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Incentive Effects in Asymmetric Tournaments - Empirical Evidence from the German Hockey League

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Abstract

Following tournament theory, incentives will be rather low if the contestants of a tournament are heterogeneous. We empirically test this prediction using a large dataset from the German Hockey League. Our results show that indeed the intensity of a game is lower if the teams are more heterogeneous. This effect can be observed for the game as a whole as well as for the first and last third. When dividing the teams in the dataset into favorites and underdogs, we only observe a reduction of effort provision from favorite teams. As the number of games per team changes between different seasons, we can also investigate the effect of a changing spread between winner and loser prize. In line with theory, teams reduce effort if the spread declines. Interestingly, effort is also sensitive to the total number of teams in the league even if the price spread remains unchanged.

Key words: Tournaments, Heterogeneity, Incentives, Effort

JEL codes: J33

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1 Introduction

The focus of this paper is to investigate the effect of heterogeneity between the contestants on effort provision in a tournament. A large dataset of the German Hockey League is used to test the theoretical predictions made by tournament theory. We analyze this effect for the whole game and also for each third separately. Furthermore, we test if favorites and underdogs behave differently in a tournament. Our last research question is if a change of the prize spread affects effort provision in hockey.

Tournament situations are a common occurrence in business and even day-to-day life. Be it two agents competing for a job promotion (see Baker, Gibbs & Holmström (1994)) or a higher share in bonus pools (see Rajan & Reichelstein (2006)). One can observe salesman who are compensated based on relative performance (see Murphy, Dacin & Ford (2004)) and election tournaments between politicians (see Gersbach (2009)). Firms compete in R&D contests (see Zhou (2006)) as well as patent rights competitions (see Waerneryd (2000)) while singers fight for the first prize in singing contests (see Amegashie (2009)). Furthermore, sports contests like basketball, soccer or hockey have the structure of tournaments.

Lazear & Rosen (1981) have shown that effort levels in tournaments depend on several parameters. The spread between the winner and the loser prizes, the number of participants as well as the heterogeneity of the contestants, to name the most important ones, all influence the agents' effort choices. For example it is rather intuitive that agents exert more effort if the prize spread is high as has been shown for instance by Ehrenberg & Bognanno (1990*a*), Ehrenberg & Bognanno (1990*b*) and Heyman (2005). Furthermore as Nalebuff & Stiglitz (1983) and McLaughlin (1988) have shown,the prize spread has to rise with an increased number of participants. Experimental evidence regarding the number of participants and heterogeneous tournaments comes from Orrison, Schotter & Weigelt (2004). For an overview on contests and tournaments see Konrad (2009).

But how does heterogeneity influence the effort levels? If we consider a tournament with perfectly homogeneous agents, it is fairly obvious that the ex ante chances of winning are equal for all participants. The incentives to work are therefore high, since no agent has an advantage. However, in real world tournament situations, contestants are often rather heterogeneous. Since effort is costly, the underdog will reduce his effort compared to the homogeneous case, as his winning probability is smaller due to his handicap. The higher the disadvantage of the underdog, the stronger this effect. The favorite will anticipate this behavior and can consequentially reduce his effort without endangering his favorable position. In a heterogeneous tournament both agents will therefore exert lower effort levels compared to the homogeneous case.

While this effect is well documented in the theoretical literature (see for example O'Keeffe, Viscusi & Zeckhauser (1984) and Kräkel & Sliwka (2004)) and properly examined with experimental data (see Bull, Schotter & Weigelt (1987) or Harbring & Luenser (2008)), only few papers investigate this topic with real life data. Hence, empirical evidence regarding this - in the real world common - situation is still sparse.

We extend the existing literature by investigating tournaments between heterogeneous teams in the German Hockey League. These data are well suited for analysis as hockey tournaments provide the two key features which are essential to all tournament models. First, only the relative performance determines who wins a given game. The absolute performance compared to e.g. preceding games is irrelevant since only the number of scored goals in the game decides which team wins. Second, the prizes have been fixed in advance. The number of points awarded for a win has been fixed prior to the season. Additionally, the number of points is independent of the winning margin.

For our analysis, we use data from the German Hockey League encompassing the three seasons from 2006/07 to 2008/09. Our data show that teams commit less infractions if the ex ante heterogeneity measured by the differences between winning probabilities derived from betting odds is higher. This result also holds for the first and the last third of each game while heterogeneity has no significant impact on penalties during the second third. We also observe that teams in the role of the favorite are sensitive to heterogeneity while underdogs generally do not react to ex ante heterogeneity. However, a deeper analysis reveals that this pattern is only true if the home team is the favorite. If the visiting team is the favorite, both teams do not adjust effort to ex ante heterogeneity. Our last research question is if we observe less penalties when the spread between winner and loser prize is lower. We can analyze this by comparing season 2006/07 to season 2007/08. In season 2007/08 the number of games per team was higher, since one team joined the league. Hence, a single game in season 2007/08 lead to a lesser percentage of all reachable points than a single game in the previous season. In line with theory, teams received less penalties in season 2007/08 per game. The league was joined by another team in season 2008/09 and then encompassed 16 teams. However, due to a revised schedule, all teams played 52 games in season 2008/09 as they did in the first season 2006/07. Therefore the prize spread (percentage of all reachable points) remained unchanged. Hence, we should not observe different behavior regarding penalties when comparing those two seasons. Interestingly, our data show that teams committed significantly less penalties in season 2008/09 than in season 2006/07.

Papers related to our work are from Sunde (2009), Bach, Prinz & Gürtler (2009) and Frick, Gürtler & Prinz (2008). Using data from professional tennis, Sunde (2009) provides evidence that heterogeneity of players in elimination tournaments reduces the average number of games won per set. Furthermore, heterogeneity has a negative impact on games won per set for underdogs while it affects the behavior of the favorite to a smaller extent. In his study ranking lists are used as a heterogeneity measure. However, ranking lists or standings do not contain all available information about the players since e.g. recent injuries or suspensions (in team sports) are not included. Bach, Prinz & Gürtler (2009) investigating data from the Olympic Rowing Regatta 2000 use the achieved tournament stage as a proxy for heterogeneity. In contrast to Sunde (2009), they report that favorites hold back effort in heterogeneous situations, whereas underdogs do not adjust their effort when competing with dominant opponents. While the first observation is in line with theory, the latter contradicts the theoretical prediction. Bach, Prinz & Gürtler (2009) argue that underdogs - following the Olympic spirit - always give their best in Olympic contests. Closest to the paper at hand are Frick, Gürtler & Prinz (2008) who analyze data from the German soccer league. They use betting odds to measure heterogeneity and penalties as a proxy of effort, an approach also pursued in the present paper. In contrast to soccer, penalties in hockey are rather common, therefore providing a better database. Additionally, our study goes beyond Frick, Gürtler & Prinz (2008) as we also analyze each individual period of the game as well as the behavior of ex ante favorites and underdogs separately. This enables us to shed some light into the questions if the ex ante heterogeneity influences the whole game or only the first period and if underdogs and favorites behave differently in team sports. Besides, our data feature a kind of natural experiment as the number of teams and the spread between winner and loser prize vary between the seasons. Hence, we also analyze the effect of a changing prize spread on effort provision between different seasons.

As hockey is a team sport our paper is also related to the literature about collective tournaments and group contests (see Drago, Garvey & Turnbull (1996) and Gürtler (2008)). In contrast to two-player tournaments free-riding can be an issue in collective tournaments. However, as all teams have equal size on ice this effect is not relevant for our research question.

The remainder of the paper is organized as follows. The dataset is described in the next section while we derive our hypotheses and explain our empirical setting in section 3. We present the results in section 4 and conclude the paper in section 5.

2 The Data

Hockey, in the American meaning of the word, is a team sport played on an ice rink. Two teams on ice skates compete for who scores more goals. To score a goal the teams have to direct the puck, a small black hard disk of vulcanized rubber, into their opponent's goal using sticks made of wood or nowadays carbon fiber.

A regular game comprises of three periods. Each third has a net playing time of 20 minutes. The breaks between the first and the second and between the second and the third period last 15 minutes. In case of a tied game after the regulation, a five minute overtime is played in sudden death modus. If neither of the two teams is able to score in the overtime the game is decided by a shootout.

Each team is allowed to name up to 20 outfield players and 2 goalkeepers for a particular game. Out of those players on the roster, six players (normally five outfield players and one goalkeeper) are playing at any given time during the game. Changing is unlimited and allowed at any time as long as only a total of six players are on the ice at the same time.

Hockey is a very fast and therefore physical sport. Nevertheless, some physical actions are prohibited and others are only allowed if they are carried out in a non-dangerous matter. The most common penalties are called for minor infractions. They cover actions like high-sticking, tripping or hooking which are meant to interrupt the opponent's flow of the game. The offending player is sent to the penalty bench for two minutes. His team is not allowed to replace this player and therefore has a disadvantage by playing short handed. Major penalties result in a five minute penalty time handled accordingly. They are called for infractions which are more severe instances of minor penalties or are potentially dangerous to the health of the attacked player. In addition, players can or, depending on the severity of the infraction, must be punished with a misconduct penalty. A player penalized with a misconduct penalty is not allowed to play for 10 or 20 minutes, while his team is allowed to substitute him. It is worth emphasizing that, contrary to the NHL, consensual fighting is prohibited in the German Hockey League, and normally leads to minor penalties plus ten minute misconduct penalties for both fighting players.[1]

For the empirical analyses in chapter 4, we retrieve the official game report sheets for the three seasons from 2006/07 to 2008/09. The raw data are available from the German Hockey League (DEL). From those we extract detailed information per game like, amongst others, the names of the playing teams, the number of goals per third, number of spectators, numbers and causes of penalties and the names of the game officials. We add information about the venue and calculate travelling distances and standing tables for both teams prior to every game. Furthermore, we retrieve information on the betting odds from a betting information website.

The dataset encompasses 364 games (14 teams) in season 2006/2007, 420 games (15 teams) in 2007/08 and 416 games (16 teams) in 2008/2009. In total we therefore have information on 1200 games of which three games are dropped due to missing information or premature cancellation. While the teams played a pure quadruple round robin tournament in the first two seasons, a special quadruple round robin tournament was established in the last season to limit the number of games per team.

Since there is no relegation in the DEL, the 14 teams from the first season played throughout the whole observation period. In 2007/08 as well as in 2008/09 one more team joined the league. This leaves us with 160 observations for each of the 14 original teams, 108 observations for the 2007/08 addition and 52 observations for the team joining in 2008/2009.

[1] This is only a brief description of hockey to lay ground for understanding the empirical analyses. For more details on hockey see e.g. the rulebook of the IIHF or any national hockey league.

3 Hypotheses and Empirical Setting

The following analyses focus on the effects of heterogeneity on effort provision in the premier league of German hockey. According to the two-player tournament model which has been developed by Lazear & Rosen (1981), ex ante heterogeneity leads to reduced effort of both contestants. It is fairly obvious that a larger initial disadvantage of the underdog will reduce his incentives to exert effort, as it is more costly (in terms of effort) for him to compensate his handicap. Given this behavior, the favorite can reduce his effort level as well without compromising his position. For a formal model see Lazear & Rosen (1981) or Frick, Gürtler & Prinz (2008).

To test this theoretical prediction we have to find proxies for effort and heterogeneity of the contestants. Regarding effort one could suspect that goals or shots at goal might be a good proxy. However, both not only depend on the "offensive" effort of one team but also on the "defensive" effort of the other team. Hence, a game with many goals or shots at goal can be due to the good offensive performance of one team (indicating high effort) or a bad defensive effort of the opposing team (indicating low effort) (see Frick, Gürtler & Prinz (2008) for a similar reasoning regarding soccer). Therefore, we expect the number of two minute penalties to be a better measure of effort in hockey. Those minor penalties are called for lesser infractions like tripping or high-sticking. If a game is very intense there are more infractions as the players are more likely to act slightly against the rules. Of course, detected infractions of the rules are costly for a team. Nevertheless, those infractions lead to benefits such as destroying the opposing team's scoring opportunity or protecting the star players of the team (see Levitt (2002)).

We use winning probabilities of the respective team instead of standings to measure heterogeneity of teams because standings do not contain information about injuries or suspension of top players. The winning probabilities can be calculated from the retrieved betting odds. This additional information about injuries or suspensions is incorporated into betting odds by bookmakers and gamblers. In a sense odds and hence winning probabilities have similar qualities as stock quotations in financial markets (see Fama (1970) and Woodland & Woodland (1994)). We measure heterogeneity as the absolute difference between the winning probability of the home team and the winning probability of the visiting team. If this difference is high, the heterogeneity is high, too. Hence, our first hypothesis is:

> H1: If the heterogeneity of two competing teams is high, we will observe a rather low number of 2 minute penalties.

We are the first who not only investigate the effect of heterogeneity on the game as a whole but also for each third separately. As the ratio of the winning probabilities is a proxy for the ex ante heterogeneity of the competing teams, we expect the effect of this difference to be strongest in the first third of the game. After the first period, both teams might have developed a better feeling for the physical performance of their opponents which can be measured by the goals after the previous third.

> H2: Over the course of the game, the heterogeneity derived from the winning probabilities becomes less important. We expect the goal difference after the previous third to be a better measure of heterogeneity for the second and the last third of the game.

Following theory, both teams should reduce effort if the ex ante heterogeneity (measured by winning probabilities) is high. Hence, both the favorite and the underdog should receive less penalties.

> H3: Both favorites and underdogs will receive less penalties if the heterogeneity is high.

It is quite obvious that effort in a tournament will decline if the spread between winner and loser prize is smaller. In our dataset the teams play more games in the second season than in the first and the third season. Hence, in some sense, the value of winning a single game is smaller in the second season than it is in the other two seasons. A single game in the first and the third season yields 1.92% of all reachable points. But in the second season only 1.79% of all points can be won in a single game.

> H4: If the number of games rises we expect the 2 minute penalties to decline in each game.

Obviously, the method of choice for the statistical analyses of the proposed hypotheses is a count data regression. As reasoned before, only the number of minor penalties is used as a measure of effort. The dependent variable therefore can only take natural numbers including zero. As can be seen from table 1, the minimum for the dependent variable is 2 while the maximum value is 36, leaving us with at most 35 distinct values. Because of the discrete nature of the dependent variable, a linear regression seems inappropriate.

Furthermore, table 1 shows the variance of the number of two minute penalties to be considerably higher than their mean. This observation holds for the games in whole as well as for each individual third. To account for the observed overdispersion we choose the Negative Binomial Regression over the more common Poisson Regression (as reference see e.g. Winkelmann (2008)).[2] For the negative binomial distribution the first two moments of a nonnegative random variable Y are given by

$$\begin{aligned} E\left[Y \mid \lambda, \alpha\right] &= \lambda, \\ V\left[Y \mid \lambda, \alpha\right] &= \lambda\left(1+\alpha\lambda\right) \end{aligned}$$

[2] In this paper the formulation of the negative binomial distribution commonly known as NB2 is used.

where the parameter $\lambda \in \mathbb{R}^+$ equals the expected value of Y and $\alpha \in \mathbb{R}^+$ is an overdispersion parameter. From the estimated means and variances we therefore are able to retrieve an estimate for the overdispersion parameter. For the games in whole we obtain for example $\widehat{\alpha} = 0.0411$.

	Mean	Variance	Minimum	Maximum
Total Game	14.6525	23.3825	2	36
1. Period	5.0359	5.5246	0	15
2. Period	5.1161	6.4940	0	18
3. Period	4.5004	6.8522	0	16

Table 1: Descriptive statistics for the number of 2 minute penalties.

The negative binomial distribution is characterized by its probability function

$$P\left(Y = k \mid \lambda, \alpha\right) = \frac{\Gamma\left(\alpha^{-1} + k\right)}{\Gamma\left(\alpha^{-1}\right)\Gamma\left(k+1\right)} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \lambda}\right)^{\alpha^{-1}} \left(\frac{\lambda}{\alpha^{-1} + \lambda}\right)^{k}$$

with $\alpha, \lambda \in \mathbb{R}^+$ and $k \in \mathbb{N}_0$ where $\Gamma(\cdot)$ denotes the gamma integral.

The estimation model specifies the conditional mean of Y as a log-linear function of $\mathbf{x}$ and $\boldsymbol{\beta}$ using the mean function or regression

$$E\left[Y_i \mid \mathbf{x}_i\right] = \exp\left(\mathbf{x}_i'\boldsymbol{\beta}\right),$$

where $\mathbf{x}_i$ is a $(k \times 1)$ vector of explanatory variables and $\boldsymbol{\beta}$ a $(k \times 1)$ parameter vector. The log-likelihood can be easily constructed out of the preceding two equations. The estimation of $\boldsymbol{\beta}$ then can be achieved using maximum likelihood method (see e.g. Cameron & Trivedi (2001)).

The last feature of the data we have to take into account to conduct a sound statistical analysis, is the present panel structure. Since we observe 16 teams over three seasons, we have to control for the unobservable heterogeneity of the individual teams. Obviously the usage of a fixed effect model is appropriate since the abilities of the teams have an effect on the independent variables and therefore the individual effects are correlated with the independent variables. To eliminate the individual effects, we use a two-way fixed effects model to control for both the home and the visiting team. As Allison & Waterman (2002) pointed out, the fixed effects negative binomial regression model proposed by Hausman, Hall & Griliches (1984) is not a true fixed effects regression model. Since this model is widely incorporated into statistical packages (see e.g. Allison (2009)) we achieve a two-way fixed effects negative binomial regression by incorporating dummies for home and visiting teams into the regressions.

Despite the fact that all publicly available information should be contained in the winning probabilities, we add some additional independent variables. These variables are supposed to catch other factors that might influence the dependent variable like e.g. the atmosphere and the quality of the game.

We control for the quality of a given game by adding the goals scored by the home and the visiting team into the regression. As the atmosphere strongly depends on the number of spectators, we also include the total number of spectators and the square. However, the venues have different capacities ranging from $4,500$ to $18,500$. Therefore, we also include the occupation of the venue as a control variable.

The geographic distance between two teams has a strong effect on the rivalry between those teams. Teams that are geographically close often have a stronger rivalry. For this reason we control for the distance between the home venues of the respective teams[3].

Furthermore, it might be that some referees and linesmen are more lenient than others. Therefore, we use dummy variables to control for referees and linesmen.[4] Since the game officials are known prior to the game one might argue that

[3] For an overview over team locations see figure 1 and table A1 in the appendix.

[4] Some of the top games in season 2008/2009 have been attended by two referees. We do not control for those games as already Levitt (2002) has shown that a second referee has only little effect on the probability of punishment in the NHL.

information regarding their leniency is already incorporated into the winning probabilities. On the other hand more lenient officials just lead to less penalties for both teams which does not change the winning probabilities of the teams. Since our data clearly exhibit differences between the average numbers of penalties different officials assign per game, we follow the second arguing and therefore control for those effects.

	Mean	Variance	Minimum	Maximum
Winning Probability				
Home Team	0.4741	0.0133	0.1448	0.7866
Visitor Team	0.3266	0.0111	0.0961	0.6919
Difference	0.2076	0.0273	0	0.6904
Goals				
Home Total	3.3968	3.3600	0	11
Home 1. Period	0.9925	1.0241	0	6
Home 2. Period	1.2322	1.1935	0	6
Home 3. Period	1.0643	1.0134	0	7
Visitor Total	2.8530	2.8546	0	11
Visitor 1. Period	0.8312	0.7909	0	5
Visitor 2. Period	1.0033	0.9649	0	6
Visitor 3. Period	0.9206	0.8474	0	5
Crowd & Distance				
Spectators (in 1000)	5.8334	12.1736	1.0840	18.5000
Occupancy	0.6592	0.0488	0.2182	1.0000
Distance (in 100km)	2.9758	2.1645	0.1500	5.8500

Table 2: Descriptive statistics for the independent variables.

4 Results

We start by analyzing the key question of this paper whether heterogeneity has an impact on effort. The results of the respective regression for the game as a whole are reported in column (1) in table 3.

2 Minute Penalties	Total (1)	First (2)	Second (3)	Third (4)
Heterogeneity	-0.2020^{**}	-0.3350^{***}	0.1110	-0.4310^{***}
(diff. win. prob.)	(0.0813)	(0.1290)	(0.1290)	(0.1510)
Goals Home	0.0217^{***}	0.0531^{***}	0.0280^{***}	0.0297^{***}
(after current third)	(0.0049)	(0.0135)	(0.0093)	(0.0090)
Goals Visitor	-0.0014	0.0191	-0.0054	-0.0076
(after current third)	(0.0052)	(0.0156)	(0.0104)	(0.0097)
Season 07/08	-0.1100^{***}	-0.1080^{**}	-0.1060^{**}	-0.1020^{*}
	(0.0302)	(0.0480)	(0.0476)	(0.0564)
Season 08/09	-0.1770^{***}	-0.1570^{***}	-0.1530^{***}	-0.2140^{***}
	(0.0359)	(0.0574)	(0.0567)	(0.0670)
Constant	2.7780^{***}	0.1840	1.9190	2.2660^{*}
	(0.6670)	(1.1400)	(1.2420)	(1.3660)
Obs.	1197	1197	1197	1197
Pseudo-R^2	0.0543	0.0465	0.0470	0.0425

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table 3: Negative binomial regressions for the number of 2 minute penalties in the whole game and each third separately with the difference between winning probabilites as heterogeneity measure. The full table including variables for spectators, occupancy and distances between team locations can be found in table A2 in the appendix. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

The coefficient of heterogeneity is negative and significant, hence effort (measured as 2 minute penalties) is lower in the whole game if the teams are more heterogeneous (measured as absolute difference between winning probabilities) ex ante. This result is perfectly in line with the theoretical prediction from tournament theory. Hence, our data support hypothesis H1.

To investigate if the ex ante heterogeneity is less important over the course of the game, we first divide our dataset and estimate the effect separately for each third (see table 3 columns (2) – (4)). As we have expected, we observe a highly significant effect of heterogeneity on effort in the first third while the coefficient for the second third is not significant. However, we also observe a significant influence of heterogeneity on effort in the last third. Hence, the ex ante heterogeneity has an impact on effort provision in the whole game as well as in the first and last third.

We have argued that the goal difference after the previous third may be a better measure of heterogeneity in the second and last third of the game than the ex ante proxy given by winning probabilities. Therefore, for the regressions reported in table 4 we use dummies for different goal differences. We include a dummy for rather low differences of one or two goals, one dummy for intermediate differences of three to four goals and one dummy for rather high differences (five or more goals). Our reference group are homogeneous games with a goal difference of zero after the previous third.

As we can see in column (1) of table 4, in the second third a small difference of one to two goals has a significant negative impact on effort which occurs in roughly 60% of the games. A higher difference does not affect effort in the second third. The first observation is clearly in line with theory: If teams are heterogeneous (have a goal differences of more than zero), they reduce their effort and commit less infractions in the second third. Hence, our data support hypothesis H2 for the second third.

2 Minute Penalties	Second Period (1)	Third Period (2)
1 - 2 Goals Difference (after previous third)	-0.0812^{***} (0.0296)	0.0660 (0.0411)
3 - 4 Goals Difference (after previous period)	0.0158 (0.0614)	0.1170^{**} (0.0526)
≥ 5 Goals Difference (after previous period)	-0.2710 (0.2080)	0.2920^{***} (0.0929)
Goals Home (after current period)	0.0297^{***} (0.0097)	0.0193^{**} (0.0095)
Goals Visitor (after current period)	-0.0058 (0.0105)	-0.0075 (0.0096)
Season 07/08	-0.1110^{**} (0.0475)	-0.109^{*} (0.0562)
Season 08/09	-0.1580^{***} (0.0566)	-0.2180^{***} (0.0669)
Constant	2.0410^{*} (1.2390)	2.2220 (1.3640)
Obs.	1197	1197
Pseudo-R^2	0.0487	0.0431

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table 4: Negavite binomial regressions for the number of 2 minute penalties with goal difference as heterogeneity measure. The full table including variables for spectators, occupancy and distances between team locations can be found in table A3 in the appendix. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

The picture changes in the last third which is reported in column (2) of table 4. Here, rather low differences of one or two goals have no significant impact on effort provision. However, if the difference is rather high (more than 2 goals difference which occurs in 20.72% of the cases), effort rises. This observation is not in line with theory. We would expect both teams to receive less penalties if the goal difference was high after the second third. Note that this result does not change even if we control for the ex ante heterogeneity (see table A4 in the appendix). It is puzzling that ex ante heterogeneity has a significant negative impact on penalties in the last third while rather high goal differences after the second third have the opposite effect on penalties. Therefore, rather high goal differences before the last third do not serve as a measure of heterogeneity here. When controlling for ex ante heterogeneity, our results show that games between teams which are ex ante equally heterogeneous will lead to more penalties if the goal difference after the second third is high.

Since these results are not covered by tournament theory, alternative reasonings are necessary. One possible explanation might be that the presumably losing team might get frustrated. A goal difference of two or more goals after the second period shows a clear dominance of the leading team. The trailing team might get frustrated about its inferiority and this frustration entices it to commit more infractions.

Another possible explanation takes the conditional winning probability after the second third into account. As Gill (2000) and Nieken & Stegh (2009) show for different sport leagues worldwide, the conditional winning probability after the second period for a team which has to catch up more than two goals is rather small. For the German hockey league Nieken & Stegh (2009) find an average value of $0,4750\%$. Hence, the trailing team might accept its defeat and try to cut its losses. Even though the absolute goal difference is irrelevant in tournament theory, in real life the extent of the defeat clearly is of a certain importance. For once, the clearer the defeat, the bigger the embarrassment for the losing team. Furthermore, the number of goals received in a season might become the decision criterion about who is ranked higher if two or more teams reach identical point scores at the end of the season. Hence, we might observe more infractions in such games since the losing team switches to a strategy of averting additional goals against at any cost.

A third possible explanation considers that a team consists of individual players. Those players have their own objectives, primarily to maximize their own market value. In normal situations, winning the game is the best the players can do to increase their own market value. For this reason the players exert effort to win as a team. But in situations in which the loss of the team is more or less apparent, individual players might switch to another strategy to maximize their personal statistic. If we consider a defense player, his performance is mainly judged on his ability to circumvent goals. Committing an infraction can be an effective way to stop goals against and therefore represents a proper way for him to conduct his job. If the probability of winning is rather low, a defense player therefore might try to stop goals against by any means. Even if he is penalized for his actions, he benefits since goals scored in this time are not attributed to him. On the other hand the forwards of the leading team might see a good chance to improve their scoring statistic. They therefore increase pressure on the other team which in return leads to more penalties against the already struggling trailing team.

Next we split our dataset and estimate the regressions for favorites and underdogs separately[5]. While regression (1) reports the effect of heterogeneity on effort for the favorite, regression (2) gives the results for the underdog in table 5. We see that only the favorite adjusts effort to heterogeneity. If teams are in a highly superior position (according to winning probabilities), they reduce their effort provision even though underdogs do not react to heterogeneity. Our results are in line with the findings of Bach, Prinz & Gürtler (2009) but contradict the findings of Sunde (2009), as in tennis tournaments underdogs are more sensitive regarding heterogeneity than favorites. The experimental results for ef-

[5] Note that we have to drop three games because the winning probabilities are equal for both contestants.

fort reduction or dropping out of underdogs in asymmetric tournaments are also mixed. While Bull, Schotter & Weigelt (1987) report that in their experiment the mean effort level of disadvantaged subjects was higher than equilibrium effort, Fershtman & Gneezi (2009) show that quitting may depend on the relation of tournament incentives and social costs of quitting. Regarding our setting in hockey the social costs of reducing effort might be higher for underdogs as those teams are the presumable losers of the match.

2 Minute Penalties	Favorite (1)	Underdog (2)
Heterogeneity (diff. win. prob.)	-0.3260^{***} (0.1170)	0.1350 (0.1060)
Goals Favorite	0.0149^{**} (0.0065)	-0.0020 (0.0068)
Goals Underdog	0.0074 (0.0072)	0.0196^{***} (0.0062)
Season 07/08	-0.0915^{**} (0.0408)	-0.1170^{***} (0.0385)
Season 08/09	-0.1580^{***} (0.0488)	-0.2060^{***} (0.0464)
Constant	2.1830^{**} (0.8760)	1.9660^{**} (0.9010)
Obs.	1194	1194
Pseudo R^2	0.0587	0.0558

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table 5: Negative binomial regressions for the number of 2 minute penalties for favorites and underdogs separately. The full table including variables for spectators, occupancy and distances between team locations can be found in table A5 in the appendix. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

If we further distinguish between being a favorite at home or being a favorite away, we observe an interesting pattern (see table 6). If the home team is the favorite (which is very likely due to home advantage), heterogeneity has a significant and negative impact on the effort of the favorite (see column (1) in table 6). As we have already seen in table 5, the visiting team in the role of the underdog does not adjust effort (see column (4) of table 6). In contrast if the visiting team is the favorite, both teams do not react to heterogeneity (see columns (2) and (3) in table 6). Hence, only if the home team is the favorite, those teams react according to our expectations of hypothesis H3.

Let us now first look at the games where the home team is the underdog. Given this constellation the respective home teams might not reduce effort because they do not want to perform badly and try to give their best in front of their fans in order to avoid negative social costs.

The economic effect of the home crowd is not modeled in standard tournament theory. However, teams need the financial support of their fans and the money raised from entrance fees and merchandising. Therefore, not reducing effort as an underdog may have purely economic reasons for the home team as home and visiting teams may have different tournament prizes. The opposing team might anticipate this behavior and choose to not adjust effort either. If the home team is the favorite, our results show reduced effort. The team can afford to commit a smaller number of infractions as it is already in a favorable position and therefore likely to win the game at home. Still, it remains puzzling why the visiting team does not adjust effort.

2 Minute Penalties	Favorite Home (1)	Favorite Visitor (2)	Underdog Home (3)	Underdog Visitor (4)
Heterogeneity (diff. win. prob.)	-0.2620^{*} (0.1480)	-0.3180 (0.3920)	0.0209 (0.3930)	0.0366 (0.1380)
Goals Home	0.0187^{**} (0.0078)	0.0432^{***} (0.0166)	0.0157 (0.0172)	0.0233^{***} (0.0071)
Goals Visitor	-0.0011 (0.0086)	-0.0038 (0.0143)	0.0098 (0.0148)	-0.0063 (0.0079)
Season 07/08	-0.0865^{*} (0.0481)	-0.1460 (0.0902)	-0.1400 (0.0935)	-0.1240^{***} (0.0441)
Season 08/09	-0.1530^{***} (0.0564)	-0.2420^{**} (0.1190)	-0.2440^{**} (0.1220)	-0.2110^{***} (0.0524)
Constant	1.7070^{*} (1.0290)	2.0340^{**} (0.9990)	1.5820 (1.0370)	1.4360 (1.0450)
Obs.	906	288	288	906
Pseudo R^2	0.0597	0.1143	0.0965	0.0524

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table 6: Negative binomial regressions for the number of 2 minute penalties for favorite and underdog and home and away separately. The full table including variables for spectators, occupancy and distances between team locations can be found in table A6 in the appendix. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

To investigate the last hypothesis H4, we have to look at the effects of seasons on effort. In all regressions reported in this paper, season 2006/07 is the reference group. As more games have been played by each team in season 2007/08 than in the previous one, we expect the respective dummy to be significantly negative. Our results confirm this expectation of hypothesis H4 which can be seen in tables 3, 4 and 5. We can conclude that, in line with theory, effort declines if the prize spread is smaller.

Interestingly, also the dummy for season 2008/09 is negative and significant. Hence, teams committed less penalties in this season than in season 2006/07 even though they played an equal number of games and the spread between winner and loser prize remained unchanged. Only the number of teams changed from 14 to 16 which might have led to a kind of perceived change in the value of each game. However, we have to be careful as this observation could also indicate that we observe less penalties over the years in German hockey. We need a broader database to investigate this effect further.

5 Conclusion

We have investigated the impact of heterogeneity on effort provision in hockey. Our results show, that in line with theory, both contestants reduce effort if they are ex ante more heterogeneous. Hence, if two teams of very different ability compete against each other, we will observe lower effort levels. This observation holds especially for the favorite.

These observations should have consequences for the design of the premier hockey league in Germany as well as for any other sports league. As fans like the tension of a close game, a very intense game will attract more spectators. The league and the teams are naturally interested in attracting a lot of spectators in order to increase entrance fee revenues and the value of TV broadcasting rights. Hence, the league should design games as homogeneous as possible to ensure a close and interesting contest. To ensure a certain amount of homogeneity the league can resort to four concrete policies. To equalize the number of players each team can use in a game, the league should limit the number of players on the roster. A regular promotion and relegation rule should be implemented so weak teams drop out and are replaced by the strongest teams from the second league. Since the dropping out would be costly in terms of lost revenues and disappointed fans the teams would try hard to avert the relegation and therefore exert more effort. In addition to limiting the number of players on the roster the league should try to equalize the quality of the teams, too. By introducing a salary and, more important, a payroll cap the league can prevent teams from having highly different budgets and therefore highly different levels of abilities.

Up to now only the limiting of the roster to 22 players and 2 goalkeepers is implemented in the German hockey league. Since there have not been enough teams to fill the designed 18 team spots of the league for over a decade now (in the last years only 14 to 16 spots were filled), no regular promotion and relegation takes place. All teams able to meet the financial licence criteria are allowed to stay in the premier league. The champion of the second German hockey league is allowed but not forced to climb even if he satisfies the licence criteria. Furthermore, the league has not imposed any kind of salary or payroll cap. Since hockey is a fringe sport in Germany the highest payroll has not exceeded 8 million Euro in the last years. Nevertheless, the differences between the teams' payrolls are quiet substantial, since e.g. in the season 2007/2008 the highest payroll was around 50% higher than the second highest. On basis of our findings a downsizing of the league to e.g. 14 teams, the introduction of a regular promotion and relegation rule and a restriction of the payrolls seems appropriate.

Furthermore, our analysis has shown that effort declines if the number of games per team rises and therefore the prize spread declines. The league has reacted to this phenomenon and has reduced the number of games per team in season 2008/09. However, even then we observe a lower effort provision than in the first season. A possible explanation might be that a larger number of teams in the league leads to a perceived lower value of a single game. This finding strengthens our earlier proposal to reduce the total number of teams in favor of using a special round robin tournament to decrease the number of games.

Appendix

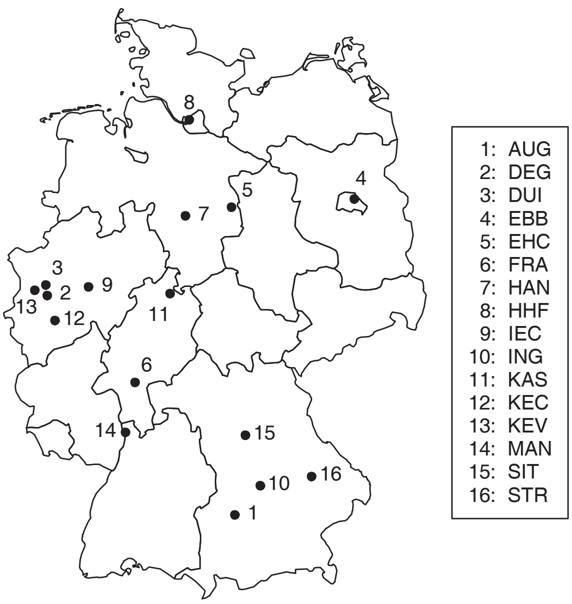

Figure 1: Geographical distrubution of hockey teams in Germany. For full team names see table A1.

AUG	Augsburger Panther	IEC	Iserlohn Roosters
DEG	DEG Metro Stars	ING	ERC Ingolstadt
DUI	Foxes Duisburg	KAS	Kassel Huskies
EBB	Berlin Polar Bears	KEC	Cologne Sharks
EHC	Grizzly Adams Wolfsburg	KEV	Krefeld Penguins
FRA	Frankfurt Lions	MAN	Mannheim Eagles
HAN	Hanover Scorpions	SIT	Sinupret Ice Tigers
HHF	Hamburg Freezers	STR	Straubing Tigers

Table A1: Names of all teams participating in the German hockey league in the seasons 2006/2007 to 2008/2009.

2 Minute Penalties	Total (1)	First (2)	Second (3)	Third (4)
Heterogeneity (diff. win. prob.)	-0.2020^{**} (0.0813)	-0.3350^{***} (0.1290)	0.1110 (0.1290)	-0.4310^{***} (0.1510)
Goals Home (after current third)	0.0217^{***} (0.0049)	0.0531^{***} (0.0135)	0.0280^{***} (0.0093)	0.0297^{***} (0.0090)
Goals Visitor (after current third)	−0.0014 (0.0052)	0.0191 (0.0156)	−0.0054 (0.0104)	−0.0076 (0.0097)
Spectators (per 1000)	0.0314 (0.0241)	0.0215 (0.0384)	0.0188 (0.0383)	0.0593 (0.0451)
Spectators^2 (per 1000)	−0.0017 (0.0011)	−0.0013 (0.0018)	−0.0012 (0.0018)	−0.0028 (0.0021)
Occupancy	0.1310 (0.1100)	0.1090 (0.1750)	0.3300^{*} (0.1740)	−0.0864 (0.2050)
Distance between teams in 100km	0.0053 (0.0072)	−0.0029 (0.0115)	0.0135 (0.0115)	0.0035 (0.0136)
Season 07/08	-0.1100^{***} (0.0302)	-0.1080^{**} (0.0480)	-0.1060^{**} (0.0476)	-0.1020^{*} (0.0564)
Season 08/09	-0.1770^{***} (0.0359)	-0.1570^{***} (0.0574)	-0.1530^{***} (0.0567)	-0.2140^{***} (0.0670)
Constant	2.7780^{***} (0.6670)	0.1840 (1.1400)	1.9190 (1.2420)	2.2660^{*} (1.3660)
Obs.	1197	1197	1197	1197
Pseudo-R^2	0.0543	0.0465	0.0470	0.0425

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A2: Negative binomial regression for the number of 2 minute penalties in the whole game and each third separately with the difference between winning probabilites as heterogeneity measure. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

2 Minute Penalties	Second Period (1)	Third Period (2)
1 - 2 Goals Difference (after previous third)	-0.0812^{***} (0.0296)	0.0660 (0.0411)
3 - 4 Goals Difference (after previous period)	0.0158 (0.0614)	0.1170^{**} (0.0526)
$\geq$ 5 Goals Difference (after previous period)	-0.2710 (0.2080)	0.2920^{***} (0.0929)
Goals Home (after current period)	0.0297^{***} (0.0097)	0.0193^{**} (0.0095)
Goals Visitor (after current period)	-0.0058 (0.0105)	-0.0075 (0.0096)
Spectators (per 1000)	0.0264 (0.0385)	0.0519 (0.0449)
Spectators^2 (per 1000)	-0.0015 (0.0018)	-0.0026 (0.0021)
Occupancy	0.3160^{*} (0.1750)	-0.0459 (0.2050)
Distance between teams in 100km	0.0127 (0.0115)	0.0050 (0.0136)
Season 07/08	-0.1110^{**} (0.0475)	-0.109^{*} (0.0562) 0
Season 08/09	-0.1580^{***} (0.0566)	-0.2180^{***} (0.0669)
Constant	2.0410^{*} (1.2390)	2.2220 (1.3640)
Obs.	1197	1197
Pseudo-R^2	0.0487	0.0431

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A3: Negavite binomial regression with goal difference as heterogeneity measure. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

2 Minute Penalties	Second Period (1)	Third Period (2)
Heterogeneity (diff. win. prob.)	0.1190 (0.1290)	-0.4400^{***} (0.1510)
1 - 2 Goals Difference (after previous third)	-0.0820^{***} (0.0296)	0.0698^{*} (0.0410)
3 - 4 Goals Difference after previous third)	0.0153 (0.0613)	0.1270^{**} (0.0526)
$\geq$ 5 Goals Difference after previous third)	-0.2700 (0.2080)	0.2880^{***} (0.0927)
Goals Home (after current period)	0.0294^{***} (0.0097)	0.0202^{**} (0.0095)
Goals Visitor (after current period)	-0.0058 (0.0105)	-0.0073 (0.0096)
Spectators (per 1000)	0.0250 (0.0385)	0.0577 (0.0449)
Spectators^2 (per 1000)	-0.0014 (0.0018)	-0.0028 (0.0021)
Occupancy	0.3210^{*} (0.1750)	-0.0659 (0.2050)
Distance between teams in 100km	0.0129 (0.0115)	0.0041 (0.0135)
Season 07/08	-0.1140^{**} (0.0475)	-0.1010^{*} (0.0562)
Season 08/09	-0.1580^{***} (0.0566)	-0.2210^{***} (0.0668)
Constant	2.0390^{*} (1.2390)	2.2740^{*} (1.3630)
Observations	1197	1197
Pseudo-R^2	0.0489	0.0446

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A4: Negavite binomial regression with difference between winning probabilities and goal difference as heterogeneity measures. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

2 Minute Penalties	Favorite (1)	Underdog (2)
Heterogeneity (diff. win. prob.)	-0.3260^{***} (0.1170)	0.1350 (0.1060)
Goals Favorite	0.0149^{**} (0.0065)	-0.0020 (0.0068)
Goals Underdog	0.0074 (0.0072)	0.0196^{***} (0.0062)
Spectators (per 1000)	0.0571^{***} (0.0219)	0.0135 (0.0206)
Spectators^2 (per 1000)	-0.0026^{**} (0.0012)	-0.0010 (0.0011)
Occupancy	0.0675 (0.0915)	0.1830^{**} (0.0885)
Distance between teams in 100km	0.0350^{***} (0.0113)	0.0160^{**} (0.0081)
Season 07/08	-0.0915^{**} (0.0408)	-0.1170^{***} (0.0385)
Season 08/09	-0.1580^{***} (0.0488)	-0.2060^{***} (0.0464)
Constant	2.1830^{**} (0.8760)	1.9660^{**} (0.9010)
Obs.	1194	1194
Pseudo R^2	0.0587	0.0558

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A5: Negative binomial regression with difference between winning probabilities as heterogeneity measure for favorites and underdogs separately. Controls for home teams, visiting teams, referees and linesmen are included but not reported..

	Favorite		Underdog	
2 Minute Penalties	Home (1)	Visitor (2)	Home (3)	Visitor (4)
Heterogeneity (diff. win. prob.)	−0.2620* (0.1480)	−0.3180 (0.3920)	0.0209 (0.3930)	0.0366 (0.1380)
Goals Home	0.0187** (0.0078)	0.0432*** (0.0166)	0.0157 (0.0172)	0.0233*** (0.0071)
Goals Visitor	−0.0011 (0.0086)	−0.0038 (0.0143)	0.0098 (0.0148)	−0.0063 (0.0079)
Spectators (per 1000)	0.0697** (0.0352)	0.1150 (0.2290)	0.2480 (0.2390)	−0.0147 (0.0319)
Spectators^2 (per 1000)	−0.0031* (0.0016)	−0.0074 (0.0091)	−0.0110 (0.0094)	0.0003 (0.0015)
Occupancy	0.1210 (0.166)	−0.1030 (0.993)	−0.6570 (1.033)	0.1570 (0.152)
Distance between teams in 100km	−0.0071 (0.0117)	0.0302 (0.0219)	0.0238 (0.0226)	0.0025 (0.0108)
Season 07/08	−0.0865* (0.0481)	−0.1460 (0.0902)	−0.1400 (0.0935)	−0.1240*** (0.0441)
Season 08/09	−0.1530*** (0.0564)	−0.2420** (0.1190)	−0.2440** (0.1220)	−0.2110*** (0.0524)
Constant	1.7070* (1.0290)	2.0340** (0.9990)	1.5820 (1.0370)	1.4360 (1.0450)
Obs.	906	288	288	906
Pseudo R^2	0.0597	0.1143	0.0965	0.0524

Standard errors in parentheses, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$.

Table A6: Negative binomial regression for favorite and underdog by home and away. Controls for home teams, visiting teams, referees and linesmen are included but not reported.

References

Allison, Paul D. (2009): Fixed Effects Regression Models, Quantitative Applications in the Social Sciences 160, SAGE, Los Angeles.

Allison, Paul D.; Waterman, Richard (2002): Fixed Effects Negative Binomial Regression Models, in: Ross M. Stolzenberg (Ed.), Sociological Methodology, Basil Blackwell, Oxford, pp. 155 – 172.

Amegashie, J. Atso (2009): American Idol: Should it be a Singing Contest or a Popularity Contest?, in: Journal of Cultural Economics, Vol. 33 (4), pp. 265 – 277.

Bach, Norbert; Prinz, Joachim; Gürtler, Oliver (2009): Incentive Effects in Tournaments with Heterogeneous Competitors - An Analysis of the Olympic Rowing Regatta in Sydney 2000, in: Management Review, Vol. 20 (3), pp. 239 – 253.

Baker, George P.; Gibbs, Michael; Holmström, Bengt (1994): The Wage Policy of a Firm, in: Quarterly Journal of Economics, Vol. 109 (4), pp. 921 – 955.

Bull, Clive; Schotter, Andrew; Weigelt, Keith (1987): Tournaments and Piece Rates: An Experimental Study, in: Journal of Political Economy, Vol. 95 (1), pp. 1 – 33.

Cameron, A. Colin; Trivedi, Pravin K. (2001): Essentials of Count Data Regression, in: Badi H. Baltagi (Ed.), A Companion to Theoretical Econometrics, Blackwell, Oxford, pp. 331 – 348.

Drago, Robert; Garvey, Gerald T.; Turnbull, Geoffrey K. (1996): A Collective Tournament, in: Economics Letters, Vol. 50 (2), pp. 223 – 227.

Ehrenberg, Ronald G.; Bognanno, Michael L. (1990*a*): Do Tournaments Have Incentive Effects?, in: Journal of Political Economy, Vol. 98 (6), pp. 1307 – 1324.

Ehrenberg, Ronald G.; Bognanno, Michael L. (1990*b*): The Incentive Effects of Tournaments Revisited: Evidence from the European PGA Tour, in: Industrial and Labor Relations Review, Vol. 43 (3, Special Issue), pp. 74 – 88.

Fama, Eugene (1970): Efficient Capital Markets: A Review of Theory and Empirical Work, in: Journal of Finance, Vol. 25 (2), pp. 383 – 417.

Fershtman, Chaim; Gneezi, Uri (2009): The Trade-off between Performance and Quitting in High-Power Tournaments, in: Journal of the European Economic Association, forthcoming.

Frick, Bernd; Gürtler, Oliver; Prinz, Joachim (2008): Anreize in Turnieren mit Heterogenen Teilnehmern - Eine Empirische Untersuchung mit Daten aus der Fußball-Bundesliga, in: Zeitschrift für betriebswirtschaftliche Forschung, Vol. 60 (6), pp. 385 – 405.

Gersbach, Hans (2009): Competition of Politicians for Wages and Office, in: Social Choice and Welfare, Vol. 33 (1), pp. 51 – 71.

Gill, Paramjit S. (2000): Late-Game Reversals in Professional Basketball, Football, and Hockey, in: The American Statistician, Vol. 54 (2), pp. 94 – 99.

Gürtler, Oliver (2008): On Sabotage in Collective Tournaments, in: Journal of Mathematical Economics, Vol. 44 (3/4), pp. 383 – 393.

Harbring, Christine; Luenser, Gabriele (2008): On the Competition of Asymmetric Agents, in: German Economic Review, Vol. 9 (3), pp. 373 – 395.

Hausman, Jerry; Hall, Bronwyn H.; Griliches, Zvi (1984): Econometric Models for Count Data with an Application to the Patents - R & D Relationship, in: Econometrica, Vol. 52 (4), pp. 909 – 938.

Heyman, Fredrik (2005): Pay Inequality and Firm Performance: Evidence from Matched Employer-Employee Data, in: Applied Economics, Vol. 37 (11), pp. 1313 – 1327.

Konrad, Kai A. (2009): Strategy and Dynamics in Contests, Oxford Business Press, Oxford.

Kräkel, Matthias; Sliwka, Dirk (2004): Risk Taking in Asymmetric Tournaments, in: German Economic Review, Vol. 5 (1), pp. 103 – 116.

Lazear, Edward P.; Rosen, Sherwin (1981): Rank-Order Tournaments as Optimum Labor Contracts, in: Journal of Political Economy, Vol. 89 (5), pp. 841 – 864.

Levitt, Steven D. (2002): Testing the Economic Model of Crime: The National Hockey League's Two Referee Experiment, in: Contributions to Economic Analysis and Policy, Vol. 1 (1), pp. 1 – 19.

McLaughlin, Kenneth J. (1988): Aspects of Tournament Models: A Survey, in: Ronald G. Ehrenberg (Ed.), Research in Labor Economics, Vol. 9, JAI Press, Greenwich, Connecticut, pp. 225 – 256.

Murphy, William H.; Dacin, Peter A.; Ford, Neil M. (2004): Sales Contest Effectiveness: An Examination of Sales Contest Design Preferences of Field Sales Forces, in: Journal of the Academy of Marketing Science, Vol. 32 (2), pp. 127 – 143.

Nalebuff, Barry J.; Stiglitz, Joseph E. (1983): Prizes and Incentives: Towards a General Theory of Compensation and Competition, in: Bell Journal of Economics, Vol. 14 (1), pp. 21 – 43.

Nieken, Petra; Stegh, Michael (2009): Distribution of Goals and Late-Game Reversals in the German Hockey League, mimeographed.

O'Keeffe, Mary; Viscusi, W. Kip; Zeckhauser, Richard J. (1984): Economic Contests: Comparative Reward Schemes, in: Journal of Labor Economics, Vol. 2 (1), pp. 27 – 56.

Orrison, Alannah; Schotter, Andrew; Weigelt, Keith (2004): Multiperson Tournaments: An Experimental Examination, in: Management Science, Vol. 50 (2), pp. 268 – 279.

Rajan, Madhav V.; Reichelstein, Stefan (2006): Subjective Performance Indicators and Discretionary Bonus Pools, in: Journal of Accounting Research, Vol. 44 (3), pp. 585 – 618.

Sunde, Uwe (2009): Heterogeneity and Performance in Tournaments: A Test for Incentive Effects Using Professional Tennis Data, in: Applied Economics, Vol. 41 (25), pp. 3199 – 3208.

Waerneryd, Karl (2000): In Defense of Lawyers: Moral Hazard as an Aid to Cooperation, in: Games and Economic Behavior, Vol. 33 (1), pp. 145 – 158.

Winkelmann, Rainer (2008): Econometric Analysis of Count Data, Springer, Berlin, 5. ed.

Woodland, Linda; Woodland, Bill (1994): Market Efficiency and the Favorite-Longshot Bias: The Baseball Betting Market, in: Journal of Finance, Vol. 49 (1), pp. 269 – 280.

Zhou, Haiwen (2006): R&D Tournaments with Spillovers, in: Atlantic Economic Journal, Vol. 34 (3), pp. 327 – 339.