The Effect of Ambiguity Aversion on Reward Scheme Choice

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Abstract

We test the implications of ambiguity aversion in a principal-agent problem with multiple agents. Models of ambiguity aversion suggest that, under ambiguity, comparative compensation schemes may become more attractive than independent wage contracts. We test this by presenting agents with a choice between comparative reward schemes and independent contracts, which are designed such that under uncertainty about output distributions (that is, under ambiguity), ambiguity averse agents (and only those) should typically prefer comparative reward schemes, independent of their degree of risk aversion. We indeed find that the share of agents who choose the comparative scheme is higher under ambiguity than in the case of known output distributions.

JEL classification: D01; D03; D81; M55
Keywords: Ambiguity aversion; comparative compensation schemes; Ellsberg urn; contract design

1 Introduction

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

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From a theoretical point of view, Kellner (2010) argues that in many situations ambiguity aversion could make comparative reward schemes (like touraments) more attractive than other types of incentive contracts. This result occurs because even if outcome distributions are uncertain, comparative schemes can be designed such that they eliminate all payoff-relevant ambiguity from a wage contract, while they 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 such as tournaments play an important role in the determination of wages in firms. The theoretical foundations for the use of 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 are typically associated with promotions within firms, which are often granted to the best employees. In this sense, promotion awards such as monetary prizes are given to the agent with the highest performance, as in a tournament. In the absence of ambiguity (or if agents are assumed to be 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 may prefer tournaments in situations in which the (effort-dependent) output distributions are uncertain whereas they would prefer an independent contract if output distributions are purely risky.

To determine whether this theoretical argument for the use of rank-dependent reward regimes effectively could have empirical relevance for the optimal design of incentive contracts under ambiguity, we experimentally investigate how decision makers evaluate two types of payment schemes under ambiguity. Each of two agents draws a ball, labeled with a number, from an identical urn with unknown composition. The first payment scheme is a rank-dependent scheme (a special case of a comparative reward scheme): The participant whose ball is labeled with the higher number receives a monetary prize, the other participant is awarded only a show-up fee. In the second type of payment scheme the participant receives a monetary price if she draws a sufficiently high number, independent of the draw of the other agent.

Because 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,

[1] In 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.

uncertainty about probabilities is payoff relevant only in the independent payment scheme. For comparative schemes, the probability of drawing a higher number does not depend on the distribution of balls in the urn. Hence, for ambiguity averse agents, comparative schemes could become more attractive over independent payment schemes, a hypothesis we wish to test.

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

More generally, to the best of our knowledge, no other experiment has studied the evaluation of rank-dependent contracts such as tournaments under ambiguity. A number of experiments have tried to refine our understanding of the behavior of agents under ambiguity, which provide important insights into the design and the interpretation of our experiment. For instance, Fox & Tversky (1995) show that the effect of ambiguity seems to be greater if agents are confronted with choices in which ambiguity matters only for some payment options; however, 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 the distribution of which is determined at random. Hence, failure to reduce compound lotteries could be the underlying factor behind the Ellsberg paradox. Therefore, one possible reason for why even ambiguity averse agents may not prefer rank-dependent contracts is that agents may find the exact implications of the payment schemes difficult to understand. Hence, if mathematical difficulties are the main reasons why agents fail to reduce compound lotteries, agents may fail to understand the fact that certain rank-dependent contracts 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 this important issue, we offer mathematical help to some of the participants in our experiment. Moreover, after the experiment we asked participants a question which reveals whether the participants understood the ambiguity eliminating character of the rank-dependent contract.

Additionally, other concerns, and not ambiguity aversion, may motivate agents to prefer comparative reward schemes. It has been suggested that some agents may prefer situations in which they compete against others (as they do in tournaments), for instance because they find such situations more exciting. Other agents may instead be "competition averse", which means that they seek to avoid competition. For example, Niederle & Vesterlund (2007) argue that women tend to belong more often to the second group than men. To determine to what extent the agents' preference for tournaments can actually be attributed to ambiguity aversion (in comparison with other motives such as "competition aversion") we expose some of the agents 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 conduct (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 as in real tournaments. Our approach abstracts from strategic ambiguity or ambiguity about skills, as we do not include effort choice. In order to focus on the role of ambiguity in the outcome process.

We find that ambiguity in fact increases the share of subjects choosing the comparative schemes significantly – in particular among ambiguity averse agents. However, this effect is not equally strong for all agents. One reason is that around a third of participants fail to recognize the fact that the comparative scheme eliminates ambiguity. Furthermore, intrinsic aversion against competitive situations seem to play a minor role to explain why some ambiguity averse agents do not find comparative schemes more attractive even under ambiguity.

The paper is organized as follows: In Section 2 we provide 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 rank-dependent payment schemes 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 agents. We discuss to what extent our results may be specific to the context of our experiment in Section 5.

2 Theory

We present the agents with the choice of different types 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 of 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 in which an agent's payment depends only on whether she draws a ball higher or lower than the ball of the other agent.

Now we describe the environment that the agents faced, 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 given the total number of balls (100) and 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 randomly divided into pairs with another anonymous subject, 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 rank-dependent scheme or the independent scheme, respectively, while p_I (p_T) is the bonus payment for reaching a target in the independent scheme or winning under the rank-dependent scheme.

$$I_1 = \begin{cases} x_I + p_I & \text{if own ball 6 or above} \\ x_I & \text{else} \end{cases}$$

$$I_2 = \begin{cases} x_I + p_I & \text{if own ball 5 or below} \\ x_I & \text{else} \end{cases}$$

$$T_1 = \begin{cases} x_T + p_T & \text{if own ball higher than ball of other participant} \\ x_T & \text{if own ball lower than ball of other participant} \\ \text{coin flip} & \text{between the above if both balls equal} \end{cases}$$

$$T_2 = \begin{cases} x_T + p_T & \text{if own ball lower than ball of other participant} \\ x_T & \text{if own ball higher than ball of other participant} \\ \text{coin flip} & \text{between the above if both balls equal} \end{cases}$$

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, these schemes share many features of 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 with respect to any probability distribution) prefers the rank-dependent scheme to both individual schemes, while ambiguity averse agents would typically do so. On the other hand, the extent to which agents prefer the rank-dependent scheme 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). 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 rank-dependent schemes over both individual schemes: Suppose they consider the probability that the ball drawn at random has a label of 6 or above to equal a (presumably because they expect the number of balls with a label of 6 or above is $100a$). 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.[2] Ambiguity averse agents however can strictly prefer the rank-dependent scheme. The independent scheme yields a prize with an unknown probability, but the rank-dependent scheme 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 rank-dependent scheme over any of the two independent schemes, provided the difference in expected payoffs (corresponding to $x_I - x_T$) is sufficiently small. Appendix A.1 discusses the evaluation of the two types of payment schemes in greater detail.

We offered agents the choice between two types of independent schemes because otherwise agents may choose the rank-dependent scheme if they expect that those balls that lead to high payoffs in the independent scheme are underrepresented in the urn. We included a second type of rank-dependent scheme for symmetry reasons, but both ambiguity averse and ambiguity

[2]For the rank-dependent scheme to eliminate all ambiguity, it is not necessary that the winning probability is equal to 50 percent, as argued in (Kellner 2010). This could arise in situations where skills of agents differ. However, to the extent that differences in skills are perceived to be ambiguous, rank-dependent contracts would become ambiguous as well.

neutral agents should always be indifferent between the two types of rank-dependent schemes.

Purely risky environment

In the purely risky environment a is known to be 0.5; hence, $U(I_1) = U(I_2) > U(T_i)$, regardless of whether agents are ambiguity averse (because 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 rank-dependent scheme. (b) In particular, this will be true for those agents who are ambiguity averse.*

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 rank-dependent scheme is close to zero, as the rank-dependent scheme results in a distribution of wages dominated by the independent schemes.*

This design – despite the absence of effort – helps 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. When a principal implements an independent contract she faces the problem that the agents perceive such contracts as ambiguous when the output distribution is unknown. Rank-dependent payment schemes can in many cases eliminate all ambiguity about equilibrium wages and still provide incentives for effort provision (see (Kellner 2010)).

Potential confounds

We expected that the following confounds could either prevent participants from choosing 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).[3] Second, people might prefer the rank-dependent scheme if they consider it more exciting to compete against

[3] For 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 rank-dependent scheme 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

another participant. Alternatively, they might avoid the rank-dependent scheme 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 balls labeled 1 and 10 balls labeled 2, while urn B contained an unknown, but fixed distribution of those balls. Subjects then had to choose an urn and a number: If the number was drawn from urn B, subjects received 7.20 if the chosen number matched the drawn number and 1.20 otherwise; if the number was drawn from urn A subjects received ECU 6.90 if the chosen number matched the drawn number and ECU 0.90 otherwise. An ambiguity neutral subject should never choose urn A, the risky urn. Sufficient ambiguity aversion assuming symmetric beliefs would induce subjects to choose urn A. Note that the rewards were smaller in this bonus round than in the main experiment.

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 balls in the urn,[4] while half are presented with an "unambiguous" urn resulting in a purely risky environment.[5] We also informed them that the process of drawing balls from the urn will be simulated by the computer. They never learned the payoff or choices of the other participants. Prizes were chosen to equal the following amounts (in ECU, the exchange rate to Euro was 1ECU=0.4 €).

Schemes offered to the agents

All participants were presented with a choice between the four schemes introduced in the theoretical discussion above. The schemes were described

for any hypothesized winning probability. However, if a participant understands that a rank-dependent scheme 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.

[4]The 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.

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

using the following terminology:

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 receive 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 receive the higher or the lower amount.

Comprehension of Payment Options

To address the issue whether subjects fully understood the consequences of the contract options presented, we offered half of the agents in each of the ambiguous treatment a what-if calculator with which agents could enter beliefs over the composition of the urn and were shown the resulting probabilities over possible payments over each contract. Analogously, in the risky treatment we informed the agents about the associated probabilities, given the known composition of the urn. In order to evaluate the effectiveness of this treatment we included questions about the winning probabilities in a certain scenario.[6]

When presenting these schemes to the agents, we use the neutral term "payment option" and we also do not use any words or abbreviations that would have suggested a rank-dependent scheme 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

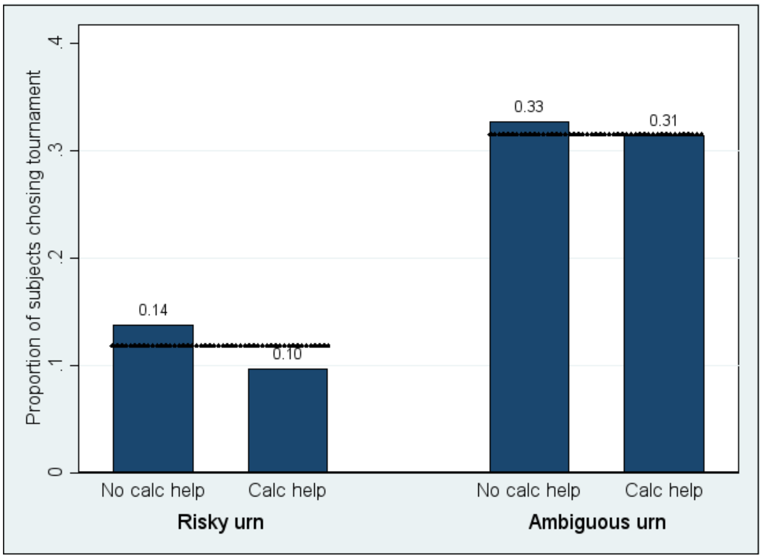
[6]We did not do so before the experiment in order to avoid experimenter demand effects that may lead to over-estimation of the true effect.

competitive situations and not how she feels about forcing others to compete. We decided to allow agents to choose between a few specific schemes instead of using a mechanism that elicited their willingness to pay, because we felt that agents may find it easier to understand direct choices than an abstract mechanism. This may be an important concern particularly under ambiguity aversion, because incentive compatible mechanisms such as 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 than when in situations in which their direct choices are used to elicit their attitude towards ambiguity.

Implementation

The experiment was programmed using zTree ((Fischbacher 2007)). In total 202 subjects in 13 session (16 subjects per session) from May 2010 until June 2010 participated in the experiment at the laboratory at the University of Jena. Participants were recruited via the ORSEE recruitment system ((Greiner 2004)). 52.9% of the participants were female. The experiment lasted 45 minutes and the average payment was 7.11 Euro with a maximum of 12.70 Euro and a minimum of 2.20 Euro.

4 Results



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

Figure 1: Tournament share over treatments

Figure 1 summarizes the shares of participants who chose the rank-dependent scheme in each of the four treatments in the experiment, as well as the pooled results over the ambiguous and the risky urn.[7] As our theory predicts, the rank-dependent scheme is chosen more often under ambiguity. Among those participants who did not face ambiguity regarding the output distribution, only 14% choose the rank-dependent scheme. Under ambiguity, the share of rank-dependent schemes chosen increased to 31%. A mean comparison test confirms that the difference between the ambiguous and the unambiguous environment is significant at the 1 percent level according to a χ^2-Test (and according to Fisher's distribution-free test).

Whether 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 rank-dependent schemes chosen dropped slightly from 33% to 31%). When agents know the output distribution, mathematical help decreases the share of participants choosing rank-dependent schemes (from 14% to 10%). The effect of ambiguity remains significant in both cases.[8] Hence, our experiment strongly confirms part a) of Hypothesis 1: Under ambiguity, rank-dependent schemes become more attractive than independent schemes.

The regressions in Table 1 further explain the choices of the participants. In particular, we also discuss to what 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 rank-dependent scheme, 0 if an agent chose an independent scheme).

The first regression includes only the effect of the key treatment variables on the share of rank-dependent schemes chosen. The effect of ambiguity is positive (0.19) and significant.[9] 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

[7] We do not find a significant difference between the two types of rank-dependent schemes or the two types of individual contracts chosen. Hence we report results only for the pooled contracts.

[8] 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.

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

Table 1: Linear Probability Model. Dependent variable: Rank-dependent scheme choice

	(1)	(2)	(3)	(4)	(5)	(6)
Ambiguous	0.193**	0.252**	0.198**	0.283***	0.284**	0.309**
	(0.083)	(0.109)	(0.080)	(0.105)	(0.134)	(0.134)
Calc	-0.038	-0.036	-0.030	-0.026	-0.075	-0.061
	(0.068)	(0.066)	(0.064)	(0.063)	(0.083)	(0.084)
Ambiguous × calc	0.022	0.015	0.013	0.003	-0.014	-0.020
	(0.112)	(0.112)	(0.112)	(0.112)	(0.143)	(0.145)
Not ambiguity averse		0.030		0.050	0.076	0.119
		(0.072)		(0.067)	(0.084)	(0.096)
Ambiguous × not amb.av.		-0.097		-0.138	-0.281**	-0.325**
		(0.120)		(0.117)	(0.140)	(0.151)
Female			0.080	0.093		0.014
			(0.088)	(0.089)		(0.114)
East			-0.009	-0.003		-0.015
			(0.085)	(0.087)		(0.110)
Female × east			-0.190*	-0.209*		-0.179
			(0.113)	(0.118)		(0.158)
Constant	0.167	0.142	0.143**	0.106	0.113*	0.132
	(0.130)	(0.145)	(0.071)	(0.081)	(0.066)	(0.097)
Session dummies	Yes	Yes	No	No	No	No
Control for mistake	No	No	No	No	Yes	Yes
Symmetric expectations	No	No	No	No	Yes	Yes
Observations	206	206	206	206	206	206
R^2	0.122	0.126	0.093	0.100	0.134	0.178

Robust standard errors in parentheses

Controlled for session effects and age in columns 1 and 2.

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

ambiguity (0.15) becomes insignificant for this group.[10]

The effect of offering mathematical help (calc) is small and insignificant: With help, subjects chose rank-dependent schemes in the risky environment slightly less often (so the number of people who behaved consistent with expected-utility maximization increased) while the difference in the rank-dependent scheme share between the risky and the ambiguous urn treatment increased 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 Hypothesis 1: Under ambiguity, rank-dependent schemes are more attractive. However, the evidence for part b) of Hypothesis 1 is less strong. The difference in the effect of the ambiguity treatment between agents for which the bonus round confirms that they are ambiguity averse and presumably ambiguity neutral agents is large but not statistically significant. Our data do not support the claim that ambiguity has an effect even for the agents who appear ambiguity neutral.

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 weaker financial consequences. Hence the effect of ambiguity aversion might outweigh the difference in expected prizes only in one of the two parts of the experiment for some participants who are almost indifferent between the contracts.

Second, it has been argued that demographic factors are correlated with attitudes towards comparative payment schemes. To control for this, the third and fourth regressions include additional demographic information about the participants (regression four allows the effect of ambiguity to differ according to the behavior in the second part of the experiment, 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 who are not ambiguity averse, since according to regression 4 the effect of the ambiguous treatment is 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 towards competitive payment schemes), participants behave somewhat more closely as both parts of our main hypothesis would suggest. The effects that these demographics have on the participant's propensity to choose rank-dependent schemes are as follows. There is no significant difference between males and females and between East and West Germans. However, females from East Germany choose rank-dependent schemes significantly less often than males from West Germany

[10] The share of people who appear ambiguity averse according to their Ellsberg choices is 41.7%.

(-0.11, the net effect of being a women 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 (such as 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. The results are available upon request.

Third, our post experimental questionnaire suggests that, even in the group which had the calculation aid available, one third (31.1%) of the participants was not aware of the fact that the distribution of balls in the urn is always irrelevant under the comparative reward scheme (Calculation aid did increase this awareness insignificantly, by 8.7 %). In regression 5 and 6 we show the regression coefficients that apply to participants who did not make this mistake.[11] (Regression 6 also considers the effect of demographics). Moreover, these columns consider only participants who did not expect an asymmetric distribution of balls in the urn, as these could prefer independent contracts even if ambiguity averse. For the group of participants defined in this way, the data fully supports both parts of Hypothesis 1. Ambiguity has a significant effect on the share of rank-dependent schemes for ambiguity averse participants (around 30 percent), but this effect is significantly lower for participants who are not ambiguity averse (where the net effect appears to be around zero.)[12]

5 Discussion

In our experiment we have focused so far on the effects of ambiguity on the agents' preferences between rank-dependent schemes and independent schemes. We found that in principle, ambiguity does effect the evaluation of such payment schemes, making rank-dependent schemes more favorable. Moreover, we find evidence that for the larger part of the participants this

[11] We used the answer to the following question: "Suppose you knew that more balls with a number 6 or above then balls with a number 5 or below are in the Urn. What is the probability to win the higher prize under the following option: You get ECU 24 if the number of your ball is larger then the number of the ball of your co-player. You get ECU 5 if the number of your ball is smaller. If both numbers are the same, a fair coin decides whether you get the higher or the lower prize. Answer options: a) above 50 percent b) 50 percent c) below 50 percent." Any answer other then b) is considered a mistake.

[12] In columns 5 and 6 of table 1 we do not report the coefficients for subjects who did make the mistake. The ambiguity treatment had a positive effect on the choice of the rank-dependent scheme (coefficient: 0.307, p-value: 0.004) for those subjects. In the ambiguous treatment, even an ambiguity neutral decision-maker could choose the rank-dependent payment scheme if he believes that the winning chances differ from 50% on average. For the case of the uniform distribution (as in the unambiguous treatment) it might be easier to infer that this is not the case. Moreover, this effect is somewhat weaker (coefficient for the difference: -0.155, p-value: 0.476) for the ambiguity averse subjects, as they may mistakenly perceive the rank-dependent scheme as ambiguous.

is due to ambiguity aversion. The difference between the choice of the rank-dependent scheme and the Ellsberg choices might be to some extent explained by an intrinsic attitude towards competition.

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 agents think about the strategy of the other player may 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 regarding 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 may be, in a sense, less risky than the best rank-dependent scheme (while it would still be more ambiguous than the optimal rank-dependent scheme). Hence, if the agent's risk aversion would be large in comparison to their ambiguity aversion, rank-dependent schemes may 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 Appendix

A.1 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.1.1 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 rank-dependent scheme is always $\frac{1}{2}$, irrespective of a, for the rank-dependent scheme 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.1.2 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 labeled 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 agent's 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 rank-dependent scheme still does not vary with the elements of Π (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 rank-dependent schemes 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 labeled 6 or above. Ambiguity aversion is modeled 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, rank-dependent schemes can be preferred only under ambiguity aversion.

A.1.3 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.

A.2 Robustness checks

The Logit regressions in Table (2) yield results similar to the OLS regressions in table (1).

Table 2: Logit Model. Dependent variable: Rank-dependent scheme choice

	(1)	(2)	(3)	(4)	(5)	(6)
Ambiguous	1.217**	1.646**	1.207**	1.758**	1.751**	2.018**
	(0.522)	(0.769)	(0.514)	(0.752)	(0.854)	(0.917)
Calc	-0.403	-0.360	-0.345	-0.284	-0.734	-0.602
	(0.635)	(0.642)	(0.630)	(0.639)	(0.787)	(0.814)
Ambiguous × calc	0.316	0.247	0.257	0.169	0.249	0.159
	(0.774)	(0.781)	(0.765)	(0.774)	(0.977)	(1.012)
Not ambiguity averse		0.323		0.395	0.730	1.022
		(0.685)		(0.665)	(0.770)	(0.797)
Ambiguous × not amb.av.		-0.667		-0.859	-1.830*	-2.219**
		(0.830)		(0.803)	(0.982)	(1.041)
Female			0.448	0.542		0.140
			(0.470)	(0.481)		(0.629)
East			-0.051	-0.023		-0.098
			(0.504)	(0.508)		(0.605)
Female × east			-1.311*	-1.434*		-1.550
			(0.737)	(0.748)		(1.012)
Constant	-1.709**	-1.981**	-1.829***	-2.145***	-2.143***	-2.113***
	(0.710)	(0.873)	(0.508)	(0.704)	(0.692)	(0.820)
Session dummies	Yes	Yes	No	No	No	No
Control for mistake	No	No	No	No	Yes	Yes
Symmetric expectations	No	No	No	No	Yes	Yes
Observations	206	206	206	206	206	206
R^2						

Standard errors in parentheses

Controlled for session effects and age in columns 1 and 2.

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

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