Risk Taking in Winner-Take-All Competition*

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Abstract

We analyze a two-stage game between two heterogeneous players. At the first stage, one of the players decides on risk. At the second stage, both players observe the given level of risk and simultaneously invest in a winner-take-all competition. The game is solved theoretically and then tested by using a laboratory experiment. According to theory, there are three effects that determine risk taking at stage one – a discouragement effect, a cost effect and a likelihood effect. For the likelihood effect, risk taking and investments in the lab are clearly in line with theory. Pairwise comparison of the corresponding treatments shows that the cost effect seems to be more relevant than the discouragement effect. Our experimental findings also show that, for given risk, investments are mostly in line with theory under all three effects. Hence, subjects indeed adjust their investment levels to risk taking. For the case of the discouragement effect, this means that subjects are discouraged by high risk but risk-taking players do not really make use of this effect.

Key Words: Competition, Risk Taking, Tournaments

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1 Introduction

In many real-world situations, competition can be characterized as a winner-take-all contest or tournament. Typically, in sports contests there is only one winner who gets the high winner prize (Konrad 2009). When arranging a singing contest, only one participant wins the final round (Amegashie 2007). In job-promotion tournaments, workers compete for a more attractive and better paid position at the next hierarchy level (Baker et al. 1994, Orrison et al. 2004). Firms and individuals invest in external or internal rent-seeking contests (Gibbons 2005). In politics, individuals compete for being elected. Firms often compete in R&D (Loury 1979, Zhou 2006) and invest resources for advertising to become the market leader (Schmalensee 1976, Schmalensee 1992). Moreover, firms are involved in litigation contests for brand names or patent rights (Waerneryd 2000). Finally, oligopolistic competition in new markets often looks like a tournament: only the firm that implements a new technical standard as a first-mover can realize substantial profits from network externalities (Besen and Farrell 1994).

Most of the models on winner-take-all competition focus on the effort or investment decisions of the contestants: the higher the effort/investment of a single player relative to those of his opponents, the more likely he will win the tournament. However, in real tournaments, players also choose the risk of their strategic behavior. For example, politicians do not only invest resources during the election campaign, but also decide on the composition and, therefore, on the risk of their agenda. Participants of a singing contest choose the difficulty and, hence, the risk of their songs. Athletes decide whether to switch to a new – and often more risky – training method or not. Prior to the choice of their advertising expenditures, firms have to decide on radical product innovation or new marketing concepts, which would be a quite risky strategy. Our paper addresses this two-dimensional decision problem of individuals in winner-take-all competition. First, we develop a theoretic model with both risk taking and effort/investment decisions. Thereafter, we test the main results of our model by running a laboratory experiment.

Our starting point is a tournament situation where the decision makers first have the choice between using a standard technique or solution (low risk) or switching to a new one (high risk); then they decide on effort or, more generally, on input to win the tournament.[1] Two different situations can be observed in practice. Given a two-player game, either both players are actual risk takers (bilateral risk taking) or one player has already chosen risk but the other player still has to decide on risk (unilateral risk taking) before the players choose efforts/investments. There exist several examples for such unilateral risk taking. Consider, for example, a market where an incumbent firm decided on product and market concept innovation in the past and now offers its well-known product. If, in this situation, a new firm enters the market, this new entrant first has to decide on the supply of a new

[1] In case of singing and sports contests, inputs are the training intensities of the players.

kind of product and on an innovative marketing strategy.[2] Thereafter, both firms compete for market leadership by choosing their advertising expenditures. As another example consider the case of two politicians competing in an election campaign. Often there is an incumbent politician that already stands for a certain well-known agenda and a challenger that first has to choose the risk of his agenda before both politicians simultaneously invest their resources during the election campaign. It is important to emphasize that although one player chooses risk, this risk taking influences both players since relative performance is decisive in winner-take-all competition. If, on the one hand, the risk taker has good luck ex post, this outcome will enhance his own relative performance and worsen that of his opponent. On the other hand, in case of bad luck the risk taker suffers but the opponent benefits in terms of relative performance.

In our paper, we concentrate on the case of unilateral risk taking, which has neither theoretically nor experimentally been analyzed so far. At the first stage, the challenger chooses risk. At the second stage, both the challenger and the incumbent simultaneously decide on efforts or investments. We consider an asymmetric tournament game with discrete choices to derive several hypotheses which are then tested in a laboratory experiment. In our asymmetric tournament, a more able player (the "favorite") competes against a less able one (the "underdog"). Suppose that the challenger is the favorite. At first sight, one would expect that the challenger does not prefer a high risk which can jeopardize his favorable position. Accordingly, if the challenger is the underdog he might strictly benefit from a high risk since he has nothing to lose but good luck may compensate for the lower ability. Our theoretical results show that this first guess is not necessarily true.

Consider the situation with the challenger being the favorite.[3] Imagine, for example, a scenario where a monopoly is liberalized and the former public monopolist is challenged by a new private entrant. In such a situation, the challenger often has lower costs than the former monopolist and can be labeled favorite. More generally, if a new entrant challenges an incumbent firm the challenger should typically be the favorite because he would not have decided to enter the market otherwise. We can differentiate between three effects that determine his risk taking: first, risk taking at stage 1 of the game may influence the equilibrium investments and, hence, investment costs at stage 2 (*cost effect*). According to this effect, the challenger (as well as the incumbent) prefers a high-risk strategy since high risk reduces overall incentives and, therefore, investment costs at the second stage.

[2] Often, a new entrant introduces a radical product innovation whereas the incumbent is not able to react in the same way. Chandy and Tellis (2000) call this phenomenon the "incumbent's curse". See also Rosenbloom and Christensen (1994) and Hill and Rothaermel (2003). As a typical example, IBM used product innovation to challenge Apple in the business market for personal computers. However, as we can see from the discussion in Schnaars (1986) and Shankar et al. (1998), challengers sometimes do not choose an innovative strategy but prefer aggressive advertising in a second step after market entry.

[3] Of course, if the underdog chooses risk, the following three effects just turn around from his perspective.

Here, high risk serves as a commitment device for the players at the second stage, leading to a kind of implicit collusion. Second, the choice of risk by the challenger also influences the players' likelihood of winning. If equilibrium investments do not react to risk taking the more able challenger will prefer a low-risk strategy to hold his predominant position (*likelihood effect*). Third, if only the equilibrium investments of the incumbent do react to risk taking, the more able challenger may choose a high risk to discourage the less able incumbent (*discouragement effect*). In this situation, high risk destroys the incumbent's incentives at the second stage since it does not pay for him to invest as he would bear high costs but the outcome of the tournament is mainly determined by luck. However, the challenger still invests at the second stage as he has to bear significantly less costs, being the more able player. Such discouragement will be very attractive for the challenger if the gain of winning the tournament is rather large.

The theoretical results show that, in our discrete setting, all three effects will be relevant if the challenger is the favorite whereas taking high risk becomes dominant when the challenger is the underdog. For this reason, our experimental analysis focuses on risk taking by the favorite and the subsequent investment or effort choices by both players. For each effect we ran one treatment with four sessions – labeled discouragement treatment, cost treatment, and likelihood treatment. Descriptive results indicate that both the cost effect and the likelihood effect are relevant for the subjects when choosing risk, but they do not often make use of the discouragement effect. The results from non-parametric tests and probit regressions reveal that the likelihood effect turns out to be very robust. The two other effects are not confirmed by a sign test, but a pairwise comparison of the treatments shows that the findings for the cost effect are more in line with theory than our results for the discouragement effect. As theoretically predicted, favorites choose significantly more investment or effort than underdogs in the discouragement treatment and the likelihood treatment. In the cost treatment, players' behavior does not significantly differ given low risk, which follows theory, but for high risk underdogs exert more effort than favorites, which contradicts theory. The subjects' effort choices as reactions to given risk are very often in line with theory. Hence, subjects do react to different amounts of risk. This means that the fundamentals of the three effects are confirmed by our data, but subjects do not make use of them as often as predicted by theory, which particularly holds for the discouragement effect.

We can also interpret our experimental findings in a broader context. At the risk-taking stage, the likelihood effect turns out to be very robust, whereas the two other effects do not get substantial support. From society's point of view, this means that high-potential challengers (i.e., favorites) cannot always be expected to be innovative (i.e., choose high risk) in winner-take-all situations. Instead, they will rely on cost advantages from their existing technologies not to jeopardize their favorable position when competing with the incumbent. At the second stage, subjects clearly react to all three risk-taking effects when choosing their efforts. This finding is interesting from a principal-agent perspective. According to our data, agents' behavior in tournaments (e.g., sales contests or job-promotion tournaments) can be effectively controlled by the principal's risk-taking decisions. For example, following the cost effect it will pay for an employer to improve the monitoring precision in order to elicit significantly higher efforts from his workers.

Previous work on risk taking in tournaments either fully concentrates on the players' risk choices by skipping the effort decisions, or considers symmetric effort choices within a two-stage game. The first strand of this literature is better in line with risk behavior of mutual fund managers or other players that can only influence the outcome of a winner-take-all competition by choosing risk (see, for example, Gaba and Kalra 1999, Hvide and Kristiansen 2003 and Taylor 2003). The second strand of the risk-taking literature is stronger related to our paper. Hvide (2002) and Kräkel and Sliwka (2004) consider a symmetric two-stage tournament with bilateral risk taking at stage 1 and subsequent effort choices at stage 2. However, symmetry of the equilibrium at the effort stage renders one of the three main effects impossible, namely the discouragement effect. Nieken (2009) experimentally investigates only the cost effect within a symmetric setting with bilateral risk taking. On the one hand, her results show that subjects rationally reduce their efforts when risk increases. On the other hand, subjects do not behave according to the cost effect very well as only about 50% (instead of 100%) of the players choose high risk. Altogether, her findings indicate that subjects are overstrained by a strategic situation with bilateral risk taking, which further justifies our simplified setting with unilateral risk taking. Our paper is most strongly related to Kräkel (2008), who analyzes the three effects in an asymmetric two-stage tournament model with bilateral risk taking. Unfortunately, this setting is so complex that closed-form solutions can hardly be derived.

The paper is organized as follows. The next section introduces the game and the corresponding solution. In Section 3, we point out the three main effects of risk taking – the discouragement effect, the cost effect, and the likelihood effect. In Section 4, we describe the experiment. Our testable hypotheses are introduced in Section 5. The experimental results are presented in Section 6. We discuss three puzzling results in Section 7. Section 8 concludes.

2 The Game

We consider a two-stage tournament game with two risk neutral players. At the first stage (risk-taking stage), one of the players – the challenger – chooses the variance of the underlying probability distribution that characterizes risk in the tournament. At the second stage (effort stage), both players – the challenger and the incumbent – observe the chosen risk and then simultaneously decide on their efforts. The player with the better relative performance is declared the winner of the tournament and receives the benefit

$B > 0$, whereas the other one gets nothing. Relative performance does not only depend on the effort choices but also on the realization of the underlying noise term.

The two players are heterogeneous in ability. These ability differences are modeled via the players' effort costs. The more able player F ("favorite") has low effort costs, whereas exerting effort entails rather high costs for player U ("underdog"). In particular, both players can only choose between the two effort levels $e_i = e_L$ and $e_i = e_H > 0$ $(i = F, U)$ with $e_H > e_L$ and $\Delta e := e_H - e_L > 0$. The choice of $e_i = e_L$ leads to zero effort costs for player i, but choosing high effort $e_i = e_H$ involves positive costs c_i $(i = F, U)$ with $c_U > c_F > 0$. Relative performance of challenger i is described by[4]

$$RP = e_i - e_j + \varepsilon \tag{1}$$

with ε as noise term which follows a symmetric distribution around zero with cumulative distribution function $G(\varepsilon; \sigma^2)$ and variance σ^2. At the risk-taking stage, the challenger has to decide between two variances or risks. He can either choose a high risk $\sigma^2 = \sigma_H^2$ or a low risk $\sigma^2 = \sigma_L^2$ with $0 < \sigma_L^2 < \sigma_H^2$. Challenger i is declared winner of the tournament if and only if $RP > 0$. Hence, his winning probability is given by

$$\text{prob}\{RP > 0\} = 1 - G\left(e_j - e_i; \sigma^2\right) = G\left(e_i - e_j; \sigma^2\right) \tag{2}$$

where the last equality follows from the symmetry of the distribution. In analogy, we obtain for incumbent j's winning probability:

$$\text{prob}\{RP < 0\} = G\left(e_j - e_i; \sigma^2\right) = 1 - G\left(e_i - e_j; \sigma^2\right). \tag{3}$$

The symmetry of the distribution has two implications: first, each player's winning probability will be $G(0; \sigma^2) = \frac{1}{2}$ if both choose the same effort level. Second, if both players choose different effort levels, the one with the higher effort has winning probability $G(\Delta e; \sigma^2) > \frac{1}{2}$, but the player choosing low effort only wins with probability $G(-\Delta e; \sigma^2) = 1 - G(\Delta e; \sigma^2) < \frac{1}{2}$. Let

$$\Delta G\left(\sigma^2\right) := G\left(\Delta e; \sigma^2\right) - \frac{1}{2} \tag{4}$$

denote the *additional winning probability* of the player with the higher effort level *compared to a situation with identical effort choices* by both players. Note that $\Delta G(\sigma^2) \in \left(0, \frac{1}{2}\right)$. We assume that increasing risk from σ_L^2 to σ_H^2 shifts probability mass from the

[4] Note that, technically, our model equals the rank-order tournament model introduced by Lazear and Rosen (1981) with ε as difference of the two players' i.i.d. noise terms.

mean to the tails so that $G(\Delta e; \sigma_L^2) > G(\Delta e; \sigma_H^2)$, implying

$$\Delta G\left(\sigma_L^2\right) > \Delta G\left(\sigma_H^2\right). \tag{5}$$

When looking for subgame-perfect equilibria by backward induction we start by considering the effort stage 2. Here, both players observe $\sigma^2 \in \{\sigma_L^2, \sigma_H^2\}$ and simultaneously choose their efforts according to the following matrix game:

	$e_F = e_H$	$e_F = e_L$
$e_U = e_H$	$\frac{B}{2} - c_U$, $\frac{B}{2} - c_F$	$B \cdot G(\Delta e; \sigma^2) - c_U$, $B \cdot G(-\Delta e; \sigma^2)$
$e_U = e_L$	$B \cdot G(-\Delta e; \sigma^2)$, $B \cdot G(\Delta e; \sigma^2) - c_F$	$\frac{B}{2}$, $\frac{B}{2}$

The first (second) payoff in each cell refers to player U (F) who chooses rows (columns).

Note that $(e_U, e_F) = (e_H, e_L)$ can never be an equilibrium at the effort stage since

$$\begin{aligned} & B \cdot G\left(-\Delta e; \sigma^2\right) \geq \frac{B}{2} - c_F \Leftrightarrow c_F \geq B \cdot \left(\frac{1}{2} - G\left(-\Delta e; \sigma^2\right)\right) \\ \Leftrightarrow \quad & c_F \geq B \cdot \left(\frac{1}{2} - \left[1 - G\left(\Delta e; \sigma^2\right)\right]\right) \Leftrightarrow c_F \geq B \cdot \Delta G\left(\sigma^2\right) \end{aligned}$$

and

$$B \cdot G\left(\Delta e; \sigma^2\right) - c_U \geq \frac{B}{2} \Leftrightarrow B \cdot \Delta G\left(\sigma^2\right) \geq c_U$$

lead to a contradiction as $c_U > c_F$. Combination $(e_U, e_F) = (e_H, e_H)$ will be an equilibrium at the effort stage if and only if

$$\frac{B}{2} - c_i \geq B \cdot G\left(-\Delta e; \sigma^2\right) \Leftrightarrow B \cdot \Delta G\left(\sigma^2\right) \geq c_i \Leftrightarrow B \geq \frac{c_i}{\Delta G\left(\sigma^2\right)}$$

holds for player $i = F, U$. In words, each player will not deviate from the high effort level if and only if, compared to $e_i = e_L$, the additional expected gain $B \cdot \Delta G(\sigma^2)$ is at least as large as the additional costs c_i. Similar considerations for $(e_U, e_F) = (e_L, e_L)$ and $(e_U, e_F) = (e_L, e_H)$ yield the following result:

Proposition 1 *At the effort stage, in equilibrium players U and F choose*

$$(e_U^*, e_F^*) = \begin{cases} (e_H, e_H) & \text{if} \quad B \geq \frac{c_U}{\Delta G(\sigma^2)} \\ (e_L, e_H) & \text{if} \quad \frac{c_U}{\Delta G(\sigma^2)} \geq B \geq \frac{c_F}{\Delta G(\sigma^2)} \\ (e_L, e_L) & \text{if} \quad B \leq \frac{c_F}{\Delta G(\sigma^2)} \end{cases} \tag{6}$$

Our findings are quite intuitive: the favorite chooses at least as much effort as the underdog because of higher ability and, hence, lower effort costs. If the underdog's (and, thus, also the favorite's) effort costs are sufficiently small relative to the benefit B, it will pay off for both players to choose a high effort level. However, if the underdog's costs are sufficiently large and the favorite's ones sufficiently small relative to the benefit, only the favorite will prefer high effort. For sufficiently large costs of both players neither one exerts high effort.

At the risk-taking stage 1, the challenger chooses risk σ^2. Equations (2) and (3) show that risk taking directly influences both players' winning probabilities. Furthermore, Proposition 1 points out that risk also determines the players' effort choices at stage 2. We obtain the following proposition:

Proposition 2 *(i) If* $B \leq \frac{c_F}{\Delta G(\sigma_L^2)}$ *or* $B \geq \frac{c_U}{\Delta G(\sigma_H^2)}$*, then the challenger will be indifferent between* $\sigma^2 = \sigma_L^2$ *and* $\sigma^2 = \sigma_H^2$*, irrespective of whether he is the favorite or the underdog. (ii) Let* $B \in \left(\frac{c_F}{\Delta G(\sigma_L^2)}, \frac{c_U}{\Delta G(\sigma_H^2)}\right)$*. When* F *is the challenger, he will choose* $\sigma^2 = \sigma_L^2$ *if* $B < \frac{c_U}{\Delta G(\sigma_L^2)}$ *and* $\sigma^2 = \sigma_H^2$ *if* $B > \frac{c_U}{\Delta G(\sigma_L^2)}$*. When* U *is the challenger, he will always choose* $\sigma^2 = \sigma_H^2$*.*

Proof: See Appendix.

The result of Proposition 2(i) shows that risk taking becomes unimportant if the effort costs of both players are very large or very small compared to the benefit B. In the first case, it never pays for the players to choose a high effort level, irrespective of the underlying risk. In the latter case, both players prefer to exert high effort for any risk level since winning the tournament is very attractive. Hence, the risk-taking decision is only interesting for moderate parameter values that do not correspond to one of these extreme cases.

Proposition 2(ii) deals with the situation of moderate cost values. Here, the underdog always prefers the high risk when being the challenger. The intuition for this result comes from the fact that U is in an inferior position at the effort stage according to Proposition 1 (i.e., he will never choose a higher effort than player F), irrespective of the chosen risk level. Therefore, he has nothing to lose and unambiguously gains from choosing the high risk: in case of good luck, he may win the competition despite his inferior position; in case of bad luck, he will not really worsen his position as he has already a rather small winning probability. The favorite is in a completely different situation when being the challenger at the risk-taking stage. According to Proposition 1, he is the presumable winner of the tournament (i.e., he will never choose less effort than player U) and does not like to jeopardize his favorable position by choosing high risk. However, Proposition 2(ii) shows that F's preference for low risk will only hold if the benefit is smaller than a certain cut-off value. If B is rather large, then it will pay for the favorite to choose high risk at stage 1. By this, he strictly gains from discouraging his rival U: given $\sigma^2 = \sigma_L^2$, we have $(e_U^*, e_F^*) = (e_H, e_H)$ at the effort stage, but $\sigma^2 = \sigma_H^2$ induces $(e_U^*, e_F^*) = (e_L, e_H)$.

3 Discouragement Effect, Cost Effect and Likelihood Effect

The results of Proposition 2 have shown that the risk behavior of player U is rather uninteresting as he has a (weakly) dominant strategy when being the challenger. Therefore, the remainder of this paper focuses on the strategic risk taking of player F. As an illustrating example, consider the case of liberalization of monopoly where a new private entrant can challenge a former public enterprise. In this situation, the former monopolist is typically the weaker player with higher costs whereas the challenger can be roughly characterized as the favorite.[5] In practice, concerning the situation with an incumbent firm and a new entrant the latter one should typically be the favorite, because otherwise he would not try to challenge the incumbent.

Recall that risk taking may influence both the players' effort choices and their winning probabilities. As mentioned in the introduction, particularly three main effects determine the challenger's risk taking – a discouragement effect, a cost effect and a likelihood effect. These three effects depend on the relationship between the benefit B and the four cutoff values $\frac{c_F}{\Delta G(\sigma_L^2)}$, $\frac{c_F}{\Delta G(\sigma_H^2)}$, $\frac{c_U}{\Delta G(\sigma_L^2)}$ and $\frac{c_U}{\Delta G(\sigma_H^2)}$. Obviously, the first cutoff value is the smallest and the last cutoff value the largest one. The ranking of the two other cutoffs is not clear so that we have to differentiate between two scenarios:

$$\begin{aligned} &\text{scenario 1:} \qquad && \frac{c_F}{\Delta G(\sigma_L^2)} < \frac{c_F}{\Delta G(\sigma_H^2)} < \frac{c_U}{\Delta G(\sigma_L^2)} < \frac{c_U}{\Delta G(\sigma_H^2)} \\ &\text{scenario 2:} \qquad && \frac{c_F}{\Delta G(\sigma_L^2)} < \frac{c_U}{\Delta G(\sigma_L^2)} < \frac{c_F}{\Delta G(\sigma_H^2)} < \frac{c_U}{\Delta G(\sigma_H^2)}. \end{aligned}$$

Whereas the discouragement effect is possible under either scenario, the cost effect only appears in scenario 2 and the likelihood effect only in scenario 1.

If F's incentives to win the competition are sufficiently strong, that is if $B > \max\left\{\frac{c_F}{\Delta G(\sigma_H^2)}, \frac{c_U}{\Delta G(\sigma_L^2)}\right\}$, he wants to deter U from exerting high effort, which we call the *discouragement effect*. From the proof of Proposition 2, we know that low risk σ_L^2 leads to $(e_U^*, e_F^*) = (e_H, e_H)$, but high risk σ_H^2 induces $(e_U^*, e_F^*) = (e_L, e_H)$. Hence, when choosing high risk at stage 1, the favorite completely discourages his opponent and increases his winning probability by $G(\Delta e; \sigma_H^2) - \frac{1}{2} = \Delta G(\sigma_H^2)$, compared to low risk. This

[5] Such situation is typical for the liberalization of network industries in the European Union, in particular for the telecommunication market and the airline sector; see, among many others, Geradin (2006). For economic modeling of the new entrant as the low-cost firm and the incumbent being the high-cost firm, see, for example, Caplin and Nalebuff (1986).

effect is shown in Figure 1. There, the cumulative distribution function given high risk, $G(\cdot;\sigma_H^2)$, is obtained from the low-risk cdf, $G(\cdot;\sigma_L^2)$, by flattening and clockwise rotation in the point $\left(0,\frac{1}{2}\right)$.

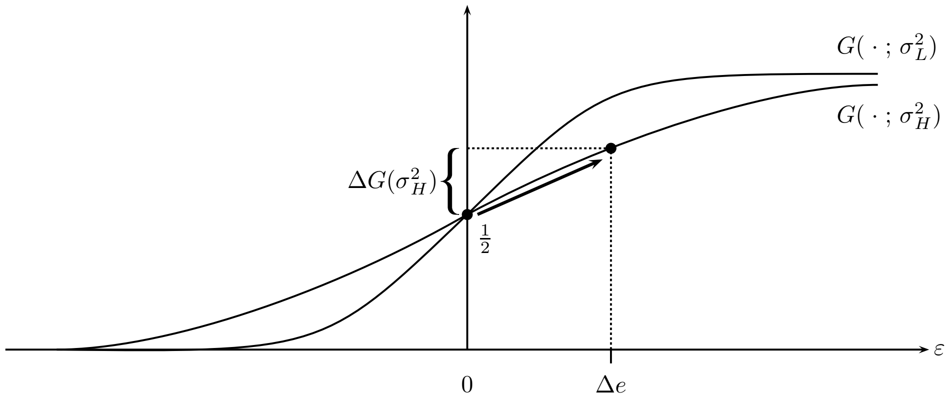

Figure 1: Discouragement effect

Low risk makes high effort attractive for both players since effort has still a real impact on the outcome of the tournament, resulting into a winning probability of $\frac{1}{2}$ for each player. Switching to a high-risk strategy σ_H^2 now increases the effort difference $e_F^* - e_U^*$ by Δe, which raises F's likelihood of winning by $\Delta G(\sigma_H^2)$ without influencing his effort costs.

The second effect can be labeled *cost effect*. In our discrete setting, this effect will determine F's risk choice if $\frac{c_U}{\Delta G\left(\sigma_L^2\right)} < B < \frac{c_F}{\Delta G\left(\sigma_H^2\right)}$.[6] In this situation, $\sigma^2 = \sigma_L^2$ leads to aggressive effort choices $(e_U^*, e_F^*) = (e_H, e_H)$ at stage 2, but $\sigma^2 = \sigma_H^2$ implies $(e_U^*, e_F^*) = (e_L, e_L)$. Hence, in any case the winning probability of either player will be $\frac{1}{2}$, but only under low risk each one has to bear positive costs. Consequently, the challenger prefers high risk at stage 1 to commit himself (and his rival) to choose minimal effort at stage 2 in order to save costs. Concerning the cost effect, both players' interests are perfectly aligned as each one prefers a kind of implicit collusion in the tournament, induced by high risk.

The third effect arises when $\frac{c_F}{\Delta G\left(\sigma_H^2\right)} < B < \frac{c_U}{\Delta G\left(\sigma_L^2\right)}$.[7] In this situation, the outcome at the effort stage is $(e_U^*, e_F^*) = (e_L, e_H)$, no matter which risk level has been chosen at stage 1. Here, risk taking only determines the players' likelihoods of winning so that this effect is called *likelihood effect*. If F chooses risk, he will unambiguously prefer low risk $\sigma^2 = \sigma_L^2$. Higher risk taking would shift probability mass from the mean to the tails. This is detrimental for the favorite, since bad luck may jeopardize his favorable position at the effort stage. By choosing low risk, his winning probability becomes $G(\Delta e;\sigma_L^2)$ instead of $G(\Delta e;\sigma_H^2)$ $(< G(\Delta e;\sigma_L^2))$. A technical intuition can be seen from Figure 2.

[6] See the proof of Proposition 2 in the Appendix.
[7] See again the proof of Proposition 2.

At Δe the cdf describes the winning probability of player F, whereas U's likelihood of winning is computed at $-\Delta e$.

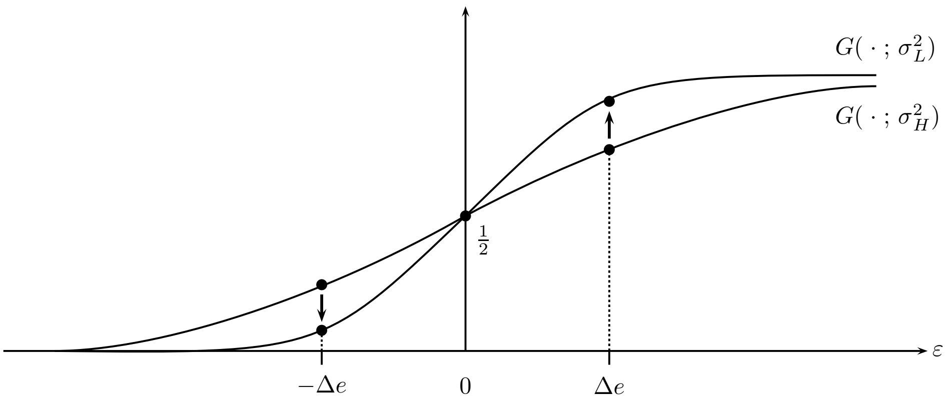

Figure 2: Likelihood effect

Thus, by choosing low risk instead of high risk, the favorite maximizes his own winning probability and minimizes that of his opponent. To sum up, the analysis of risk taking by the favorite points to three different effects at the risk-taking stage of the game. These three effects were tested in a laboratory experiment which will be described in the next section.[8] Thereafter, we will present the exact hypotheses to be tested and our experimental results.

4 Experimental Design and Procedure

We designed three different treatments corresponding to our three effects – the discouragement effect, the cost effect, and the likelihood effect. For each treatment we conducted four sessions, each including 5 groups of 6 participants. Each session consisted of 10 trial rounds and 5 rounds of the two-stage game. During each round, pairs of two players were matched anonymously within each group. After each round new pairs were matched in all groups. The game was repeated five times so that each player interacted with each other player exactly one time within a certain group. This perfect stranger matching was implemented to prevent reputation effects. Altogether, for each treatment we have 60 independent observations concerning the first round (15 pairs, 4 sessions) and 20 independent observations based on all rounds.

Before the 5 rounds of each session started, each participant got the chance to become familiar with the complete two-stage game of Section 2 for 10 rounds. During the trial rounds, a single player had to make all decisions on his own so that he learned the role

[8] Note that we will not consider the case $B < \min\left\{\frac{c_F}{\Delta G\left(\sigma_H^2\right)}, \frac{c_U}{\Delta G\left(\sigma_L^2\right)}\right\}$ in the lab. Here, low risk would imply a higher winning probability at higher costs for the favorite. Hence, we would have a mixture of the likelihood effect and the cost effect, which would not lead to additional insights when testing in an experiment.

of the favorite as well as that of the underdog. Within the 5 rounds of the experiment the participants got alternate roles. Hence, each individual either played three rounds as a favorite and two rounds as an underdog or vice versa.

In each session, the players competed for the same benefit ($B = 100$) and chose between the same alternative effort levels ($e_L = 0$ and $e_H = 1$). We used a uniformly distributed noise term ε for each session which was either distributed between -2 and 2 ("low risk"), or between -4 and 4 ("high risk"). Hence, we had $\Delta G(\sigma_L^2) = \frac{1}{4}$ and $\Delta G(\sigma_H^2) = \frac{1}{8}$. However, we varied the effort costs between the treatments. In the *discouragement treatment* (focusing on the discouragement effect) we used $c_U = 24$ and $c_F = 8$, in the *cost treatment* we had $c_U = 24$ and $c_F = 22$, and in the *likelihood treatment* we had $c_U = 60$ and $c_F = 8$. All parameter values B, e_L, e_H, c_U, c_F, as well as the intervals for ε were common knowledge. It can easily be checked that the three different parameter constellations of the treatments satisfy the three different conditions for the benefit corresponding to the discouragement effect, the cost effect and the likelihood effect, respectively. The subgame perfect equilibria can be summarized as follows:

	discouragement	cost	likelihood
risk choice	high risk	high risk	low risk
efforts (e_U^*, e_F^*)	(e_L, e_H)	(e_L, e_L)	(e_L, e_H)

Table 1: subgame perfect equilibria

The experiment was conducted at the Cologne Laboratory of Economic Research at the University of Cologne in January 2008 and January 2009. Altogether, 360 students participated in the experiment. All of them were enrolled in the Faculty of Management, Economics, and Social Sciences. The participants were recruited via the online recruitment system by Greiner (2003). The experiment was programmed and conducted with the software z-tree (Fischbacher, 2007). A session approximately lasted one hour and 15 minutes and subjects earned on average 13.85 Euro.

At the outset of a session the 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 aloud by the experimenters.[9] Thereafter, the subjects had time to ask clarifying questions if they had any difficulties in understanding the instructions. Communication – other than with the experimental software – was not allowed. To check for their comprehension, subjects had to answer a short questionnaire. After each of the subjects correctly solved the questions, the experimental software was started.

At the beginning of each session, the players got 60 units of the fictitious currency "Taler". Each round of the experiment then proceeded according to the two-stage game described in Section 2. It started with player F's risk choice at stage 1 of the game. He

[9] The instructions can be obtained from the authors upon request.

could either choose a random draw out of the interval $[-2, 2]$ ("low risk") or from the interval $[-4, 4]$ ("high risk"). When choosing risk, player F knew the course of events at the next stage as well as both players' effort costs. At the beginning of stage 2, both players were informed about the interval that had been chosen by player F before. Then both players were asked about their beliefs concerning the effort decision of their respective opponent. Thereafter, each player i ($i = U, F$) chose between score 0 (at zero costs) and score 1 (at costs c_i) as alternative effort levels. Next, the random draw was executed. In two of the four sessions for each effect, the final score of player F consisted of his initially chosen score 0 or 1 plus the realization of the random draw, whereas the final score of player U was identical with his initially chosen score 0 or 1. In the other two sessions, the final score of player U was the sum of his chosen score and the realization of the random draw. The final score of player F was his initially chosen score.[10] The player with the higher final score was the winner of this round and the other one the loser. Both players were informed about both final scores, whether the guess about the opponent's choice was correct, and about the realized payoffs. Then the next round began.

Each session ended after 5 rounds. At the end of the session, one of the 5 rounds was drawn by lot. For this round, each player got 15 Talers if his guess of the opponent's effort choice was correct and zero Talers otherwise. The winner of the selected round received $B = 100$ Talers and the loser zero Talers. Each player had to pay zero or c_i Talers for the chosen score 0 or 1, respectively. The sum of Talers was then converted into Euro by a previously known exchange rate of 1 Euro per 10 Talers. Additionally, each participant received a show up fee of 2.50 Euro independent of the outcome of the game. After the final round, the subjects were requested to complete a questionnaire including questions on gender, age, loss aversion and inequity aversion. Furthermore, the questionnaire contained questions concerning the risk attitude of the subjects. These questions were taken from the German Socio Economic Panel (GSOEP) and dealt with the overall risk attitude of a subject.

The language was kept neutral at any time. For example, we did not use terms like "favorite" and "underdog", or "player F" and "player U", but instead spoke of "player A" and "player B". Moreover, we simply described the pure random draw out of the two alternative intervals without speaking of low or high risk. Instead favorites chose between "alternative 1" and "alternative 2".

[10] Note that both procedures lead to identical theoretic outcomes since exogenous noise is symmetrically distributed around zero. There are no significant differences between the behavior of the subjects in the different sessions for each treatment pooled over all rounds. Hence, in the following we pool the data of those sessions.

5 Hypotheses

We tested four hypotheses, three of them deal with the risk behavior and one of them with the players' behavior at the effort stage.

The first three hypotheses test the relevance of the discouragement effect, the cost effect and the likelihood effect at stage 1 of the game. Since we designed three different constellations by changing one of the cost parameters, respectively, each effect could be separately analyzed in a single treatment. The cost treatment is obtained from the discouragement treatment by increasing the favorite's cost parameter, whereas the design of the likelihood treatment results from increasing the underdog's cost parameter in the discouragement treatment.

Hypothesis 1: *In the discouragement treatment, (most of) the favorites choose the high risk.*

Hypothesis 2: *In the cost treatment, (most of) the favorites choose the high risk.*

Hypothesis 3: *In the likelihood treatment, (most of) the favorites choose the low risk.*

In a next step, we test the players' chosen efforts at the second stage of the game. Since in any equilibrium at the effort stage the favorite should not choose less effort than the underdog, we have the following hypothesis:

Hypothesis 4: *The favorites choose at least as much effort as the underdogs.*

6 Experimental Results

6.1 The Risk-Taking Stage

We test the hypotheses with the data of our experiment, starting with the risk choices of the favorites. Figure 3 shows the fraction of favorites who choose the high risk in the respective treatment.[11] Contrary to Hypothesis 1, most of the favorites choose low risk in the discouragement treatment. Furthermore, concerning Hypothesis 2, only slightly more than 50% of the favorites choose high risk in the cost treatment. In the likelihood treatment the majority of the favorites chooses low risk, which is in line with Hypothesis 3. The results of one-tailed sign tests confirm these first impressions: in the likelihood treatment significantly more favorites choose low risk than high risk ($p = 0.0002$), while

[11] While all figures consider fractions relating to the whole number of observations of a particular situation, non-parametric tests take into account that we have one independent observation per group over all rounds.

we cannot reject the null hypothesis that 50% or less of the favorites choose high risk in the discouragement and cost treatment.

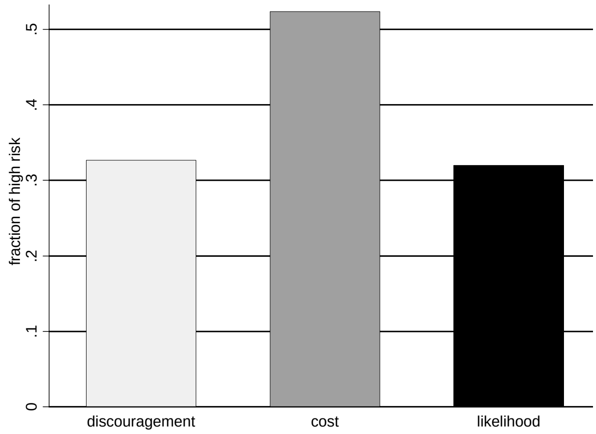

Figure 3: Choice of risk

Note that we pool our data over all rounds. To check whether our test results are distorted by learning effects, we run different regressions with risk choice as the dependent variable including round dummies (see Tables 2 to 4 in the Appendix). As the subjects play the game five times, we compute robust standard errors clustered by subjects. The regression results reveal that there are no significant learning effects over time in all treatments, since there is no significant influence of a certain round on risk taking.[12] This can be explained by the relatively large number of 10 trial rounds at the beginning of the experiment which helped the subjects to study the consequences of different strategies. If there are any learning effects, these should only be relevant in the trial phase.

In addition, we pairwisely compare the risk choices in the three treatments. Whereas the sign test has shown that favorites do not prefer high risk significantly more than low risk in the cost treatment, the relative comparison and the results of Mann-Whitney-U tests support the initial impression from Figure 3: favorites seem to choose the high risk more often in the cost treatment compared to the discouragement treatment. Favorites' risk taking in the cost treatment significantly differs from that in the discouragement treatment (two-tailed U-test, $p = 0.001$). Therefore, the cost effect seems to be more relevant for subjects when choosing risk than the discouragement effect. Furthermore, the probit regressions with the risk choice as the dependent variable (see Table 2 in the Appendix) show that the dummy variable for the cost treatment is highly significant. This confirms our test result.

Favorites' risk taking in the discouragement treatment is not significantly higher than that in the likelihood treatment (one-tailed U-test). This test result is in line with our

[12] Additionally, we compare the risk taking in a particular round with the risk taking of the following round but do not find significant differences except a weakly significant result for the comparision of round 1 with round 2 in the discouragement treatment ($p = 0.065$, two-tailed sign test).

previous observation: in the likelihood treatment, favorites choose low risk as theoretically expected. Since, contrary to theory, they also often choose low risk in the discouragement treatment, risk taking is not significantly higher in the discouragement treatment.[13]

As predicted by theory, favorites' risk taking is significantly higher in the cost treatment than in the likelihood treatment (one-tailed U-test, $p = 0.000$). Further confirmation comes from the respective probit regressions (see Table 4 in the Appendix). Note that all probit regressions show that the subjects' risk attitude does not have a significant influence on the favorites' risk taking.

6.2 The Effort Stage

Given the favorite's risk choice at stage 1, the underdog and the favorite have to decide on their efforts at the second stage of the game. According to the subgame perfect equilibria, we would expect that the favorite chooses a higher effort level than the underdog in the discouragement and the likelihood treatments, whereas both players' efforts should be the same in the cost treatment. Altogether, in stage 2 favorites should be more aggressive (i.e., choose higher efforts) than underdogs on average.[14] Figure 4 shows the fraction of players spending high effort over all treatments. In line with theory and our Hypothesis 4, favorites are clearly more aggressive than underdogs which is supported by a one-tailed sign test ($p = 0.000$). Recall that in the discouragement and the cost treatments different risk levels lead to different equilibria at the effort stage. Since both risk levels have been chosen at stage 1, we can test whether players rationally react to a given risk level. In the discouragement treatment, the favorite should always choose the large effort level independent of given risk, whereas the underdog should prefer small (large) effort if risk is high (low).

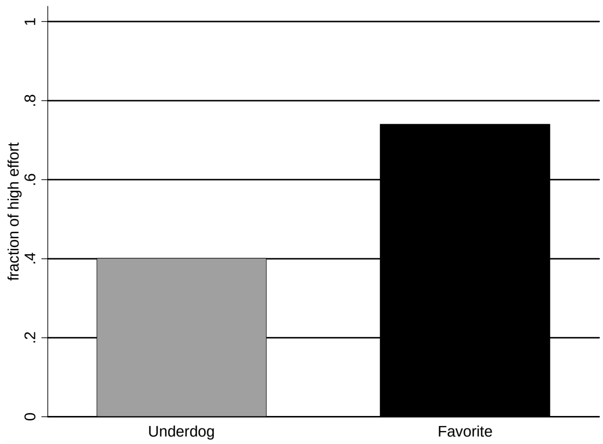

Figure 4: Effort over all treatments

[13] Again, the probit regressions confirm this result since we do not find a significant treatment dummy.

[14] Uneven tournaments in the notion of O'Keeffe et al. (1984) were also considered in the experiments by Bull et al. (1987), Schotter and Weigelt (1992) and Harbring et al. (2007). In each experiment, favorites choose significantly higher effort levels than underdogs.

Figure 5 shows the effort decisions of the favorites and underdogs for the different levels of risk in the discouragement treatment. In the high-risk as well as in the low-risk situation most of the favorites decided to choose high efforts. Consequently we cannot find significant differences between the favorites' effort decisions (two-tailed sign test), which strictly confirms theory. If the risk is high, favorites spend significantly more effort than underdogs (one-tailed sign test, $p = 0.000$) which is also perfectly in line with theory. As can already be seen from Figure 5 favorites choose higher efforts than underdogs if the risk is low, too (two-tailed sign test, $p = 0.000$).

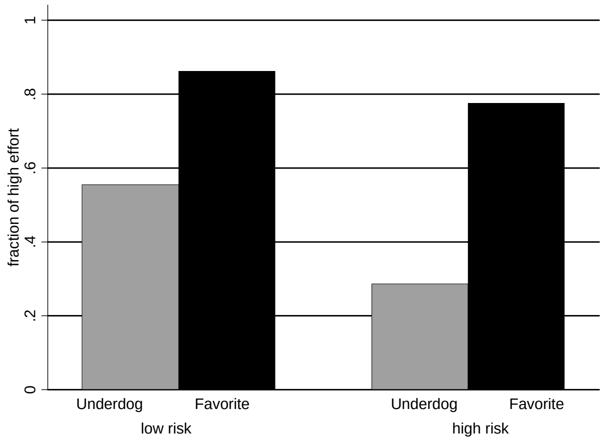

Figure 5: Effort in the discouragement treatment

Surprisingly many underdogs do not choose the high effort level although this would increase their chance of winning the competition. However, note that the underdogs show a clear reaction to the underlying risk: their efforts are significantly higher if the favorite has chosen low risk (one-tailed sign test, $p = 0.021$). Altogether, our findings support the fundamentals of the discouragement effect at the effort stage, but the underdogs do not react strong enough and – as we have seen at the risk-taking stage – the favorites do not make use of the discouragement effect as often as theoretically predicted.

Additionally, we run probit regressions with chosen efforts as the dependent variable and a dummy variable for the type of the player which are reported in Table 5 in the Appendix. These regressions qualitatively lead to the same results as the sign tests. We also control for learning effects in the regressions and compute robust standard errors clustered on subjects. Similar to the risk-taking stage, we do not observe learning effects.[15] Furthermore, we include a dummy variable for risk averse subjects and one for risk loving ones (so risk neutral is the control group) in the regression. The risk aversion of the subjects has no significant impact.[16]

[15] Except for round 2 if risk is high.

[16] Only risk loving subjects spend more effort if the risk is high. However, only about 26% of the observations are from risk loving players which drive this result.

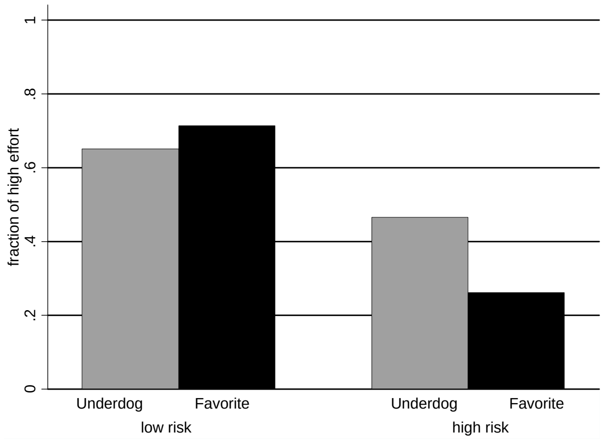

Figure 6: Effort in the cost treatment

In Figure 6 we report the effort decisions of the subjects in the cost treatment. It is obvious that they choose different effort levels depending on the chosen risk, as predicted by theory. This can be supported by the results of sign tests which show that underdogs as well as favorites choose more effort if risk is low (one-tailed, underdogs: $p = 0.002$, favorites: $p = 0.000$). In the situation with low risk both players should prefer aggressive behavior at the effort stage. Indeed we do not find significant differences when comparing efforts of favorites and underdogs. However, underdogs supply weakly significantly more effort than their opponents if risk is high (sign test $p = 0.064$) which is not in line with theory. Interestingly, favorites are more sensitive to risk than underdogs although subjects change their roles after each round. Again we run probit regressions which confirm our findings (see Table 6 in the Appendix). Note that we do not find any learning effects and that the risk attitudes of the subjects have no significant influences on their effort decisions.

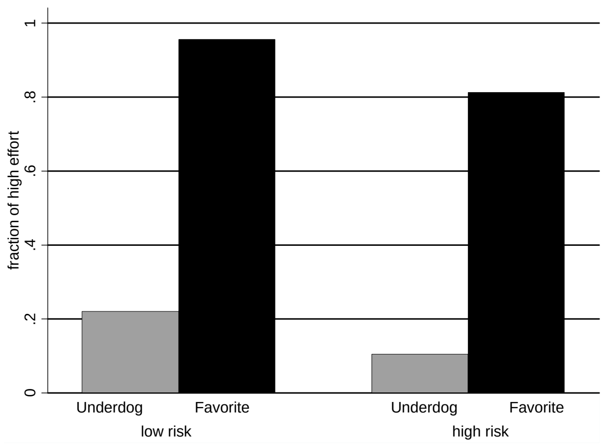

Figure 7: Effort in the likelihood treatment

As Figure 7 shows, the results for the likelihood treatment are perfectly in line with theory. In the likelihood treatment, for both risk levels favorites (underdogs) should choose high (low) efforts. Indeed, we do not find significant differences between the underdogs' effort choices. The favorites' efforts are higher if risk is low (two-tailed sign test, $p = 0.039$) but nevertheless the majority of the observations reveals a tendency to high effort. In both situations favorites exert significantly more effort than underdogs (one-tailed sign test, low risk $p = 0.000$ and high risk $p = 0.000$). The probit regressions reported in Table 7 in the Appendix lead to the same results and show that, similar to the cost treatment, neither learning effects nor risk attitude have significant effects on the chosen efforts.[17]

7 Discussion

The experimental results of Section 6 show that individuals often behave rationally when deciding on risk and, in general, do react to risk when deciding on effort. However, our findings also point to three puzzles, which should be discussed in the following: (1) favorites significantly more often choose the low risk than the high risk in the discouragement treatment; (2) given low risk in the discouragement treatment, favorites supply significantly more effort than underdogs; (3) given high risk in the cost treatment, underdogs are significantly more aggressive than favorites at the effort stage.

Inspection of the players' beliefs concerning their opponents' effort decisions shows that puzzles (1) and (2) seem to be interrelated. It turns out that in the low-risk state of the discouragement treatment, favorites' equilibrium beliefs differ from their reported beliefs in the experiment. About 53.47% of the favorites expect the underdogs to choose low effort. Actually, about one half of the underdogs choose a low effort level. Given that the favorites already had these beliefs when taking risk at stage 1, puzzle (1) can easily be explained: a favorite expecting low effort by an underdog in both a low-risk and a high-risk state, should unambiguously prefer the high effort level in both states. The results of our sign tests from Subsection 6.1 show that indeed favorites highly significantly react in this way. When the favorites decide on risk taking at stage 1 and anticipate $(e_U, e_F) = (0, 1)$ under both risks, the underlying discouragement problem now turns into a perceived likelihood problem from the viewpoint of the favorites. Given a perceived likelihood problem, the favorites should optimally choose a low risk in order to maximize their winning probability (see Figure 2), which explains puzzle (1). Some of the underdogs might choose low effort even in the low-risk state since they feel discouraged because of their cost disadvantage. The underdogs have the same cost parameter in the discouragement and cost treatment. However, underdogs act more aggressively in the cost treatment than in the discouragement treatment. Therefore, we suspect that the underdogs rather react to the cost difference between favorites and underdogs than

[17] To check if most of the subjects of a certain type choose the predicted effort level under a given risk, we used one-tailed sign tests. See Table 8 in the Appendix for the complete results.

to their absolute cost value. This can explain puzzle (2).

Concerning puzzle (3) controlling for risk aversion, loss aversion, inequity aversion and the history of the game does not yield new insights. In particular, one might expect the players' history in the game to have explanatory power: intuitively, subjects might react to the outcomes of former rounds when choosing efforts in the actual round. However, our results do not show a clear impact of experienced success or failure in previous tournaments. As a possible explanation of puzzle (3), we suppose that underdogs react too strongly to the close competition with the favorites. In the cost treatment, costs for high effort were $c_U = 24$ and $c_F = 22$. Hence, the cost difference is rather small – particularly compared to the two other treatments –, and the underdogs might have chosen high effort due to perceived homogeneity in the tournament. Inspection of the players' beliefs reveals that about 60% of the favorites expect their opponents to choose a low effort level whereas about 52% of the underdogs believe the favorites will prefer low effort. Underdogs might select high effort because they expect favorites to choose high effort levels as well. 65% of the underdogs who believe the favorite to behave aggressively choose high effort, too. Similarly, about 71% of the underdogs who believe the favorite to choose low effort also choose low effort. These observations are supported by a probit regression in Table 9 in the Appendix. In this regression the effort decision of the underdogs is the dependent variable. Here the belief about the effort decision of the opponent has a significant impact on the own effort choice. However, in the concrete situation given $\sigma^2 = \sigma_H^2$ and $e_F = 1$, an underdog should prefer $e_U = 1$ to $e_U = 0$ if and only if $\frac{B}{2} - c_U > B \cdot G\left(-\Delta e; \sigma_H^2\right) \Leftrightarrow B \cdot \Delta G\left(\sigma_H^2\right) > c_U$, and for our chosen parameter values this condition (12.5 Talers > 24 Talers) is clearly violated.

While in the cost treatment a considerable fraction of the underdogs do not act in line with theory favorites mostly play the equilibrium prediction at the effort stage. 87% of the favorites who believe the underdog to choose low effort also choose low effort while still about 55% of the favorites who believe the underdog to choose high effort choose low effort. This different behavior of underdogs and favorites is surprising because the players changed roles after each round. However, as the regression in Table 9 in the Appendix shows, underdogs that were in the role of favorites in the previous round and selected high risk act significantly less aggressively than others in the effort stage. It seems that subjects who understood the game as favorites and therefore selected high risk also acted in line with theory as underdogs. Favorites who preferred the low risk tend to play a suboptimal strategy as underdogs as well. Another possible explanation might be that favorites play the more active part in this game as they select the risk which affects the outcome of the tournament. Therefore, we conducted two sessions where the random draw (risk choice) contributed to the final score of the favorite and two sessions where it contributed to the final score of the underdog. In the latter sessions the risk choice of the favorite has a direct impact on the final score of the underdog. However, we do not find significant differences between those sessions. To sum up, as we can see from Figure 6, underdogs do reduce their efforts when risk increases, which is qualitatively in line with the cost effect, but for some reason underdogs do not react as strongly as favorites to different risks.

8 Conclusion

In many winner-take-all situations, a challenger first decides whether to use a more or less risky strategy and then both players decide on their investments or efforts. Risk taking at the first stage of the game determines both the optimal investment or effort levels at stage two and the players' likelihood of winning the competition. In our model, we find three effects that mainly determine risk taking – a cost effect, a likelihood effect, and a discouragement effect. This theoretical result can be applied to the cases mentioned in the introduction. Reconsider, for example, the stylized market situation where an incumbent firm and a challenging firm compete for market leadership. The challenger who enters the market first has to decide whether to use a less risky strategy (e.g., a conservative product line or advertising strategy) or a more risky one (e.g., a radical product innovation or a new marketing concept). Thereafter, both firms compete to become market leader by choosing advertising expenditures. The normative findings on the three effects then recommend the following marketing strategies: (1) if optimal advertising of both firms is sensitive to risk taking, the challenger should prevent mutually aggressive advertising (i.e., high expenditures) by choosing a very innovative product or marketing concept when entering the market (cost effect); (2) if the optimal advertising expenditures of both firms are not sensitive to risk, the challenging firm should rely on its significant cost advantage at the advertising stage and prefer low risk (likelihood effect); (3) if only the incumbent's optimal advertising expenditure is sensitive to risk and market leadership is very attractive, the challenger should choose both to become market leader – a radical product or marketing concept innovation and aggressive advertising (discouragement effect).

Our experimental findings point out that subjects understand the implications of risk taking since effort decisions are mostly in line with theory under all three effects. In other words, the fundamentals of the three effects are confirmed by our data. However, the subjects do not make use of the three effects as often as predicted by theory, which is particularly true for the discouragement effect. We can apply the experimental results also to other situations than those mentioned in the introduction. At the risk-taking stage, we observed that the likelihood effect is really robust, whereas we got mixed results for the two other effects. If high risk corresponds to innovative behavior, this means that high-potential challengers (i.e., favorites) tend to avoid innovations in winner-take-all situations. Instead, they will rely on cost advantages from their existing technologies.

From society's perspective such conservative behavior may not be desirable since high-potentials are most likely to develop new and pioneering ideas. At the effort stage, we observe that subjects clearly react to all three risk-taking effects. This result is interesting from a principal-agent perspective, implying that agents' behavior in tournaments can be directly influenced by the principal if he decides on risk. For example, concerning the cost effect it may be beneficial for an employer to increase the monitoring precision in order to induce higher effort levels of workers competing in sales contests, job-promotion tournaments or forced-ranking systems.

Appendix

Proof of Proposition 2:

(i) Since we have two risk levels, σ_L^2 and σ_H^2, there are four cutoffs with $\frac{c_F}{\Delta G(\sigma_L^2)}$ being the smallest one and $\frac{c_U}{\Delta G(\sigma_H^2)}$ the largest one because of (5). According to (6), both players will always (never) choose high effort levels if $B \geq \frac{c_U}{\Delta G(\sigma_H^2)}$ $(B \leq \frac{c_F}{\Delta G(\sigma_L^2)})$, irrespective of risk taking in stage 1.

(ii) We have to differentiate between two possible rankings of the cutoffs:

$$\begin{array}{ll} \text{scenario 1:} & \dfrac{c_F}{\Delta G(\sigma_L^2)} < \dfrac{c_F}{\Delta G(\sigma_H^2)} < \dfrac{c_U}{\Delta G(\sigma_L^2)} < \dfrac{c_U}{\Delta G(\sigma_H^2)} \\ \text{scenario 2:} & \dfrac{c_F}{\Delta G(\sigma_L^2)} < \dfrac{c_U}{\Delta G(\sigma_L^2)} < \dfrac{c_F}{\Delta G(\sigma_H^2)} < \dfrac{c_U}{\Delta G(\sigma_H^2)}. \end{array}$$

If $B < \min\left\{\frac{c_F}{\Delta G(\sigma_H^2)}, \frac{c_U}{\Delta G(\sigma_L^2)}\right\}$, then in both scenarios the choice of σ_L^2 will imply $(e_U^*, e_F^*) = (e_L, e_H)$ at stage 2, whereas $\sigma^2 = \sigma_H^2$ will lead to $(e_U^*, e_F^*) = (e_L, e_L)$. In this situation, a F-challenger prefers $\sigma^2 = \sigma_L^2$ since

$$B \cdot G\left(\Delta e; \sigma_L^2\right) - c_F > \frac{B}{2} \Leftrightarrow B > \frac{c_F}{\Delta G(\sigma_L^2)}$$

is true. However, a U-challenger prefers $\sigma^2 = \sigma_H^2$ because of

$$\frac{B}{2} > B \cdot G\left(-\Delta e; \sigma_L^2\right).$$

If $B > \max\left\{\frac{c_F}{\Delta G(\sigma_H^2)}, \frac{c_U}{\Delta G(\sigma_L^2)}\right\}$, then in both scenarios the choice of σ_L^2 will result into $(e_U^*, e_F^*) = (e_H, e_H)$ at stage 2, but $\sigma^2 = \sigma_H^2$ will induce $(e_U^*, e_F^*) = (e_L, e_H)$. In this case, a F-challenger prefers the high risk σ_H^2 since

$$B \cdot G\left(\Delta e; \sigma_H^2\right) - c_F > \frac{B}{2} - c_F.$$

Player U has the same preference when being the challenger because

$$B \cdot G\left(-\Delta e; \sigma_H^2\right) > \frac{B}{2} - c_U \Leftrightarrow \frac{c_U}{\Delta G(\sigma_H^2)} > B$$

is true.

Two cases are still missing. Under scenario 1, we may have that

$$\frac{c_F}{\Delta G(\sigma_H^2)} < B < \frac{c_U}{\Delta G(\sigma_L^2)}.$$

Then any risk choice leads to $(e_U^*, e_F^*) = (e_L, e_H)$ at stage 2 and a F-challenger prefers

σ_L^2 because of

$$B \cdot G\left(\Delta e; \sigma_L^2\right) - c_F > B \cdot G\left(\Delta e; \sigma_H^2\right) - c_F,$$

but U favors σ_H^2 when being active at stage 1 since

$$B \cdot G\left(-\Delta e; \sigma_H^2\right) > B \cdot G\left(-\Delta e; \sigma_L^2\right).$$

Under scenario 2, we may have that

$$\frac{c_U}{\Delta G\left(\sigma_L^2\right)} < B < \frac{c_F}{\Delta G\left(\sigma_H^2\right)}.$$

Here, low risk σ_L^2 implies $(e_U^*, e_F^*) = (e_H, e_H)$, but high risk σ_H^2 leads to $(e_U^*, e_F^*) = (e_L, e_L)$. Obviously, each type of challenger prefers the choice of high risk at stage 1. Our findings are summarized in Proposition 2(ii).

	(1)	(2)
Dummy Cost Treatment	0.509***	0.506***
	(0.14)	(0.14)
Risk averse		0.0512
		(0.13)
Risk loving		−0.0621
		(0.14)
Dummy Round 2	0.134	0.131
	(0.19)	(0.19)
Dummy Round 3	0.0892	0.0887
	(0.12)	(0.13)
Dummy Round 4	0.0886	0.0877
	(0.15)	(0.15)
Dummy Round 5	0.0220	0.0206
	(0.16)	(0.16)
Constant	−0.517***	−0.516**
	(0.16)	(0.20)
Observations	600	600
Pseudo R^2	0.0303	0.0312
Log Pseudolikelihood	−396.71272	−396.35534

The dependent variable is risk choice. Dummy cost treatment is 1 for the cost treatment and 0 for the discouragement treatment. Robust standard errors in parentheses are calculated by clustering on subjects.
***p < 0.01, **p < 0.05, *p < 0.1

Table 2: Probit regression: comparison of discouragement and cost treatment

	(1)	(2)
Dummy Likelihood Treatment	−0.0191	−0.0233
	(0.14)	(0.14)
Risk averse		−0.146
		(0.14)
Risk loving		−0.0333
		(0.16)
Dummy Round 2	0.160	0.167
	(0.14)	(0.15)
Dummy Round 3	0.160	0.157
	(0.11)	(0.11)
Dummy Round 4	0.0235	0.0266
	(0.16)	(0.16)
Dummy Round 5	−0.148	−0.148
	(0.13)	(0.13)
Constant	-0.491^{***}	-0.433^{**}
	(0.14)	(0.17)
Observations	600	600
Pseudo R^2	0.0061	0.0079
Log Pseudolikelihood	−375.30969	−374.61791

The dependent variable is risk choice. Dummy likelihood treatment is 1 for the likelihood treatment and 0 for the discouragement treatment. Robust standard errors in parentheses are calculated by clustering on subjects.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 3: Probit regression: comparison of discouragement and likelihood treatment

	(1)	(2)
Dummy Cost Treatment	0.528^{***}	0.539^{***}
	(0.14)	(0.15)
Risk averse		0.0555
		(0.16)
Risk loving		0.193
		(0.19)
Dummy Round 2	−0.0660	−0.0473
	(0.15)	(0.14)
Dummy Round 3	0.109	0.119
	(0.12)	(0.12)
Dummy Round 4	0.0211	0.0237
	(0.12)	(0.12)
Dummy Round 5	−0.115	−0.0987
	(0.13)	(0.13)
Constant	-0.460^{***}	-0.547^{***}
	(0.11)	(0.17)
Observations	600	600
Pseudo R^2	0.0340	0.0367
Log Pseudolikelihood	−394.59834	−393.48415

The dependent variable is risk choice. Dummy cost treatment is 1 for the cost treatment and 0 for the likelihood treatment. Robust standard errors in parentheses are calculated by clustering on subjects.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 4: Probit regression: comparison of likelihood and cost treatment

	High risk	High risk	Low risk	Low risk
Dummy Favorite	1.330***	1.428***	0.957***	0.967***
	(0.19)	(0.19)	(0.17)	(0.18)
Risk averse		−0.123		−0.291
		(0.29)		(0.25)
Risk loving		0.640**		0.271
		(0.25)		(0.22)
Dummy Round 2	0.124	0.0698	0.356*	0.387*
	(0.28)	(0.28)	(0.21)	(0.21)
Dummy Round 3	0.153	0.115	0.167	0.175
	(0.21)	(0.23)	(0.15)	(0.16)
Dummy Round 4	0.238	0.130	0.210	0.255
	(0.32)	(0.33)	(0.18)	(0.19)
Dummy Round 5	−0.0976	−0.129	0.228	0.257
	(0.23)	(0.25)	(0.17)	(0.17)
Constant	−0.665***	−0.784***	−0.0481	−0.0388
	(0.23)	(0.26)	(0.16)	(0.21)
Observations	196	196	404	404
Pseudo R^2	0.1870	0.2215	0.1036	0.1264
Log Pseudolikelihood	−110.15352	−105.47966	−218.74212	−213.17795

The dependent variable is effort. Robust standard errors in parentheses are calculated by clustering on subjects.

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

Table 5: Probit regression Hypothesis 4: discouragement treatment

	High risk	High risk	Low risk	Low risk
Dummy Favorite	-0.555^{***}	-0.566^{***}	0.178	0.171
	(0.13)	(0.13)	(0.16)	(0.16)
Risk averse		-0.145		-0.120
		(0.20)		(0.24)
Risk loving		0.306		0.333
		(0.36)		(0.32)
Dummy Round 2	-0.0940	-0.0846	-0.0362	-0.0479
	(0.18)	(0.20)	(0.20)	(0.22)
Dummy Round 3	0.0880	0.0822	0.0223	0.0259
	(0.18)	(0.18)	(0.20)	(0.20)
Dummy Round 4	0.0633	0.0589	-0.357	-0.362
	(0.21)	(0.22)	(0.23)	(0.23)
Dummy Round 5	0.221	0.206	0.0251	0.0446
	(0.19)	(0.19)	(0.19)	(0.19)
Constant	-0.147	-0.160	0.456^{***}	0.430^{**}
	(0.17)	(0.23)	(0.13)	(0.21)
Observations	314	314	286	286
Pseudo R^2	0.0394	0.0533	0.0135	0.0266
Log Pseudolikelihood	-197.61873	-194.76213	-176.47632	-174.12409

The dependent variable is effort. Robust standard errors in parentheses are calculated by clustering on subjects.

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

Table 6: Probit regression Hypothesis 4: cost treatment

	High risk	High risk	Low risk	Low risk
Dummy Favorite	2.168***	2.188***	2.481***	2.485***
	(0.25)	(0.24)	(0.21)	(0.21)
Risk averse		0.321		0.0626
		(0.34)		(0.20)
Risk loving		0.187		−0.0348
		(0.32)		(0.25)
Dummy Round 2	−0.0365	0.00545	−0.270	−0.275
	(0.34)	(0.34)	(0.21)	(0.21)
Dummy Round 3	0.212	0.254	−0.0465	−0.0519
	(0.27)	(0.27)	(0.28)	(0.28)
Dummy Round 4	0.0921	0.101	−0.162	−0.165
	(0.32)	(0.32)	(0.23)	(0.23)
Dummy Round 5	−0.262	−0.213	−0.246	−0.253
	(0.30)	(0.29)	(0.24)	(0.24)
Constant	−1.296***	−1.492***	−0.627***	−0.635***
	(0.30)	(0.36)	(0.17)	(0.21)
Observations	192	192	408	408
Pseudo R^2	0.4145	0.4190	0.4802	0.4806
Log Pseudolikelihood	−77.528258	−76.933222	−143.69467	−143.57859

The dependent variable is effort. Robust standard errors in parentheses are calculated by clustering on subjects.

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

Table 7: Probit regression Hypothesis 4: likelihood treatment

	player: data	discouragement	cost	likelihood
high	F	$e_F = 1^{***}$	$e_F = 0^{***}$	$e_F = 1^{***}$
risk	U	$e_U = 0^{***}$	$e_U = 0$	$e_U = 0^{***}$
low	F	$e_F = 1^{***}$	$e_F = 1^{***}$	$e_F = 1^{***}$
risk	U	$e_U = 1^{**}$	$e_U = 1^{*}$	$e_U = 0^{***}$

($^{*}0.05 < \alpha \leq 0.1$; $^{**}0.01 < \alpha \leq 0.05$; $^{***}\alpha \leq 0.01$)

Table 8: Results on choice of effort (one-tailed sign tests)

	High risk	High risk
Lagged Favorite High Risk	-0.606^{***}	-0.545^{**}
	(0.224)	(0.240)
Belief Player		0.968^{***}
		(0.235)
Round 3	0.151	-0.000141
	(0.324)	(0.380)
Round 4	-0.136	-0.144
	(0.314)	(0.369)
Round 5	0.124	0.192
	(0.332)	(0.380)
Constant	0.198	-0.289
	(0.248)	(0.295)
Observations	126	126
Pseudo R^2	0.0437	0.1387
Log Pseudolikelihood	-83.502283	-75.205655

The dependent variable is effort. The dummy variable "lagged favorite high risk" is 1 if the underdog was in the role of a favorite one round before and selected high risk. Robust standard errors in parentheses are calculated by clustering on subjects. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 9: Probit regression cost treatment only underdogs

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