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## ABSTRACT

# Risk-Taking Tournaments: Theory and Experimental Evidence*

We study risk-taking behavior in a simple two person tournament in a theoretical model as well as a laboratory experiment. First, a model is analyzed in which two agents simultaneously decide between a risky and a safe strategy and we allow for all possible degrees of correlation between the outcomes of the risky strategies. We show that risk-taking behavior crucially depends on this correlation as well as on the size of a potential lead of one of the contestants. We find that the experimental subjects acted mostly quite well in line with the derived theoretical predictions.

JEL Classification: M51, C91, D23

Keywords: tournaments, competition, risk-taking, experiment

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# 1 Introduction

In tournaments, contestants compete against each other for a limited set of given prizes. Typically, one contestant with the best performance receives the winner prize and the less successful competitors only receive lower loser prizes. Tournament situations have been analyzed analytically within many different frameworks since the seminal article of Lazear and Rosen (1981) (for early contributions compare also Nalebuff and Stiglitz (1983) or Green and Stokey (1983)).

However, most contributions have focussed on optimal effort choices, i.e. contestants can choose among different outcome distributions with the same variance but different means where higher means are associated with higher effort costs. Yet, in real world tournaments contestants often also make decisions determining the variance of outcomes. For example mutual fund managers have to decide between risky or safe portfolios, or firms have to choose between implementing a new technology or staying with the standard one. In politics a "gambling for resurrection" phenomenon has often been observed. That is, political leaders who fear defeat in an election sometimes seem to choose risky policy alternatives in order to turn around their fate.

A key intuition often expressed is that a front runner should aim at safe policy options whereas a contestant trailing in the competition has incentives to choose a riskier strategy. However, this intuition disregards the possibility that often the sets of policy options from which the contestants can choose are very similar, making it harder for the trailing candidate to differentiate from the front runner. That is, a front runner may try to imitate a risky policy chosen by the competitor exactly in order to protect his lead: independent of whether the policy fails or succeeds with the voters the relative position remains unchanged when the policy can be exactly replicated.

In this paper we study risk taking in a formal tournament model as well as a laboratory experiment. We analyze a simple tournament in which two contestants can choose among a safe or a risky policy option. We investigate under which circumstances a trailing agent indeed gambles and a front runner goes for the safe option. Our main theoretical and empirical observation is that the result strongly depends on the correlation between the outcomes of the risky strategies measuring the similarity of the set of policy options available to the contestants. When the correlation is low, the standard intuition indeed holds but when the correlation is higher this is no longer clear as the front runner may have an incentive to imitate a risky strategy choice of his opponent.

Bronars (1986) was the first to discuss risk taking as a choice variable in a tournament context arguing that leading agents in sequential tournaments prefer a low risk strategy and whereas their opponents prefer a high risk. Hvide (2002) or Kräkel and Sliwka (2004) show that when the contestants first make a risk and then an effort choice, a risky strategy may be attractive even for a trailing agent as it serves as a commitment device for exerting lower efforts at the later stage. But in both models the outcomes of the risky strategies are uncorrelated. Gaba and Kalra (1999), Hvide and Kristiansen (2003) or Taylor (2003) concentrate on the choice of risk in tournaments without endogenous efforts. Most closely related to our paper is the model by Taylor (2003), analyzing the behavior of mutual fund managers who can invest in portfolios that contain safe and risky assets. In his model the outcomes of the risky strategies are perfectly correlated such that both managers receive exactly the same return when they invest in the risky asset. In this game only a mixed equilibrium exists in which the leading agent chooses the riskier strategy more often than the trailing agent. In a sense, our model nests Taylor's model with the more standard tournament models where the outcomes are uncorrelated.

There are now numerous examples of empirical studies on tournaments and some of them analyze risk taking. Becker and Huselid (1992) investigate individual behavior in stock car racing and show that drivers take more risk if prizes and prize spreads are large. Brown et al. (1996) or Chevalier

and Ellison (1997) analyze the behavior of mutual fund managers. They find that expected losers prefer high risks while expected winners prefer low risks. Tournaments have been investigated in laboratory experiments as well but all of the existing contributions focus on effort rather than risk taking decisions (see for instance Bull et al. (1987), Harbring and Irlenbusch (2003), Orrison et al. (2004), Eriksson et al. (2006), Sutter and Strassmair (2007) or Carpenter et al. (2007)).
The remainder of the paper is organized as follows. In section 2 we introduce the model and analyze the possible Nash equilibria. Section 3 describes the experimental design and procedures. The hypotheses are shown in section 4 and in section 5 we present the experimental results. Section 6 concludes.

# 2 Theoretical Analysis

## 2.1 The Model

We consider a simple tournament between two agents $A$ and $B$. We focus on the risk taking decisions of the contestants and assume that both agents simultaneously decide among a risky and a safe strategy, i.e. $d_i \in \{r, s\}$ for $i = A, B$. Each agent's decision affects the distribution of his performance $y_i$ as:

$$\begin{array}{ll} y_i = \mu_s & \text{when } d_i = s \\ y_i = \tilde{y}_i \sim N(\mu_r, \sigma^2) & \text{when } d_i = r \end{array}$$

We allow for the possibility that one of the agents initially has a lead which may for instance be due to differences in ability or the outcome of some prior stage in the competition. Without loss of generality we assume that agent $A$ has a lead and wins the tournament when the sum of his performance $y_A$ and the lead $\Delta y_A$ exceeds his rival's performance $y_B$ where $\Delta y_A \geq 0$. When $y_A + \Delta y_A = y_B$ each agent wins the tournament with probability $\frac{1}{2}$.
Note that the variance of the risky option is the same for both agents. The

performance outcomes $\tilde{y}_i$ are correlated with correlation coefficient $\rho$. Hence, we allow for the possibility that $\rho = 0$ as in Hvide (2002) and Kräkel and Sliwka (2004) or that $\rho = 1$ as in Taylor (2003) but also consider intermediate cases. The winner of the tournament receives a prize giving him a utility normalized to 1 and the loser's utility is zero. It is important to note that risk attitudes do not matter at all for the equilibrium outcomes as any rescaling of these two utility values does not alter the best responses.

## 2.2 Equilibrium Analysis

When both agents choose the safe option $d_A = d_B = s$ of course $A$ always wins the tournament when $\Delta y_A$ is strictly positive. When $\Delta y_A = 0$ each agent wins with probability $\frac{1}{2}$. When $A$ plays safe agent $B$'s only chance of winning is to choose the risky strategy. In this case $A$'s winning probability is

$$P_A^{sr} = \Pr\left(\Delta y_A + \mu_s > \tilde{y}_B\right) = \Phi\left(\frac{\Delta y_A + \mu_s - \mu_r}{\sigma}\right)$$

where $\Phi(\cdot)$ is the cumulative distribution function of a standard normal distribution. When both agents choose the risky strategy player $A$ wins with probability $P_A^{rr} = \Pr\left(\tilde{y}_B - \tilde{y}_A \leq \Delta y_A\right)$. Note that $\tilde{y}_B - \tilde{y}_A$ follows a normal distribution with mean 0 and variance $2\sigma^2(1-\rho)$. Hence,

$$P_A^{rr} = \begin{cases} \Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) & \text{when } \rho < 1 \\ 1 \text{ when } \rho = 1. \end{cases}$$

Finally, when $A$ plays risky and $B$ plays safe, $A$'s winning probability is

$$P_A^{rs} = \Pr\left(\Delta y_A + \tilde{y}_A > \mu_s\right) = 1 - \Phi\left(\frac{\mu_s - \Delta y_A - \mu_r}{\sigma}\right).$$

For ease of notation let $\Delta\mu = \mu_r - \mu_s$ which is positive if the risky strategy has a higher expected outcome than the safe one and negative in the opposite case. It is instructive to start with the case that $\Delta y_A = 0$. In that case the following simple game is played.

| | Risky | Safe |
|---|---|---|
| Risky | $\frac{1}{2}, \frac{1}{2}$ | $\Phi\left(\frac{\Delta\mu}{\sigma}\right), \quad \Phi\left(\frac{-\Delta\mu}{\sigma}\right)$ |
| Safe | $\Phi\left(\frac{-\Delta\mu}{\sigma}\right), \quad \Phi\left(\frac{\Delta\mu}{\sigma}\right)$ | $\frac{1}{2}, \frac{1}{2}$ |

When $\Delta\mu = 0$ both players are indifferent between both strategies. But there is a unique Nash equilibrium in dominant strategies in which both agents choose the risky strategy when the risky strategy has a higher return, i.e. $\Delta\mu > 0$. Whatever the opponent's strategy, a player can always raise the probability of winning by deviating to the risky strategy. If $\Delta\mu < 0$ the unique Nash equilibrium in dominant strategies is $(safe, safe)$.
Much more interesting is the case where one player has a lead, i.e. where w.l.o.g. $\Delta y_A > 0$. The agents then play the following zero sum game where the leading player $A$ is the row and player $B$ the column player.

| | Risky | Safe |
|---|---|---|
| Risky | $\Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right), \quad \Phi\left(\frac{-\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right)$ | $\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right), \quad \Phi\left(\frac{-\Delta y_A-\Delta\mu}{\sigma}\right)$ |
| Safe | $\Phi\left(\frac{\Delta y_A-\Delta\mu}{\sigma}\right), \quad \Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right)$ | $1, \quad 0$ |

First, it is straightforward to see that $(risky, safe)$ and $(safe, safe)$ can never be Nash equilibria. In the first case, the leading player $A$ wins for sure when deviating to the safe strategy. In the second, player $B$ will always deviate to the risky strategy as he otherwise loses for sure.

When agent $B$ plays risky the leading player $A$ can indeed lose the tournament with a positive probability. It is interesting to investigate under what conditions he still prefers to stick to the safe strategy. He will do so when

$$\Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) \leq \Phi\left(\frac{\Delta y_A - \Delta\mu}{\sigma}\right) \Leftrightarrow \frac{\Delta\mu}{\Delta y_A} \leq \left(1 - \frac{1}{\sqrt{2(1-\rho)}}\right).$$

As playing risky leaves player $B$ the only chance to win the tournament, we can directly conclude:

**Proposition 1** *A pure strategy Nash Equilibrium exists in which the leading player $A$ plays the safe strategy and player $B$ plays the risky strategy if and only if*

$$\frac{\Delta\mu}{\Delta y_A} \leq 1 - \frac{1}{\sqrt{2(1-\rho)}}. \tag{1}$$

Hence, higher values of the lead $\Delta y_A$ and smaller values of $\Delta\mu$ tend to make it more likely that the leading player sticks to the safe strategy. To understand the result it is instructive first to consider the case where the performance outcomes of the risky strategies are uncorrelated (i.e. $\rho = 0$). In this case, condition (1) is equivalent to $\frac{\Delta\mu}{\Delta y_A} \leq 1 - \frac{1}{2}\sqrt{2}$. When the risky strategy does not lead to a higher expected performance such that $\Delta\mu \leq 0$ the leading agent $A$ will then always stick to the safe strategy as playing the risky strategy will only raise the probability to forgo the leading position. The larger $\Delta\mu$ the more attractive it of course becomes to switch to the risky strategy. This will be the more so, the smaller the initial lead $\Delta y_A$ as protecting a small lead is not worthwhile when the risky strategy becomes more attractive in terms of expected performance. But it is interesting that this picture changes when the outcomes of the risky strategies are correlated. Note that condition (1) is always violated if $\rho$ tends to one.

The larger the correlation between the risky strategies the more attractive it becomes for player $A$ to choose the risky strategy when $B$ has done the same – even when his lead $\Delta y_A$ is large and even when the risky strategy does not lead to a much higher expected performance. The reason is that with correlated performance outcomes, choosing the risky strategy becomes a means to protect the lead. Hence, we now have to check under which conditions a Nash equilibrium exists in which both agents play the risky strategy.

As analyzed above, when $B$ plays risky the leading player $A$ will prefer to play risky as well when condition (1) is violated, i.e.

$$\frac{\Delta\mu}{\Delta y_A} \geq \left(1 - \frac{1}{\sqrt{2\left(1-\rho\right)}}\right). \tag{2}$$

Player $B$ then indeed also prefers the risky option when

$$\Phi\left(\frac{-\Delta y_A}{\sigma\sqrt{2\left(1-\rho\right)}}\right) \geq \Phi\left(\frac{-\Delta\mu - \Delta y_A}{\sigma}\right) \Leftrightarrow \frac{\Delta\mu}{\Delta y_A} \geq \left(\frac{1}{\sqrt{2\left(1-\rho\right)}} - 1\right). \tag{3}$$

Hence we can conclude:

**Proposition 2** *A pure strategy Nash Equilibrium exists in which both players choose the risky strategy if and only if*

$$\frac{\Delta\mu}{\Delta y_A} \geq \max\left\{1 - \frac{1}{\sqrt{2\left(1-\rho\right)}}, \frac{1}{\sqrt{2\left(1-\rho\right)}} - 1\right\}. \tag{4}$$

Note that condition (4) is always violated if $\Delta\mu < 0$. If the risky strategy does not lead to a higher expected outcome than the safe one the players will never play $(risky, risky)$.

For $\Delta\mu > 0$ consider first again the case where the outcomes of the risky strategies are uncorrelated (i.e. $\rho = 0$). Condition (4) is now equivalent to $\frac{\Delta\mu}{\Delta y_A} \geq 1 - \frac{1}{2}\sqrt{2}$. Note that this is the opposite of condition (1) given in Proposition 1. The reason is that player $B$ always prefers the risky strategy when $\rho = 0$ irrespective of $A$'s decision. As already laid out, when $A$ plays safe playing the risky strategy is the only way for player $B$ to have at least a chance of winning. When, however, $A$ plays risky, player $B$ has such a chance already when playing safe, but can increase the odds by playing risky. Hence, for $\rho = 0$ only player $A$'s considerations determine which equilibrium is played. Both play risky in this case if and only if $\frac{\Delta\mu}{\Delta y_A}$ is sufficiently large as only then it will be reasonable for player $A$ to take the risk and not to protect the lead.

As pointed out above, the reasoning is different if the outcomes of the risky strategies are correlated. As we have already seen, agent $A$ has an incentive to imitate a risky strategy of his opponent if the correlation gets larger. To see that consider figure 1, in which the equilibrium conditions are mapped in the $\left(\rho, \frac{\Delta\mu}{\Delta y_A}\right)$-space. Condition (2) determines the downward sloping curve that separates the region in which agent $A$ plays safe and agent $B$ plays risky from that where both play risky. The higher $\rho$ the more attractive it becomes for agent $A$ to switch to the risky strategy as well. A special case is $\rho = \frac{1}{2}$. In this case condition (4) simplifies to $\frac{\Delta\mu}{\Delta y_A} \geq 0$ and, hence, the agents will always play $(risky, risky)$ whenever $\Delta\mu \geq 0$ no matter how large the initial lead is.

But when the correlation gets larger, choosing the risky strategy becomes less attractive for player $B$. The stronger the correlation the smaller is the probability for player $B$ to overtake player $A$ when both play risky. In the extreme, when $\rho = 1$, both agents will always attain the same outcome when playing the risky strategy and, hence, agent $A$ would win for sure in this case. In that case, however, player $B$ has an incentive to deviate to the safe strategy when player $A$ plays risky. Playing safe leaves at least the possibility that $A$ is unlucky and falls behind. But of course, when player $A$ in turn knows

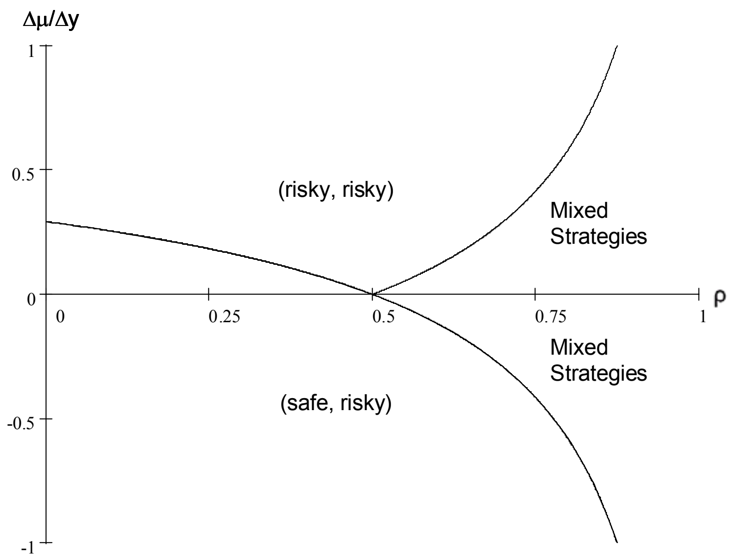


Figure 1: Nash equilibria of the game

that $B$ chooses the safe strategy, he would again want to deviate and choose the safe strategy as well. Hence, we cannot have equilibria in pure strategies if $\rho = 1$ as has already been shown by Taylor (2003). But note that we can already conclude from Propositions 1 and 2 that a similar reasoning must hold for a larger set of parameters. As we already have checked the existence conditions for all potential pure strategy equilibria, when conditions (1) and (4) are both violated only mixed strategy equilibria can exist. Hence, we can show the following result:

**Proposition 3** *A Nash Equilibrium in mixed strategies exists if and only if*

$$1 - \frac{1}{\sqrt{2(1-\rho)}} \leq \frac{\Delta\mu}{\Delta y_A} \leq \frac{1}{\sqrt{2(1-\rho)}} - 1. \tag{5}$$

*In any mixed strategy equilibrium, player $A$ chooses the risky strategy with a larger probability than player $B$ if the risky strategy leads to a higher expected outcome than the safe one. If $\Delta\mu < 0$ player $B$ chooses the risky strategy* *with a higher probability than his opponent.*

**Proof:** See appendix.

Hence, only mixed strategy equilibria exist in the area between the both curves in figure 1 if $\rho > \frac{1}{2}$. The larger the correlation between the outcomes of the risky strategies and the smaller $\frac{\Delta\mu}{\Delta y_A}$ the more likely it is that a mixed strategy is played. In such an equilibrium, the leading player always chooses the risky strategy with a higher probability than his opponent if $\Delta\mu > 0$. In this case, the higher expected payoff of the risky strategy makes it more attractive to gamble and the leading player can afford to gamble with a higher probability due to his lead. If the outcome of the safe strategy is equal to the expected outcome of the risky strategy both players will choose the risky strategy with equal probability. The trailing player chooses the risky strategy with a higher probability than the leading one if $\Delta\mu < 0$. Here, the trailing player has a stronger incentive to play risky although this entails a loss in expected payoffs.

# 3 Experimental Design and Procedure

We implemented the simple risk taking tournament in a laboratory experiment. We ran three different treatments for each of which we conducted one session with 24 participants. In each of 23 periods two players were matched together randomly and anonymously. Hence, each participant played 23 times and each time with a different opponent. This perfect stranger matching was implemented to prevent reputation effects. We varied the correlation coefficient of the risky strategy between the treatments. The first treatment had a correlation coefficient of zero, the second of one and the third of $\frac{1}{2}$. Furthermore, we varied the lead $\Delta y_A$ between the periods such that we are able to investigate the effects of $\Delta y_A$ on player's strategy choices.

The experiment was conducted at the Cologne Laboratory of Economic Research at the University of Cologne in January 2007. Altogether 72 students participated in the experiment. All of them 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 a session the subjects were randomly assigned to a cubical where they took a seat in front of a computer terminal. The instructions were handed out and read out by the experimenters.[1] 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.

Each session started with 5 trial periods so that the players could get used to the game. In the trial rounds each player had the opportunity to simulate the game by choosing the strategies for both players and observing the outcomes. After that the 23 main periods started. All periods were identical but played with a different partner. In the beginning of each period the players were informed about their score of points which they had in the beginning and the score of their opponent. So they knew whether they were the player in lead and how large the difference between the scores was. The initial scores of points were drawn from a normal distribution with a mean of 150 points and a standard deviation of 42 points. Then the players had to decide whether they wanted to play a safe or a risky strategy. If a player chose the safe strategy he received 80 additional points for sure. When choosing the risky strategy the additional points awarded where determined by a random draw from a normal distribution with a mean of 100 points and a standard deviation of 20 points. In the first treatment the risky strategies of both

[1]The full set of all our experimental instructions can be obtained from the authors upon request.

players were uncorrelated. In the second treatment the risky strategies were perfectly correlated and in the third they were correlated with $\rho = \frac{1}{2}$. This information was common knowledge. The key concepts where explained in the instructions and the players had the opportunity to develop a "feel" for the distribution in the trial rounds. After each player made his decision they were informed about the additional points received and the final score of the game. The final score was the sum of the initial points of each player and his additional points won in the game. They were also informed which player was the winner of the period. They played 23 periods with different partners. In the end of the experiment one of the 23 periods was drawn by lot. Each player who won the tournament in which he participated in the drawn period earned 25 Euro each loser earned only 5 Euro. Additionally, all subjects received a show up fee of 2.50 Euro independent of their status as winner or loser. After the last period the subjects were requested to complete a questionnaire including questions on gender and age. The whole procedure took about one hour.

# 4 Hypotheses

First of all, based on the theoretical reasoning above, we expect that in the treatment without correlation the leader plays the safe strategy more often than the trailing player (Hypothesis 1). But of course, the model makes a more precise prediction. Recall that the trailing player should always choose the risky strategy. The leader should play the safe strategy if and only if the lead is sufficiently large and the expected gains from playing risky are low. In our experiment the expected gains from playing risky were fixed for all treatments ($\Delta\mu = 20$). In other words the player in lead should choose the safe strategy if $\Delta y_A > \frac{20}{1-\frac{1}{2}\sqrt{2}} = 68.28$ and otherwise should prefer the risky strategy.

In the second treatment the performance outcomes of the risky strategies are

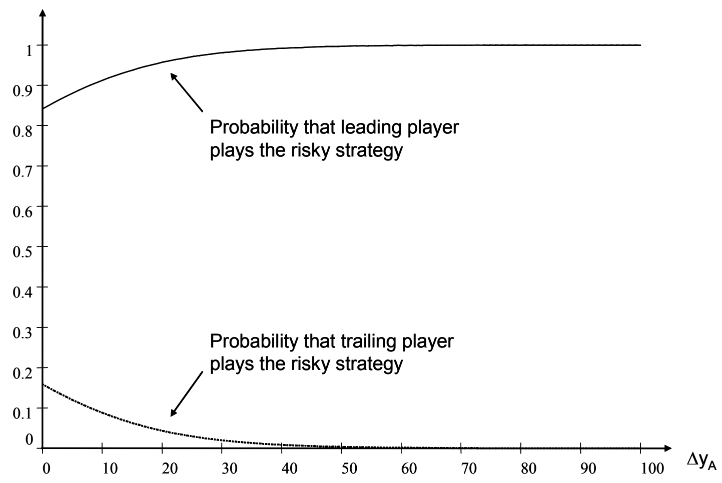


Figure 2: Equilibrium mixed strategies if $\rho = 1$

perfectly correlated and therefore only an equilibrium in mixed strategies exists in the theoretical model. But the most important and testable implication is that – in contrast to the zero correlation case – we expect that the player in lead will play risky more often than his opponent (Hypothesis 2). Although we cannot expect that participants in the experiment are able to coordinate on the mixed strategies equilibrium perfectly, the data should at least be in line with some qualitative features of the equilibrium. Therefore it is useful to consider the probabilities with which the players choose the risky strategy derived in the proof of proposition 3. Figure 2 shows these probabilities as a function of $\Delta y_A$ for the parameter values used in the experiment. Note that the leading player should choose the risky strategy in more than 80% and the trailing player in less than 20% of the cases. Furthermore we expect that the probability that the trailing player plays the risky strategy should decrease in $\Delta y_A$ and the probability that the leader does the same should increase in his lead.

For the third treatment we predict that both players will always choose the risky option no matter how large the lead is (Hypothesis 3) or at least that

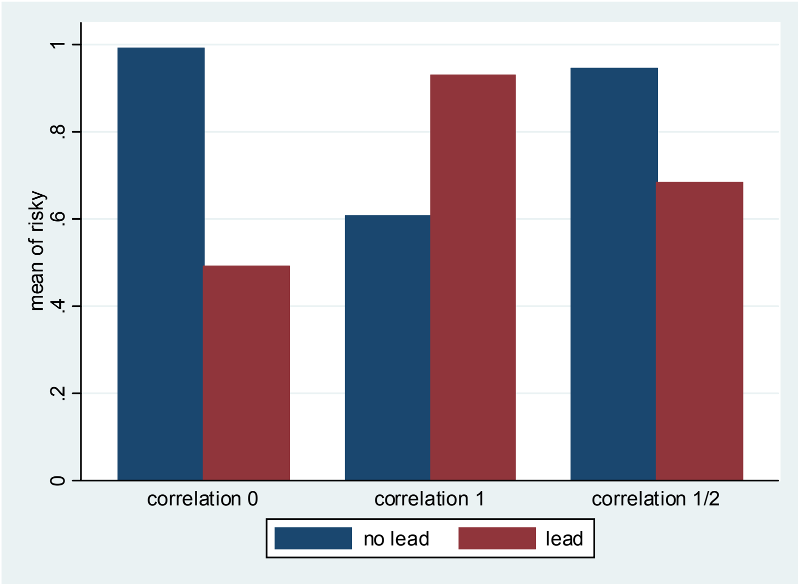


Figure 3: Overview

they both learn during the course of the experiment that the risky strategy is beneficial.

# 5 Results

We now test these hypotheses with the data from our experiment. Figure 3 shows the fraction of rounds in which the players in each treatment chose the risky strategy depending on whether the player had a lead.[2]

We start by investigating the results from treatment 1 where the outcomes of the risky strategies were uncorrelated. Looking at figure 3 we see already that the trailing player almost always chose the risky strategy when the risky strategies were uncorrelated but that the leading player chose the safe strategy in nearly 50% of the cases. Hence, these observations are well in line

[2] Table A1 in the Appendix gives the precise values.

with hypotheses 1. To analyze whether the lead had an effect on the choice of strategy for the leader we ran a binary probit regression. The dependent variable is the probability that the leading agent chooses the risky strategy. The observations are not independent from each other as one subject plays the game 23 times. Therefore we report robust standard errors clustered by subject.[3] The results are reported in table 1.[4]

| | (1) Leading player | (2) Leading player |
|---|---|---|
| Lead | $-0.0284^{***}$ | |
| | (0.0043) | |
| Lead > 68.28 | | $-1.399^{***}$ |
| | | (0.22) |
| Period | 0.00588 | 0.00523 |
| | (0.012) | (0.0095) |
| Constant | $1.192^{***}$ | 0.244 |
| | (0.22) | (0.19) |
| Observations | 276 | 276 |
| Pseudo Log Likelihood | −136.62092 | -163.80531 |
| Pseudo $R^2$ | 0.2858 | 0.1436 |

Robust standard errors in parentheses are calculated by clustering on subjects

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 1: Probit regression for leading players in treatment 1

The period is included to check for time trends capturing possible learning effects. We see from column (1) that in line with the theoretical prediction, a larger lead makes it indeed more likely for the leader to choose the safe strat-

[3] As an alternative we ran random effects regressions. The results remain qualitatively unchanged and are reported in the Appendix.

[4] In the Appendix we report the marginal effects for all probit regressions.

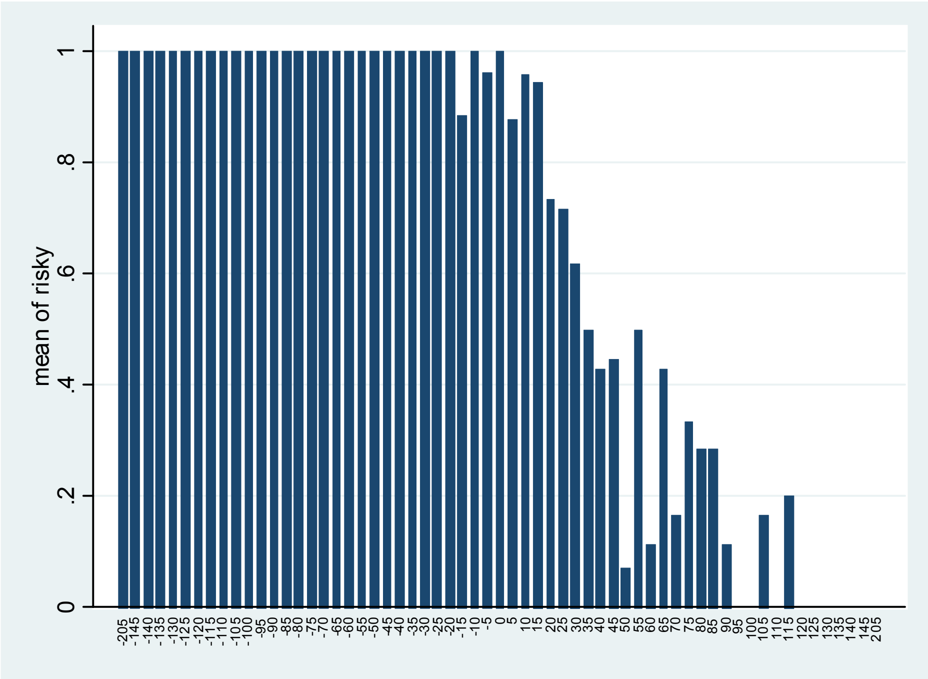


Figure 4: Choice of the risky strategy for different leads in treatment 1

egy. This effect is highly significant. Regression (2) uses a dummy variable which takes value one if the lead is larger than 68.28 and zero otherwise. The results are qualitatively similar to those of regression (1). Note that there are no significant time trends. Of course, the participants did not switch to the safe strategy precisely at the predicted cut-off value, but still they learned surprisingly well that playing safe is preferable when the lead gets larger as is also illustrated in figure 4. It shows the frequencies of the risky strategy choice for different leads in treatment 1 (interval size 5).

We can summarize these observations as follows.

**Result 1 ($\rho = 0$):** *When the outcomes of the risky strategies are uncorrelated the leading players choose the safe strategy more often than their opponents. The trailing players nearly always choose the risky strategy (98.9%). The size* *of the lead has a strong influence on the probability that the leader chooses the safe strategy: The larger the lead, the more often the safe strategy is chosen.*

We now turn to the perfect correlation case in treatment 2. A look at figure 3 already indicates that the leading player picked the risky option more often than his opponent which is in stark contrast to the results from treatment 1 but well in line with the theoretical prediction.

| | (1) Leading player | (2) Trailing player |
|---|---|---|
| Lead | $-0.00540^{*}$ | $0.00941^{***}$ |
| | (0.0031) | (0.0035) |
| Period | $0.0775^{***}$ | $-0.0332^{***}$ |
| | (0.016) | (0.011) |
| Constant | $0.976^{***}$ | 0.246 |
| | (0.21) | (0.19) |
| Observations | 276 | 276 |
| Pseudo Log Likelihood | −63.417594 | −173.62979 |
| Pseudo $R^2$ | 0.1161 | 0.0623 |

Robust standard errors in parentheses are calculated by clustering on subjects

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 2: Probit regression for treatment 2

Furthermore, as the theory predicts the leading players chose the risky strategy in more than 80% (92.8%) of the cases. But the trailing players also chose the risky option in 60.5% of the cases and not as we predicted in less than 20% of the cases. This behavior may be due to the false intuition that they had nothing to lose and therefore they preferred to gamble. The trailing players seemed to disregard at least partially that the leader may also want to play the risky strategy in which case the best reply is to play safe as only this leaves a chance to win the tournament. Again, we ran probit regressions to test the predictions of the model. We first consider the leading players' behavior in model (1) and then that of the trailing players in model (2) of table 2. First note, that we have to reject our prediction concerning the effect of the lead in both cases. The theoretical model predicted that the leader plays the risky strategy more often the larger the lead and the trailing player plays risky less often for larger initial differences. The empirical analysis shows the opposite signs for both effects. It seems that initially the players followed the much more straightforward intuition from the case where the outcomes were uncorrelated, i.e. that the leader should protect his lead by playing safe and the trailing player can only 'attack' the leader by choosing the risky strategy. But note that we observe strong learning effects that seem to direct the players closer to the equilibrium prediction. Over the course of the experiment the leading players significantly increased the probability of playing the risky strategy and the trailing players reduced this probability. We can summarize:

**Result 2 ($\rho = 1$):** *When the outcomes of the risky strategies are perfectly correlated the leading players choose the risky strategy more often than their opponents. The leaders choose the risky strategy in* 92.8% *and the trailing players in* 60.5% *of the cases. Over the course the leading players increased the probability of playing the risky strategy, whereas the trailing players reduced this probability.*

Finally, we consider the results from the third treatment in which the correlation coefficient between the outcomes of the risky strategies was $\rho = \frac{1}{2}$. According to our theoretical predictions both players should always play the risky strategy regardless how large the lead is. As we see in figure 3 this prediction is true only for the trailing players. Leading agents chose the risky option only in 68.1% of the cases. To analyze learning effects and the effect of the lead on the choice of the strategy we use again a probit regression with the choice of strategy as dependent variable. The results of the regression are reported in table 3. The regression shows that the lead indeed had an effect on the choice of the strategy. The probability that the leader played the safe option rises when the lead got larger. This effect might occur because the leader thought that playing safe was an appropriate way to protect his leading position. During the experiment the leader learned that this assumption is not true and played risky more often.

| | Leading player |
|---|---|
| Lead | $-0.0139^{***}$ |
| | (0.0034) |
| Period | $0.0263^{***}$ |
| | (0.0094) |
| Constant | $0.807^{***}$ |
| | (0.20) |
| Observations | 276 |
| Pseudo Log Likelihood | −153.97572 |
| Pseudo $R^2$ | 0.1088 |

Robust standard errors in parentheses are calculated by clustering on subjects, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 3: Probit regression for leading players in treatment 3

When we take a look at the decisions the leading players made in the last 5 periods, we see that $76,7\%$ of them preferred the risky strategy. We can conclude:

**Result 3 ($\rho = \frac{1}{2}$):** *When the outcomes of the risky strategies are correlated with $\rho = \frac{1}{2}$ the trailing players play the risky strategy nearly in all cases* (94.6%). *The leading players choose the risky strategy in only* 68.1% *of the cases but increase this probability over the course of the experiment.*

Hence, it seems to be the case that learning directed the players towards the equilibrium prediction.

# 6 Conclusion

We have investigated a simple tournament model in which two agents simultaneously choose between a risky and a safe strategy. We have shown that the equilibrium outcome strongly depends on the correlation between the outcomes of the risky strategy. We then tested the predictions made based on the model in a laboratory experiment. The key predictions have been confirmed: The leading players choose the safe strategy more often than the trailing players if the outcomes are uncorrelated, but the contrary is true if the outcomes are perfectly correlated.

From a more general standpoint, our model as well as the empirical results have cast some light on the attractiveness of gambling in competitive situations. One interpretation of the correlation between the risky strategies is the similarity in the set of available policy options. When the competitors have access to similar policies, the correlation between the outcomes of the risky strategies will be high. In this case, a trailing contestant can no longer be certain that his opponent will stick to the safe strategy when choosing to gamble. It even has turned out that the leading player will have a stronger incentive to gamble than his trailing opponent when the risky strategy has higher rewards in expected terms.

There are many open questions for future research. For instance, we so far did not consider endogenous effort choices and focused only on risk-taking behavior. Moreover, it would be interesting to study risk taking behavior in dynamic tournaments where the agents can react to past choices of their opponents, for instance, to cast more light on the timing of risk-taking decisions in competitive environments.

# 7 Appendix

**Proof of Proposition 3:**

Both players will randomize only if they are indifferent between the payoffs of both strategies. Suppose that player $A$ chooses the risky strategy with probability $p$ and player $B$ with probability $q$. Hence, we must have that

$$p \cdot \Phi\left(\frac{-\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) + (1-p)\cdot\Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right) = p\cdot\ \Phi\left(\frac{-\Delta y_A-\Delta\mu}{\sigma}\right) + (1-p)\cdot 0 \Leftrightarrow$$

$$p = \frac{\Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right)}{\Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right)+\Phi\left(\frac{-\Delta y_A-\Delta\mu}{\sigma}\right)-\Phi\left(\frac{-\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right)}$$

and

$$q\cdot\Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) + (1-q)\cdot\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right) = q\cdot\Phi\left(\frac{\Delta y_A-\Delta\mu}{\sigma}\right) + (1-q)\cdot 1 \Leftrightarrow$$

$$q = \frac{1-\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right)}{1+\Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right)-\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right)-\Phi\left(\frac{\Delta y_A-\Delta\mu}{\sigma}\right)}.$$

Player $A$ will indeed choose the risky strategy with higher probability than player $B$ when

$$\frac{\Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right)}{\Phi\left(\frac{-\Delta y_A+\Delta\mu}{\sigma}\right)+\Phi\left(\frac{-\Delta y_A-\Delta\mu}{\sigma}\right)-\Phi\left(\frac{-\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right)}$$

$$> \frac{1-\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right)}{1+\Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right)-\Phi\left(\frac{\Delta y_A+\Delta\mu}{\sigma}\right)-\Phi\left(\frac{\Delta y_A-\Delta\mu}{\sigma}\right)}$$

using that $\Phi(x) = 1 - \Phi(-x)$ this is equivalent to

$$\begin{aligned}
& \frac{\Phi\left(\frac{-\Delta y_A + \Delta\mu}{\sigma}\right)}{1 + \Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) - \Phi\left(\frac{\Delta y_A - \Delta\mu}{\sigma}\right) - \Phi\left(\frac{\Delta y_A + \Delta\mu}{\sigma}\right)} \\
> & \frac{1 - \Phi\left(\frac{\Delta y_A + \Delta\mu}{\sigma}\right)}{1 + \Phi\left(\frac{\Delta y_A}{\sigma\sqrt{2(1-\rho)}}\right) - \Phi\left(\frac{\Delta y_A + \Delta\mu}{\sigma}\right) - \Phi\left(\frac{\Delta y_A - \Delta\mu}{\sigma}\right)} \\
\Leftrightarrow & \ \Phi\left(\frac{-\Delta y_A + \Delta\mu}{\sigma}\right) > 1 - \Phi\left(\frac{\Delta y_A + \Delta\mu}{\sigma}\right) \\
\Leftrightarrow & \ \Phi\left(\frac{-\Delta y_A + \Delta\mu}{\sigma}\right) > \Phi\left(\frac{-\Delta y_A - \Delta\mu}{\sigma}\right)
\end{aligned}$$

which is true if $\Delta\mu > 0$. In the special case $\Delta\mu = 0$ both players choose the risky strategy with equal probability. If $\Delta\mu < 0$ Player $B$ will choose the risky strategy with a higher probability than player $A$. ■

| | Correlation 0 | | Correlation 1 | | Correlation $\frac{1}{2}$ | |
|---|---|---|---|---|---|---|
| | no lead | lead | no lead | lead | no lead | lead |
| safe | 0.011 | 0.507 | 0.395 | 0.072 | 0.054 | 0.319 |
| risky | 0.989 | 0.493 | 0.605 | 0.928 | 0.946 | 0.681 |

Table A1: Distribution of strategy choices for all treatments

| | (1)<br>Leading player | (2)<br>Leading player |
|---|---|---|
| Lead | $-0.0453^{***}$ | |
| | (0.0057) | |
| Lead > 68.28 | | $-1.852^{***}$ |
| | | (0.26) |
| Period | 0.00586 | 0.00791 |
| | (0.017) | (0.014) |
| Constant | $1.962^{***}$ | 0.334 |
| | (0.43) | (0.25) |
| Observations | 276 | 276 |
| Log Likelihood | −110.38209 | −147.50784 |

random effects estimation, standard errors in parentheses,
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A2: Probit regressions with random effects for leading players in treatment 1

| | (1) Leading player | (2) Trailing player |
|---|---|---|
| Lead | $-0.00665$ | $0.0140^{***}$ |
| | (0.0047) | (0.0029) |
| Period | $0.0927^{***}$ | $-0.0501^{***}$ |
| | (0.027) | (0.014) |
| Constant | $1.406^{***}$ | 0.361 |
| | (0.45) | (0.29) |
| Observations | 276 | 276 |
| Log Likelihood | $-56.693898$ | $-151.3198$ |

random effects estimation, standard errors in parentheses,
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A3: Probit regressions with random effects for treatment 2

| | Leading player |
|---|---|
| Lead | $-0.0252^{***}$ |
| | (0.0043) |
| Period | $0.0460^{***}$ |
| | (0.017) |
| Constant | $1.286^{***}$ |
| | (0.40) |
| Observations | 276 |
| Log Likelihood | $-117.24643$ |

random effects estimation, standard errors in parentheses,
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A4: Probit regression with random effects for leading players in treatment 3

| | (1) Leading player | (2) Leading player |
|---|---|---|
| Lead | $-0.0113^{***}$ | |
| | (0.0016) | |
| Lead > 68.28 | | $-0.483^{***}$ |
| | | (0.062) |
| Period | 0.00233 | 0.00208 |
| | (0.0046) | (0.0038) |
| Observations | 276 | 276 |
| Pseudo Log Likelihood | −136.62092 | −163.80531 |
| Pseudo $R^2$ | 0.2858 | 0.1436 |

Robust standard errors in parentheses are calculated by clustering on subjects, Marginal effects reported, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A5: Probit regressions for leading players in treatment 1

| | (1) Leading player | (2) Trailing player |
|---|---|---|
| Lead | $-0.000545^{*}$ | $0.00361^{***}$ |
| | (0.00041) | (0.0013) |
| Period | $0.00783^{***}$ | $-0.0127^{***}$ |
| | (0.0027) | (0.0043) |
| Observations | 276 | 276 |
| Pseudo Log Likelihood | −63.417594 | −173.62979 |
| Pseudo $R^2$ | 0.1161 | 0.0623 |

Robust standard errors in parentheses are calculated by clustering on subjects, Marginal effects reported, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A6: Probit regressions for treatment 2

| | Leading player |
|---|---|
| Lead | $-0.00483^{***}$ |
| | (0.0015) |
| Period | $0.00918^{***}$ |
| | (0.0033) |
| Observations | 276 |
| Pseudo Log Likelihood | $-153.97572$ |
| Pseudo $R^2$ | 0.1088 |

Robust standard errors in parentheses are calculated by clustering on subjects, Marginal effects reported, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table A7: Probit regression for leading players in treatment 3

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