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by

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Ambiguity aversion as a reason to choose tournaments*

Christian Kellner[†], Gerhard Riener[‡]

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Abstract

We test the implications of ambiguity aversion in a principal-agent problem with multiple agents. When output distributions are uncertain, models of ambiguity aversion suggest that tournaments may become more attractive than independent wage contracts, in contrast to the case where output distributions are known. We do so by presenting agents with a choice between tournaments and independent contracts, which are designed in a way that under uncertainty about output distribution (that is, under ambiguity), ambiguity averse agents should typically prefer tournaments, while ambiguity neutral agents prefer independent contracts, independent of their degree of risk aversion. This is the case, because the tournament removes all ambiguity about the equilibrium wages. We compare the share of participants who choose the tournament under ambiguity with the share of participants choosing the tournament in a control treatment, where output distributions are known. As the theory predicts, we find indeed that under ambiguity the share of agents who choose the tournaments is higher than in the case of known output distributions.

JEL classification: D01; D03; D81; M55

Keywords: Ambiguity aversion; tournaments; Ellsberg urn; contract design

1 Introduction

We analyze experimentally the effect of subjective uncertainty about the outcome distributions (ambiguity) on the evaluation of outcome-dependent payment schemes, as they arise for instance in principal-agent problems. Particularly, we are interested to verify whether ambiguity aversion has important consequences for the design of optimal contracts.

From a theoretical point of view, Kellner (2010) argues that in many situations ambiguity aversion could make tournaments more attractive than other types of incentive contracts. This is the case because, even if outcome distributions are uncertain, tournaments can be designed so that they eliminate all payoff-relevant ambiguity from a wage contract, but at the same time still provide incentives to the agents to exert effort. Hence taking ambiguity aversion into account could narrow the gap between the predictions of theoretical models and the type of incentive contracts that are actually used in practice.

For instance, it is often claimed that rank-dependent wage regimes – like tournaments – play an important role in the determination of wages in firms. Theoretical foundations for the use of

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tournaments are often considered unsatisfactory. For instance Prendergast (1999) argues that the way incentives are provided to white-collar workers could be best understood as a tournament: In many firms wages vary little with performance, but wage increases typically go together with promotions within the firm, which is often granted to the best of the current employees. In this sense, a promotion awards a monetary prize to the agent with the highest performance, as in a tournament. In the absence of ambiguity (or if agents are assumed ambiguity neutral) there are few reasons why a principal would actually prefer tournaments.¹ Thus, a principal who seeks to design the optimal incentive contract might prefer tournaments in situations where the (effort-dependent) output distributions are uncertain, while they would prefer an independent contract if output distributions are purely risky.

To see whether this theoretical argument for the use of rank-dependent payment regimes effectively bears empirical relevance and helps to answer the question of how to design incentive contracts optimally under ambiguity, we investigate experimentally how decision-makers evaluate two types of payment schemes under ambiguity. Each of two agents draw a ball, labelled with a number, from an identical urn with unknown composition. The first payment scheme resembles a tournament: The participant whose ball is labelled with the higher number gets a monetary prize, the other participant only a show-up fee. In the second type of payment scheme the participant gets a monetary price if she draws a sufficiently high number, independently of the draw for the other agent.

As the participants do not know the composition of the urn, they face uncertainty about the probabilities of drawing a ball with a certain label. Hence, they are confronted with ambiguity. We study whether such ambiguity affects the evaluation of the two types of payments schemes. Here, uncertainty about probabilities is payoff relevant only in case of the independent payment scheme. For tournaments, the probability of drawing a higher number does not depend on the distribution of balls in the urn. Hence, for ambiguity averse agents, tournaments could become more attractive over independent payment schemes, and we want to test this hypothesis.

Numerous experiments based on the Ellsberg's well-known thought experiment have suggested that many decision makers are ambiguity averse. However tournaments become more attractive under ambiguity only if agents perceive a bet on drawing the higher of two balls from an urn indeed as unambiguous, even if the composition of the underlying urn is uncertain. Many models of ambiguity aversion who accommodate the typical Ellsberg choices would suggest this, but experiments in the style of Ellsberg-paradox do not shed any light on this question.

More generally, to the best of our knowledge, no other experiment has studied the evaluation of rank-dependent contracts like tournaments under ambiguity. A number of experiments tried to refine our understanding of the behavior of agents under ambiguity, which provide important insights for the design and the interpretation of our experiment. For instance, (Fox & Tversky 1995) show that the effect of ambiguity seems to be larger if agents are confronted with choices where ambiguity matters only for some payment options, while it becomes less relevant if agents only have ambiguous choices available. Halevy (2007) suggests that agents who dislike bets on the composition of an ambiguous urn also dislike bets from an urn of which the distribution was determined at random. Hence, failure to reduce compound lotteries could be the underlying factor behind the Ellsberg paradox. Therefore, one possible reason why even ambiguity averse agents might not prefer tournaments is that agents might find the exact implications of the payment schemes hard to understand. Hence, if mathematical difficulties are the main reasons why agents fail to reduce compound lotteries, they may fail to understand the fact that certain

¹In general, other types of incentive contracts lead to higher payoffs for the principal. See Kellner (2010) for a more detailed discussion of the theoretical literature on tournaments as incentive contracts.

tournaments eliminate all ambiguity about wages. If this was in fact the case, failure to reduce compound lotteries could make such agents appear less ambiguity averse (in contrast to Halevy (2007)). To address the importance of this issue, we offer mathematical help to some of the participants in our experiment.

Additionally, it might also be true that not ambiguity aversion, but other concerns motivate agents to prefer tournaments. It has been suggested that some agents might prefer situations in which they compete against others (as they do in tournaments), for instance as they find such situations more exciting. Other agents might instead be “competition averse”, that is they seek to avoid competition. Niederle & Vesterlund (2007) argue for instance that women tend to belong more often to the second group than men. To see to which extent the agents’ preference for tournaments can actually be attributed to ambiguity aversion (in comparison to other motives like “competition aversion”, we expose some of the agents instead to a similar environment without ambiguity, where both ambiguity averse agents as well as ambiguity neutral agents should never find it optimal to choose a tournament. In addition we conducted (in an unannounced bonus round after the actual experiment) a classical Ellsberg type experiment to control for ambiguity aversion.

We have ruled out some issues that are present in the evaluation of payments schemes like tournaments in reality. Our approach abstracts from strategic ambiguity or ambiguity about skills. We do this in order to be able to focus on the role of the ambiguity of the outcome process.

We find that ambiguity in fact increases the share of subjects choosing tournaments significantly – in particular among ambiguity averse agents. However, this effect does not appear equally strong for all agents, and it seems that an intrinsic aversion against competitive situations could explain why even some ambiguity averse agents do not find tournaments more attractive under ambiguity.

The paper is organized as follows: In Section 2 we will give an outline of the underlying theoretical predictions. Section 3 focuses on the implementation of the experiment. Section 4 describes and discusses the experimental results. First, we focus on the share of people choosing the tournament and how it varies between treatments in the experiment and characteristics of the participants. Second, we use OLS and Logit regressions to illustrate how ambiguity, ambiguity aversion and other factors influence the choices of the agents. We will discuss to which extent our results might be specific to the context of our experiment, and how we could clarify this and other issues using further experiments in Section 5.

2 Theory

We present the agents with the choice of different kinds of payment schemes in a particularly simple setting: The output of the agents is just a random draw from an urn with balls labeled 1 to 10. Half of the agents are presented with an ambiguous environment, in which the composition of the balls in the urn is unknown, the other half are presented with an unambiguous environment, in which the distribution over balls is known to be uniform. Agents are given a choice between independent schemes, in which the payoff of the agents depends only on the ball they draw themselves, or payment schemes where an agent’s payment depends only on whether she draws a ball higher or lower than the ball of the other agent.

Despite the absence of effort, this setting can help us to understand the importance of ambiguity and ambiguity aversion also in the case of incentive contracts (with multiple agents) where such payment schemes are most commonly used. From a principal’s point of view, without effort

there is no reason to reward the agents using a non-constant contract. Yet, in this experiment we are mainly interested to see how the agent's preference between different types of contracts changes with ambiguity, and hence it should not be a very relevant whether in fact these contracts were offered out of a principal's need to prevent the agents from deviating to another action, or presented to the agents by the experimenter, without including the principal's role in the experiment at all.

Now we describe the environment that the agents are facing, and the payment schemes offered to them in more detail. Then we derive theoretical predictions of the agents' behavior.

Ambiguous environment

In the ambiguous environment, agents are first presented with the following information about an urn, from which their "output" is drawn: They are told the total number of balls (100), the fact that the balls are labeled with numbers (1 to 10), but not how they are distributed within the urn.

Purely risky environment

In the purely risky environment, agents are also presented with an urn containing 100 balls, but they have additional information about the urn: They know that the labels are uniformly distributed (10 balls of each label).

Schemes offered to the agents

Participants are divided into pairs, and they are presented with the following four payment schemes to choose from. Each of these schemes specifies the way how the agent's payout depends on the outcomes of a stochastic process. We denote by x_T (x_I) the base payment for the tournament or the independent scheme, respectively, while p_I (p_T) is the bonus payment for reaching a target in the independent scheme or winning the tournament.

$$\begin{aligned}
 I_1 &= \begin{cases} x_I + p_I & \text{if own ball 6 or above} \\ x_I & \text{else} \end{cases} \\
 I_2 &= \begin{cases} x_I + p_I & \text{if own ball 5 or below} \\ x_I & \text{else} \end{cases} \\
 T_1 &= \begin{cases} x_T + p_T & \text{if own ball higher than ball of other participant} \\ x_T & \text{if own ball lower than ball of other participant} \\ \text{coin flip} & \text{between the above if both balls equal} \end{cases} \\
 T_2 &= \begin{cases} x_T + p_T & \text{if own ball higher than ball of other participant} \\ x_T & \text{if own ball lower than ball of other participant} \\ \text{coin flip} & \text{between the above if both balls equal} \end{cases}
 \end{aligned}$$

The first two schemes (I_1 and I_2) are individual schemes where wages depend only on each participant's own draw, while the latter (T_1 and T_2) introduce an elementary form of competition: Wages depend on a comparison with the other agent, in which only the rank of the agent matters, not the difference in the number drawn by the agents. Hence, we refer to these schemes as tournaments.

2.1 Predicted Behavior and Hypotheses

In determining the payment options, we chose payments such that the following two properties are satisfied. On the one hand, we wanted to make sure that no ambiguity neutral agent (who maximizes her expected utility) prefers the tournament, while ambiguity averse agents would typically do so. On the other hand, the extent to which agents prefer the tournament should depend as little as possible on the agent's risk attitude. Hence, we chose the "prize" that each scheme pays in case of a favorable draw to be equal for all types of payment schemes (i.e. $p_I = p_T = p$), while the guaranteed payment, which the agent gets independent of her draw, to be slightly higher for the independent scheme (i.e. $x_I - x_T > 0$, but small). In this case, based on the model by (Kellner 2010), we would expect the agents to behave in the following way, depending on the environment:

Ambiguous environment

Participants who maximize their expected utility cannot prefer the tournament: Suppose they consider the probability that the ball drawn at random has a label of 6 or above to equal a (presumably because they think the number of balls with a label of 6 or above is $100a$, at least in an average sense). In this case, one of the two individual schemes promises an incremental prize of p with a probability of at least 50% (precisely, either a or $1 - a$), while the schemes T_1 and T_2 promise the same prize with a probability of 50% irrespective of the distribution of balls. Ambiguity averse agents however can strictly prefer the tournament. The independent scheme yields a price with an unknown probability, but the tournament does not. Hence, ambiguity aversion makes only the independent schemes less attractive. In particular, if agents perceive ambiguity to be symmetric (at least in some average sense, they think that the number of balls above 5 equals the number of balls 5 or below), they will prefer the tournament over any of the two independent schemes, provided the difference in expected payoffs (corresponding to $x_I - x_T$) is small enough. Appendix A discusses the evaluation of the two types of payment schemes in greater detail.

We offered agents to choose between two kinds of independent schemes because otherwise agents might choose the tournament if they expect that those balls which lead to high payoffs in the independent scheme are underrepresented in the urn. We included a second kind of tournaments for reasons of symmetry, but both ambiguity averse and ambiguity neutral agents should always be indifferent between the two types of tournaments.

Purely risky environment

In the purely risky environment a is known to be 0.5 and hence $U(I_1) = U(I_2) > U(T_i)$, whether or not agents are ambiguity averse (as ambiguity is absent).

We summarize by postulating the following hypotheses: Hypothesis 1 describes how the behavior of ambiguity averse agents is expected to differ from the behavior of ambiguity neutral agents.

Hypothesis 1. *(a) In the ambiguous environment, a larger share of participants will choose the tournament. (b) In particular, participants who are ambiguity averse will choose the tournament, as only for these agents ambiguity matters. Ambiguity neutral agents should not choose the tournament.*

Hypothesis 2 postulates that, in the absence of ambiguity, agents behave like Expected utility maximizers.

Hypothesis 2. *In the unambiguous environment, the number of agents who choose the tournament is close to zero, as the tournament results in a distribution of wages dominated by the independent schemes.*

Potential confounds

We expected that the following confounds could either prevent participants to choose as hypothesized or suggest alternative explanations for our findings. First, people might find some kinds of payment schemes harder to understand than others (even if it is not entirely evident which kind of scheme should be easier to understand).² Second, people might prefer the tournament if they consider it more exciting to compete against another participant. Alternatively, they might avoid the tournament if they feel uncomfortable with the fact that they are compared with someone else (even if they have no real way to influence their own outcome). Hence in designing the experiment we tried to either rule out these possible confounding effects or to elicit in which way they affect our results, as we will now describe in greater detail.

Furthermore, in order to control whether the effects we find can be attributed to ambiguity aversion as understood by Ellsberg, we added a standard two-color Ellsberg urn at the end of the experiment. Subjects were presented with two urns. Urn A contained 10 ball labelled 1 and 10 balls labelled 2, while urn B contained an unknown, but fixed distribution of those balls. Subjects then had to chose an urn and a number, and if the number was drawn from the chosen urn, subjects received ECU 6.90. The results of this experiment we used then in the regression analysis.

3 Design

To test our main hypothesis (1a) we present half of the participants with the ambiguous environment, where subjects were not informed about the process that distributes the ball in the urn,³ while half are presented with an “unambiguous” urn resulting in a purely risky environment.⁴ We also informed them that the process of drawing balls from the urn will be simulated by the computer. Prizes were chosen to equal the following amounts (in ECU, the exchange rate to Euro was 1ECU=0.4 €).

Schemes offered to the agents

Participants are divided into pairs, and they are all presented with a choice between the four schemes introduced in the theoretical discussion above. The schemes were described using the following terminology:

²For the independent schemes it is quite clear that the probability of winning the higher price depends only on the (expected) number of balls above 5 in the urn in relation to the number of balls 5 or below. If those numbers are expected to be identical, it appears rather easy to understand that the chance of winning p is 0.5. For the tournament it appears very hard to compute the chances of winning if one tries to compute the winning chances by aggregating the likelihood of observing every outcome combination for any hypothesized winning probability. However, if a participant understands that a tournament would give a prize to exactly one of two agents treating them identically (even if the other agent has the option to be rewarded in another way), it might be at least equally easy to see that the winning probability is always 0.5.

³The actual distribution was known to the experimenters. For subjects with even subject number, only balls from the range 4-10 were contained in the urn (and each of those labels on average equally often), while for subjects with odd subject numbers, the urn consisted only of balls labeled 1-7.

⁴These subjects were informed that 100 balls labeled 1-10 were in that urn and they were uniformly distributed.

Independent schemes

- You receive ECU 24.40 if your ball shows 6 or a higher number. You receive ECU 5.40 if your ball shows 5 or a smaller number. The number on the ball of your partner does not play a role.
- You receive ECU 24.40 if your ball shows 5 or a lower number. You receive ECU 5.40 if your ball shows 6 or a higher number. The number on the ball of your partner does not play a role.

Tournament schemes

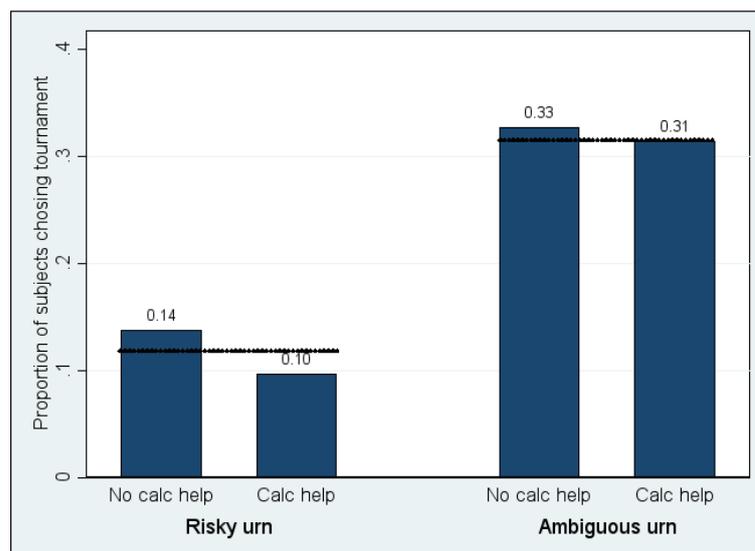
- You receive ECU 23.60 if your ball shows a higher number than the ball of your competitor. You receive ECU 4.60 if the number is smaller. If both balls show the same number, a fair coin decides whether you get the higher or the lower amount.
- You receive ECU 23.60 if your ball shows a lower number than the ball of your competitor. You receive ECU 4.60 if the number is higher. If both balls show the same number, a fair coin decides whether you get the higher or the lower amount.

When presenting these schemes to the agents, we use the neutral term “payment option” and we also do not use any words or abbreviations suggesting an interpretation as tournament or independent scheme. Note that we did not require both agents to be rewarded according to the same type of scheme. (Alternatively we could have allowed only one of the two agents to choose the type of scheme that applies to both.) We did so to isolate the nature of a potential intrinsic preference for competitive situations. Here, all that could matter is whether the agent herself prefers competitive situations, but not how she feels about forcing others to compete. We decided to let agents choose between a few specific schemes instead of using a mechanism that elicits their willingness to pay, as we felt that agents might find it easier to understand direct choices in comparison to an abstract mechanism. This might be an important concern particularly under ambiguity aversion, as incentive compatible mechanisms like BDM (Becker, DeGroot & Marschak 1964) add a further level of uncertainty to the experiment. Additionally, Trautmann, Vieider & Wakker (forthcoming) suggest that when relying on the agents’ WTP they appear to be more ambiguity averse in comparison to situations where their direct choices are used to elicit their ambiguity attitude.

4 Results

Figure 1 summarizes the shares of participants who chose the tournament in each of the four treatments in the experiment, as well as the pooled results over the ambiguous and the risky urn. As our theory predicts, the tournament is chosen more often under ambiguity. Among those participants who do not face ambiguity about the output distribution, only 13% choose the tournament. Under ambiguity, the share of tournaments increases to 31%. A mean comparison test confirms that the difference between the ambiguous and the unambiguous environment is significant below the 1 percent level according to a χ^2 -Test (and according to Fisher’s distribution-free test).

Whether or not the agents are provided with mathematical help matters little. It has almost no effect in the presence of ambiguity (with mathematical help, the share of tournaments drops slightly from 33% to 31%). When agents know the output distribution, mathematical help



The dotted line shows the averages over the pooled risky and ambiguous treatments

Figure 1: Tournament share over treatments

decreases the share of participants choosing tournaments (from 14% to 10%). The effect of ambiguity remains significant in both cases.⁵ Hence, our experiment strongly confirms part a) of Hypothesis 1: Under ambiguity, tournaments become more attractive in comparison to independent schemes.

The regressions in Table 1 will further explain the choices of the participants. In particular, we will also discuss to which extent the data support part b) of Hypothesis 1, which links the behavior of the agents in the two rounds of the experiment. The dependent variable is a dummy variable indicating payment scheme choice (1 if an agent chose a tournament, 0 for an independent scheme).

The first regression includes only the effect of the key treatment variables on the share of tournaments being the chosen scheme. The effect of ambiguity is positive (0.19) and significant.⁶ The second regression includes the behavior of the participants in the second stage. It allows the intercept and the effect of ambiguity to differ between participants who reveal ambiguity aversion in their Ellsberg choices and those who do not (NotEllsberg). For the first group, the effect of ambiguity increases somewhat to 0.25 and remains significant. For people who do not reveal (enough) ambiguity aversion in the Ellsberg experiment, the effect of ambiguity is lower by a notable amount of 0.10 (but this decrease is not significant). The resulting net effect of ambiguity (0.15) becomes insignificant for this group.

The effect of offering mathematical help (calc) is small and insignificant: With help, subjects go slightly less often into tournaments in the risky environment (so the number of people who behave consistent with expected-utility maximization increases) while the effect of the ambiguous urn treatment increases slightly (so more people make a choice consistent with ambiguity aversion).

In line with the statistical analysis presented above, these regressions support part a) of

⁵ If mathematical help is not available, the effect of ambiguity is significant at the 5% level according to a χ^2 mean comparison test, and at the 3% level according to Fisher's (one-sided) test. When help is available, the effect is significant according to both test at the 1% level.

⁶For the linear probability model we use robust standard errors, as the dependent variable is binary. Robustness checks, using a logit specification can be found in the appendix.

Table 1: Tournament choice

	(1)	(2)	(3)	(4)	(5)
Ambiguous	0.193** (0.083)	0.252** (0.109)	0.198** (0.080)	0.283*** (0.105)	0.283*** (0.095)
Calc	-0.038 (0.068)	-0.036 (0.066)	-0.030 (0.064)	-0.026 (0.063)	0.009 (0.059)
Ambiguous × calc	0.022 (0.112)	0.015 (0.112)	0.013 (0.112)	0.003 (0.112)	-0.034 (0.108)
Not ambiguity averse		0.030 (0.072)		0.050 (0.067)	0.070 (0.067)
Ambiguous × not amb.av.		-0.097 (0.120)		-0.138 (0.117)	-0.168 (0.111)
Female			0.080 (0.088)	0.093 (0.089)	0.047 (0.087)
East			-0.009 (0.085)	-0.003 (0.087)	-0.046 (0.086)
Female × east			-0.190* (0.113)	-0.209* (0.118)	-0.114 (0.117)
Risk loving					-0.002 (0.014)
Competition averse					-0.266*** (0.076)
Constant	0.167 (0.130)	0.142 (0.145)	0.143** (0.071)	0.106 (0.081)	0.322** (0.128)
*.session_no	Yes	Yes	No	No	No
Observations	206	206	206	206	206
R^2	0.122	0.126	0.093	0.100	0.174

Standard errors in parentheses

Linear probability model. Dependent variable: Choice of tournament.

Controlled for session effects and age in columns 1 and 2 only, as sessions were either all male or all female.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Hypothesis 1: Under ambiguity, tournaments are more attractive. However, the evidence for part b) of Hypothesis 1 is less strong. While it is true that for agents who do not appear to be ambiguity averse, ambiguity does not lead to a significant increase, the difference in the effect of ambiguity between the ambiguity averse and ambiguity neutral agents is also not statistically significant. Hence, our experiment does not conclusively answer this question.

The following factors could help to understand this finding. First, note that in the second part of our experiment, the choices of the agents had less strong financial consequences for them. Hence, the second part of our experiment might miss a sharp separation of ambiguity averse and not ambiguity averse subjects. Perhaps more importantly, participants could take other considerations into account that we do not account for in our theoretical discussion. One possible reason is, that some of the subjects are competition loving. We see that the constant in the first regression – so the share of subjects who chose competition in the risky urn without mathematical help – is quite large, although not statistically significant. This indicates that some subjects are competition loving, shedding some light on hypothesis 2, claiming that no subject will choose the tournament in the risky environment. This hypothesis can not be fully supported. Our discussion of the effect of offering mathematical help seems to suggest that mathematical confusion might be an issue to a (perhaps small) extent.

In the final three regressions we explore the possibility that decision makers have an intrinsic attitude towards competition, which is not accounted for by the expected utility framework nor models of ambiguity aversion, but which do affect their choices between different payment options.

The third and fourth regression includes additional demographic information about the participants (regression four allows the effect of ambiguity to differ according to the behavior in the second part, regression three does not). The inclusion of these factors emphasizes the importance of ambiguity for payment scheme choices: comparing regression 4 to regression 2, the coefficient for the ambiguous treatments increases to 0.28. Additionally, the effect of ambiguity decreases slightly to 0.14 for agents which are not ambiguity averse, since according to regression 4 the effect of the ambiguous treatment is now lower by 0.14 for those agents who are not ambiguity averse.

Hence, accounting for demographic information (potentially acting as a proxy for an intrinsic attitude over the types of payment schemes), participants behave somewhat more closely as both parts of our main Hypothesis would suggest. The effect that these demographics have on the participant's propensity to choose tournaments are as follows. Females *per se* choose tournaments slightly more often than males (by 0.08), participants from former East-Germany virtually as frequently as others. However, females from the East choose tournaments significantly less than males from the west (-0.11, the net effect of being a woman and coming from East Germany).

We also explored whether the effects of ambiguity and ambiguity aversion are similar between the subgroups. Allowing the effect of ambiguity and ambiguity aversion to differ according to certain subgroups (like gender, calc, Ellsberg-behavior and of East German origin), changes the size of the effects, but the directions of the effects do not change for any subgroup in all reasonable specifications. Results are available upon request.

To examine more closely hypothesis 2, we include additionally statements that the participants made in the questionnaire about their real world behavior and their views on competition in the fifth regression. We included the dummy "Competition averse", which is assigned to those participants who stated in the questionnaire that the fact that their draw was compared to the draw of another agent was a disadvantage for the tournament-like schemes. The constant

increases to over 0.32 and becomes statistically significant at a five percent level. Furthermore, in this regression the effect of ambiguity differs even more strongly with the agents choices in the Ellsberg-stage: Now, the effect of being in the ambiguous treatment is 0.27 if ambiguity aversion is revealed in the first stage, but it is just 0.11 otherwise. In regression 5, also the effect of being a women from the East is much lower. This mainly reduces the effects of female East Germans who often appear to be competition averse in this regression. The extent to which participants consider themselves willing to take risks (Risk loving) has almost no effect, which is consistent with the theoretical prediction. Hence, it seems that an intrinsic attitude towards competition in fact affects the behavior of the participants.

In general, these regressions lead to similar conclusions as our previous comparison of the share of tournaments between different treatments and subgroups. Most notably, facing an ambiguous environment makes a significant difference for ambiguity averse individuals (while this effect is insignificant for agents who do not reveal ambiguity aversion through their Ellsberg-choices).

5 Discussion

In our experiment we have focused so far on the effects of ambiguity on the agents' preferences between tournaments and independent schemes. We found that in principle, ambiguity does effect the evaluation of such payment schemes, making tournaments more favorable. Moreover, we find evidence that this is to some extent due to ambiguity aversion, but the link between ambiguity aversion and a preference for tournaments is somewhat weaker than one could expect. This might be to some extent explained by an intrinsic attitude towards competition, which could interfere with the effect of ambiguity aversion.

While the experiment above addresses the fundamental source of the effect of ambiguity in agency schemes, the problem that a principal faces when designing the optimal incentive contract is somewhat more complex. Essentially, there are two issues which we have eliminated in our experimental design. First, in the absence of effort, deciding which contract to accept becomes an individual decision problem. If both agents can choose between different effort levels, however, the choice of one agent influences the payoff of another agent. Hence, what they think about the strategy of the other player might be important. Moreover, the strategy of the other player could be viewed as an alternative source of ambiguity in our model. Hence, a variation of this experiment could test whether uncertainty about the output distributions has any additional implications for ambiguity averse agents, if the agents can improve productivity by exerting effort.

Second, when a principal designs a contract to maximize her profit, the best independent contract that the principal could design might be, in a sense, less risky than the best tournament (while it would still be more ambiguous than the optimal tournament). Hence, if the agent's risk aversion would be large in comparison to their ambiguity aversion, tournaments might not be advantageous for some ambiguity averse agents. Further experiments could test to what extent differences in the agents' ambiguity aversion influence the design of incentive contracts more than differences in risk aversion.

A Ranking of contracts

For any $C \in \{T_1, T_2, I_1, I_2\}$, denote the utility that the agents uses to decide between different contracts by $U(C)$.

A.1 Expected Utility

For an expected utility maximizer, if a denotes the (expected) share of balls in the urn that have a label of 6 or above, for the independent contracts

$$U(I_1) = au(x_I + p) + (1 - a)u(x_I),$$

$$U(I_2) = au(x_I) + (1 - a)u(x_I + p).$$

Hence,

$$\max\{U(I_1), U(I_2)\} \geq \frac{1}{2}u(x_I + p) + \frac{1}{2}u(x_I).$$

Note that the inequality becomes an equality in the (natural) case where $a = \frac{1}{2}$. However, since the probability of winning the incremental prize p in a tournament is always $\frac{1}{2}$, irrespective of a , for the tournament contracts,

$$U(T_1) = U(T_2) = \frac{1}{2}u(x_T + p) + \frac{1}{2}u(x_T).$$

Since $x_T < x_I$, for every expected utility maximizer $\max\{U(I_1), U(I_2)\} > U(T_1) = U(T_2)$.

A.2 Ambiguity Aversion

To illustrate preferences under ambiguity we focus on two representative ambiguity models, the smooth ambiguity model (Klibanoff, Marinacci & Mukerji 2005) and the max-min-Expected-Utility model (Gilboa & Schmeidler 1989).

The smooth model would suggest that an agent considers a set of priors, Π , to represent the possible probability distributions for draws from the urn, and that a (second order) distribution μ indicates the likelihood that the agent attributes to each of these probability distributions. When evaluating her choices, the agents computes first the expected utility in the usual way. Hence, when looking at the independent contracts, we can replace the set of probability distributions Π with a set of probabilities A . Any member of A just describes the probability that the drawn ball is labelled 6 or above. Then the agent aggregates these expected utilities attributed to every member of A using a concave transformation function ϕ which represents the agents ambiguity attitude. Specifically,

$$U(I_1) = \int_A \phi(au(x_I + p) + (1 - a)u(x_I))d\mu(a)$$

$$U(I_2) = \int_A \phi(au(x_I) + (1 - a)u(x_I + p))d\mu(a)$$

If ϕ is strictly concave, indicating strict ambiguity aversion, and μ is not a Dirac-measure

$$U(I_1) < \phi\left(\int_A ad\mu(a)u(x_I + p) + (1 - \int_A ad\mu(a))u(x_I)\right)$$

and the same is true for $U(I_2)$. In the natural case where $\int_A ad\mu = \frac{1}{2}$, for both $i \in \{1, 2\}$

$$U(I_i) < \phi\left(\frac{1}{2}u(x_I + p) + \frac{1}{2}u(x_I)\right).$$

But the evaluation of the tournament still does not vary with the elements of Π (and hence A) so that

$$U(T_1) = U(T_2) = \phi\left(\frac{1}{2}u(x_T + p) + \frac{1}{2}u(x_T)\right).$$

When $x_I - x_T$ is small, as in the experiment, it should be typically true that for both $i \in \{1, 2\}$ it holds that $U(I_i) < U(T_1) = U(T_2)$, so that tournaments are preferred by the agent.

Similarly, the max-min Expected utility model suggests that the agent evaluates the independent contracts using a set of probability distributions A , where $a \in A$ specifies a possible probability for drawn ball to be labelled 6 or above. Ambiguity aversion is modelled by assuming that the agents evaluates every contract using the worst possible element of a , so that

$$U(I_1) = \min_{a \in A} [au(x_I + p) + (1 - a)u(x_I)]$$

and

$$U(I_2) = \min_{a \in A} [au(x_I) + (1 - a)u(x_I + p)]$$

but

$$U(T_1) = U(T_2) = \frac{1}{2}u(x_T + p) + \frac{1}{2}u(x_T).$$

Hence, if A contains elements both above and below $\frac{1}{2}$, then for both $i \in \{1, 2\}$, $U(I_i) < \frac{1}{2}u(x_I + p) + \frac{1}{2}u(x_I)$ and hence $U(I_i) < U(T_1) = U(T_2)$ whenever $x_I - x_T$ is sufficiently small.

In either case, tournaments can be preferred only under ambiguity aversion.

B Screenshots of the Experiment

Complete instructions (in German and English translations) as well as screen-shots of the experimental stages can be obtained from the authors upon request.

B.1 The What-if-calculator

The wording of the calculation help in the ambiguous environment:

You can now calculate, how probable the different payments are under the four options presented, if you knew how often each number of balls was present in the urn. Please enter for every number that could be on a ball a value of 0-100. Then press "Calculate". You can repeat this as often as you wish, your payment will not be influenced by how often you use this or which values you enter. Please note that the entered values have to add up to 100.

C Robustness checks

Logit regressions (similar to table 1).

Table 2: Tournament choice. Logit regressions

	(1)	(2)	(3)	(4)	(5)
Ambiguous	1.217** (0.522)	1.646** (0.769)	1.207** (0.514)	1.758** (0.752)	1.964*** (0.712)
Calc	-0.403 (0.635)	-0.360 (0.642)	-0.345 (0.630)	-0.284 (0.639)	0.057 (0.616)
Ambiguous \times calc	0.316 (0.774)	0.247 (0.781)	0.257 (0.765)	0.169 (0.774)	-0.192 (0.784)
Not ambiguity averse		0.323 (0.685)		0.395 (0.665)	0.588 (0.681)
Ambiguous \times not amb.av.		-0.667 (0.830)		-0.859 (0.803)	-1.162 (0.845)
Female			0.448 (0.470)	0.542 (0.481)	0.275 (0.534)
East			-0.051 (0.504)	-0.023 (0.508)	-0.337 (0.583)
Female \times east			-1.311* (0.737)	-1.434* (0.748)	-0.861 (0.831)
Risk loving					-0.010 (0.096)
Competition averse					-1.477*** (0.410)
Constant	-1.709** (0.710)	-1.981** (0.873)	-1.829*** (0.508)	-2.145*** (0.704)	-1.157 (0.956)
*.session_no	Yes	Yes	No	No	No
Observations	206	206	206	206	206
Pseudo R^2	0.126	0.129	0.095	0.102	0.167

Standard errors in parentheses

Logistic model. Dependent variable: Choice of tournament.

Controlled for session effects and age in columns 1 and 2 only, as sessions were either all male or all female.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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