Optimal Monitoring Schemes in Principal Agent Games

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Abstract

In this paper, we experimentally investigate the design of monitoring schemes in competitive rank-order tournaments and their effects on agents' behavior. Specifically, principals can choose between different bonus levels, the number of monitoring occasions and the minimum output gap between two competing agents necessary to receive the bonus. At the lowest level of the output gap, we find that agents' chosen effort levels comply with the theoretical solutions under risk neutrality. Increasing the output gap, however, produced significantly higher efforts than predicted. Principals correctly set higher bonuses and converge to the contract that performs best given agents' actual behavior. We observe vanishing effectiveness of tournaments in the sense that principals' initial rents cannot be sustained over time.

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1 Introduction

Consider a principal in an insurance company that wishes to promote her[1] best employee to a more senior position in the firm. The principal repeatedly monitors the output of her employees (e.g., turnovers, costly claims, or client reactions), and makes it clear that the promoting decision is solely dependent on an employee's position in a firm-wide ranking of peers. It is a well-known fact that such tournaments are able to elicit additional effort from employees (Lazear and Rosen (1981)). The positive effect on effort provision has also been confirmed empirically (Harbring and Irlenbusch (2003), Harbring and Irlenbusch (2005) and Harbring and Lünser (2008)). Suprisingly, however, while there is quite some work on the optimal prize structure in tournaments, other important aspects have largely been neglected. In this paper, we focus on the rules that determine the prize allocation and their incentive effects.

Let us come back to the example of the principal in an insurance company. In essence, she has to fix two dimensions regarding prize allocation: (i) How often does she monitor the output of her employees, before the best employee is going to be promoted; and (ii) How often does she require the top-ranked employee to perform better in each of the monitoring instances than the second-ranked employee in order to implement the promotion? Both aspects of the tournament have important incentive effects that we analyze in this paper in the context of symmetric and asymmetric contests by conducting controlled laboratory experiments based on theoretical predictions from a model that captures basic features of our initial example. Furthermore, we endogenize the contract choice of principals and study whether they offer (behaviorally) optimal tournament contracts to employees.

In our setting, a principal employs two agents (with potentially different skills) who compete for an indivisible bonus by providing effort. Their effort levels determine the probability of a high output in a stochastic production environment. At the beginning of the interaction, the principal decides on the level of the bonus and determines the criteria under which an agent is awarded the bonus by determining two dimensions of the bonus allocation: the number of monitoring instances (NMI), i.e. how often she wishes to control the agents' output, and the minimum output gap (MOG), i.e. the minimum number of monitoring instances where one agent has to produce a higher output than the other agent to qualify for the bonus. The principal can only observe outputs and not individual effort levels. By choosing a certain tournament scheme from these three categories, the principal fixes the work incentives for the two agents.

[1] Inspired by Cabrales and Charness (2003) but using a different assignment of gender, we assume throughout the paper that the principals are female and the agents are male.

We first derive theoretical results that allow us to form hypotheses regarding the behavior of agents and principals in the laboratory setting. Given the increasing popularity of tournaments as incentive devices in firms, the question of their precise design is of importance for the understanding of organisations. Note that the details of the bonus allocation structure entail important incentive and fairness effects: When monitoring the output levels of different agents, the principal cannot be sure whether a better performing agent has exerted a higher effort level or just been lucky. However, by requiring a higher NMI and/or a higher MOG, the principal can obviously reduce the risk of erroneously awarding the bonus to the agent with lower effort provision. Intuitively, a higher NMI reduces the randomness in assessing the performance of the individual agents which, in case of asymmetric agents, may bring about ambiguous incentive effects. By setting a higher MOG the principal can in turn limit the probability of awarding the bonus and can avoid paying it when agents coordinate on shirking (a drawback of most tournament studies, e.g. Lazear and Rosen (1981)).

So far, the experimental literature on tournament incentive schemes is exclusively focusing on the behavior of agents in exogenously implemented tournaments (Harbring and Irlenbusch (2003), Harbring and Irlenbusch (2005) and Harbring and Lünser (2008)). Our paper, therefore, closes a gap in the literature by analyzing tournaments incentives that are set endogenously by principals in the experiment.

We find that agents behave in line with theoretical predictions when NMI=1 and MOG=1. Indeed, behavior is amazingly close to the normative solution with this contract regardless of the size of the bonus. However, an increasing MOG induces higher exerted effort levels than predicted by theory for low- and high-cost agents as well as for both agents in the treatment with asymmetric effort costs. Increasing the MOG seems to induce a certain level of "tournament fever" that is beneficial to the principal. Not surprisingly, principals adapt their contract choices to this bias of agents' behavior in our experiment.

Our basic scenario is similar to that of Avrahami et al. (2007) who, however, neglect not only the principal's choice of the tournament scheme but also the possibility to vary the MOG. In their setting, regardless of how agents differ in performance, the uniquely best performing one is awarded (MOG=1). Our research essentially sits at the intersection of three strands of the literature. First, relative performance evaluation and as a special form tournaments date back to the seminal works of Holmström (1982). The subsequent tournament literature is very much influenced by the theoretical study on the optimality of rank-order tournaments by Lazear and Rosen (1981) which, however, is not experimentally implementable.[2]

[2]Since output is additively determined by effort and normally distributed noise, the usual constraints do not hold (in an experiment the carrier of noise has to be bounded). For further theoretical analyses of tournaments see Green and Stokey (1983), Nalebuff and Stiglitz (1983), Rosen (1986).

Second, the different effects of monitoring in principal agent relationships have first been analysed by Frey (1993). Cowen and Glazer (1996) establish an inverse relationship between the monitoring frequency and an agent's effort level in a setting where a single agent has to pass a predefined threshold to be awarded an indivisible prize. Whether such a result of a principal-agent problem can also apply in competitive settings, i.e. with more than one agent, is theoretically explored by Dubey and Wu (2001). They confirm that the principal does best by choosing a small sample size, thus creating uncertainty among the competing agents to keep work incentives high. Dubey and Haimanko (2003) extend the analysis to the case of heterogeneous agents in multi-period tournaments, i.e. where interim outcomes are observable by agents and efforts chosen can be made contingent upon past play. Ichino and Muehlheusser (2008) develop monitoring schemes for principals to screen heterogeneous agents, where they focus on the optimality of low monitoring at the beginning of a relationship to allow for learning about the agent's type.

Third, there is a substantial empirical literature on the behavior of agents within tournaments. Field studies are, of course, restricted to explore what has been implemented, if at all it is implementable from a legal point of view (see e.g. Becker and Huselid (1992), Main et al. (1993), Knoeber and Thurmann (1994) and Eriksson (1999)).[3] The main advantage of experimental studies in this area is therefore that one can compare different tournament incentive schemes, even those which have not been tried out in the field, i.e. the lab is used as a test bed before actually considering field applications. The experimental literature starts with Bull et al. (1987) who find surprisingly large variance in the effort of agents in tournaments compared to piece rates. Weigelt et al. (1989) and Schotter and Weigelt (1992) focus on the reaction to asymmetric tournaments with a special focus on discrimination and affirmative action. Harbring and Irlenbusch (2003) compare the effects of different tournament sizes and prize structures to find a positive relationship between efforts and the proportion of winner prizes. The effects of sabotage among agents are experimentally analyzed by Harbring and Irlenbusch (2005) based on the theoretical work of Lazear (1989). More related to our design, Kareev and Avrahami (2007) experimentally investigate and confirm the validity of the so-called "less-is-more" hypothesis with respect to monitoring and effort. Nevertheless, they let subjects perform real effort tasks taking the form of calculation exercises, leading to a loss of control compared to experimentally induced effort costs.

So far, however, experimental studies have exclusively been addressing the question of how agents behave within different tournament setups. Surprisingly, there is only little research

[3]For example a field experiment where an agent's wage was only to be paid if an agent outperforms his peers, would be clearly illegal.

on how tournaments are actually designed by principals. To the best of our knowledge and with the exception of the study by Falk et al. (2008), we are the first to experimentally address this question. Falk et al. (2008) also endogenize the principal's choice of the tournament scheme, but their focus is directed towards the prize spread, the possibility of sabotage and the effects of loss aversion among agents. Their main finding is that principals use essentially the prize spread in tournaments as a powerful incentive device. However, the strength of tournaments as an effort elicitation device is quickly lost when agents either can make losses and are prone to loss averse behavior or are allowed to sabotage their competitor's outcome; in these cases principals rather choose a small than a large prize spread. The authors disregard monitoring and output gaps, which are our main research interests.

In section 2, we introduce the game model and its solution. The experimental protocol is described in section 3. The data are analysed in section 4. Section 5 concludes.

2 Theoretical Analysis

2.1 The Model

The game model relies on two decision stages. In the second stage, the two agents $i = 1, 2$, being aware of the tournament scheme (B, n, m) with $B \in \{\underline{B}, \overline{B}\}$ and $0 \leq \underline{B} < \overline{B}$, denoting the size of the bonus, independently choose their probability $p_i \in [0, 1]$ for high output (H). This determines the probability p_i and $(1 - p_i)$ for high (H) and low (L) output on each production event in an i.i.d. fashion. Higher probabilities p_i are more costly where the cost structure is

$$C_i(p_i) = \frac{c_i}{2} p_i^2$$

with $c_i > 0$ for $i = 1, 2$. The costs $C_i(p_i)$ are private costs of the agents i. In our analysis it is assumed that (c_1, c_2) is commonly known, but that the principal can not verify (p_1, p_2) but only the output levels (H or L) when auditing a production event. On the first stage, the principal chooses the tournament incentive scheme (B, n, m) with $n \in \mathbb{N}$, $1 \leq m \leq n$ and $B \in \{\underline{B}, \overline{B}\}$. Besides the level of the bonus, the principal can choose a monitoring scheme that governs the conditions under which the bonus is actually paid out. This scheme consists of two things: the number of monitoring instances (NMI) denoted by n, i.e. how often he wishes to audit the output from the agents, and a minimum output gap (MOG) where he specifies the *minimum* number of occasions m in which one agent has to produce a high outcome (H) when the other agent produces a low outcome (L) to be awarded the bonus.[4] Each agent's payoff[5] is given by

$$U_i = \delta_i B - C_i(p_i)$$

for $i = 1, 2$ where $\delta_i = 1$ when the agents receive the bonus B and $\delta_i = 0$ when not. According to the principal's choice of (n, m) the case $\delta_i = 1$ applies if on the n monitored production events, agent i has in sum at least m more H outcomes than her competitor $j(\neq i)$. More formally, the probability $P_i^{n,m}(p_i, p_j)$ that an agent is awarded the bonus depends on his own effort p_i and on his competitor's effort level p_j through the following binomial distribution

$$P_i^{n,m}(p_i, p_j) = \sum_{k=m}^{n} \left[\binom{n}{k} p_i^k (1 - p_i)^{n-k} \sum_{e=0}^{k-m} \binom{n}{e} p_j^e (1 - p_j)^{n-e} \right] \tag{1}$$

[4] We make interchangeable use of the two terms in the text: NMI is the same as n, MOG is identical to m.

[5] We assume common knowledge of risk neutrality in the following.

For the principal the payoff is given by

$$\pi = a(p_1 + p_2) - (\delta_1 + \delta_2)B - C(n)$$

with $C(n) = tn$ for $t > 0$, denoting the costs of monitoring and $a(> 0)$ capturing how the principal linearly gains from the sum of efforts (which, in case of more and more stochastically independent production events, measures more and more exactly total output). There are two things to note: First, unlike as in Falk et al. (2008), in our scenario the bonus is not paid out in any case, i.e. if neither of the agents qualifies for it, the principal is not paying out anything. This is supposed to capture the realistic feature, that the firm is not willing to pay out a bonus if it is bankrupt neither if both agents shirked. Second, we assumed monitoring costs to be linear in the number of controls rather than assuming economies of scale in the monitoring technology which would add considerable complexity at only little additional insight, especially for the experimental implementation. This concludes the description of the game model.

Solving by backward induction meaning to derive the subgame perfect equilibrium requires to (i) first solve the equilibria $p^*(B, n, m) = (p_1^*(B, n, m), p_2^*(B, n, m))$ of all (B, n, m)-subgames (stage 2 games) and (ii) then to derive the optimal tournament incentive scheme (B^*, n^*, m^*) anticipating the equilibria of these subgames.

Doing so is straightforward, but far from easily tractable except for the simple cases like $n = 1 = m$, as the binomial distribution from (1) quickly creates extremely tedious expressions.[6] We therefore restrict our analysis to the situations which were actually implemented experimentally, namely $n \in \{1, 2, 3\}$ restricting m in a way such that $m = 1$ if $n = 1$, $m \in \{1, 2\}$ if $n = 2$ and $m \in \{1, 2, 3\}$ if $n = 3$. Altogether we distinguish six different (n, m)-constellations for the parameters

$$a = 12, t = 1, \underline{B} = 3, \text{ and } \overline{B} = 7.$$

Thus the principal can select between 12 different tournament incentive schemes (B, n, m) for each of which one has to derive the subgame perfect equilibrium $p^*(B, n, m)$.

In the situation at hand abilities are captured by the cost parameters c_1 and c_2. In view of the fact that when facing agents of different abilities, tournaments are often used to determine the best agent, we are interested in two constellations: asymmetric costs which we explore by setting $c_i = 11$ and $c_j = 22$ for $i \neq j$ and so as to compare the reactions to such asymmetry

[6] For the derivations of the simpler cases $(1, 1)$, $(2, 1)$ and $(2, 2)$ see the Appendix.

in effort costs, we also have studied the symmetric cost constellations

$$(c_1, c_2) = (11, 11) \text{ and } (c_1, c_2) = (22, 22).$$

One could also justify exploring symmetric costs by arguing that they appear as less complex and might inspire more equilibrium-like behavior.

Optimal Effort Levels for Symmetric Agents

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$		
			n			n		
			1	2	3	1	2	3
		1	0.214	0.270	0.302	0.120	0.169	0.191
B=3	m	2		0.000	0.122		0.000	0.000
		3			0.000			0.000
		1	0.389	0.483	0.582	0.241	0.299	0.337
B=7	m	2		0.114	0.344		0.000	0.161
		3			0.000			0.000

Table 1: Symmetric subgame perfect equilibria $p^*(B, n, m)$ for all 12 (B, n, m) tournament schemes in the symmetric treatments $c_1 = c_2$.

Furthermore, $c_1 = c_2$ for most cases implies $p_1^*(B, n, m) = p_2^*(B, n, m)$ which explains why in Table 1 one has only one entry when listing $p^*(B, n, m)$ for symmetric cost constellations. The table is constructed in such a way that the submatrices for each $B, (c_1, c_2)$-constellation list $n = 1, 2, 3$ as columns and $m = 1, 2, 3$ as rows. Impossible cases of (n, m) are left blank.[7]
In the asymmetric case, Table 2 displays the equilibrium efforts for the disadvantaged agent (left column) and the advantaged agent (right column) separately.
Note that the optimal effort level in the symmetric setting is non-decreasing in n and in B, but non-increasing in m. In the asymmetric cases, the comparative statics with respect to B do not change. The effects of n and m are less clear due to the asymmetry between the agents.[8]
What remains to be determined is the optimal tournament incentive scheme for each of the possible cost constellations $(c_1, c_2) = (11, 11), (22, 22)$ and $(11, 22)$. In our parameter constellation, the optimal scheme for principals in the highcost and the asymmetric treatment

[7]For symmetric cost constellations, there exist also the following asymmetric equilibria (p_1^*, p_2^*) in the respective incentive scheme (B, n, m): In the low-cost constellation with $c_1 = c_2 = 11$ we have $(0.00, 0.39)$ in $(3, 3, 2)$, $(0.35, 0.64)$ in $(7, 3, 1)$ and $(0.00, 0.73)$ in $(7, 3, 2)$. In the high-cost constellation with $c_1 = c_2 = 22$, we have $(0.00, 0.48)$ in $(7, 3, 2)$. In the asymmetric case, we have $(0.48, 0.00)$ and $(0.35, 0.09)$ both in $(7, 3, 2)$. For further analysis however, we restrict ourselves to the symmetric equilibria mentioned in the table.

[8]See the Appendix for the derivations of the equilibria in $(1, 1)$, $(2, 1)$ and $(2, 2)$, as well as an explanation of the $(2, 2)$ equilibrium in the asymmetric case with the high bonus.

Optimal Effort Levels for Asymmetric Agents

			$c_1 = 22$			$c_2 = 11$		
				n			n	
			1	2	3	1	2	3
		1	0.103	0.125	0.130	0.245	0.322	0.345
B=3	m	2		0.000	0.000		0.000	0.389
		3			0.000			0.000
		1	0.145	0.142	0.144	0.544	0.576	0.561
B=7	m	2		0.000	0.000		1.000	0.738
		3			0.000			0.000

Table 2: Subgame perfect equilibria $p^*(B,n,m)$ for all 12 (B,n,m) tournament schemes in the asymmetric treatment $(c_1 = 22, c_2 = 11)$.

assuming optimal behavior by agents is given by

$$(B^*, n^*, m^*) = (7, 1, 1)$$

and in the lowcost treatment with $(c_1, c_2) = (11, 11)$ by

$$(B^*, n^*, m^*) = (7, 3, 1)$$

Under the assumption that agents behave as the theoretical model predicts, it is hence always optimal for the principal to set a high incentive, i.e. bonus, to elicit high effort levels from the agents. Furthermore, he is best off by a low NMI and a low MOG, with the exception of $(7, 3, 1)$ in the lowcost treatment where the additional efforts from a high NMI outweigh the monitoring-related costs.

Table 3 is similarly composed as Tables 1 and 2 and lists the (expected) profit π of the principal for all tournament incentive schemes (B, n, m) and all three cost constellations when anticipating that agents act optimally, i.e. when anticipating the equilibria $p^*(B, n, m)$ outlined above in Tables 1 and 2. Due to the probabilistic nature of effort and hence the bonus payment, the entries in Table 3 represent expected payoffs rather than deterministic ones.

2.2 Research Hypotheses

Our main research interest lies in analyzing the contract setting behavior of principals and in studying incentive effects of contracts for agents. By implementing our setup in the laboratory, we intend to investigate the following specific hypotheses that are apparent from

Principals' Expected Profit

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$			$c_1 = 22, c_2 = 11$		
				n			n			n	
			1	2	3	1	2	3	1	2	3
		1	6.13	5.82	5.29	4.24	3.73	2.86	5.28	5.26	4.54
B=3	m	2		1.00	2.76		1.00	0.00		1.00	3.50
		3			0.00			0.00			0.00
		1	8.00	8.22	9.20	5.23	4.15	3.42	6.55	5.74	4.65
B=7	m	2		3.58	6.91		1.00	3.26		6.00	3.69
		3			0.00			0.00			0.00

Table 3: Expected Profit of the Principal π assuming agents to act optimally in each incentive scheme (B, n, m).

the theoretical analysis in subsection 2.1.

Hypothesis 1: Agents' effort is increasing in the price spread, i.e. the bonus B.

Hypothesis 2: Principals anticipate this and stick to high bonus schemes.

Hypothesis 3: Agents provide higher efforts under a high NMI and a low MOG.

Hypothesis 4: Principals behaviorally respond by choosing the contract that maximizes their profits, *given* the actual behavior of agents.

Hypothesis 4 is non-standard. It postulates our expectation that if agents systematically deviate from the normative predictions in hypotheses 1-3, principals will adjust contracts in a way that maximizes their profits. In other words, we are interested in whether and to what extent principals respond to the behavior of agents in their contract setting conduct over time.

As far as the asymmetric treatment is concerned, our prime focus is on the way participants cope with the different ability levels of the two competing agents.

Hypothesis 5: Disadvantaged (i.e., high-cost) agents lay back under high NMIs and MOGs.

Hypothesis 6: Principals opt for little scrutiny as they especially want to induce the less skilled worker to exert positive efforts.

3 Experimental Protocol

The experiments were conducted in the computer laboratory of the Max-Planck-Institute of Economics in Jena using z-Tree (Fischbacher (2007)). Participants were recruited using ORSEE (Greiner (2004)). A session involved 27 participants of which 9 permanently assumed the role of a principal and 18 that of an agent. Roles were kept constant throughout the whole experiment. Without informing participants of the matching procedure (in order to discourage repeated game effects with respect to reputation even more) random rematching was restricted to matching groups of 9 participants. Each of these groups consisted of 3 principals and 6 agents. Every session involved 45 rounds of play in a random stranger design what, on average, took 90 minutes including reading instructions aloud. We altogether ran 6 sessions, two for each cost constellation $(c_1, c_2) = (11, 11), (22, 22)$ and $(c_i = 11, c_j = 22)$ for $i, j = 1, 2; i \neq j$. Thus there are 6 independent matching group observations for each of the three cost constellations (c_1, c_2).

The instructions were read aloud to create common knowledge among participants.[9] Subsequently, the participants played 45 rounds of the two-stage game, described and solved above. In order to prevent behavior largely driven by the fear of making losses, we endowed all subjects with a fixed income per period. This fixed payment amounted to 3 experimental currency units (ECU) for principals and 6 ECU for agents. After each round the three interacting participants learned about the outcome, i.e. (i) whether or not they had been awarded the bonus (as agents) or whether they had to pay the bonus (as principals), (ii) their one-period payoff consisting of fixed payments, the effort costs $C_i(p_i)$ and the potential bonus (as agents) or the fixed payment, the output from the agents' total effort $p_1 + p_2$, the potential bonus payment and the monitoring costs (as principals) and (iii) their accumulated payoff. Then, except for the last round, the new round began in which one confronted randomly changing partners. Participants' total earnings are listed in Table 4 where we distinguish between roles and cost constellations.

Accumulated Earnings

	$c_1 = c_2 = 11$	$c_1 = c_2 = 22$	$c_1 = 22$	$c_2 = 11$
Principals	18.62	12.39	14.45	
Agents	13.14	12.40	11.91	13.81

Table 4: Accumulated Earnings in EUR (without show-up fee of 3 Euro) for agents and principals and different cost constellations

Overall earnings per participant have been 16.59 EUR including the show-up fee of 3 Euro.

[9] A German version of the instructions is available from the others upon request.

4 Results

We begin by providing a general overview of results where we mainly focus on deviations from the benchmark solution before turning to a more in-depth analysis of the behavior of principals.

4.1 Description of the data

In line with the principle of backward induction let us first consider the agents' effort choices from the second stage of the game.

4.1.1 Agents' Behavior in Symmetric Treatments

Table 5 is similarly composed as the former tables, especially in the way that the submatrices for each $B, (c_1, c_2)$-constellation lists $n = 1, 2, 3$ as columns and $m = 1, 2, 3$ as rows. Impossible cases of (n, m) are left blank. In cases of both symmetric costs constellations, the deviations of actual efforts from equilibrium efforts are captured by the average deviation for all participants.[10]

Deviations from Equilibrium Effort (Symmetric Treatments)

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$		
			n			n		
			1	2	3	1	2	3
B=3	m	1	0.043	0.002	0.012	0.050	0.068	0.073
		2		0.277**	0.118		0.164**	0.188
		3			0.321*			0.125
B=7	m	1	0.118**	0.062	-0.008	0.115	0.044**	0.031
		2		0.253**	0.086		0.286**	0.136
		3			0.321*			0.208**

Table 5: Deviations of actually exerted average effort p from equilibrium effort p^* in the symmetric treatments. ** indicates 5%-significance and * indicates 10%-significance in a two-sided (one-sided) sign test on the median of the differences between actual efforts and theoretical values for all $p^* \in (0, 1)$ (for all $p^* \in \{0, 1\}$) within the matching groups.

As stated earlier, our main focus being the behavior of principals we are not focusing as much on the agents' behavior, but to analyse the principals' reaction to agent behavior, a word on the agents is in order here. To our surprise given the complexity of the task, when the MOG is kept constant at $m = 1$, agents on average provide very close to equilibrium efforts across all treatments and bonus levels. Averages are only significantly different from the theoretical solutions in 2 out of 12 cases when $m = 1$. If, however, m is increased above

[10]The average efforts by agents are listed in Table 13 in the appendix.

1, deviations from equilibrium become more pronounced. Particularly striking is the fact that in the symmetric treatments, agents generally overperform compared to the theoretical value in $(2,2)$, $(3,2)$ and $(3,3)$ which leads us to our first result.

Result 1 *In the symmetric treatments, agents provide very close to equilibrium efforts for low MOGs ($m = 1$), but exert more than optimal levels of effort if $m \geq 2$.*

4.1.2 Agents' Behavior in Asymmetric Treatment

Concerning the asymmetric treatments in Table 6, the above result holds especially true for the disadvantaged agents who overperform in all of the twelve incentive schemes. The evidence is less clear for the agents endowed with a cost advantage, who provide close to and even lower than equilibrium efforts under $m = 1$ and deviate for $m \geq 2$. [11]

Result 2 *In the asymmetric treatment, the disadvantaged agents also provide higher than equilibrium efforts, whereas the evidence from the advantaged agent is mixed.*

This finding could be explained by disadvantaged agents who try to overcome the ability gap to their colleagues by providing substantial amounts of effort.

Deviations from Equilibrium Effort (Asymmetric Treatment)

			$c_1 = 22$			$c_2 = 11$		
				n			n	
			1	2	3	1	2	3
		1	0.075	0.051	0.068	0.067	-0.049	0.020
B=3	m	2		0.184**	0.104**		0.332**	-0.148
		3			0.337*			0.316
		1	0.117	0.028	0.154*	-0.105	-0.014	-0.052
B=7	m	2		0.197**	0.190**		-0.554**	-0.119
		3			0.144*			0.557*

Table 6: Deviations of actually exerted average effort p from equilibrium effort p^* in the asymmetric treatment. ** indicates 5%-significance and * indicates 10%-significance in a two-sided (one-sided) sign test on the median of the differences between actual efforts and theoretical values for all $p^* \in (0,1)$ (for all $p^* \in \{0,1\}$) within the matching groups.

As a general finding it seems that both, the larger bonus as well as a larger MOG (in the sense of $m > 1$) trigger larger deviations from equilibrium efforts. Altogether this suggests a kind of "tournament fever" in the sense that larger B and larger MOGs inspire excessive efforts.

[11] The comparison to $p = 1$ for $(2,2)$ leads to a deviation of -0.554 and has to be taken with a caveat.

4.1.3 Principals' Choice of Tournament Schemes

However, the average effort levels from above do not take into account that principals could choose different incentive schemes differently often. The 18 principals could choose (B, n, m) combinations in each of the 45 rounds, hence 810 tournament incentive schemes were chosen overall per treatment. The subsequent Table 7 lists the mere number of tournament incentive choices by principals per treatment.

Chosen Tournament Schemes

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$			$c_1 = 22, c_2 = 11$		
				n			n			n	
			1	2	3	1	2	3	1	2	3
		1	84	54	19	223	77	10	166	30	12
B=3	m	2		38	7		86	19		55	12
		3			9			6			7
		1	227	103	43	216	53	16	251	48	39
B=7	m	2		165	41		62	18		117	58
		3			20			24			15

Table 7: Number of chosen tournament incentive schemes per treatment.

4.2 Testing Hypotheses

Based on the descriptives, we now present a series of findings from the experiment in the form of results before proceeding to the analysis of behavior over time in the next section.

Result 3 *A higher bonus set by the principal yields higher efforts by the agents in all treatments.*

In the symmetric treatments holding the incentive scheme (n, m) constant, we find significantly higher levels of effort under $B = 7$ ($p \leq 0.05$; Wilcoxon signed rank test) in 5 out of the 12 (B, n, m) combinations. In a similar manner, the advantaged agent in the asymmetric treatment provides lower efforts if competing for a small bonus (highly significant in $(1, 1)$, $(2, 1)$ and $(3, 2)$ out of the 6 (n, m) combinations, $p \leq 0.05$; Wilcoxon signed rank test), whereas the disadvantaged agent only reacts with high efforts to the high bonus in $(3, 2)$ ($p \leq 0.05$; Wilcoxon signed rank test). This confirms findings of several other studies (e.g. Harbring and Lünser (2008), Falk et al. (2008)) in the sense that agents make their tournament effort dependent on the level of the bonus. Moreover, this is also very much in line with the theoretical literature (e.g. Lazear and Rosen (1981), which identifies the prize spread as the key effort elicitation device in the design of tournaments. So there is empirical evidence that this holds independent of whether the principal can actually commit to pay out the bonus in any case through a tie-braking rule or not. We identify further driving forces among agents to exert effort through a series of regressions with effort level as the dependent variable. For the contractual incentives in our baseline specification, we include dummies for all (n, m) constellations other than $(1, 1)$, a dummy for high bonus schemes labeled *bonus7* and indicators of gender and if a participant majors in economics. We moreover conjecture over the 45 rounds that agents are influenced by the recent history of the game such that they condition their effort on whether they indeed obtained a bonus in the previous periods and their profit levels in the past periods. Treatment effects are captured by a dummy for both the lowcost and the highcost agents in the asymmetric treatment as well as for the entire highcost treatment with symmetric agents. We finally include a linear time trend to account for a change of the willingness to provide effort over time. Table 8 in the two first columns reports the results of a Tobit regression and in the last two columns the results from a panel data estimation with random effects.[12] All dummies from the (n, m) have the expected sign and are mostly significant, i.e. a higher NMI holding the MOG fixed leads to higher efforts compared, but increasing the MOG reduces efforts. In order of size, it is interesting to note that especially a high bonus induces agents to exert efforts by far more than increasing the NMI. In our second specification, there is strong evidence from the coefficient on *bonuspaid(t-1)* in favor of our hypothesis that a recently earned award greatly amplifies the willingness to exert effort. This is counterbalanced, however, by a ”leaning-back” effect where agents’ effort is inversely related to the level of recent profits. Comparing the order of magnitudes reveals that the two effects roughly cancel each other out as the average of profits if agents earned a bonus is about 8.4 across all treatments.

Pertaining to the differences between treatments, agents with higher costs of effort in both the asymmetric and the symmetric highcost treatment provide significantly lower levels of effort (*asym-highcost* and *highcost*). But taking the symmetric lowcost agents as a benchmark, there is no difference to the lowcost agents from the asymmetric treatment. Although not explicitly presented here this does not hold for the comparison of highcost agents between asymmetric and symmetric highcost treatment. In the asymmetric treatment disadvantaged agents exert significantly less effort by a coefficient of -0.08 than symmetric highcost agents. This suggests that tournaments among agents of different skills lead to a situation where the high skilled agent behaves similar to a setting where his competitor was of equal skill, whereas the low skilled agent exerts less effort compared to a competition with an identically skilled peer.

[12] We present OLS regressions and fixed effect estimates in the Appendix, since they yield qualitatively similar results.

	Tobit I	Tobit II	Random Effects I	Random Effects II
(2,1)	0.045	0.003	0.017	0.003
	(0.01)	(0.86)	(0.23)	(0.78)
(2,2)	-0.057	-0.129	-0.058	-0.104
	(0.00)	(0.00)	(0.00)	(0.00)
(3,1)	0.101	0.047	0.044	0.028
	(0.00)	(0.03)	(0.10)	(0.31)
(3,2)	-0.004	-0.072	-0.028	-0.072
	(0.87)	(0.00)	(0.17)	(0.00)
(3,3)	-0.083	-0.169	-0.063	-0.146
	(0.01)	(0.00)	(0.04)	(0.00)
bonus7	0.204	0.229	0.169	0.200
	(0.00)	(0.00)	(0.00)	(0.00)
female	0.008	0.029	-0.024	-0.002
	(0.49)	(0.01)	(0.57)	(0.95)
econ	-0.044	-0.033	-0.065	-0.081
	(0.46)	(0.52)	(0.06)	(0.01)
bonuspaid(t-1)		0.483		0.254
		(0.00)		(0.00)
profit(t-1)		-0.069		-0.037
		(0.00)		(0.00)
profit(t-2)		-0.005		-0.003
		(0.04)		(0.08)
profit(t-3)		-0.004		-0.002
		(0.09)		(0.43)
asym-lowcost		0.018		0.010
		(0.22)		(0.86)
asym-highcost		-0.219		-0.186
		(0.00)		(0.00)
highcost		-0.139		-0.116
		(0.00)		(0.00)
period		-0.004		-0.003
		(0.00)		(0.00)
N	4860	4536	4860	4536
(Pseudo) R^2	0.06	0.31	0.07	0.32

Table 8: Tobit Regressions and Random Effects Estimations on the level of effort. p-values are given in brackets, based on clustered robust standard error by subject for the panel estimation. The censoring limits of the Tobit regression are 0 and 1 naturally.

Result 4 *Asymmetric treatments reduce the disadvantaged agents' efforts, but leave the advantaged agents' effort unchanged compared to a competition with equally skilled agents.*

Finally we observe in both regressions a small but significant time effect indicating that agents's effort decreases over time.

In line with the principle of backward induction, we now turn to the main results for the principals' choices. Overall, principals could choose 810 tournament incentives schemes per treatment. One can discern a considerable bias in the low cost (511/299, $p \leq 0.05$, Wilcoxon signed rank test) and the asymmetric treatment (528/282, $p = 0.109$, Wilcoxon signed rank test) towards the high bonus schemes ($B = 7$). In the high-cost treatment (389/421), we observe no such tendency which could be explained by the rationale that principals are aware of the fact that efforts are relatively costly for agents and hence expect only low effort levels by agents. As a consequence, principals' earnings generated through their agents' effort run the risk of not being high enough to pay the high bonus without making losses. So loss aversion among principals may well yield an explanation for the above result.

Principals' Payoff

	$c_1 = c_2 = 11$	$c_1 = c_2 = 22$	$c_1 = 22, c_2 = 11$
All B	8.27	5.51	6.42
$B = 3$	6.47	4.95	6.22
$B = 7$	8.91	6.11	6.53

Table 9: Profits for principals per period pooled over all (n, m) constellations

Table 9 shows the profits principals made for the two different levels of bonus across all (n, m) constellations. Clearly, the profits are increasing in the level of the bonus for the principals, and significantly greater for $B = 7$ in the low-cost and the asymmetric treatment, but not in the high-cost treatment, where principals earned the least in terms of per period payoff across all incentive schemes (B, n, m).[13] The evidence on profits complements the loss aversion argument from above, as purely money-maximizing principals would ideally choose $B = 7$ rather than $B = 3$ also in the highcost treatment.

Result 5 *In contrast to the high cost treatment where they choose both bonus levels equally often due to loss averse behavior, principals have a strong preference for high bonus schemes in the low cost and the asymmetric treatment.*

Holding the bonus constant, principals could choose between 6 different tournament schemes (n, m). In all three cost constellations $(n, m) = (1, 1)$ is the most frequent choice, while this

[13] Table 14 in the Appendix lists detailed per period profits of principals for all tournament incentive schemes (B, n, m).

predominance of $(n, m) = (1, 1)$ is weakest in case of $(c_1, c_2) = (11, 11)$ when agents, due to low costs, can be more easily induced to attempt outperformance even when $nm > 1$. Although $(n, m) = (3, 1)$ under a high bonus is the benchmark choice for $(c_1, c_2) = (11, 11)$, it is chosen quite infrequently. Despite $m > 1$ never being supported as a benchmark behavior, a non-neglible share of used (n, m)-constellations relies on $m > 1$. This is especially puzzling as theoretically expected payoffs for principals in these schemes is very low (see Table 3). Note that $(n, m) = (2, 2)$ is second in being used by principals whenever $B = 7$ and mostly

Share of Actual Bonus Payments

	$c_1 = c_2 = 11$	$c_1 = c_2 = 22$	$c_1 = 22, c_2 = 11$
$(1,1)$	50.8%	38.7%	42.4%
$(2,1)$	59.8%	62.3%	62.8%
$(2,2)$	33.0%	18.2%	30.2%
$(3,1)$	77.4%	61.4%	70.6%
$(3,2)$	45.8%	29.6%	51.4%
$(3,3)$	10.2%	6.7%	18.2%

Table 10: Share of tournaments where the bonus was effectively paid out over all (n, m) constellations

for $B = 3$, except when $(c_1, c_2) = (11, 11)$. Table 14 in the Appendix gives an explanation for these choices by listing in detail the per period profit for principals disaggregated for the respective contracts. Holding the bonus level constant, principals earn most indeed in the $(1, 1)$ contract and a somewhat smaller amount in $(2, 2)$. Even though $(2, 2)$ triggered higher monitoring costs and induced less efforts from agents than $(1, 1)$, this was compensated by a lower number of tournaments where the bonus actually had to be paid out to the agents as can be seen from Table 10. Moreover, choosing $(2, 2)$ directly generated high payoffs for principals given the excessive effort provision of agents under this incentive scheme. There are two different interpretations for this finding, namely fairness or cost saving. As one possibility principal participants could be concerned by fairness in awarding the bonus such that, if they award the bonus, the winner should be substantially outperforming rather than just lucky. This would justify setting $m \geq 2$. As a further motive, $m > 1$ can be justified as an attempt to reduce costs by rendering it less likely that the bonus will be paid as Table 10 points out.

We are particularly interested in the interaction between principals and agents, in the sense that each party may well condition its behavior upon the actually observed actions rather than theoretical predictions. It is in this dimension, that the frequent choice of a theoretically unattractive incentive scheme like $(2, 2)$ by principals gains behavioral appeal as they deliberately may want to benefit from excessive efforts from agents. We will return to this point in the next section.

Result 6 *Across all treatments and all bonus levels, principals most often opt for the most rewarding monitoring scheme* $(1,1)$*, but a non-negligible number of principals also chooses* $(2,2)$ *to benefit from excessive efforts by agents.*

We analyze the principals' decisions in a multinomial logit model, as we do not want to impose a qualitative ordering on the 12 different incentive schemes the principal can choose. We take the scheme $(3,1,1)$ in the lowcost treatment as the basecase for our estimation.[14] We include the profit level of the three last periods as explanatory variables to see whether recent profits have an impact on the probability of choosing a certain tournament scheme. Besides the treatment dummies, we include a time trend to account for the attractiveness of contracts over time, the gender dummy and a dummy if the course of study is economics. Finally, we construct a dummy *samecc* that takes on value 1 if a principal chooses the identical contract as in the previous period and zero otherwise. For brevity reasons, we

Multinomial Logit Estimation

	$(3,2,2)$	$(7,1,1)$	$(7,2,2)$
profit(t-1)	-0.0002	0.069	0.018
	(0.99)	(0.00)	(0.26)
profit(t-2)	-0.025	0.038	0.006
	(0.23)	(0.00)	(0.68)
profit(t-3)	-0.011	0.028	-0.013
	(0.58)	(0.02)	(0.36)
period	-0.064	0.035	-0.005
	(0.00)	(0.00)	(0.42)
asym	-0.327	-0.313	-0.964
	(0.29)	(0.08)	(0.00)
highcost	0.144	-0.790	-1.809
	(0.61)	(0.00)	(0.00)
female	0.177	-0.566	0.399
	(0.41)	(0.00)	(0.02)
econ	1.133	0.729	1.736
	(0.28)	(0.36)	(0.02)
samecc	-0.440	0.254	-0.148
	(0.04)	(0.07)	(0.37)

Table 11: Results from a Multinomial Logit Estimation on all 12 possible tournament schemes. p-values are given in brackets. $(3,1,1)$ is taken as a basecase for the regression.

restrict ourselves to the presentation of the three most important contracts $(3,2,2)$, $(7,1,1)$ and $(7,2,2)$ in Table 11. We observe that recent profits are particularly relevant for the $(7,1,1)$ contract, i.e. the higher last round's profit has been, the probability that principals

[14]The results are not altered if we were to take a different basecase, $(3,1,1)$ only seems a natural candidate for comparison.

opt for the $(7, 1, 1)$ contract this period is significantly higher as in the basecase. In a similar manner, the later the period the lower is the probability for a principal to choose $(3, 2, 2)$ compared to $(3, 1, 1)$ from the coefficient on *period*. The attractiveness of $(3, 2, 2)$ is similar to the basecase across all treatments, but the two high bonus contracts from the table are less likely to be chosen in the asymmetric and the highcost treatment compared to the lowcost treatment, which confirms the findings from above.

Most interestingly, the coefficient on *samecc* indicates that the log of $\frac{P((3,2,2))}{P((3,1,1))}$ significantly decreases by 0.44 for a unit change in the dummy. So if the principal stays with the same contract from the previous round, he is doing so less likely for $(3, 2, 2)$ than for $(3, 1, 1)$. In an identical manner we can document her propensity to stay with the $(7, 1, 1)$ contract through the positive coefficient on *samecc* for $(7, 1, 1)$. Predicting the probabilities of each of the possible 12 contracts according to whether the principal stays with the same contract leads to the following table where we fix all other explanatory variables at their respective means: The column named different contract measures the attractiveness of each available

Predicted Probabilities

	same contract	different contract
$(3, 1, 1)$	23.8%	19.4%
$(3, 2, 1)$	3.7%	10.7%
$(3, 2, 2)$	4.3%	5.4%
$(3, 3, 1)$	0.0%	1.3%
$(3, 3, 2)$	0.0%	0.1%
$(3, 3, 3)$	0.0%	0.0%
$(7, 1, 1)$	39.3%	24.9%
$(7, 2, 1)$	5.7%	10.8%
$(7, 2, 2)$	15.6%	14.7%
$(7, 3, 1)$	2.0%	3.1%
$(7, 3, 2)$	3.9%	5.7%
$(7, 3, 3)$	1.5%	2.9%
Total	$\approx$ 100.0%	$\approx$ 100.0%

Table 12: Predicted probabilities from the Multinomial Logit for the chosen contract

contract, where the probability is presented conditional on a contract change. Clearly, the most frequent choices are $(7, 1, 1)$, $(3, 1, 1)$ and $(7, 2, 2)$. Now if we condition upon principals staying with the same contract, $(7, 1, 1)$ is even more likely to be chosen. Hence we can document on the one hand contracts (e.g. possibly those which serve to test their effects upon agents) where the probability of immediate contract re-use is low and contracts that are more likely to be chosen again in the next round.

Result 7 *The contracts* $(7, 1, 1)$*,* $(3, 1, 1)$ *and* $(7, 2, 2)$ *are most likely to be re-used.*

We next turn to an analysis of subjects' behavior over time.

4.3 The Dynamics of Behavior over Time

In this heavily stochastic environment a certain degree of experimentation at the beginning seems natural, such that participants may try out different tournament schemes (as principals) or provide varying levels of effort under the same incentive scheme (as agents).

Result 8 *In the lowcost and the asymmetric treatment, principals converge to the high bonus level. This is not true for the highcost treatment.*

We first take a closer look on the behavior of principals. The dynamics of using $B = 7$ rather than $B = 3$ are displayed in Figure 1 showing a widening gap between the frequency of using the high bonus rather than the low bonus in the tournament scheme. This applies for $(c_1, c_2) = (11, 11)$ and the asymmetric cost treatment, where principals quickly form a majority in recurring to the high bonus level. For $(c_1, c_2) = (22, 22)$ (right hand graph), however, there is no clear tendency identifiable in favor of either bonus scheme.

The evidence over time complements the analysis from above, i.e. efforts are not high enough

Development of Bonus Level over Time

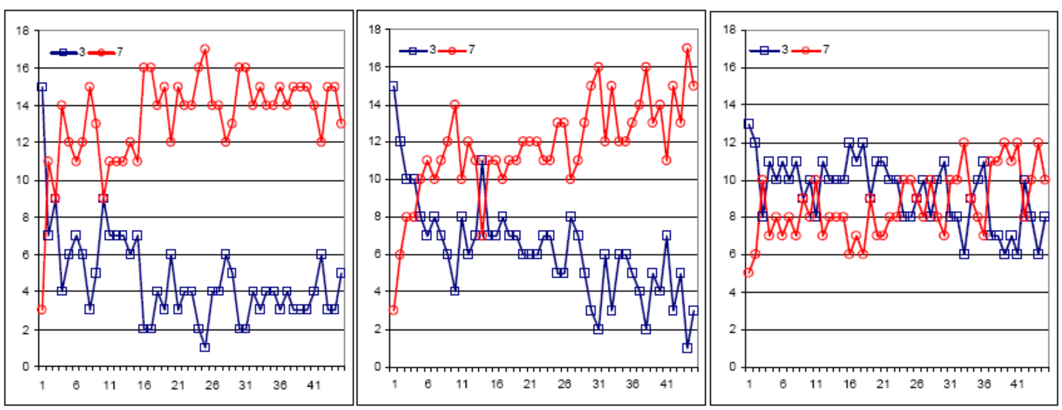

Figure 1: Dynamics of bonus levels in the three treatments: symmetric lowcost (left), asymmetric (middle) and symmetric highcost (right). Each graph shows the number of high and low bonus choices (which necessarily add up top 18) over the 45 periods.

in the highcost treatment that principals unhesitatingly set the high bonus and converge to a unique bonus level as the two other treatments. To properly assess developments in subjects' behavior over time, we divide the 45 rounds into five subsets of 9 periods each. We are primarily interested in the role of per period profits for both agents and principals, as we conjecture that subjects will condition their behavior mainly on preceding profits in the absence of reputational concerns. Figure 2 displays the average profits for principals (left) and agents (right) for the five subsets.

Result 9 *Principals' profits are decreasing and agents' profits increasing over time.*

Development of Profits over Time

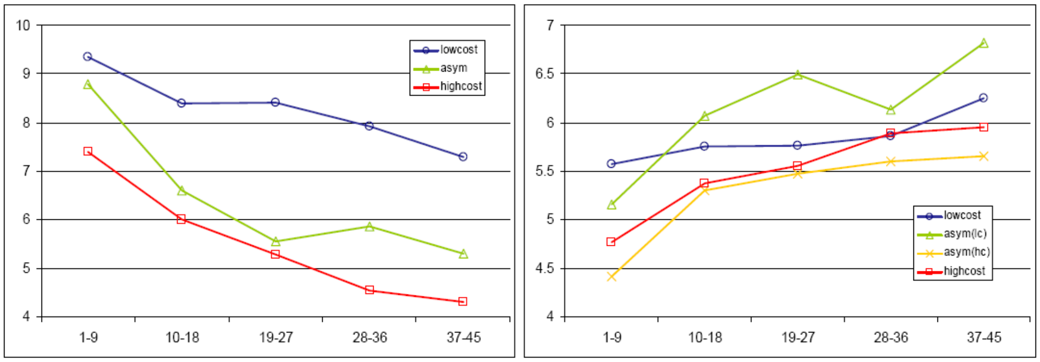

Figure 2: Dynamics of average profit levels in the three treatments for principals (left) and agents (right). Average profits for agents in the asymmetric treatment are split into the highcost and the lowcost agent.

There is a surprisingly robust inverse relationship between the per period profits for principals and agents. At the beginning of the experiment, principals earn high rents from the relationship since agents provide excessive effort in the bonus competition, much in the sense of a "tournament fever". So in the first subperiod (round 1-9) and depending on the different treatments, principals earn between 10.3 and 12.8 per period by e.g. setting the tournament scheme $(7, 1, 1)$. As the experiment proceeds, agents adjust downward their excessive effort levels from the beginning for all incentive schemes (B, n, m) leading to higher profits for them and a decrease in the principals' payoff. As far as $(7, 1, 1)$ is concerned, this reduces principals' earnings to a range 5.9 and 9.4 for the same tournament scheme in rounds 37-45. As a further example that we alluded to earlier, take the incentive scheme $(7, 2, 2)$: Average per period earnings for principals decrease from a range between 7.8, 8.4 and 8.7 (highcost, asymmetric, lowcost treatment) in the first nine rounds to 2.4, 5.5 and 5.7 in the last rounds respectively.[15]

This decay is robust across all treatments for the big majority of the 12 possible contracts and suggests that tournaments are indeed a very powerful device to elicit effort from agents upon their introduction. Agents, however, adapt their behavior over time such that an initial tournament fever is lost. After an initial period of experimentation in contract setting where they gain the tournament fever rents, principals exceedingly converge to the contract that performs best for them given the behavior of their contracting partners. In the case under consideration this is the $(7, 1, 1)$ contract that gets chosen an increasing number of times over the duration of the experiment across all treatments.

[15]See the Appendix A2 with Figures 3 to 5 for a detailed overview of the dynamics of effort levels in all tournament schemes

5 Conclusion

Tournament incentives in the sense of awarding a bonus only to the outperforming agents can be described as attempts to introduce some ”the winner takes it all” - incentives when trying to incentivize effort choices. This must not always be appropriate. In case of piece-rate incentives it may, for instance, be irritating when the principal would award a substantial bonus to the outperforming agents since such a bonus would question the equity of individual wages (Homans (1961)). Thus one typically will rely on such bonus incentive schemes when total output levels of the individual agents are unobservable or at least only observable at prohibitively high costs.

The basic idea of such bonus incentive schemes is, of course, to inspire competition among agents. Similar to Avrahami et al. (2007) we have therefore assumed a production technology allowing for stochastic tournament outcomes where agents determine the success probability of a high outcome through their effort. Tournament incentives arise endogenously through the principal's choice of the bonus, the number of monitoring instances (NMI) and the minimum output gap (MOG). Whereas Avrahami et al. (2007) are only concerned about the uncertainty of the tournament outcome as depending on the scrutiny level NMI, our basic intuition is that principals, who cannot observe total individual output levels, nevertheless want to award the truly best performing agents through sampling.

We find that agents' effort is very close to equilibrium behavior for MOG=1, but not so for higher output gaps where agents significantly overperform. This renders theoretically unattractive tournament schemes like $(7, 2, 2)$ profitable for principals. We observe a vanishing effect of tournament fever, such that effort levels generally decline over all incentive contracts. Principals correctly set higher bonus schemes and after initial experimentation with different contracts choose more and more often the scheme $(7, 1, 1)$ yielding the highest per period profit for them. Rents from the relationship decrease for principals and increase for agents as the latter provide lower levels in later stages of the experiment.

We were able to show that the idea of behaviorally orientated contracts has a lot of appeal in the laboratory since theoretically very unattractive contracts were chosen rather frequently without major losses in profits due to a bias in the behavior of the contracting partner. We also find evidence for this process of finding the right contract to take time.

Appendix A1: Tables

Averages of Actual Efforts by Agents

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$			$c_1 = 22$			$c_2 = 11$		
				n			n			n			n	
			1	2	3	1	2	3	1	2	3	1	2	3
		1	0.257	0.272	0.314	0.170	0.237	0.264	0.178	0.176	0.198	0.312	0.272	0.365
B=3	m	2		0.277	0.240		0.164	0.188		0.184	0.104		0.332	0.241
		3			0.321			0.125			0.337			0.316
		1	0.507	0.545	0.574	0.356	0.343	0.368	0.262	0.171	0.298	0.439	0.562	0.508
B=7	m	2		0.366	0.430		0.286	0.297		0.197	0.190		0.446	0.619
		3			0.321			0.208			0.144			0.557

Table 13: Average effort by agents in each tournament incentive scheme.

Average per Period Payoff for Principals

			$c_1 = c_2 = 11$			$c_1 = c_2 = 22$			$c_1 = 22, c_2 = 11$		
				n			n			n	
			1	2	3	1	2	3	1	2	3
		1	6.85	5.92	5.17	5.29	4.89	4.53	6.71	4.77	5.01
			(0.40)	(0.65)	(0.99)	(0.25)	(0.41)	(1.55)	(0.33)	(0.71)	(1.39)
B=3	m	2		7.11	4.90		4.58	3.71		6.31	3.13
				(0.76)	(1.39)		(0.43)	(0.85)		(0.70)	(0.94)
		3			7.70			3.00			7.41
					(1.61)			(1.29)			(2.53)
		1	10.43	9.67	8.40	6.95	4.62	4.45	7.25	4.99	4.47
			(0.46)	(0.65)	(1.11)	(0.37)	(0.63)	(0.95)	(0.36)	(0.76)	(0.94)
B=7	m	2		7.24	6.91		5.95	4.79		6.56	5.85
				(0.48)	(0.87)		(0.69)	(1.41)		(0.52)	(0.72)
		3			6.64			4.42			7.02
					(1.25)			(0.83)			(1.67)

Table 14: Average profit per period for principals by tournament incentive scheme (B, n, m). The corresponding standard deviations are listed in brackets.

OLS and Fixed Effects Regressions

	OLS I	OLS II	Fixed Effects I	Fixed Effects II
(2,1)	0.041	0.007	0.016	0.002
	(0.00)	(0.57)	(0.26)	(0.87)
(2,2)	-0.041	-0.096	-0.058	-0.109
	(0.00)	(0.00)	(0.00)	(0.00)
(3,1)	0.075	0.034	0.043	0.023
	(0.00)	(0.05)	(0.11)	(0.42)
(3,2)	-0.007	-0.056	-0.029	-0.082
	(0.73)	(0.00)	(0.16)	(0.00)
(3,3)	-0.068	-0.139	-0.063	-0.148
	(0.01)	(0.00)	(0.04)	(0.00)
bonus7	0.174	0.191	0.168	0.207
	(0.00)	(0.00)	(0.00)	(0.00)
female	-0.024	-0.004	-	-
	(0.02)	(0.66)	(-)	(-)
econ	-0.068	-0.065	-	-
	(0.16)	(0.13)	-	(-)
bonuspaid(t-1)		0.411		0.128
		(0.00)		(0.00)
profit(t-1)		-0.059		-0.018
		(0.00)		(0.00)
profit(t-2)		-0.005		-0.001
		(0.00)		(0.53)
profit(t-3)		-0.004		-0.001
		(0.06)		(0.00)
asym-lowcost		0.006		-
		(0.63)		(-)
asym-highcost		-0.180		-
		(0.00)		(-)
highcost		-0.117		-
		(0.00)		(-)
period		-0.002		-0.004
		(0.00)		(0.00)
N	4860	4536	4860	4536
(Pseudo)R^2	0.07	0.34	0.07	0.21

Table 15: OLS regressions and fixed effects estimation on the level of effort. p-values are given in brackets, based on clustered robust standard error by subject for the panel estimation.

Appendix A2: Figures

We henceforth present the relationship between chosen (n, m) constellation and the exerted effort by agents over time, disaggregated by the level of bonus (low bonus in the upper six graphs, high bonus in the lower six graphs). The arrangement of the figures is structured in the same was as the results are presented in the appendix, i.e. $n \in \{1, 2, 3\}$ is given in the columns, $m(\leq n) \in \{1, 2, 3\}$ in the rows.

Dynamics of Effort Levels - Lowcost treatment

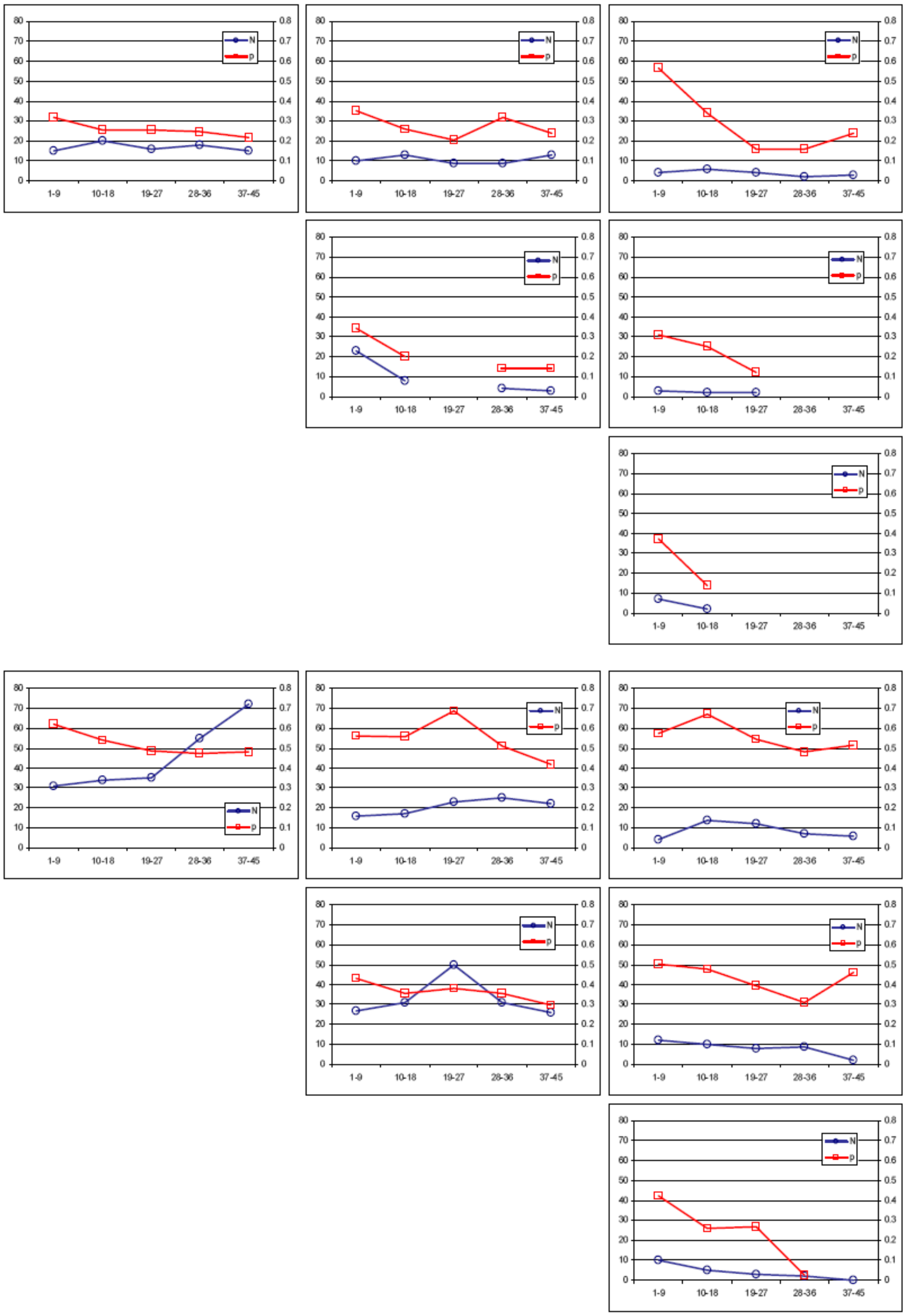

Figure 3: Dynamics of effort levels (right scale) and chosen (n, m) constellations (left scale) in the lowcost treatment over time. Low bonus schemes ($B = 3$) in the first three rows, high bonus schemes ($B = 7$) in the last three rows. $n \in \{1, 2, 3\}$ is given in the columns, $m(\leq n) \in \{1, 2, 3\}$ in the rows.

Dynamics of Effort Levels - Asymmetric treatment

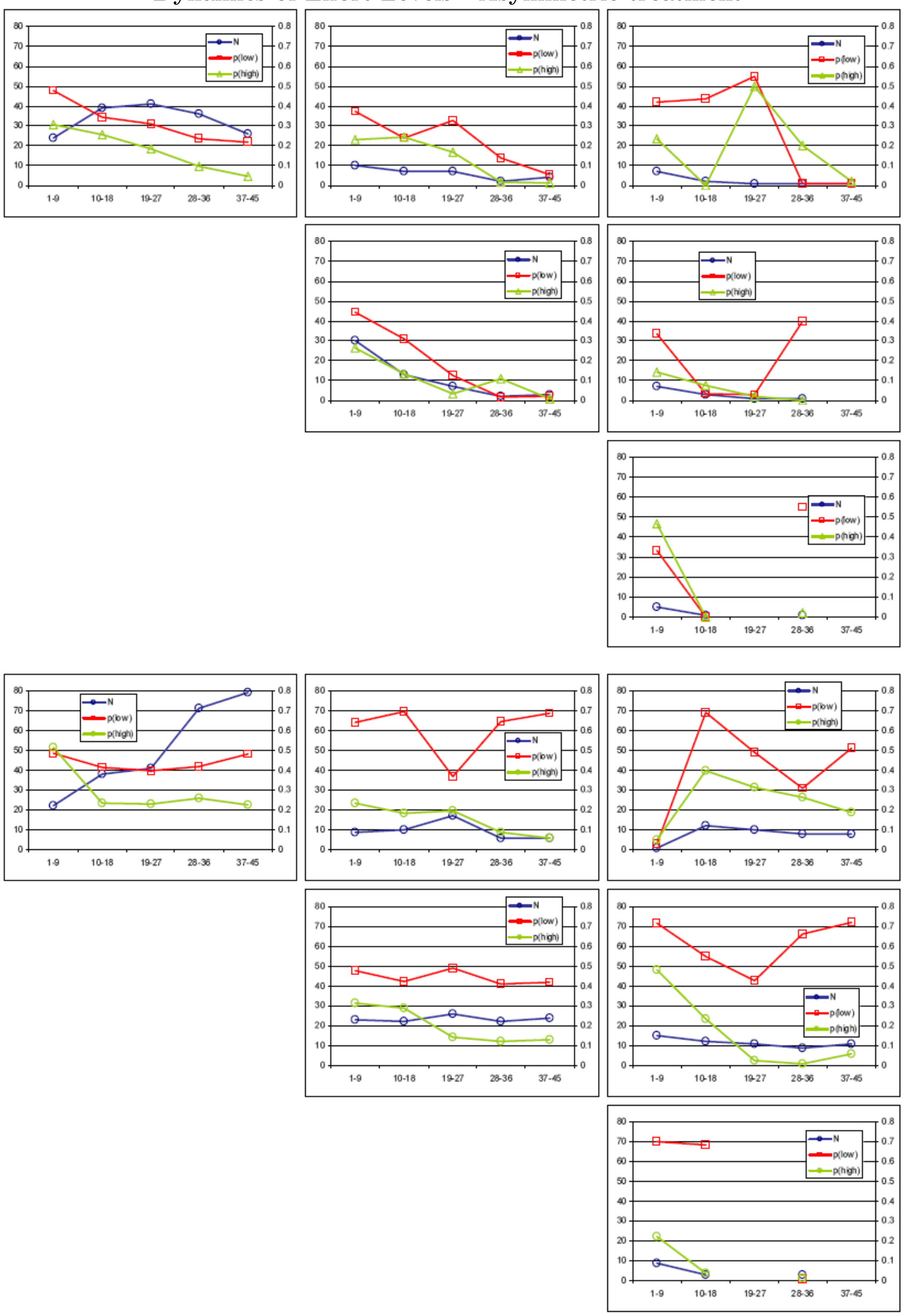

Figure 4: Dynamics of effort levels (right scale) and chosen (n, m) constellations (left scale) in the asymmetric treatment over time. Low bonus schemes ($B = 3$) in the first three rows, high bonus schemes ($B = 7$) in the last three rows. $n \in \{1, 2, 3\}$ is given in the columns, $m(\leq n) \in \{1, 2, 3\}$ in the rows. p(low) refers to the lowcost agent, p(high) to the highcost agent.

Dynamics of Effort Levels - Highcost treatment

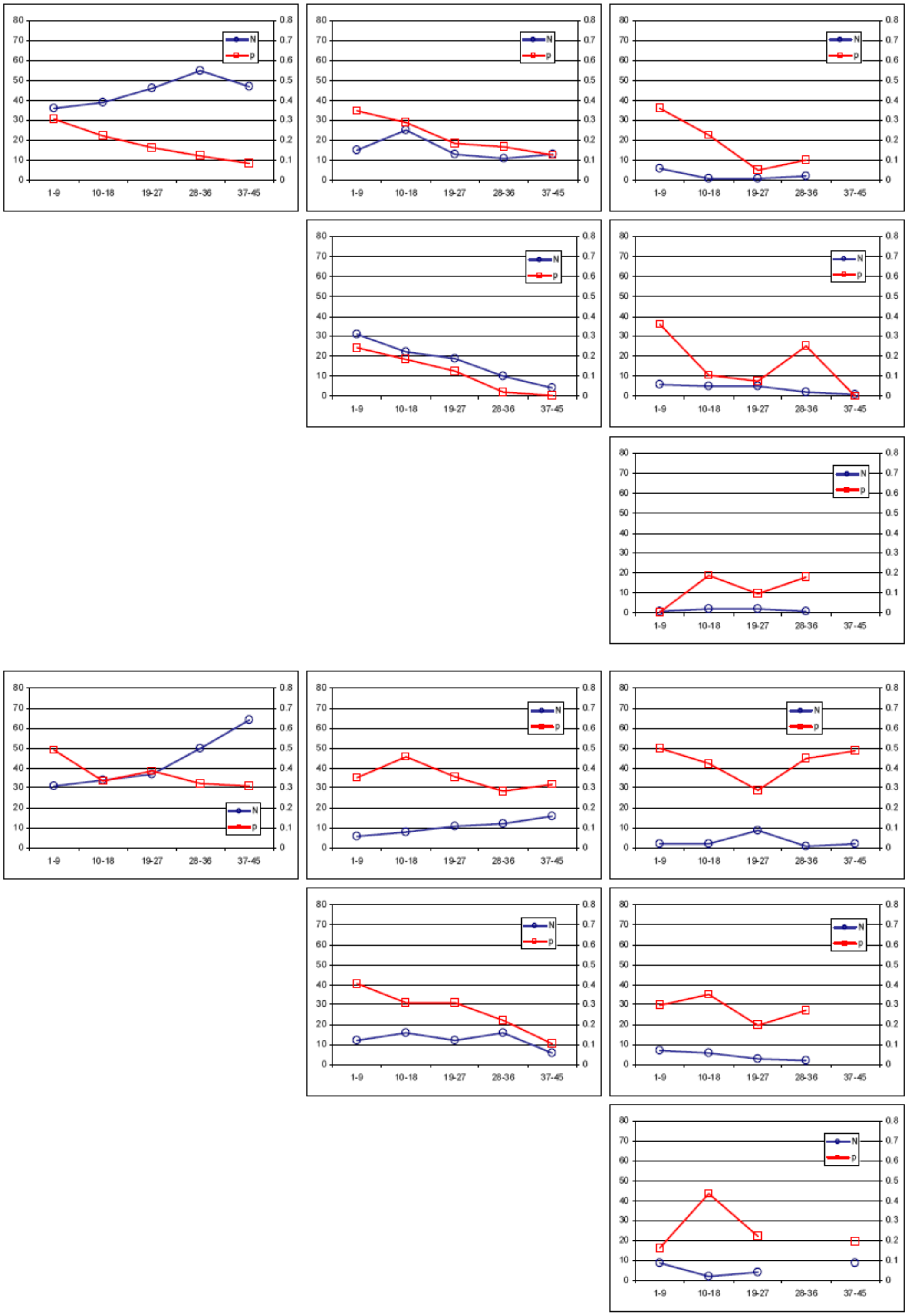

Figure 5: Dynamics of effort levels (right scale) and chosen (n, m) constellations (left scale) in the highcost treatment over time. Low bonus schemes $(B = 3)$ in the first three rows, high bonus schemes $(B = 7)$ in the last three rows. $n \in \{1, 2, 3\}$ is given in the columns, $m(\leq n) \in \{1, 2, 3\}$ in the rows.

Appendix A3: Derivations

Solving the model by backward induction, we derive optimal effort levels of the agents first. For every incentive scheme, the expected utility of each risk-neutral agent is given by

$$U_i = F + P_i^{n,m}(p_i, p_j)B - C_i(p_i)$$

where $P_i^{n,m}(p_i, p_j)$ captures the probability of being awarded the bonus given by

$$P_i^{n,m}(p_i, p_j) = \sum_{k=m}^{n} \left[\binom{n}{k} p_i^k (1-p_i)^{n-k} \sum_{e=0}^{k-m} \binom{n}{e} p_j^e (1-p_j)^{n-e} \right]$$

The optimal effort level p^* clearly depends on the incentive scheme chosen by the principal. We do not derive the optimal effort levels for all of the 6 possible incentive schemes analytically here for reasons of brevity and the fact that solutions have to be computed numerically for certain combinations of (n, m). We hereafter present the most simplest cases $(1, 1)$, $(2, 1)$ and $(2, 2)$.

- For $(1, 1)$, the F.O.C.s are given by

  $$\frac{\partial U_i}{\partial p_i} = B(1-p_j) - c_i p_i \quad = \quad 0$$

  which by symmetry of the agents' maximisation problem leads to

  $$p_i^* = \frac{B(B-c_j)}{B^2 - c_i c_j}$$

  The S.O.C. are fulfilled by

  $$\frac{\partial^2 U_i}{\partial p_i^2} = -c_i < 0 \qquad \forall p_i, p_j \in [0,1], c_i > 0$$

- For $(2, 1)$, the F.O.C.s are given by

  $$\frac{\partial U_i}{\partial p_i} = B(1-p_j)[2p_i(1-p_j) + 4p_ip_j + 2(1-2p_i)(1-p_j)] - c_ip_i = 0$$

  $$p_i = \frac{2B(p_j - 1)^2}{c_j + 2B(1 - 4p_j + 3p_j^2)}$$

Since the analytical solution to this problem is rather tedious and adds little insight, we do not present it here, but compute the optimal effort levels numerically for our parameter constellations.

The S.O.C. are fulfilled if

$$\frac{\partial^2 U_i}{\partial p_i^2} = 8Bp_j - 6Bp_j^2 - 2B - c_i < 0 \qquad \forall p_i, p_j \in [0,1]$$

which holds if $\frac{2}{3}B - c_i < 0$, a condition met in all our treatments.

- For $(2,2)$, the F.O.C.s are given by

$$\frac{\partial U_i}{\partial p_i} = 2Bp_i(1-p_j)^2 - c_i p_i \quad = \quad 0$$

which has the obvious solution $p_i = 0$.

The S.O.C. are fulfilled if

$$\frac{\partial^2 U_i}{\partial p_i^2} = 2B(1-p_j)^2 - c_i < 0 \qquad \forall p_i, p_j \in [0,1]$$

which in our case holds for all schemes with $B = 3$ or $c_i = c_j = 22$.

For all other cases, symmetry of the problem yields four other solution pairs (p_i^*, p_j^*) from the quadratic nature of the equation of which only

$$p_i^* = 1 - \frac{\sqrt{2c_j}}{\sqrt{B}} \qquad \text{and} \qquad p_j^* = 1 - \frac{\sqrt{2c_i}}{\sqrt{B}}$$

yields solutions for $p_i, p_j \in [0,1]$ in the two following cases:

  - $B = 7$ and $c_i = c_j = 11$: $(0.114, 0.114)$ does not fulfill the strict S.O.C., since $\frac{\partial^2 U_i}{\partial p_i^2} = 0$. We nevertheless use it as a benchmark solution in this case, as both agents are best responding to each other.
  - $B = 7$ and $c_i = 22, c_j = 11$: In this case, the disadvantaged agent will not provide any effort $p_j = 0$ from the F.O.C. and the S.O.C. Knowing this, the advantaged agent is best responding by exerting maximal effort $p_j = 1$ since his utility is increasing for all levels of $p_j > 0$: $\frac{\partial U_j}{\partial p_j} = p_j(2B - c_j) > 0$

The three other incentive schemes ($(3,1)$, $(3,2)$ and $(3,3)$) are not explicitly dealt with here, as the structure is similar to the derivations above.

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