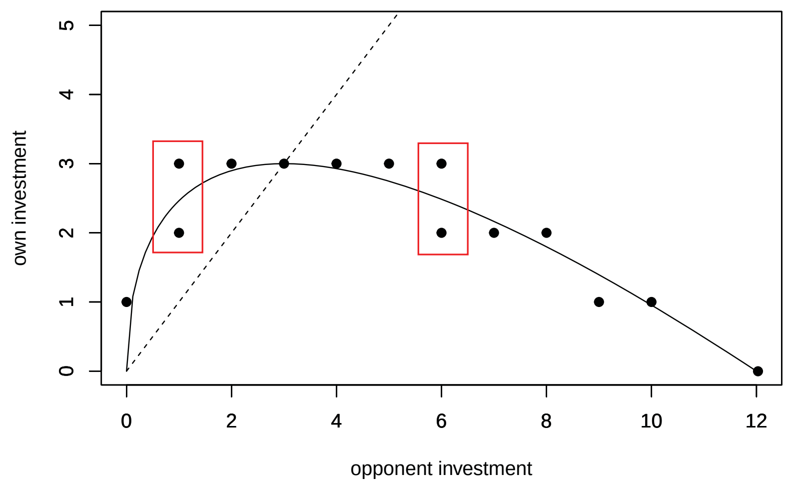
5 Additional Results

5.1 Off-Equilibrium Effects

We have so far only considered the part of elicited best-response functions that delivers a proxy for equilibrium investment choices in tournaments with homogeneous participants if homogeneity is common knowledge. Subsequently, we can investigate how outcome risk and prize risk affect off-equilibrium responses along the best-response function.

Theory predicts that outcome risk has non-monotonic effects on the best-response function of risk averse agents. Intuitively, agents face a trade-off between insuring themselves against the bad outcome ('losing') and gambling for the good outcome ('winning') when choosing their investments, just as in self-protection models (Ehrlich and Becker, 1972). This implies that risk averse agents will invest *more* (*less*) than risk neutral ones if the probability of winning is high (low) due to low (high) investment by the opponent (McGuire et al., 1991). Consequently, the best-response function of risk averse agents in `OR` is predicted to be *above* the one in `BL` initially when the winning probability is sufficiently high due to low levels of opponent investment. As opponent investment increases along the best-response function, the critical switching probability will eventually be reached, and subsequently the best-response function in `OR` is predicted to be *below* the one in `BL`. Regarding prize risk, theory predicts that risk averse agents respond to prize risk by investing less, independent of opponent investment. Consequently, the best-response function of risk averse agents in `PR` is predicted to be *below* the one in `BL` throughout.

Figure 6: Continuous Best-Response Function and Implementation in the Experiment



Note: The figure displays the best-response functions of all agents in the baseline condition (BL) for $\tilde{R} = 12$, and of risk neutral agents in the prize risk (PR) and outcome risk (OR) condition.

We exploit a particular feature of our experimental design to test these predictions that is highlighted in red in Figure 6. In particular, parameters were chosen such that risk neutral decision makers are indifferent between investing 2.00 € and 3.00 € in case the opponent decides to invest either 1.00 € or 6.00 €. Consequently, risk averse decision makers should be indifferent between investing 2.00 € and 3.00 € in BL for given opponent investments of 1.00 € and 6.00 €, respectively, but not in OR and PR. For given opponent investments of 1.00 €, risk averse participants should thus strictly prefer to invest 3.00 € rather than 2.00 € in OR, and instead strictly prefer to invest 2.00 € rather than 3.00 € in PR, respectively. Said differently, risk averse participants are expected to respond differently to outcome risk than to prize risk if the amount invested by the opponent is low. If the amount invested by the opponent is high, however, the reactions by risk averse participants to outcome risk and prize risk, respectively, should work in the same direction. In particular, risk averse participants should strictly prefer to invest 2.00 € rather than 3.00 € both in OR and in PR for given opponent investments of 6.00 €.

Interestingly, we find some evidence that the reaction to outcome risk by risk averse participants is non-monotonic.[24] First, participants who are classified as being risk averse respond to outcome risk by (weakly) increasing their investment from 2.089 in BL to 2.607 in OR if the opponent invests 1.00 €, while they (weakly) reduce their investment from 2.643 units in BL to 2.357 units in OR if the opponent invests 6.00 €. Even though the respective investment changes are not significant at

[24]In what follows, we restrict attention to 56 participants classified as being risk averse who did not indicate that they had problems to understand the instruction in BL, PR, and/or OR. Adding those participants who had problems to understand the instructions leaves all qualitative findings unaffected, but increases the p-values. Details available from the authors upon request.

conventional levels, we find some evidence that subjects respond differently to outcome risk when comparing the differences between investments in `BL` and `OR` for given opponent investments of 1.00 € and 6.00 €, respectively (WSR: $p = 0.078$). When considering prize risk, participants who are classified as being risk averse invest slightly less in `PR` than in `BL` if the opponent invests 1.00 € (2.036 vs. 2.089), and the same holds if the opponent invests 6.00 € (2.286 vs. 2.643). These effects are not significant at conventional levels, however.

To gather additional evidence for the non-monotonic effect of risk aversion on investment choices in the presence of outcome risk, we conducted an additional experimental treatment in part III of two experimental sessions, i.e. after participants completed our main treatment. In this treatment, subjects faced a lottery that paid either 5.25 € or 2.25 €, and we asked them to enter their maximum willingness to pay to increase the chances of the high payoff state by 5 percentage points.[25] These three decision problems covered the low, medium and high probability range: In decision one, subjects could pay for increasing the likelihood of the high payoff state from 45 to 55%, in decision two from 75 to 80%, and in decision three from 20 to 25%. Arguably, the value of this 5 percentage point increase of the high payoff state equals 0.15 € in all cases for risk neutral decision makers. For risk averse decision makers, however, we expect that the willingness to pay is highest when the probability of the high payoff state is high already, and lowest when the probability of the high payoff state is low. When considering decisions of 27 participants who are classified as being risk averse, we find that the willingness to pay equals 0.17 € if the probability of the high-payoff state equals 75%, compared to 0.11 € if the probability of the high-payoff state equals 25%.[26] A Wilcoxon signed-rank test indicates that this difference is significant at conventional levels (p-value = 0.024).

Taken together, our finding provide some evidence for the theoretical prediction that outcome risk has non-monotonic effects on the best-response function of risk averse agents, while the effect of prize risk on investment appears to be negative independent of opponent investment.

5.2 Over-dissipation in Lottery Contests

In line with what we find in our experiment, average contest investments are usually much closer to equilibrium predictions in a share than in a strategically equivalent lottery contest (Baik et al., 1999; Linster et al., 2001). Even though this is not the main focus of this study, our within-subject design has some advantages over existing between-subject studies and thus allows us to shed new light on over-dissipation in lottery contests. In particular, our design allows us to analyze behavioral differences across share and lottery contests that are not yet well understood. First, our experimental design tries to account for potentially bounded rationality of decision makers: We

[25] The elicitation procedure is describe in more detail in Appendix A.

[26] The willingness to pay in the intermediate case is in between and equals 0.16 €.

provide participants with outcome tables and calculators, and force them to think about the decision environment in a mandatory training program prior to each condition. We do this to account for findings by Masiliunas et al. (2014) and Sheremeta (2015) that over-dissipation in lottery contest is related to bounded rationality rather than preferences, or to lacking cognitive reflection, respectively. Second, the within-subject design allows us to account for individual preferences that are unrelated to the difference between conditions `BL` and `OR`. In particular, we can systematically test hypotheses that Chowdhury et al. (2014) discuss in their conclusion according to which differences in behavior across share and lottery contest might either be related to differences in objective risk and strategic uncertainty, or to the fact that there is a clear winner in a lottery contest, but not in a share contest – suggesting that a non-monetary utility of winning such as the 'thrill of victory' affects behavior in a lottery contest, but not in the share contest.

As previously discussed, we find that differences in objective risk are unlikely to explain over-dissipation in the lottery contest condition `OR` relative to share contest condition `BL` (and to the theoretical equilibrium prediction), since participants classified as being risk neutral drive the effect. Moreover, we can rule out any effect of strategic uncertainty in our setting, since we use the elicited best-response function to determine equilibrium investment choices rather than unconditional investment choices as in previous studies. At the same time, over-dissipation in condition `OR` relative to the `BL` condition is systematically related to gender even after controlling for second- and third-order risk attitudes, as well as for a cognitive ability proxy, and for problems to understand the experimental instructions. In particular, male participants invest almost 0.90 € more than female participants ($p < 0.01$) in equilibrium, or close to 30% more than the risk neutral equilibrium prediction. These behavioral differences between female and male participants disappear, however, in a control treatment where participants compete against a computerized opponent who implements choices made by subjects in previous sessions, consistent with the view that males are typically more competitive than female participants and thus more responsive to the 'thrill of victory'. In this sense, our study provides some support to the often made claim that preferences to outperform others deliver a non-monetary value of winning through the 'thrill of victory' and induce over-dissipation in lottery contests through this channel.

6 Concluding Remarks

This paper has investigated empirically how agents react to the uncertainty they are exposed to in tournaments. The results suggest that outcome risk increases average effort choices, while prize risk leaves average effort unaffected. Additional analyses have revealed that these average effects hide substantial variation in individual responses to outcome and prize risk that depend on gender as well as on second- and third-order risk attitudes. Moreover, the paper has shown that agents take strategic uncertainty into account when choosing effort. Specifically, the results indicate that strategic uncertainty might have a pronounced negative impact on effort provision, in particular if the variance of effort choices by the opponent is high due to the presence of outcome or prize risk.

While this study uses controlled variation from laboratory experiments, it appears to be a logical next step to investigate how risk and uncertainty affect performance in tournaments using personnel data. While it is arguably much more difficult to identify reactions on the intensive margin in the field, the results of this paper provide clear-cut predictions for selection effects of promotion tournaments on internal labor markets due to outcome and prize risk, respectively. In particular, the observation that risk averse agents respond to outcome and prize risk by providing less effort than risk neutral or risk loving agents delivers the testable prediction that promotion probabilities of employees are ceteris paribus decreasing in the degree of risk aversion. Given that current income in lower ranks of organizations is often not directly tied to individual performance measures, while the income of managers is typically tied to individual performance measures, it might well be the case that promotion tournaments on internal labor markets are at least partly responsible for the empirical finding based on cross-sectional data that risk averse employees are less likely to face income risk due to pay for performance schemes – see Grund and Sliwka (2010), for example. In particular, risk averse employees might often remain in positions where current income is not tied to individual performance measures because they are less successful in promotion tournaments than their risk neutral or risk loving colleagues. We leave this question for future work.

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Supplementary Appendix

A Experimental Design: Task Substitutions

As already noted in section 3, some parts of the experiment differed across sessions. This section provides reasons for omissions or substitutions of tasks and describes omitted tasks. First, note that all seven sessions had a fourth part which took place between part III and the questionnaire. This part was unrelated to the present experiment and conducted by a third researcher, unaffiliated with the present study. Second, sessions shared the same design if they were conducted during the same month, sessions one and two were conducted in March, sessions three through five were conducted in May, sessions six and seven were conducted in September. Table 8 gives an overview of the sequence of tasks in each session.

Sessions one through five had an additional treatment (`SR`), which was also part of order variation. In this treatment, we sought to identify the effect of strategic risk on investment behavior. It differed from `BL` only insofar, as both players made only the unconditional choice of the type 2 player. Since our analysis focuses on best-response functions only, we decided to not incorporate the measure in the analysis and instead use elicited beliefs to analyze the effect of strategic risk within each condition, starting with session three.

To obtain a measure for the attitude towards strategic risk, sessions one and two contained a choicelist where participants could repeatedly choose between an increasing fixed amount or having to play matching pennies, with payoffs of either €5 or €1. The correlation of this measure is extremely high with our measure of risk aversion ($\rho = 0.717$, $p < .0001$) and thus does not add sufficient explanatory power to our observed effects. Starting from session three, we therefore omit this measure in lieu of eliciting beliefs about the conditional choice. We subsequently moved our test for prudence to take place after the risk elicitation task such that part III now solely consisted of a test for ambiguity preferences.

This test was conducted using a novel and not very time-consuming measure (Kocher, 2015). The measure is based on the risk measure by Gneezy and Potters (1997) and asks subjects to invest any integer amount of 100 points (worth €2 in our experiment) in a risky asset and then another amount of 100 points in an ambiguous asset. Investing into the risky asset yielded a return of 2.5× the amount invested with 50% probability and the investment was lost with 50% probability. For the ambiguous asset, those probabilities remained unknown. At the end of Part II, subjects had to pick a favorite color, either red or blue without knowing the purpose of their choice as the instructions for part III had not yet been distributed. During part III, one participant was

Table 8: Order of Treatments by Session

#	Part Ia	Part Ib	Part IIa	Part IIb	Part IIc	Part IId	Part IIIa	Part IIIb	Other diff.
1	Risk	Str. Risk	BL	SR	OR	PR	Prudence	Ambiguity	n/a
2	Risk	Str. Risk	BL	OR	SR	PR	Prudence	Ambiguity	n/a
3	Risk	Prudence	BL	PR	OR	SR	Ambiguity	n/a	BE
4	Risk	Prudence	BL	SR	PR	OR	Ambiguity	n/a	BE
5	Risk	Prudence	BL	OR	PR	SR	Ambiguity	n/a	BE
6	Risk	Prudence	BL	PR	OR	n/a	T/O probs	n/a	BE
7	Risk	Prudence	BL	PR	OR	n/a	T/O probs	n/a	Comp.

Note: BL: Baseline condition, OR: Outcome risk condition, PR: Prize risk condition, SR: Strategic risk condition, Risk: Risk elicitation task, Str. Risk: Strategic risk elicitation task, Ambiguity: Ambiguity elicitation task, Prudence: Prudence elicitation task, T/O probs: trade off probabilities and outcomes task, Comp.: Opponent was a computer, BE: Belief elicitation about conditional choice of partner in part II.

randomly designated to draw one chip from each of two urns. The first (opaque) urn was used to determine the payoff of the risky asset, and filled with 50 red and 50 blue chips.

We explicitly filled the urn in front of participants after showing them the two stacks of equal size with red and blue chips. The second (opaque) urn was used to determine the payoff from the ambiguous investment and had been filled by a student helper prior to the experiment randomly drawing blue and red chips from a much larger urn containing only blue and red chips. Subjects were free to inspect the urns after the experiment, but no participant chose to do so. Additionally, the subject drawing the chips also drew a ball from a bag of two balls that determined whether the risky or the ambiguous investment decision was payoff relevant.

Given the results of the first five sessions, ambiguity preferences did not have any explanatory power for our results. Sessions six and seven were conducted to find potential explanations for our findings. We therefore removed the test for ambiguity preferences and instead included a task to test for how subjects trade off probabilities versus expected value. In three decisions, subjects were given a lottery that paid 5.25 € in a high payoff state and 2.25 € in a low payoff state. They were then asked to state their willingness to pay (i.e. the amount to subtract from each payoff state) for experiencing a 5 percentage point increase in the probability to end up in the high payoff state. This decision was incentivized using the Becker-deGroot-Marschak mechanism (Becker et al., 1964). The associated probabilities were 45/55 to 50/50 in decision one, 75/25 to 80/20 in decision two, and 20/80 to 25/85 in decision three. One decision problem was randomly selected for payment.

B Experimental Instructions

Welcome to the experiment and thank you for your participation

Please refrain from talking to other participants from now on

General information about the experiment

The purpose of this experiment is to examine economic behavior. You will be able to earn money by participating in this experiment. You will be paid anonymously and in cash at the end of the session.

The experiment will take approximately two hours and a half and consists of four independent parts, which in turn consist of individual sections. At the beginning of every part and section you will be given specific instructions. If you have questions after this or at any time during the experiment, please raise your hand. One of the experimenters will then come to you and answer your questions privately.

During the experiment you, and the other participants, will be asked to make decisions. Your earnings depend on the decisions that you and the other participants make. The exact composition of your earnings is explained below.

While you are making your decisions, the upper right corner of your screen will show the remaining amount of time for this decision. It is possible to exceed the time limit if you need more time for your decisions. This might often be the case at the beginning of the experiment. However, if the screen is only showing information and no decision needs to be made, the screen will fade after the time is over.

Remuneration

Your payoff for today's experiment will mostly be shown directly in Euros. In some of the sections of the experiment, however, you will see your possible earnings in points instead of Euros. The corresponding exchange rate will be explained at the beginning of each relevant section.

You will get a payoff for every one of the four parts of the experiment. However, within each part the computer will randomly and with an equal probability choose which section is relevant for your remuneration. In other words, your remuneration consists from the payoff of one randomly selected section in Part I, Part II, Part III and Part IV.

You will receive 4 €, in addition to the earnings you make in the experiment, for your punctuality and participation.

Anonymity

We only use the aggregate data of the experiment for our analysis and never link names with the data. At the end of the experiment you will be required to sign a receipt with the amount you earned, for the financial statement that our sponsors receive. This information won't be used for any other purpose.

Auxiliary materials

You will find a pen on your desk. Please leave it there at the end of the experiment.

Part I

The first part of the experiment consists of two sections (a and b). As **payment for Part I** you will either receive the payoff from **section a** or the payoff from **section b**. The computer will randomly and with equal probability choose which section is relevant for your remuneration. As you will only be told about which section was chosen for your payment at the end of the experiment, it lies in your own interest to focus equally on each section.

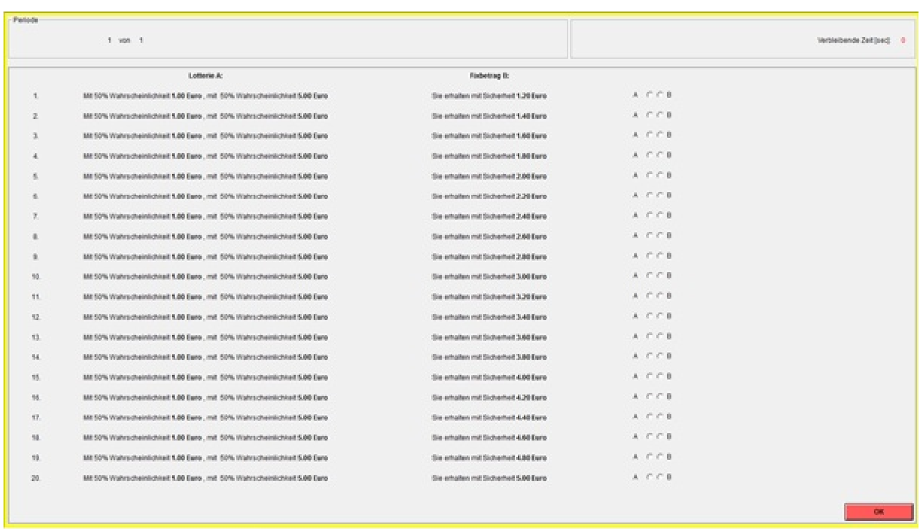
You will find the instructions for Part Ia bellow. You will receive the instructions from Part Ib after completing section a.

Part I, section a (=Part Ia)

Task

You need to solve **20 decision problems** in Part Ia. In every problem you will be able to decide between **a lottery and a certain amount of money**. The lottery is identical for each of the 20 problems, but the certain amount of money increases with each successive decision problem.

Your screen will look like this:



Lottery A pays off **1.00 Euro** with a **50 percent probability** and **5.00 Euros** with a **50 percent probability**. The certain amount B begins with 1.20 Euro and increases to 5.00 Euro (in decision 20) in 0.20 Euro (=20 cents) intervals.

Please choose between Lottery A and the certain amount B for every of the 20 problems . Please notice: Once you change from Lottery A to the safe amount B, you should choose B in every successive decision problem. This is due to the fact that the certain amount B increases for every decision problem.

Estimation questions

After making the 20 decisions, you will be asked to estimate the decisions of the other participants in this section. You will be asked to answer 3 questions in total.

1. What do you think is the average amount of all participants in the room, from which the fixed amount B is preferred over Lottery A?

2. What do you believe is the lowest individual amount among all the participants in this room, from which the fixed amount B is preferred over the Lottery A?

3. What do you believe is the highest individual amount among all the participants in this room, from which the fixed amount B is preferred over the Lottery A?

Please enter your answers in the corresponding field. Please notice that for all three questions your answer should be at least **1.00 Euro** and at most **5.00 Euros**.

Hint: If you do not know what the amount is at which the fixed amount is preferred over the lottery, it is the point at which B is ticked for the first time, instead of A.

Remuneration

Your remuneration from Part Ia will be determined in the following way: First, **the computer will choose, randomly and with an equal probability, one of the 20 decisions you made.** If you chose the lottery A for this problem, the computer will simulate it and you will earn the result from the lottery. Your earnings will correspond to the fix amount if you instead chose B.

Example: Suppose that the computer randomly chooses the first decision problem and that you ticked the Lottery A in that problem. The computer will simulate the lottery and your earnings will be either 1.00 Euro (with a probability of 50 percent) or 5.00 Euros (with a probability of 50 percent).

Additionally, your answers in the estimation questions will add up to your earnings. For this, the computer will, randomly and with an equal probability, choose one of the three questions. The payout from this subsection depends on how close your guess was to the real answer. The closer your answer, the higher the payout. **You will receive a maximum of 2.00 Euros** (if your answer is the correct one), **and a minimum of 0.00 Euros** (if your answer differs too much from the correct one).

In mathematical terms, your payout from this subsection is calculated in the following way:

$$\text{Payout in Euro} = \max\{2 - 2 \cdot (\text{your answer} - \text{correct answer})^2, 0\}$$

Your total earnings from Part Ia will be the sum of your earnings from one of the twenty decision problems and your earnings from one of the three estimation questions. Please note: Even though the computer will calculate your earnings at the end of this section, you will not find out about this information until you have completed all parts of the experiment. At the end of the experiment, you will be able to see your earnings for each individual part.
You will receive the instructions from Part Ib after completing section a.

Part Ib

Task

You need to solve **5 decision problems** in Part Ib. In every problem you will be able to decide between **two lotteries.** Take your time for each decision, your choices – as described below – will determine your payout.
Here is an example of how a decision problem will look like:

Lotterie A	Lotterie B	Ihre Wahl
Sie erhalten 2,75 Euro mit Wahrscheinlichkeit 25% oder 1,75 Euro mit Wahrscheinlichkeit 25% oder 1,50 Euro mit Wahrscheinlichkeit 50%	Sie erhalten 2,25 Euro mit Wahrscheinlichkeit 50% oder 2 Euro mit Wahrscheinlichkeit 25% oder 1 Euro mit Wahrscheinlichkeit 25%	Lotterie A Lotterie B

Remuneration

You profit for this section will be determined in the following way: First, **the computer will choose randomly and with equal probability one of the 5 decisions you made.** The computer will subsequently simulate the lottery you chose.
Example: Suppose that the computer randomly chooses the decision problem above, for which you picked Lottery A. The computer will then simulate Lottery A and you will earn either 2.75 Euros (with a probability of 25 percent), 1.75 Euros (with a probability of 25 percent) or 1.50 Euros (with a probability of 50 percent) in this section of the experiment.
Please notice: Even though the computer will calculate your earnings at the end of this section, you will not find out about this information until you have completed all parts of the experiment. At the end of the experiment, you will be able to see your earnings for each individual part.

Part II

The second part part of the experiment consists of three sections (a,b and c). As **payment for Part II** you will either receive the payoff from **section a** or the payoff from **section b** or the payoff from **section c**. The computer will randomly and with equal probability choose which section is relevant for your remuneration. As you will only be told about which section was chosen for your payment at the end of the experiment, it lies in your own interest to focus equally on each section. You will find the instructions for Part II below.

Short description

In this part, you and a second randomly selected participant will decide over the division of a **prize** in the amount of [[SP: of either **24.00 Euro.** or **0.00 Euro.**. The computer randomly chooses the amount of the prize with a 50-50 percent probability.]] **12.00 Euro.** The division of the prize depends on your investment **X** and the investment **Y** of the second participant in the following way:

Your share of the prize= $\frac{X}{X+Y}$

Your **share** of the **prize** hence equals exactly your investment divided by the total amount of investments. The same applies to the second participant. Your share of the prize is the higher,

- the more you invest.
- the less the other participant invests.

If you and the other participant invest the same amount of money, both of you will receive an equal share of the prize. This also applies for an investment of zero. This means that if you and the other participant both invest 0, you will share the prize equally.

Because you have to make your investment decision independently from the other participant and before you find out about your share of the prize, you and the other participant start this task with an **initial endowment** of 12.00 Euro.

Example: You invest 6.00 Euros and the other participant invests 4.00 Euros. Your share of the prize is the following:

$$\text{Your share} = \frac{X}{X+Y} = \frac{6}{6+4} = \frac{6}{10} = 60 \text{ percent.}$$

You would thus receive 60 percent · 12.00 EUR= 7.20 EUR and the other participant would get 40 percent · 12.00EUR= 4.80 EUR.

[[SP: You would thus receive 60 percent · 24.00 EUR= 14.40 EUR and the other participant would get 40 percent · 24.00EUR= 9.60 EUR if the prize is high. If the prize is low, neither participant would receive a share of the prize.]]

[[OR: In this part, you <u>or</u> a second randomly selected participant, will earn a **prize** in the amount of **12.00 Euro.**. The probability of winning the prize depends on your investment **X** and the investment **Y** of the second participant in the following way:

Your winning probability= $\frac{X}{X+Y}$

Your **probability of winning** of the prize hence equals exactly your investment divided by the total amount of investments. The same applies to the second participant. Your winning probability is the higher,

- the more you invest.
- the less the other participant invests.

If you and the other participant invest the same amount of money, both of you will have a 50 percent probability of earning the prize. This also applies for an investment of zero. This means that if you and the other participant invest 0 each, you get the prize with an equal probability.

Because you have to make your investment decision independently from the other participant and before you find out about your probability of winning the prize, you and the other participant start this task with an **initial endowment** of 12.00 Euro.

Example: You invest 6.00 Euros and the other participant invests 4.00 Euros. Your probability of winning the prize is the following:

$$\text{Your winning probability} = \frac{X}{X+Y} = \frac{6}{6+4} = \frac{6}{10} = 60 \text{ percent.}$$

You would thus earn the prize of 12.00 Euro with a probability of 60 percent and the other participant would get it with a probability of 40 percent.]]

Remuneration

Your **earnings** consist of three components: Your initial endowment, your investment and your share of the prize. Suppose you invested **X Euros** while the other participant invested **Y Euros**. Your payout is calculated in the following way:

$$\textbf{Payout} = \text{Initial endowment - } \mathbf{X} \text{ Euro} + \frac{X}{X+Y} \cdot \text{Prize}$$
$$= 12 \text{ Euro - } \mathbf{X} \text{ Euro} + \frac{X}{X+Y} \cdot 12 \text{ Euro}$$

[[SP:

$$\textbf{Payout} = \text{Initial endowment - } \mathbf{X} \text{ Euro} + \frac{X}{X+Y} \cdot \text{Prize}$$
$$= 12 \text{ Euro - } \mathbf{X} \text{ Euro} + \frac{X}{X+Y} \cdot 24 \text{ Euro } \textbf{(if the prize is high)}$$
$$= 12 \text{ Euro - } \mathbf{X} \text{ Euro } \textbf{(if the prize is low)}$$

]]
An increase in your investments has therefore two effects:

- Your payment will **decrease**, because you have to pay your investment.
- Your payment will **increase**, because you'll earn a bigger share of the prize.

[OR: [Your **earnings** consist of three components: Your initial endowment, your investment and the prize. Suppose you invested **X Euros** while the other participant invested **Y Euros**. Your payout is calculated in the following way:

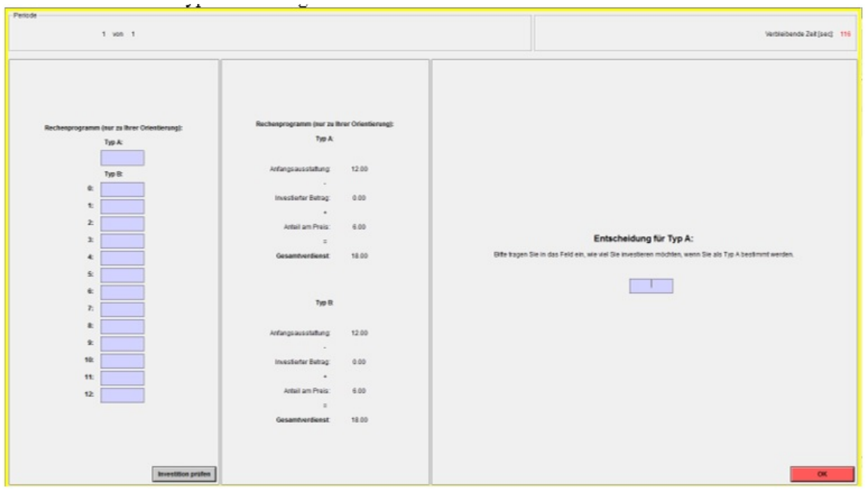
Payout= Initial endowment - **X** Euro + Prize **(if you win)**
= 12 Euro - **X** Euro + 12 Euro **(if you win)**
Payout= Initial endowment - **X** Euro **(if you don't win)**
= 12 Euro - **X** Euro **(if you don't win)**

An increase in your investments has therefore two effects:

- Your payment will **decrease**, because you have to pay your investment.
- Your probability of winning the prize **increases.**]]

You can easily calculate yourself which effect will dominate. Additionally, we will provide you with a calculation program on screen, which will help you visualize the effects of a change in your investment strategy.

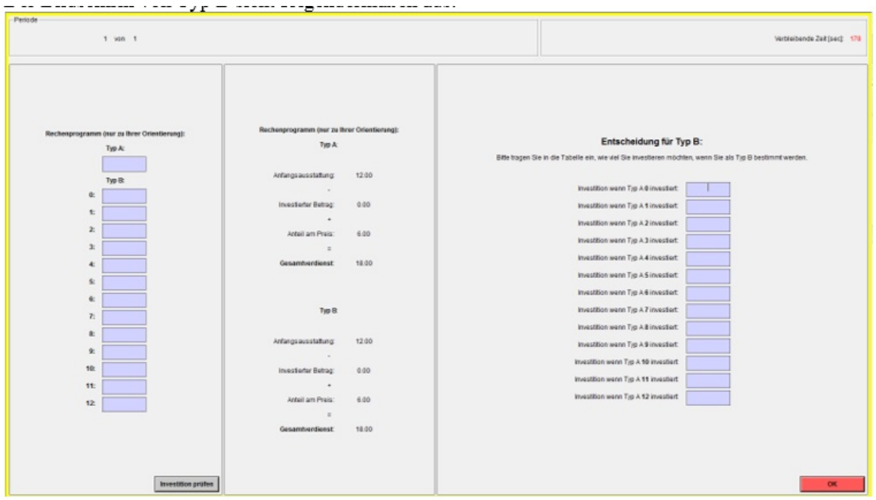
Detailed description
There are two kinds of participants in the experiment, **A** and **B**. The differences between these two types will be clearly explained below.
Type A selects its desired investment by entering the corresponding number on the screen. Any integer from 0 to 12 is permitted, which means that Type A can invest between 0 and 12 Euros.
Type A does not know what the investment decision of Type B will be, thus making its investment decision independently from Type B.
Type's A decision screen looks like this:



The left half of the screen provides you with the aforementioned program that allows you to calculate the effects of changing the investment values for Type A and Type B on your payout. The right side of the screen lets you enter the amount between 0 and 12 that you decide to invest as Type A. Type B does not know how much Type A invested, but can decide his best response to every investment decision that Type A can make. Like before, every integer between 0 and 12 is permitted as an input.

Type B makes hence 13 decisions, and has the possibility to choose an amount between 0 and 12 for each decision. At the end of the section, however, only the decision that corresponds to Type A's input is relevant for Type B's payout.

Type's B decision screen looks like this:



The left half of the screen provides you with a program that allows you to calculate the effects of changing the investment values for Type A and Type B on your payout. The right side of the screen lets you type the amount between 0 and 12 that you decide to invest as Type B for every possible decision by Type A.

Order of events

1. You are randomly matched with another participant.
2. You make your investment decision as **Type A (1 decision)** once, and once as **Type B (13 decisions)**. The same applies to the other participant.
3. The computer randomly assigns you or the other participant to Type A with an equal probability. If you are chosen as Type A, the relevant decision for your payout is the one you made as Type A. The relevant decisions for the other participant are then the ones he made as Type B (and vice versa). The computer then calculates the payouts according to the investment decisions of the assigned Type A and Type B participants.

Even though you make investment decisions both as Type A and Type B, for the payout at the end of the section only one of the two decisions will be relevant for your payout. The computer randomly decides which one it will be. Because you will not know until the end of the experiment which decision is relevant, it is in your best interest to focus equally on each decision.

Estimation question

After finishing your investment decisions, you will be asked to guess the decision that the other participant made. For this question, assume you are Type A and that the other participant is Type B. Answer the following question:

What do you think the Type B participant decided to invest in response to your selected amount as Type A?

Please enter your answer in the corresponding input field. Please notice that your answer should be **at least** 0 and **not more than** 12.

The payoff from this estimation question will be added to your earnings from this section. The closer to the correct answer you are, the higher the payout from the estimation question. You will receive a **maximum of 2.00 Euro** (if your answer is correct) and a **minimum of 0.00 Euro** (if your answer differs too much from the correct one).

In mathematical terms, your payout from this subsection is calculated in the following way:

Payout in Euro $= \max\{2 - 2 \cdot (youranswer - correctanswer)^2, 0\}$

Please notice: Even though the computer will calculate your earnings at the end of this section, you will not find out about this information until you have completed all parts of the experiment. At the end of the experiment, you will be able to see your earnings for each individual part.

You will receive the instructions for Part IIb after completing section a.

Test questions and practice round

You will have to answer a couple of test questions, to be sure that you have understood the instructions, before starting this section. You will only be able to begin with Part IIa once you have correctly answered the test questions. Additionally, you will have a practice round to see first-hand how different investment decisions affect the payout, before having to take the relevant investment decisions. A calculation program will let you change the amount that you and an imaginary second participant can invest, so you can see how the payout reacts to different decisions.

[[SP: You will receive the instructions for Part IIc after completing section b. **Difference to Part IIa**

Please notice that the difference to section a is the following:

The prize does not amount to 12.00 Euro. Instead, it amounts to 24.00 Euro with a probability of 50 percent and to 0.00 Euro with a probability of 50 percent.

Practice round

You will have a practice round to see first-hand how different investment decisions affect the payout, before having to take the relevant investment decisions. A calculation program will let you change the amount that you and an imaginary second participant can invest, so you can see how the payout reacts to different decisions.]]

[[`OR`: You will receive the instructions for Part III after completing section c.

Difference to Part IIa

Please notice that the difference to section a is the following:

The investment decisions from Type A and Type B do not determine the share of the prize. Instead, they determine the probability of winning the entire prize.

Practice round

You will have a practice round to see first-hand how different investment decisions affect the payout, before having to take the relevant investment decisions. A calculation program will let you change the amount that you and an imaginary second participant can invest, so you can see how the payout reacts to different decisions.]]

Please take enough time to understand how the payout structure works for this section. Raise your hand if you have any questions and a supervisor will come to help you.

Part III

Task

You will have to solve three decision problems in Part III. You can choose the maximum **amount** you are willing to pay for each of these problems in order to **change** the **probability** of earning either 5.25 Euro or 2.25 Euro. Take your time for each decision, your choices – as described below – will determine your payout.

Decision problem example:

Lotterie A	**Lotterie B**
Sie erhalten 5,25 Euro mit Wahrscheinlichkeit **75%** oder 2,25 Euro mit Wahrscheinlichkeit **25%**	Sie erhalten 5,25 Euro mit Wahrscheinlichkeit **80%** oder 2,25 Euro mit Wahrscheinlichkeit **20%**
Ihre maximale **Zahlungsbereitschaft** für Lotterie B (anstatt A): [ ] Cent	

You need to indicate the amount you are willing to pay in each decision problem to obtain **Lottery B** instead of **Lottery A**. You can enter a minimum of 0 Cents and a maximum of 50 cents.

Remuneration

Your remuneration for this part of the experiment is determined as follows:

1. The computer will choose **randomly and with an equal probability** one of the three decision problems.
2. The computer chooses a **random number** between 0 and 50. We will name this number the **price**.
3. If you entered a number equal or higher than the price you have to pay the price and obtain **Lottery B**. If your number was **lower** than the price, you **do not** have to pay the price and you obtain **Lottery A**.

The higher the amount you are willing to pay for Lottery B, the higher the probability that Lottery B is relevant for your payout.

If your number was lower than the price, the computer will simulate Lottery A and that will be your payout. If your number was equal or higher than the price, the computer will simulate Lottery B and the result minus the price will be your payout. (The price is the random number between 0 and 50, not the number you entered)

Example

Assume that the computer randomly chooses the decision problem of the table above. You have a maximum payment willingness of X cents and the price was randomly chosen to be Y.

Scenario 1 Your maximum willingness to pay **X** is **lower** than the price **Y**.

This means that **Lottery A** is relevant for your payout. The computer simulates Lottery A and you earn either **5.25 Euros** (with a probability of **75 percent**) or **2.25 Euros** (with a probability of **25 percent**) as your payout for this part of the experiment.

Scenario 2 Your maximum willingness to pay **X** is **equal or higher** than the price **Y**.

This means that **Lottery B** is relevant for your payout and you need to pay the price **Y**. The computer simulates Lottery B and you earn either **5.25 Euros - Y cents** (with a probability of **80 percent**) or **2.25 Euros - Y cents** (with a probability of **20 percent**) as your payout for this part of the experiment.

Please note: You only need to pay the randomly chosen price if your payment willingness is higher than this price. For this reason it is **optimal for you to indicate your actual maximum payment willingness.**

Please note: Even though the computer will calculate your earnings at the end of this section, you will not find out about this information until you have completed all parts of the experiment. At the end of the experiment, you will be able to see your earnings for each individual part.

C Outcome Tables

C.1 Baseline

INVESTMENT Y OF THE OTHER PARTICIPANT

YOUR INVESTMENT X	0	1	2	3	4	5	6	7	8	9	10	11	12
0	18.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €	12.00 €
1	23.00 €	17.00 €	15.00 €	14.00 €	13.40 €	13.00 €	12.71 €	12.50 €	12.33 €	12.20 €	12.09 €	12.00 €	11.92 €
2	22.00 €	18.00 €	16.00 €	14.80 €	14.00 €	13.43 €	13.00 €	12.67 €	12.40 €	12.18 €	12.00 €	11.85 €	11.71 €
3	21.00 €	18.00 €	16.20 €	15.00 €	14.14 €	13.50 €	13.00 €	12.60 €	12.27 €	12.00 €	11.77 €	11.57 €	11.40 €
4	20.00 €	17.60 €	16.00 €	14.86 €	14.00 €	13.33 €	12.80 €	12.36 €	12.00 €	11.69 €	11.43 €	11.20 €	11.00 €
5	19.00 €	17.00 €	15.57 €	14.50 €	13.67 €	13.00 €	12.45 €	12.00 €	11.62 €	11.29 €	11.00 €	10.75 €	10.53 €
6	18.00 €	16.29 €	15.00 €	14.00 €	13.20 €	12.55 €	12.00 €	11.54 €	11.14 €	10.80 €	10.50 €	10.24 €	10.00 €
7	17.00 €	15.50 €	14.33 €	13.40 €	12.64 €	12.00 €	11.46 €	11.00 €	10.60 €	10.25 €	9.94 €	9.67 €	9.42 €
8	16.00 €	14.67 €	13.60 €	12.73 €	12.00 €	11.38 €	10.86 €	10.40 €	10.00 €	9.65 €	9.33 €	9.05 €	8.80 €
9	15.00 €	13.80 €	12.82 €	12.00 €	11.31 €	10.71 €	10.20 €	9.75 €	9.35 €	9.00 €	8.68 €	8.40 €	8.14 €
10	14.00 €	12.91 €	12.00 €	11.23 €	10.57 €	10.00 €	9.50 €	9.06 €	8.67 €	8.32 €	8.00 €	7.71 €	7.45 €
11	13.00 €	12.00 €	11.15 €	10.43 €	9.80 €	9.25 €	8.76 €	8.33 €	7.95 €	7.60 €	7.29 €	7.00 €	6.74 €
12	12.00 €	11.08 €	10.29 €	9.60 €	9.00 €	8.47 €	8.00 €	7.58 €	7.20 €	6.86 €	6.55 €	6.26 €	6.00 €

This table displays your payoff for every possible combination of investments X and Y.

Example:
You choose an investment (X) of 5 and the other participant chooses an investment (Y) of 3. Then you will receive 14,50 €.

C.2 Outcome Risk

INVESTMENT Y OF THE OTHER PARTICIPANT

YOUR INVESTMENT X	0	1	2	3	4	5	6	7	8	9	10	11	12
0	50% 24.00 € 50% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €
1	100% 23.00 €	50% 23.00 € 50% 11.00 €	33% 23.00 € 67% 11.00 €	25% 23.00 € 75% 11.00 €	20% 23.00 € 80% 11.00 €	17% 23.00 € 83% 11.00 €	14% 23.00 € 86% 11.00 €	13% 23.00 € 88% 11.00 €	11% 23.00 € 89% 11.00 €	10% 23.00 € 90% 11.00 €	9% 23.00 € 91% 11.00 €	8% 23.00 € 92% 11.00 €	8% 23.00 € 92% 11.00 €
2	100% 22.00 €	67% 22.00 € 33% 10.00 €	50% 22.00 € 50% 10.00 €	40% 22.00 € 60% 10.00 €	33% 22.00 € 67% 10.00 €	29% 22.00 € 71% 10.00 €	25% 22.00 € 75% 10.00 €	22% 22.00 € 78% 10.00 €	20% 22.00 € 80% 10.00 €	18% 22.00 € 82% 10.00 €	17% 22.00 € 83% 10.00 €	15% 22.00 € 85% 10.00 €	14% 22.00 € 86% 10.00 €
3	100% 21.00 €	75% 21.00 € 25% 9.00 €	60% 21.00 € 40% 9.00 €	50% 21.00 € 50% 9.00 €	43% 21.00 € 57% 9.00 €	38% 21.00 € 63% 9.00 €	33% 21.00 € 67% 9.00 €	30% 21.00 € 70% 9.00 €	27% 21.00 € 73% 9.00 €	25% 21.00 € 75% 9.00 €	23% 21.00 € 77% 9.00 €	21% 21.00 € 79% 9.00 €	20% 21.00 € 80% 9.00 €
4	100% 20.00 €	80% 20.00 € 20% 8.00 €	67% 20.00 € 33% 8.00 €	57% 20.00 € 43% 8.00 €	50% 20.00 € 50% 8.00 €	44% 20.00 € 56% 8.00 €	40% 20.00 € 60% 8.00 €	36% 20.00 € 64% 8.00 €	33% 20.00 € 67% 8.00 €	31% 20.00 € 69% 8.00 €	29% 20.00 € 71% 8.00 €	27% 20.00 € 73% 8.00 €	25% 20.00 € 75% 8.00 €
5	100% 19.00 €	83% 19.00 € 17% 7.00 €	71% 19.00 € 29% 7.00 €	63% 19.00 € 38% 7.00 €	56% 19.00 € 44% 7.00 €	50% 19.00 € 50% 7.00 €	45% 19.00 € 55% 7.00 €	42% 19.00 € 58% 7.00 €	38% 19.00 € 62% 7.00 €	36% 19.00 € 64% 7.00 €	33% 19.00 € 67% 7.00 €	31% 19.00 € 69% 7.00 €	29% 19.00 € 71% 7.00 €
6	100% 18.00 €	86% 18.00 € 14% 6.00 €	75% 18.00 € 25% 6.00 €	67% 18.00 € 33% 6.00 €	60% 18.00 € 40% 6.00 €	55% 18.00 € 45% 6.00 €	50% 18.00 € 50% 6.00 €	46% 18.00 € 54% 6.00 €	43% 18.00 € 57% 6.00 €	40% 18.00 € 60% 6.00 €	38% 18.00 € 63% 6.00 €	35% 18.00 € 65% 6.00 €	33% 18.00 € 67% 6.00 €
7	100% 17.00 €	88% 17.00 € 13% 5.00 €	78% 17.00 € 22% 5.00 €	70% 17.00 € 30% 5.00 €	64% 17.00 € 36% 5.00 €	58% 17.00 € 42% 5.00 €	54% 17.00 € 46% 5.00 €	50% 17.00 € 50% 5.00 €	47% 17.00 € 53% 5.00 €	44% 17.00 € 56% 5.00 €	41% 17.00 € 59% 5.00 €	39% 17.00 € 61% 5.00 €	37% 17.00 € 63% 5.00 €
8	100% 16.00 €	89% 16.00 € 11% 4.00 €	80% 16.00 € 20% 4.00 €	73% 16.00 € 27% 4.00 €	67% 16.00 € 33% 4.00 €	62% 16.00 € 38% 4.00 €	57% 16.00 € 43% 4.00 €	53% 16.00 € 47% 4.00 €	50% 16.00 € 50% 4.00 €	47% 16.00 € 53% 4.00 €	44% 16.00 € 56% 4.00 €	42% 16.00 € 58% 4.00 €	40% 16.00 € 60% 4.00 €
9	100% 15.00 €	90% 15.00 € 10% 3.00 €	82% 15.00 € 18% 3.00 €	75% 15.00 € 25% 3.00 €	69% 15.00 € 31% 3.00 €	64% 15.00 € 36% 3.00 €	60% 15.00 € 40% 3.00 €	56% 15.00 € 44% 3.00 €	53% 15.00 € 47% 3.00 €	50% 15.00 € 50% 3.00 €	47% 15.00 € 53% 3.00 €	45% 15.00 € 55% 3.00 €	43% 15.00 € 57% 3.00 €
10	100% 14.00 €	91% 14.00 € 9% 2.00 €	83% 14.00 € 17% 2.00 €	77% 14.00 € 23% 2.00 €	71% 14.00 € 29% 2.00 €	67% 14.00 € 33% 2.00 €	63% 14.00 € 38% 2.00 €	59% 14.00 € 41% 2.00 €	56% 14.00 € 44% 2.00 €	53% 14.00 € 47% 2.00 €	50% 14.00 € 50% 2.00 €	48% 14.00 € 52% 2.00 €	45% 14.00 € 55% 2.00 €
11	100% 13.00 €	92% 13.00 € 8% 1.00 €	85% 13.00 € 15% 1.00 €	79% 13.00 € 21% 1.00 €	73% 13.00 € 27% 1.00 €	69% 13.00 € 31% 1.00 €	65% 13.00 € 35% 1.00 €	61% 13.00 € 39% 1.00 €	58% 13.00 € 42% 1.00 €	55% 13.00 € 45% 1.00 €	52% 13.00 € 48% 1.00 €	50% 13.00 € 50% 1.00 €	48% 13.00 € 52% 1.00 €
12	100% 12.00 €	92% 12.00 € 8% 0.00 €	86% 12.00 € 14% 0.00 €	80% 12.00 € 20% 0.00 €	75% 12.00 € 25% 0.00 €	71% 12.00 € 29% 0.00 €	67% 12.00 € 33% 0.00 €	63% 12.00 € 37% 0.00 €	60% 12.00 € 40% 0.00 €	57% 12.00 € 43% 0.00 €	55% 12.00 € 45% 0.00 €	52% 12.00 € 48% 0.00 €	50% 12.00 € 50% 0.00 €

This table displays **your payoff** for every possible combination of investments X and Y.

Example:

You choose an investment (X) of 5 and the other participant chooses an investment (Y) of 3. Then with 63% probability you will receive 19,00 € and with 38% probility you will receive 7,00 €.

C.3 Prize Risk

INVESTMENT Y OF THE OTHER PARTICIPANT

YOUR INVESTMENT X

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	50% 24.00 € 50% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €	100% 12.00 €
1	50% 35.00 € 50% 11.00 €	50% 23.00 € 50% 11.00 €	50% 19.00 € 50% 11.00 €	50% 17.00 € 50% 11.00 €	50% 15.80 € 50% 11.00 €	50% 15.00 € 50% 11.00 €	50% 14.43 € 50% 11.00 €	50% 14.00 € 50% 11.00 €	50% 13.67 € 50% 11.00 €	50% 13.40 € 50% 11.00 €	50% 13.18 € 50% 11.00 €	50% 13.00 € 50% 11.00 €	50% 12.85 € 50% 11.00 €
2	50% 34.00 € 50% 10.00 €	50% 26.00 € 50% 10.00 €	50% 22.00 € 50% 10.00 €	50% 19.60 € 50% 10.00 €	50% 18.00 € 50% 10.00 €	50% 16.86 € 50% 10.00 €	50% 16.00 € 50% 10.00 €	50% 15.33 € 50% 10.00 €	50% 14.80 € 50% 10.00 €	50% 14.36 € 50% 10.00 €	50% 14.00 € 50% 10.00 €	50% 13.69 € 50% 10.00 €	50% 13.43 € 50% 10.00 €
3	50% 33.00 € 50% 9.00 €	50% 27.00 € 50% 9.00 €	50% 23.40 € 50% 9.00 €	50% 21.00 € 50% 9.00 €	50% 19.29 € 50% 9.00 €	50% 18.00 € 50% 9.00 €	50% 17.00 € 50% 9.00 €	50% 16.20 € 50% 9.00 €	50% 15.55 € 50% 9.00 €	50% 15.00 € 50% 9.00 €	50% 14.54 € 50% 9.00 €	50% 14.14 € 50% 9.00 €	50% 13.80 € 50% 9.00 €
4	50% 32.00 € 50% 8.00 €	50% 27.20 € 50% 8.00 €	50% 24.00 € 50% 8.00 €	50% 21.71 € 50% 8.00 €	50% 20.00 € 50% 8.00 €	50% 18.67 € 50% 8.00 €	50% 17.60 € 50% 8.00 €	50% 16.73 € 50% 8.00 €	50% 16.00 € 50% 8.00 €	50% 15.38 € 50% 8.00 €	50% 14.86 € 50% 8.00 €	50% 14.40 € 50% 8.00 €	50% 14.00 € 50% 8.00 €
5	50% 31.00 € 50% 7.00 €	50% 27.00 € 50% 7.00 €	50% 24.14 € 50% 7.00 €	50% 22.00 € 50% 7.00 €	50% 20.33 € 50% 7.00 €	50% 19.00 € 50% 7.00 €	50% 17.91 € 50% 7.00 €	50% 17.00 € 50% 7.00 €	50% 16.23 € 50% 7.00 €	50% 15.57 € 50% 7.00 €	50% 15.00 € 50% 7.00 €	50% 14.50 € 50% 7.00 €	50% 14.06 € 50% 7.00 €
6	50% 30.00 € 50% 6.00 €	50% 26.57 € 50% 6.00 €	50% 24.00 € 50% 6.00 €	50% 22.00 € 50% 6.00 €	50% 20.40 € 50% 6.00 €	50% 19.09 € 50% 6.00 €	50% 18.00 € 50% 6.00 €	50% 17.08 € 50% 6.00 €	50% 16.29 € 50% 6.00 €	50% 15.60 € 50% 6.00 €	50% 15.00 € 50% 6.00 €	50% 14.47 € 50% 6.00 €	50% 14.00 € 50% 6.00 €
7	50% 29.00 € 50% 5.00 €	50% 26.00 € 50% 5.00 €	50% 23.67 € 50% 5.00 €	50% 21.80 € 50% 5.00 €	50% 20.27 € 50% 5.00 €	50% 19.00 € 50% 5.00 €	50% 17.92 € 50% 5.00 €	50% 17.00 € 50% 5.00 €	50% 16.20 € 50% 5.00 €	50% 15.50 € 50% 5.00 €	50% 14.88 € 50% 5.00 €	50% 14.33 € 50% 5.00 €	50% 13.84 € 50% 5.00 €
8	50% 28.00 € 50% 4.00 €	50% 25.33 € 50% 4.00 €	50% 23.20 € 50% 4.00 €	50% 21.45 € 50% 4.00 €	50% 20.00 € 50% 4.00 €	50% 18.77 € 50% 4.00 €	50% 17.71 € 50% 4.00 €	50% 16.80 € 50% 4.00 €	50% 16.00 € 50% 4.00 €	50% 15.29 € 50% 4.00 €	50% 14.67 € 50% 4.00 €	50% 14.11 € 50% 4.00 €	50% 13.60 € 50% 4.00 €
9	50% 27.00 € 50% 3.00 €	50% 24.60 € 50% 3.00 €	50% 22.64 € 50% 3.00 €	50% 21.00 € 50% 3.00 €	50% 19.62 € 50% 3.00 €	50% 18.43 € 50% 3.00 €	50% 17.40 € 50% 3.00 €	50% 16.50 € 50% 3.00 €	50% 15.71 € 50% 3.00 €	50% 15.00 € 50% 3.00 €	50% 14.37 € 50% 3.00 €	50% 13.80 € 50% 3.00 €	50% 13.29 € 50% 3.00 €
10	50% 26.00 € 50% 2.00 €	50% 23.82 € 50% 2.00 €	50% 22.00 € 50% 2.00 €	50% 20.46 € 50% 2.00 €	50% 19.14 € 50% 2.00 €	50% 18.00 € 50% 2.00 €	50% 17.00 € 50% 2.00 €	50% 16.12 € 50% 2.00 €	50% 15.33 € 50% 2.00 €	50% 14.63 € 50% 2.00 €	50% 14.00 € 50% 2.00 €	50% 13.43 € 50% 2.00 €	50% 12.91 € 50% 2.00 €
11	50% 25.00 € 50% 1.00 €	50% 23.00 € 50% 1.00 €	50% 21.31 € 50% 1.00 €	50% 19.86 € 50% 1.00 €	50% 18.60 € 50% 1.00 €	50% 17.50 € 50% 1.00 €	50% 16.53 € 50% 1.00 €	50% 15.67 € 50% 1.00 €	50% 14.89 € 50% 1.00 €	50% 14.20 € 50% 1.00 €	50% 13.57 € 50% 1.00 €	50% 13.00 € 50% 1.00 €	50% 12.48 € 50% 1.00 €
12	50% 24.00 € 50% 0.00 €	50% 22.15 € 50% 0.00 €	50% 20.57 € 50% 0.00 €	50% 19.20 € 50% 0.00 €	50% 18.00 € 50% 0.00 €	50% 16.94 € 50% 0.00 €	50% 16.00 € 50% 0.00 €	50% 15.16 € 50% 0.00 €	50% 14.40 € 50% 0.00 €	50% 13.71 € 50% 0.00 €	50% 13.09 € 50% 0.00 €	50% 12.52 € 50% 0.00 €	50% 12.00 € 50% 0.00 €

This table displays **<u>your</u> payoff** for every possible combination of investments X and Y.

Example:
You choose an investment (X) of 5 and the other participant chooses an investment (Y) of 3. Then with 50% probility you will receive 22,00 € and with 50% probability you will receive 7,00 €.