On the Choice of Risk and Effort in Tournaments
—Experimental Evidence

Petra Nieken

Session D3
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–Experimental Evidence

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Abstract

We investigate a simple two-person tournament in a controlled laboratory experiment. Each player chooses between two distributions of random shocks. After observing the overall risk, both players decide simultaneously on their effort. Theory predicts both players should choose the distribution with the higher variance of random shock, as this minimizes equilibrium effort. We show that the effort exerted is sensitive towards risk. The agents exert less effort if the random shock is high. However, agents do not learn to commit themselves by choosing a high risk in our experiment.

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1 Introduction

The purpose of this paper is to investigate empirically risk-taking and the choice of effort in a two-stage tournament model. Tournament situations can be observed frequently in practice, especially if only ordinal, relative information about the performance of the agents is available at reasonable costs. Characteristic examples of tournaments are employees competing for bonuses (Murphy et al. (2004)) or a promotion (Baker et al. (1994)) or fund managers fighting for their clients’ capital (Taylor (2003)). Compare, for instance, O’Reilly et al. (1988) or Main et al. (1993), who investigate the connection between prize differences and the number of participants in a tournament, for an empirical investigation of tournaments in executive compensation. Furthermore, Lee et al. (2008) present evidence that the dispersion of executive compensation is positively related to firm performance.\textsuperscript{1}

Most of the tournament models are based upon the seminal work of Lazear and Rosen (1981) and usually focus on the spread between winner and loser prizes, the optimal investment decision or the effort choice of the agents (see for example Green and Stokey (1983), O’Keeffe et al. (1984) or Clark and Riis (1998)). The more effort an agent exerts as compared to his opponent, the higher his chance of winning the tournament.

Yet, in the real world, agents often also have the opportunity to decide about the risk of their behavior in tournaments. For instance, a fund manager can decide whether to invest in stocks with a high or a low volatility. Managers have the option to implement a new (and often more risky) production technology or to stick to the old, standard technology. Often agents first choose between a high risk strategy and a low risk one, and then decide on their effort to win the tournament.

This paper addresses such a two-stage tournament with risk-taking at the first stage and at the second stage, the effort choice. Based on the theoretical models developed by Hvide (2002) and Kräkel and Sliwka (2004) we investigate risk choice and selection of effort in a controlled laboratory experiment. In our design, we focus on homogeneous agents and are able to

\textsuperscript{1}For a survey on tournaments and contests see e.g., Konrad (2009).
observe the agent’s choice of risk in the first stage and his effort decision in the second stage. Hence, we can (i) investigate the risk-taking behavior of the agents and (ii) analyze their effort reactions towards different states of risk. Thereby, we are able to check the central predictions of the risk-taking strand of the tournament literature.

In our experiment, the agents can choose between two levels of risk before they have to decide on their effort level. According to theory, the choice of risk influences the choice of effort. The higher the chosen risk, the lower the effort the agents will choose. As Hvide (2002) and Kräkel and Sliwka (2004) show, in the second stage, both agents will choose the same amount of effort in a symmetric tournament. In the first stage, both agents will prefer the high risk, as it does not alter their chance of winning but reduces effort costs. As this prediction is not obvious (see Lazear and Rosen (1981) footnote 1 or Hvide (2002) page 884), it is interesting to study risk-taking behavior empirically.

The results from our controlled laboratory experiment show that players act in line with theory predictions in the effort stage and in the first stage adjust their behavior to the risk chosen. However, regarding the risk stage, our results do not support theory, as only 50% of the players prefer high risk. Furthermore, a deeper analysis shows that the players only take their own risk choice into account and not that of their opponents when deciding their effort level, which also contradicts the theoretical prediction.

Previous work on risk-taking in tournaments can be divided into two strands. Examples for the first strand of literature are the papers by Hvide and Kristiansen (2003) or Taylor (2003), where the agents, for example mutual fund managers, can only decide about risk in order to raise their winning probability in a tournament. These papers concentrate on the risk choice and leave out the effort stage. For empirical examples dealing with risk-taking in tournaments, see for instance Becker and Huselid (1992) or Bothner et al. (2007) who investigate risk-taking behavior in stock car racing. Brown et al. (1996) or Chevalier and Ellison (1997) analyze the behavior of mutual fund managers and show that mid-year losers (underperforming funds) increase total risk in contrast to outperforming funds. While follow-up studies like
Koski and Pontiff (1999) or Qui (2003) confirm these findings, Busse (2001) contradicts the results by using daily returns. In his analysis, mid-year winners increase and losers decrease risk. Kempf et al. (2009) deal with these contradicting findings considering employment risk as well. If employment risk is high, mid-year losers will decrease risk-taking in order to secure their jobs. Nieken and Sliwka (2009) conducted the first laboratory experiment investigating the choice of risk in tournaments if the risky strategies are correlated. They show that heterogeneous agents play different equilibria depending on the amount of correlation of the risky strategies.

The second strand of literature which analyzes two-stage tournaments, is more closely related to our research. Closest to our paper are Hvide (2002) and Kräkel and Sliwka (2004), who investigate the problem of risk-taking in two-stage tournaments. In the first stage, the agents decide about the level of risk they want to take and in the second stage, they choose their effort. Hvide (2002) analyzes cases with homogeneous players, whereas Kräkel and Sliwka (2004) combine the choice of risk with asymmetric tournaments. In both settings, the equilibria of the effort stage are symmetric. In contrast, Kräkel (2008) investigates an uneven tournament and shows that also asymmetric equilibria are possible. Recently, Kräkel et al. (2008) have investigated unilateral risk-taking in an experiment. Our paper fills a gap in the existing literature, as we test the key prediction that risk has an influence on effort in a two-stage tournament with homogeneous agents.

The remainder of the paper is organized as follows. In section 2, we introduce the model and analyze the subgame-perfect equilibria. Section 3 describes the experimental design and procedures. The hypotheses are introduced in section 4 and in section 5, we present the experimental results which are discussed in section 6. Section 7 concludes the paper.
2 Theoretical Analysis

The experimental set-up is based on the research of Hvide (2002) and Kräkel and Sliwka (2004). Following their analysis, we present a tournament model with the choice of risk as an endogenous variable. In contrast to Kräkel and Sliwka (2004), we concentrate on the special case without differences in the ability of the agents to keep our model as simple as possible. For the same reason, we do not consider a random shock that consists of two components, a background noise and an endogenous chosen noise, as does Hvide (2002).

2.1 The Model

We consider a simple two-stage tournament between two risk-neutral agents A and B. The production function of an agent \(i\) \((i = A, B)\) will be described by

\[ y_i = e_i + \varepsilon_i \]

where \(e_i\) denotes the effort level of the agent \(i\), which cannot be observed by others. The individual noise term, which we will also refer to as random shock, is specified by \(\varepsilon_i\). \(\varepsilon_A\) and \(\varepsilon_B\) are assumed to be stochastically independent and normally distributed with \(\varepsilon_i \sim N(0, \sigma^2_{\varepsilon_i})\). The agents’ cost functions are assumed to be symmetric with \(c(e_i)\) and \(c'(e_i) > 0, c''(e_i) > 0\).

We assume that \(y_i\) is not contractible. However, the ordinal ranking of the performance results is verifiable. Hence, the optimal contract can only specify a wage payment conditional on this ranking information. The optimal contract is, therefore, a tournament.

The model starts with the first stage (risk stage), where both agents simultaneously choose the risk of their respective production technologies, \(r_i\), with

\[ r_i \in \{L, H\} \text{ and } \sigma^2_H > \sigma^2_L. \]

\(^{2}\)Note that we do not analyze a principal agent model, where the principal optimally designs the tournament game but concentrate on the behavior of the agents.

\(^{3}\)Of course, in the real world tournaments are used if there are high common shocks or if only ordinal information is available at reasonable costs. We could integrate a common shock into our design, which would not alter the results as common shocks cancel each other out in a tournament.
The agents have the chance to increase the variance of the noise term and thereby to induce a mean-preserving spread of $\mathbb{K}$. Each agent observes the chosen risk in the second stage (effort stage) and decides on his effort $e_i$. Both agents compete for the given prizes of the tournament $w_1$ and $w_2$ with $w_1 > w_2 \geq 0$. Hence, $w_1$ is the winner and $w_2$ is the loser prize. $\Delta w$ denotes the prize spread $w_1 - w_2$. The agent $i$ will win the tournament and receive $w_1$ if $y_i > y_j$ whereas agent $j$ gets the loser prize $w_2$ ($i, j = A, B; i \neq j$).

2.2 Equilibrium Analysis

We now analyze the subgame-perfect equilibria of this two-stage game. Therefore, we start with the second stage and analyze the effort. At this stage, the risk choice has already been made and is taken as given. Hence, this stage is similar to a standard tournament model with exogenous random shocks as first proposed by Lazear and Rosen (1981). The expected utility for agent $i$, $U_i$, equals

$$U_i = \Pr \{y_i > y_j\} w_1 + (1 - \Pr \{y_i > y_j\}) w_2 - c(e_i) \quad (1)$$

$$\iff U_i = w_2 + \Delta w \Pr \{y_i > y_j\} - c(e_i) \quad (2)$$

We denote $G = (\cdot; r_i, r_j)$ as the cumulative density function of the composed random variable $\varepsilon_j - \varepsilon_i$. This variable is normally distributed with $\varepsilon_j - \varepsilon_i \sim N \left(0, \sigma^2_{r_i} + \sigma^2_{r_j}\right)$. Therefore, the probability of winning the tournament is

$$\Pr \{y_i > y_j\} = G(e_i - e_j; r_i, r_j)$$

As Lazear and Rosen (1981) already discussed, the existence of pure-strategy equilibria is typically not assured automatically in tournament models. However, if we assume that the following condition holds, we can guarantee the existence of a pure-strategy equilibrium.$^4$

$$\frac{\Delta w}{\sqrt{8\pi \sigma^2_L}} \exp \left( -\frac{1}{2} \right) < \min_{e_i} c''(e_i) \quad (3)$$

$^4$The condition guarantees the concavity of the objective functions. For more details, please refer to Kräkel and Sliwka (2004) page 106.
Proposition 1  For given risk choices the agents will both exert the following effort

\[ e^*(r_i, r_j) = \frac{\Delta w}{\sqrt{2\pi (\sigma^2_{r_i} + \sigma^2_{r_j})}} \]  \hspace{1cm} (4)

The effort is strictly increasing in \( \Delta w \) and decreasing in \( \sigma^2_{r_i} + \sigma^2_{r_j} \).

Proof: See appendix.

As both agents exert the same amount of effort, the probability of winning the tournament is \( \frac{1}{2} \) and is purely random. If the spread between the winner and loser prize \( \Delta w \) increases, winning the tournament is more profitable. Therefore, the agents will exert more effort if the spread rises. The effort will decrease if the tournament becomes more noisy. A higher overall variance of the random shock will reduce the marginal gain of increasing effort.

We go on to analyze the optimal choice of risk of each agent in stage 1. We already know that a higher overall variance will induce a reduction of the equilibrium effort. Note that the choice of risk will not affect the winning probability because, as already mentioned above, both agents will exert the same effort for a given level of risk.

Proposition 2 The agents will always choose the risky strategy \( r_H \) with the higher variance \( \sigma^2_H \). The choice of risk is therefore \((r_i, r_j) = (H, H)\).

Proof: See appendix.

Both agents want to increase the risk by choosing the random shock with high variance. This choice induces a mean-preserving spread of \( y_i \), which has no direct effect on the expected output. The intuition for proposition 2 is that the agents have an incentive to raise the noise of the tournament and thereby reduce the effort level they will choose in the second stage. Note that this result can be generalized for risk-averse agents as well. For further details, please compare Hvide (2002) p. 885. Hence, by choosing the high risk strategy, the agents can commit themselves to exerting less effort, which reduces their costs but does not alter their winning probabilities.
3 Experimental Design and Procedure

We implemented a simple rank-order tournament with endogenous risk choice in a controlled laboratory experiment. As we assume in the theoretical model that only ordinal ranking information is verifiable, the players were paid based on their ordinal ranking as well. The experiment consisted of 27 periods and 30 participants and we collected 810 observations. In each of the 27 periods, two players were matched together randomly and anonymously. Hence, each participant played 27 times and each time with a different opponent. We implemented a perfect stranger matching to prevent reputation effects or reciprocity. In this experiment, the players had to choose between two different distributions of random shock, which only differed in variance. After they had both chosen the distribution of risk simultaneously and observed the choice of their opponent, they chose effort.

The experiment was conducted at the Cologne Laboratory of Economic Research at the University of Cologne in June 2007. Altogether, 30 students participated in the experiment. All participants were enrolled in the Faculty of Management, Economics, and Social Sciences and had completed their second year of studies. For the recruitment of the participants, we used the online recruitment system by Greiner (2003). We used the experimental software z-tree by Fischbacher (2007) for programming the experiment.

At the outset of the session, subjects were randomly assigned to a cubicle, where they took a seat in front of a computer terminal. The instructions were handed out and read out by the experimenters. After that, the subjects had time to ask questions if they had any difficulties in understanding the instructions. Communication - other than with the experimental software - was not allowed.

The session started with six trial periods so that the players could get used to the game. In the trial periods, each player had the opportunity to simulate the game by choosing the strategies for both players and observing

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5 The theoretical predictions for the experimental game are independent of finite repetition as the repeated game involves the choice of the Nash equilibrium's risk and effort levels of the one-shot game in each period.

6 The instructions can be obtained from the author upon request.
the outcomes. These trial periods were not related to any payment. Then the 27 main periods started. All periods were identical but played with a different partner. In each period, the player with the higher final score won the tournament. The final score was the sum of the points the player could choose (effort) and additional points that were drawn from a normal distribution (random shock). At the beginning of each period, the players had to choose between two states $A$ and $B$. If they chose state $A$ (low variance), the additional points were drawn from a normal distribution with a mean of zero and a standard deviation of 23.1 points. If they chose state $B$ (high variance), the additional points were drawn from a normal distribution with a mean of zero and a standard deviation of 46.2 points. After they had chosen the state, they were informed about the decision their opponent made. Hence, the information about the states was common knowledge.

Then, both players were asked to choose a number of points between zero and 100 (inclusive) simultaneously. The higher the number of points chosen, the higher were the costs of that decision for the player. Each player was given a cost table, where the costs were calculated using the cost function $c(e_i) = \frac{e_i^2}{100}$. Additionally, the players were asked to report their belief about the number of points their opponent would choose. After they had chosen their number and reported their belief, they observed their additional points and the final scores of both players. They were also informed which player was the winner of the period. This information enabled the players to learn over the course of the experiment. At the end of the 27 periods, one of the periods was drawn by lot. Each player who won the tournament in which he participated in the drawn period earned the winner prize of 159 taler, each loser earned the loser prize of 100 taler. The costs for the number of points chosen were subtracted from the prize. All players who had reported a correct belief received a bonus of 15 taler if the belief was exactly the number of points chosen by their opponent. If the belief was within one point of the amount chosen, the player received 12 talers and if it differed two points, he received 9 talers and so on. If the belief deviated more than 4 points, no reward was paid. Additionally, all subjects received a show up fee of 2.50 Euro independent of their status as winner or loser. The
exchange rate was 0.16 Euro per taler and on average, the players earned 19.81 Euro in this experiment. After the last period, the subjects were requested to complete a questionnaire including questions on gender and age. This questionnaire also contained questions concerning the subject’s risk attitude. These questions were taken from the German Socio Economic Panel and deal with the overall risk attitude of the subject. Dohmen et al. (2005) have shown that the general question about the willingness to take risks is a good predictor of actual risk-taking behavior and the risk choice in lotteries. The whole procedure took about one and a half hour.

4 Hypotheses

First of all, based on the theoretical reasoning above, we start by investigating the choice of effort. At this stage of the game, the decision about risk is already made. Therefore, it should be taken as exogenous in this stage. Nevertheless, the players should react to the difference of the variance of the random shock and exert more effort, if the overall variance is lower. The lowest effort should be exerted (in this experiment symbolized as the choice of the number of points), if both players have chosen state $B$ (high variance), which we will denote as state 1. In contrast, we expect the effort chosen by the player to be highest if both have chosen the state $A$ (we call that state 3 or low variance). If one player has chosen state $A$ and the other state $B$ (referred to as state 2), the effort chosen should be higher than in state 1 and lower than in state 3 (Hypothesis 1).

Of course, the model makes a more precise prediction if we -like in the theoretical model- assume that the agents are risk neutral.7 If the players are in state 1, they should choose the number of 18 points in equilibrium (Hypothesis 1.1). In state 3, they should choose 36 points in equilibrium (Hypothesis 1.2). The number of points chosen in state 2 should be 23 in equilibrium (Hypothesis 1.3). We do not expect the participants of the experiment to understand the game perfectly. But, they should at least get closer to the equilibrium over the course of the experiment.

7The effort of risk-averse players should be lower in equilibrium. See Kräkel (2008).
Let us now look at the hypothesis regarding the choice of risk. We expect the players to choose state $B$ with the high variance in all cases. Although we cannot expect that participants in the experiment are able to understand the game perfectly, the data should at least show that the players learn that state $B$ is the best choice over time (Hypothesis 2).

According to theory, only the overall variance matters. Therefore, there should be no difference in the strategy of the player if he has chosen state $A$ and his opponent state $B$ or if he was the one who has chosen state $B$ and his opponent has chosen state $A$. The effort exerted in both cases should be equal (Hypothesis 3).

5 Results

We start by investigating the effort (number of points) chosen by the players after they have observed which state of risk their opponent has selected. Figure 1 shows the mean of effort sorted by state. 188 (23.21%) of our 810 observations are of state 1 (high/high), 202 (24.94%) of our observations of state 3 (low/low) and 420 (51.85%) observations in state 2. In state 1, where both players have selected the high variance, the effort chosen is the lowest with a mean of 25.73 compared to the other states. With a mean of 47.55, the players choose the highest effort in state 3 with the low variance for both players.

![Figure 1: Mean of effort sorted by state](image_url)
The effort chosen in state 2 is, with an average of 37.57, higher than in state 1 and lower than in state 2. These observations are well in line with the theoretical prediction that the effort rises if the overall variance declines. To test whether the state has an effect on the choice of effort we run regressions. In all cases, the dependent variable is effort. The results are reported in table 1.

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†Robust standard errors in parentheses are calculated by clustering on subjects
++We report the within $R^2$ for the fixed effects regressions
***p < 0.01, **p < 0.05, *p < 0.1

Table 1: regressions for effort dependent on state

We use dummy variables for the states 1 and 3 as independent variables in all regressions. The dummy variable for state 1 (3) is one if the players are in state 1 (3) and zero otherwise. State 2, therefore, is the reference category in these regressions. We control for time trends by using the variable period, which counts the periods of the experiment. We also run regressions including period to control for non-linear time trends but the results do not change. The variable period does not show any significant influence.
intraperson correlation. The first regression (1) is a simple OLS. Regarding the results of this regression, we show that both dummies for the states are highly significant. As the reference category is state 2 the regression predicts that players choose an average effort of 37.57 if they are in state 2. The effort declines about 11.84 if the players are in state 1 with the high overall variance. Furthermore, the regression reveals that the effort selected by the players rises about 9.981 if they are in state 3 as compared to state 2. The results do not change qualitatively if we control for variables like gender or the risk attitude of the players.9 We also run fixed effects regressions reported in columns (3) and (4) of table 1 which show qualitatively the same results.10 The players act well in line with theory and adjust to the different variances of the random shock. If the tournament contains more noise in terms of a higher overall variance, the players reduce their effort significantly and choose a lower number of points.

But we have also seen that the mean of effort chosen is always higher than predicted by the theoretical equilibrium. Note that most of the players (more than 60%) state risk neutrality in our questionnaire so that we can expect them to choose the effort level predicted for risk neutral players.11 To check whether the difference is significant, we exert a one sample mean comparison test for each state and compare the theoretical and empirical mean of effort. In all states, the empirical mean is significantly higher than the theoretical mean ($p = 0.000$). This behavior has occurred in many experiments, see for example Bull et al. (1987) or Wu and Roe (2005). Grund and Sliwka (2005) offer a possible explanation and show that inequity-averse agents exert higher effort levels than purely self-interested ones. A look at regression (2) shows that the variable period has a significant negative influence on the exerted effort. Hence, the players learn over the course of

9Please refer to table A1 in the appendix for the complete results.
10Additionally, we analyze the results of only the first period, as this is similar to a one shot game. The jonckheere-trepstra test shows that there are significant differences in the effort choice depending on state. Thus, the behavior in the first period is in line with the behavior in the pooled data.
11Compare figure A1 in the appendix for an overview of the risk attitudes of the players. We do not find any significant differences in effort levels when comparing risk neutral players to the others.
the experiment and get closer to the equilibrium.\textsuperscript{12} We can summarize the observations as follows.

**Result 1** (Hypothesis 1): *If the players are in state 1 (high/high), their effort chosen is significantly lower than in state 2 (high/low or low/high). The effort is highest if they are in state 3 (low/low). Hence, the players act in line with Hypotheses 1 and adjust their behavior according to the overall variance. However, we have to reject Hypothesis 1.1, 1.2 and 1.3 because the players choose a significantly higher effort level in all states as compared to the equilibrium predictions. We observe learning behavior, which directs the players closer to equilibrium over the course of the experiment.*

Now, we investigate the choice of risk. As we pointed out in Hypothesis 2, the players should prefer state $B$ with the high variance in equilibrium. In the experiment, 49.14\% of the players choose state $B$ (high variance) and 50.86\% of the players preferred state $A$ (low variance) instead. Hence, the players do not act in line with theory. Looking at figure 2 we see that this behavior does not change over the course of the experiment.

![Figure 2: Fraction of the choice of state for two subperiods](image)

The players do not learn that state $B$ should be favored. One possible reason for this observation might be the fact that a certain amount of players (13) sticks to their decision over all 27 periods. Seven of the players always choose

\textsuperscript{12}Check figure A2 in the appendix for a graphical overview.
state A and six always prefer state B. We have to reject Hypothesis 2.

**Result 2** (Hypothesis 2): The players choose state A in 50.86% of the cases and state B in 49.14% of the cases. The players do not change their behavior over the course of the experiment. Hence, Hypothesis 2 is rejected.

To investigate Hypothesis 3 we have to divide state 2 into two different sub-states 2a and 2b. In state 2a, the player has chosen the high variance and his opponent the low one. The opposite is true for state 2b. In this state, the player has picked the low variance and his opponent the high one. Figure 3 shows the mean of effort sorted by the divided states. We see that the players act differently in state 2a (high/low) and 2b (low/high). In state 2a, the mean effort is 26.85 and in state 2b, the mean is 48.30. To test whether the means of state 2a and 2b are significantly different, we execute a Wilcoxon matched-pairs signed rank test. The mean of effort chosen in state 2a is significantly different from the mean of effort chosen in state 2b (p = 0.000). Therefore, we cannot treat state 2a and state 2b as the same state as theory predicts. A look at figure 3 shows that the players do not seem to consider the risk choice of their opponent when selecting their effort.

![Figure 3: Mean of effort sorted by state with state 2 divided in state 2a and state 2b](image)

On average, the players choose a higher effort if they have selected state A (low variance), than if they have selected state B (high variance). The means of state 1 and state 2a are very similar and the same is true for the means of state 2b and 3. In contrast, the means of state 2a and 2b are
significantly different. These observations suggest that players only react to the variance of the random shock that they have chosen and do not take into account the choice of their opponents. Then the choice of state $A$ or $B$ should be sufficient to explain the choice of effort. We investigate this by using regressions. Again, the dependent variable is the effort chosen by the player and we compute robust standard errors by clustering on subjects. The independent variables are dummy variables. The first one is a dummy for the choice of state the player himself has made whereas the second one is a dummy variable for the choice of state of his opponent. Both dummy variables are one if state $B$ is chosen, and zero otherwise. The results are reported in table 2.

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<td>(5.42)</td>
<td>(0.80)</td>
<td>(0.90)</td>
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<tr>
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<td>810</td>
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<td>810</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td>0.19</td>
<td>0.19</td>
<td>0.07$^{++}$</td>
<td>0.07$^{++}$</td>
</tr>
</tbody>
</table>

$^+$ Robust standard errors in parentheses are calculated by clustering on subjects
$^{++}$ We report the within $R^2$ for the fixed effects regressions

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2: regressions for effort dependent on choice of risk of the players

In regression (1) we see that the players choose an average effort of 47.93 if they have selected state $A$ (low variance). The effort chosen declines significantly, if they have selected the high variance (state $B$). The effort is 21.61 points lower on average if the players are in state $B$ compared to state $A$. Regression (2) contains a dummy for the choice of state of the opponent, too. If the players take the choice of risk of their opponent into account,
this variable should have a significant influence on the effort chosen by the
player. However, the dummy has no significant influence and the coefficient
is very small. This result does not change if we insert other control variables
like gender or risk attitude and we observe learning behavior if we include
the variable period.\textsuperscript{13} The fixed effects regressions reported in columns (3)
and (4) also lead to qualitatively similar results. Looking at the adjusted
$R^2$ we observe that it is higher if we use the individual risk-choice as an
independent variable, than if we use the state which denotes the overall risk
like in table 1. Hence, we can conclude that the players focus on their own
decision about the risk in a tournament. The risk-choice of their opponent
is only of minor importance for their decision on the effort.

\textbf{Result 3 (Hypothesis 3): The players choose a significantly lower effort if
they are in state 2a (high/low) than in state 2b (low/high). The experimental
results show that the players do not act in line with the prediction that they
should take into account the overall variance and not only the one they have
selected. Therefore, we have to reject Hypothesis 3.}

In our experiment, we have also collected information about the players’
belief about the effort of their opponent. To the best of our knowledge, we
are the first to investigate elicited beliefs about effort in a tournament. This
allows us to disentangle the decision process of the subjects in the experiment
to some extent. We can now investigate (i) the players ability to estimate
the effort of their opponent correctly (ii) what drives this estimation and
(iii) if the players act rationally and exert the optimal effort for their given
belief.

Figure 4 shows the mean of difference between the belief of the player
and the actual effort of his opponent.\textsuperscript{14} This difference is higher if the
players have chosen different risks than if they have chosen the same amount
of risk. It is quite intuitive that it is more difficult to put oneself into the
position of the opponent if the opponent has chosen a different risk level.
Another important observation of figure 4 is that the players overestimate
the actual effort of their opponents if their opponents have chosen high risk

\textsuperscript{13}Compare table A2 in the appendix for details of the regressions.
\textsuperscript{14}See also table A3 in the appendix.
and underestimate actual effort if they have chosen low risk. To investigate what determines the beliefs of the players we run regressions with the belief as the dependent variable. The results show that the players formulate their beliefs based upon the choice of risk of their opponent but do not take into account their own risk choice.\textsuperscript{15} As we have seen, the selected risk influences the choice of effort of the players and the selected risk of the opponent influences the stated belief. Hence, the players assume that their opponents act the same way they act themselves.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure4.png}
\caption{Mean of difference between belief of the player and effort of partner by state}
\end{figure}

Next, we investigate whether the players act rationally and exert the optimal effort given their stated belief. We can derive the optimal effort for each belief the player has about the true effort of his opponent. Of course, the optimal reaction depends not only on the belief of the player but also on the state. Therefore, we have three reaction functions, one for each state.\textsuperscript{16} The difference between the effort the player really exerts and the best response effort shows how much the player deviates from optimal behavior if he acts according to his belief. Table A5 in the appendix shows the mean of that difference sorted by state. As we have already mentioned the players exert more effort than the theory would predict in all states.

\textsuperscript{15}See table A4 in the appendix.
\textsuperscript{16}See figure A3 in the appendix.
Again the players act differently in state 2a (mean 29.26) and 2b (mean 21.05) (compared to state 1 mean 8.78 and state 2a with 6.46). The highest deviation of the optimal effort occurs in the state 2b and 3. In both states, the player has selected the low risk and selects an effort that is too high compared to the optimal one. But as can be seen from a comparison of the last two columns in table A5 in the appendix, we observe learning behavior over the course of the experiment. Over the course of the experiment, the players develop a better understanding and get closer to the optimal effort for a stated belief. This explains the learning behavior which we observe in Hypothesis 1.

6 Discussion

The experimental results of section 5 have revealed two interesting observations, which contradict the theoretical predictions. (1) the players do not take into account the overall risk when deciding about effort and (2) they do not always prefer high risk in the first stage. We will discuss these findings and offer possible explanations for the observed behavior.

Our results show that the players only respond to their own risk choice when choosing effort. It is interesting to investigate why the players fail to act in line with theory and what drives their decisions. We are able to disentangle, and thereby shed some light into, the decision process of the players by using their stated beliefs. The analysis has shown that players state their beliefs about the effort of their opponent based solely on the risk decision of this opponent. Hence, the players understand that the risk of the opponent influences the opponent’s decision at the effort stage. In other words, they expect their opponents to take into account the same decision variable (only own risk choice) as they do themselves. However, they do not take into account the risk choice of their opponent when selecting effort. They do not enter the necessary level of reasoning to solve this rather complex problem correctly. It could be too cognitively demanding or costly, as solving this kind of problem requires mental costs. In a first step, they act in line with

\[17\] For more details to the theory about depth-of-reasoning and mental costs see for
theory because if they choose high risk they prefer low effort. Hence, they understand the impact of their own risk choice on their own effort level. In a second step, players expect their opponents to react in the same way. They have formed a correct belief about the actual behavior of their opponents. In a third step, however, the players fail to understand that they should take into account the overall risk and therefore also the risk choice of their opponent when deciding about their effort. This requires comprehending that a tournament is based on a relative performance evaluation and therefore the overall risk matters. As the risk choice of the opponent influences the opponent’s effort this risk should clearly have an impact on the other player’s effort as well.

To investigate whether reducing complexity helps subjects to find the theoretical solution, we conducted an additional treatment. This treatment was only designed for the purpose of exploring this puzzle and it was conducted at the Cologne Laboratory for Economic Research in April 2009. The number of participants and the parameters were identical to the ones used in the baseline treatment.\textsuperscript{18} In contrast to the baseline treatment we simplified the risk-taking stage of the tournament. By reducing the complexity of this stage we are able to investigate whether players fail to take into account the overall risk due to complexity or not. Therefore, we modified the design in the following way. As in the baseline treatment, both players could decide between strategy $\text{A}$ (low risk) and strategy $\text{B}$ (high risk) in the first stage. However, this choice did not determine the variance of the individual noise term anymore but it did influence the overall risk. In contrast to the baseline treatment, we did not execute a random draw for each opponent separately but only one random draw from the joint distribution of risk. The players knew that their choice of strategy $\text{A}$ or $\text{B}$ influenced the variance of this joint distribution. If both chose $\text{A}$ ($\text{B}$), variance was low (high) and if one selected $\text{A}$ and the other $\text{B}$, it was moderate. The outcome of the random draw was added to the final score of the player in 50% of the cases and to the opponent’s score in the other 50% of the cases. In this setting, the players

\textsuperscript{18}The full set of instructions can be obtained from the author upon request.
knew that their risk choice affected the overall distribution of risk, which affected both players equally. As the players were explicitly informed that risk was moderate if they have chosen A and their opponent B or the other way round, we expected them to react similar in the situations low/high and high/low.

However, the data shows that players still act differently in those situations when selecting effort. Their reaction is qualitatively similar to the behavior of the subjects in the baseline treatment (see figure 3 and appendix figure A4). Surprisingly, the subjects focus on their own contribution (either $A$ or $B$) to the variance of the overall risk even though it was stated explicitly that risk would be influenced by both contestants. Given the moderate risk situation, players exerted significantly higher effort if they had chosen strategy $A$ than if they had chosen $B$. Hence, reducing the complexity of the task did not eliminate this puzzle fully. However, if we look at regression (1) in table A6 in the appendix with effort as the dependent variable and dummies for the own choice ($A$ or $B$) and the choice of the partner, we see that the partner dummy is almost significant at the 10% level. When using a fixed effects regression, the dummy gets weakly significant, which indicates that reducing complexity leads to better understanding of the task. Although the impact of the opponent’s risk choice is relatively small compared to the influence of the own risk choice the additional treatment shows that reducing complexity affects behavior. Players come a little closer to equilibrium even though their main focus lies still on their own risk choice.

However, there might be additional explanations for this kind of behavior. The players might put more weight on their own contribution due to an egocentric bias or the illusion that they can control the situation with their choice. Another possible explanation would be that their choice serves as a kind of anchor for them. As they first choose their own risk or contribution to overall risk and afterwards learn about the choice of their opponent, the players might put more weight on their first active decision than on the choice of their opponent. These suspicions are supported by the results of an experiment recently conducted by Kräkel et al. (2008). They investigate an uneven two-stage tournament where only the favorite selects risk at the
first stage. Even though subjects changed roles after each period, Kräkel et al. report that favorites react more strongly to risk than underdogs. Hence, subjects acting in the role of a favorite in the respective period react to their own chosen risk but if they switch to the role of an underdog in the next period, they react less to chosen risk. As we have shown this behavior can be reduced by a less complex task but it still remains relatively stable in our setting.

Now we discuss the second puzzle concerning risk-taking in this paper. At the risk-taking stage, only about half of the players choose the high risk, which is not in line with theory. It might not seem unreasonable to suppose that the risk attitude of the players could help to solve this puzzle. But already Hvide (2002) states there is no difference in the optimal risk choice of risk neutral and risk-averse agents. Indeed, we do not find a significant influence of the risk attitude on the risk choice in our data either (see appendix table A7). As we already mentioned in section 5, most of the players state a quite risk neutral attitude in our questionnaire. Hence, the risk attitude of the players does not explain this puzzle. We also checked whether age, gender or period have an impact on the choice of risk but do not find any significant influences (see also appendix table A7). Furthermore, agents do not learn to switch to high risk over the course of the experiment even though subjects who selected high risk earned more on average in this experiment. Hence, it was the optimal strategy to select high risk in this experiment in order to maximize earnings.

Recall that choosing the high risk no longer serves as a commitment device to reduce the effort of both players at the second stage if the risk choice has no impact on the effort decision of the opponent. Hence, players might have less incentives to select high risk because – as we know from their beliefs – they do not expect their opponent to react to overall risk. Nevertheless, following theory, the players should always prefer high risk, in

\[19\] With homogeneous agents, there is a symmetric equilibrium at the effort stage and the winning probability is therefore \(\frac{1}{2}\) no matter which risk the agents prefer. Hence, the choice of risk only influences the amount of effort chosen and not the income risk. It is therefore the best option for two risk-averse agents to choose the high risk as well and thereby reduce the costs of effort.
order to at least reduce their own effort and effort costs. However, another reason for preferring low risk might be that the players think they can gain more control over the outcome of the game if they choose low risk.

Another explanation might be that one needs to find a subgame-perfect equilibrium for solving the risk-stage of the tournament correctly. There are several papers discussing the fact that in experiments or the real world subgame-perfect equilibria or even Nash equilibria are not played. Compare for example the seminal article of Selten (1978) or the papers of Johnson et al. (2002) or Binmore et al. (2002), who show that players tend to not using backward induction in bargaining games. Johnson et al. (2002) conducts an experiment were undergraduates (mostly from business or economics) played a three round bargaining game, while Binmore et al. (2002) investigate one or two-stage alternately-offer bargaining games with undergraduates. Both report that players fail to apply the concept of backward induction or subgame-perfectness. Note that players come closer to equilibrium if trained players (those who quickly learned to apply backward induction) interact with untrained ones (see Johnson et al.). As our tournament situation is at least as complex as a bargaining game, we suspect our subjects may not have applied these concepts either. We can also show that reducing complexity of our task in the additional treatment leads players closer to equilibrium behavior, which supports this assumption. Even though players still focus on their own contribution to risk when deciding about effort, about 70% of them (compared to about 50% of them in the baseline treatment) select high risk. This indicates that players develop a better understanding of the task if the complexity at the risk stage is reduced and come closer to equilibrium. However, tournament situations in the real world often have a structure which is similar to our baseline treat-

20 Goeree and Holt (2001) and Selten and Stoecker (1986) argue that learning from past experience affects behavior in experiments. However, in our experiment the players have many opportunities to learn. In the trial periods, they could simulate the strategies for both players and observe the outcomes. Anyhow, the risk-taking behavior does not change significantly over the course of the experiment, which would be an indicator of learning effects.

21 See figure A5 in the appendix.
ment and therefore rather complex. It is very likely that subjects in those tournaments fail to take into account overall risk and do not always select the optimal risk.

7 Conclusion

We investigate a rank-order tournament with two-stages in a controlled laboratory experiment. At the first stage, the agents decide about risk. They can both choose if the variance of the individual noise term is high or low. After having observed the risk choice of their opponent, they select their effort in the second stage. We test whether the players act in line with the theoretical predictions of tournament theory. It predicts that all agents should choose the high risk in the first stage. In our experiment, the agents prefer the high risk in roughly 50% of the cases. Therefore, we are not able to confirm this prediction. Nevertheless, in the second stage the agents respond to the different variances of random shock. They exert less effort if the variance of the random shock is high, which is exactly the behavior the theory predicted. As has already been observed in other experiments with tournaments, the agents exert more effort than the theory predicts. We observe a reduction of effort over the course of the experiment due to learning effects. In theory, there is no difference between cases in which the agent selects the high risk and his opponent the low one and cases in which the agent chooses the low and his opponent the high risk. Our data shows that in the experiment the agents react differently in these cases. They mainly focus on their own decision and adjust their effort not to the overall risk but to their own choice of risk. If they have chosen the high risk, they exert less effort than if they have selected low risk.

In this paper, we concentrate on the behavior of the agents and not on the design of an optimal contract from the principal’s point of view. We do this for simplicity and because many situations in the real world have the structure of tournaments but there is no principal who designs an optimal contract as for instance in litigation contests, R&D races or political elections. Nevertheless, it is interesting to mention the implications our
research may have for contract design. From the principals point of view the purpose of a tournament is to induce incentives to work. If risk is a choice variable in a tournament and the risk is not limited, the agents will choose infinite risk and zero effort. However, in the real world in situations such as sports contests or promotion tournaments the agents will not be able to choose unlimited risk. Hence, following the theory the agents would prefer the highest risk possible in order to reduce effort. Nevertheless, given unlimited liability and risk-neutral agents the principal would be able to induce first best effort by changing the spread between winner and loser prizes. As Hvide (2002) argues the fear of excessive risk taking might be an explanation why CEO’s are not paid solely based on their ordinal ranking (see for example Murphy (1999) or Garvey and Milbourn (2003)). Yet, we observe tournaments in the real world because they are needed if only ordinal ranking information is observable. Moreover, in a tournament the principal can, ex ante, commit herself to pay a certain amount of money to the best performing employees. Hence, in contrast to other payment schemes like for example piece rates, tournaments also reduce the danger of opportunistic behavior of the principal (see Malcomson (1984) and Malcomson (1986)). If we look at our findings, we see that the players in the laboratory indeed reduce their effort if they have chosen high risk. On the other hand, only 50% of them prefer the high risk option and not 100% of them as the theory suggested. Of course, we have to be very careful when transferring our findings from the laboratory to a real world environment. Nevertheless, if the agents in the real world act similar as the players in the experiment we should not have to worry as much about excessive risk-taking in the real world.
8 Appendix

Proof of proposition 1: Given that condition 3 is met, the first order conditions of the agents’ utility will characterize the equilibrium. Notice that for all \( \phi = \phi^0 \), the first order condition is

\[
\Delta \omega \cdot g (e_i - e_j; r_i, r_j) = \frac{\partial c_i}{\partial e_i}
\]

And we know that

\[
\frac{\partial \Pr \{ y_i > y_j \}}{\partial e_i} = \frac{\partial G (e_i - e_j; r_i, r_j)}{\partial e_i} = g (e_i - e_j; r_i, r_j)
\]

\[
= \frac{\partial \Pr \{ y_j > y_i \}}{\partial e_j} = \frac{\partial [1 - G (e_i - e_j; r_i, r_j)]}{\partial e_j}
\]

Therefore, the left hand-sides of the first order condition are identical for both agents. Hence, we have a symmetric equilibrium where both agents exert identical effort given by equation 4.

Proof of proposition 2: For a given strategy \( r_j \) player \( i \) will prefer a high risk \( (\sigma_H) \) to a low risk \( (\sigma_L) \) if

\[
\Delta w \cdot G (e_i - e_j; H, r_j) - c (e^* (H, r_j)) \geq \Delta w G (e_i - e_j; L, r_j) - c (e^* (L, r_j))
\]

\[
\Leftrightarrow c \left( c^{'-1} \left( \frac{\Delta w}{2\pi (\sigma_L^2 + \sigma_H^2)} \right) \right) \geq c \left( c^{'-1} \left( \frac{\Delta w}{2\pi (\sigma_H^2 + \sigma_L^2)} \right) \right)
\]

The cost for the effort if the agent has chosen the low risk is always higher than the cost for the effort if he has chosen high risk. Hence, the inequality is always true.
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<th>(1) OLS</th>
<th>(2) OLS</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>(3.94)</td>
<td>(3.96)</td>
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Robust standard errors in parentheses are calculated by clustering on subjects

***p < 0.01, **p < 0.05, *p < 0.1

Table A1: regressions for choice of effort dependent on state

Figure A1: histogramm of the risk attitude of the players:
0 is risk-averse and 10 is risk loving
Figure A2: Mean of effort sorted by state and subperiods

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<td>(6.04)</td>
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Robust standard errors in parentheses are calculated by clustering on subjects

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A2: regressions for choice of effort dependent on choice of risk of the players
Table A3: Mean and standard deviation difference between belief of the player and effort of partner

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<th>Standard Deviation</th>
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</tr>
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<td>state 2b (low/high)</td>
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<td>state 3 (low/low)</td>
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<td>36.98</td>
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<tr>
<td>Overall</td>
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<td>32.52</td>
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Table A4: Regressions for belief dependent on state

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Observations 810 810
adj. $R^2$ 0.04 0.05++

+ Robust standard errors in parentheses are calculated by clustering on subjects
++ We report the within $R^2$ for the fixed effects regressions

***p < 0.01, **p < 0.05, *p < 0.1
Figure A3: reaction function

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<th>mean 1-13</th>
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<td>state 2b (low/high)</td>
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<td>state 3 (low/low)</td>
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<td>overall</td>
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Table A5: Mean of difference between effort and theoretical effort by state and subperiod
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<td></td>
<td>(0.184)</td>
<td>(0.0656)</td>
</tr>
<tr>
<td>gender</td>
<td>9.678</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.644)</td>
<td></td>
</tr>
<tr>
<td>risk attitude</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.024)</td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>41.96***</td>
<td>51.17***</td>
</tr>
<tr>
<td></td>
<td>(12.35)</td>
<td>(1.733)</td>
</tr>
<tr>
<td>Observations</td>
<td>809</td>
<td>809</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td>0.2196</td>
<td>0.0786</td>
</tr>
</tbody>
</table>

++Robust standard errors in parentheses are calculated by clustering on subjects
++We report the within $R^2$ for the fixed effects regressions

|*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ |

Table A6: Additional treatment: regressions for choice of effort dependent on choice of risk of the players

Figure A4: additional treatment: effort choice for different conditions
<table>
<thead>
<tr>
<th></th>
<th>(1) Probit</th>
<th>(2) Probit</th>
</tr>
</thead>
<tbody>
<tr>
<td>risk attitude</td>
<td>−0.0201</td>
<td>−0.119</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.14)</td>
</tr>
<tr>
<td>period</td>
<td>−0.00184</td>
<td>−0.00192</td>
</tr>
<tr>
<td></td>
<td>(0.0046)</td>
<td>(0.0049)</td>
</tr>
<tr>
<td>gender</td>
<td>−0.612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>0.0949</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.064)</td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>0.101</td>
<td>−1.566</td>
</tr>
<tr>
<td></td>
<td>(0.56)</td>
<td>(1.89)</td>
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<td>Observations</td>
<td>810</td>
<td>810</td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td>0.0005</td>
<td>0.06</td>
</tr>
<tr>
<td>Pseudo Loglikelihood</td>
<td>−561.04</td>
<td>−528.90</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses are calculated by clustering on subjects

***p < 0.01, **p < 0.05, *p < 0.1

Table A7: regressions for choice of risk (zero denotes low risk and one denotes high risk) dependent on the risk attitude of the players

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Figure A5: additional treatment: fraction of the choice of states

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