

The effect of the background risk in a simple chance improving decision model

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Abstract We experimentally investigate the effect of an independent and exogenous background risk to initial wealth on subjects' risk attitudes and explore an appropriate incentive mechanism when identical or similar tasks are repeated in an experiment. Taking a simple chance improving decision model under risk where the winning probabilities are negatively related to the potential gain, we find that such a background risk tends to make risk-averse subjects behave more risk aversely. Furthermore, we find that risk-averse subjects tend to show decreasing absolute risk aversion (DARA), and that a random round payoff mechanism (RRPM) would control the possible wealth effect. This suggests that RRPM would be a better incentive mechanism for an experiment where repetition of a task is used.

Keywords Background risk · Risk aversion · Opportunity effect · Wealth effect · Random round payoff mechanism

JEL classification D81 · C90 · C91

In this paper, we consider a simple chance improving decision model under risk, and experimentally investigate the effect of a background risk on subjects' decision behaviour. We attempt to address two different but entangled issues. First, we experimentally test a theoretical prediction on the effect of the independent and exogenous background risk to initial wealth. While there have been many theoretical studies on the effect of the background risk on risky choices (Pratt and Zeckhauser 1987; Kimball 1993; Eeckhoudt, Gollier and Schlesinger 1996; Gollier and Pratt 1996), only a few empirical studies exist (Guiso and Paiella 1999). Moreover, these empirical studies crucially depend on respondents' self-report on their background risk. This is due to the fact that the background risk in field data is hardly

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measurable. Hence, an experimental approach to this issue has an advantage in the sense that such a background risk can be manipulated. Furthermore, there has been no empirical or experimental study on the effect of the background risk in the situation where the winning probability of the gain is positively related to the giving-up amount among the potential gains.¹ Our study attempts to fill the gap.

There are many decision problems where the background risk would matter: portfolio building, insurance, auctions, pricing, mergers and acquisitions decisions, self-protection, and so on. Whatever the specific decision problem is, the main question is, “What is the impact of the background risk to initial wealth on a *risk-averse* person’s decision?” To concentrate on the basic question, we in this paper take a very simple and restrictive decision making model where the winning chances are positively related to a *giving-up amount among potential gains* and there is no loss of initial wealth.² We call this the *simple chance improving decision model*. In this model, a subject can choose how much he or she gives up among the potential gains in order to increase the winning probability of the gain. If he or she is rational and knows the probability distribution of the winning chance as an increasing function of the giving-up amount, he or she will choose the giving-up amount which maximises his or her expected utility. It would not be difficult to predict that the choice will depend on his or her risk attitudes. Thus, the choice could be also affected by whether a background risk exists to his or her initial wealth or not. We in this paper derive some basic theoretical predictions on the effect of the independent and exogenous background risk from this model and experimentally test the predictions. The experiment has been carefully designed to directly represent the decision situation in the model. In the experiment, subjects have to choose the giving-up amount (though the context is abstract) and we explicitly set the background risk as a treatment variable. In this way, we can directly test the theoretical prediction on the effect of the background risk on subjects’ behaviour.

Second, we also contribute to an experimental methodology issue. It has been an issue of debate whether a wealth effect exists in a laboratory experiment where a modest stake is used. The wealth effect exists if the accumulated wealth through rounds of an experiment affects subjects’ decision making.³ In theory, subjects should be approximately risk neutral in the case (e.g., see Friedman and Cassar 2004), but there has been much evidence to suggest that most subjects are risk averse even for such a modest stake (Holt and Laury 2002; Laury 2005; Harrison et al.

¹ In this kind of chance improving decision situation, the comparative static prediction is usually ambiguous and it crucially depends on the probability distribution of outcomes. The general comparative statics are analysed by McGuire, Pratt, and Zeckhauser (1991) where the decision situation problem is similar to ours in principle but different in some specific aspects. For example, their decision problem can be regarded as choosing an optimal expenditure with the possibility of the loss of the initial wealth while our problem is choosing an optimal giving-up amount among potential gains without the loss of the initial wealth.

² In the real world, there are a few situations similar to this. For example, consider a firm’s problem trying to merge with a company taking on its debt (instead of paying for the merge), a salesman who attempts to sell a car giving up a large part of his or her own potential profit, a job seeker who would be willing to lower his or her willingness-to-accept wage to take a job, and so on.

³ Repeating an identical or similar task has been one of the norms in economics experiments. Repetition is generally used for two purposes. First, it gives subjects an opportunity to learn about the experiment. Second, it gives experimenters an opportunity to get more data. Whatever the purpose is, experimenters are usually interested in subjects’ decision at the individual task. For more details, see Lee (2007).

2005; Binswanger 1980). If subjects are risk averse and do not show constant absolute risk aversion (CARA), an experimenter would need to control the possible wealth effect. In fact, whether the wealth effect exists or not directly decides which payoff mechanism has to be used in an experiment where repetition is used. In the repetition environment, there are two widely used payoff mechanisms which we could call the “accumulated payoff mechanism (APM)” and the “random round payoff mechanism (RRPM),” respectively. Under APM, subjects’ monetary rewards in the experiment are simply the sum of their monetary rewards of each round through the whole experiment. Most economics experiments have traditionally used APM. However, the wealth effect would exist and cannot be controlled under APM if subjects’ preferences are not risk neutral or CARA. By this reason, some experimenters have used RRPM. Under RRPM, subjects are given their monetary rewards based on one or only a few randomly chosen round(s) after a whole experiment has been completed. RRPM is also called “random lottery incentive mechanism” in the literature. Since the monetary earnings are not accumulated and not deterministic under RRPM, the wealth effect could be mitigated.

Grether and Plott (1979), which experimentally investigated the preference reversal phenomenon, was an example of the early use of RRPM and invoked the debate on the validity of RRPM in experiments related to the individual decision making context. While Holt (1986) raised a theoretical question that RRPM could not elicit subjects’ true preference if they are not expected utility maximisers (in the sense of violation of the independence axiom), the responding experimental studies reported that subjects tended to separate each task under RRPM and thus it could elicit subjects’ true preference (Hey and Lee 2005a, b; Cubitt, Starmer and Sugden 1998; Starmer and Sugden 1991). As a result, many recent experiments in an individual decision making context tend to use RRPM instead of APM.

However, a puzzling finding is that APM is still widely used in most experiments related to market and game theories. This seems to be due to the tendency that many game theorists and economists still presume that subjects are risk neutral in the experiment where a moderate stake is typically used. However, there is quite robust evidence that subjects are risk averse as we noted above. Thus, experimenters in such contexts may also need to carefully consider using RRPM instead of APM. This will depend on the answer to the more fundamental question of whether subjects show CARA preferences and RRPM could control the wealth effect in the case that subjects’ preferences are not CARA. While the previous studies on RRPM have focused on the validity of eliciting subjects’ true preference (implicitly assuming that RRPM can control the wealth effect), we directly address the fundamental question. The results from our experiment suggest that risk-averse subjects tend to follow decreasing absolute risk aversion (DARA) under APM, and that RRPM could control the wealth effect.

The next section presents the theoretical results and hypotheses to be tested. In this section, we introduce the simple chance improving decision model with more details. Assuming that the probabilities on outcomes are uniformly distributed, we theoretically show that DARA implies the decrease of the giving-up amount as initial wealth increases and that a risk-averse subject would behave more risk aversely if there is an independent and exogenous background risk to the initial wealth.

The experimental design to test these theoretical predictions is introduced in Section 2. In the experiment, subjects faced two different tasks in each round. One was the simple chance improving task which was introduced in the previous section (Task 1), and the other was a two-person game task (Task 2). Subjects were divided into two groups by the background risk treatment. We articulated the background risk treatment by using a different treatment on the earnings from Task 2. That is, the earnings from Task 2 were decided according to RRPM for one group while the earnings from Task 2 were accumulated through 10 rounds (APM) for the other. Hence, the former faced an independent and exogenous background risk at initial wealth in each round while the latter did not.

We find that most subjects are risk averse for the small stake and the risk-averse subjects behave more risk aversely when the background risk at their initial wealth exists. This confirms our theoretical prediction: that is, risk-averse subjects give up more potential gains to increase the winning probability under the background risk. Moreover, we also find that the risk-averse subjects tend to become less risk averse as their initial wealth is accumulated (that is, the wealth effect exists) but RRPM could control it. These results are presented in Section 3.

In Section 4, we summarise this study and discuss the implications of the results from our experiment. We conclude that the experimental method could be a good tool for testing the theoretical predictions on the effect of the background risk to wealth on subjects' behaviour while we deal with a quite restrictive decision situation. Moreover, we argue in terms of experimental methodology that our results suggest that experimenters would need to control the wealth effect and RRPM could work well for this purpose.

1 Simple chance improving decision model

In this section, we introduce the simple chance improving decision model and derive some theoretical predictions. The hypotheses, which are based on the theoretical predictions and will be experimentally tested, are also presented.

Suppose a subject whose preference follows the expected utility has the initial wealth of w_0 . Let us denote the maximum amount of potential gain by M , the giving-up amount by $x \in (0, M)$ and the probability distribution of winning the potential gain by $p(x)$. Note that the probability distribution is a function of the giving-up amount. Assume that $p'(x) > 0$ and $p''(x) \leq 0$: that is, the winning probability increases as the subject gives up more among the potential gains with a decreasing rate. Then the *risk-averse* subject whose preference is represented by von Neuman–Morgenstern utility function $u(\cdot)$ solves the following expected utility maximisation problem:

$$\text{Max}_{\{x\}} EU = p(x) \cdot u(w_0 + M - x) + (1 - p(x)) \cdot u(w_0) \quad (1)$$

where $u(\cdot) > 0$, $u'(\cdot) > 0$, and $u''(\cdot) < 0$. We find that the solution mainly depends on the property of $p(\cdot)$, and $p''(x) \leq 0$ is sufficient for the maximisation problem. To get a sharp and testable implication, assume that $p(x)$ is uniformly distributed for $x \in (0, M)$: thus, $p(x) = x/M$, $p'(x) = 1/M$, and $p''(x) = 0$. This assumption, while strongly restrictive, has merits in the experimental investigation: that is, the implication of the uniform

distribution is clear and hence it is easy to make subjects understand it. Moreover, it is easy to execute the distribution by using a simple random device. Furthermore, the prediction is sharp and clear.

The optimisation problem is a fairly standard one. So, we present the basic results without much explanation.

Proposition 1) A risk-neutral subject chooses $x_N = M/2$, and a risk-averse subject chooses $x_A > M/2$ at every initial wealth.

Proposition 2) A more risk-averse subject chooses a higher x_A : that is, he or she gives up more.

Proposition 3) If a risk-averse subject has a DARA preference (i.e., $u''' > 0$), then the optimal giving-up amount x_A decreases as his or her initial wealth w_0 increases.

Proposition 4) Suppose a mean-zero independent and exogenous background risk to the initial wealth w_0 : that is, $w_\varepsilon = w_0 + \varepsilon$ where $E(\varepsilon) = 0$. So ε can be regarded as a mean-preserving spread parameter. If $u''' > 0$ and $u'''' < 0$, then at every initial wealth level, a risk-averse subject whose initial wealth is under the background risk will give up more than one whose initial wealth does not have any risk. That is, $x_\varepsilon > x_A$ for every wealth level where x_ε denotes the optimal x under the background risk and x_A denotes the optimal x in the case that there is no background risk.

Proofs for these propositions are in Appendix A. Proposition 1 and 2 imply that a risk-averse (a more risk-averse) subject would be willing to give up more than a risk-neutral (a less risk-averse) subject does in order to increase the winning chance. This is intuitive given the definition of risk aversion. As it will become clear later, we manipulate our experimental design so that both propositions should hold rather than be tested. Proposition 3 confirms our intuition on the effect of the initial wealth on the choice of x . This proposition shows that every subject with DARA would decrease the giving-up amount as their initial wealth increases. This gives us an experimentally testable implication: DARA is consistent with the decrease of the giving-up amount x_A as the initial wealth is accumulated. So, if a risk-averse subject has a preference of DARA, the effect of an independent and exogenous background risk at any given wealth level is clear with the additional assumption as shown in Proposition 4. The additional assumption $u'''' < 0$ implies a decreasing absolute prudence. Note that $u''' > 0$ is a minimum requirement for Proposition 4. The theoretical prediction of Proposition 4 is our main hypothesis to be tested. We also empirically test whether subjects show DARA or not. This would make the test result more robust. In fact, $x_\varepsilon > x_A$ is compatible only with DARA preference. Moreover, whether subjects' risk aversion is DARA with a small stake which is typically used in laboratory experiments is a controversial issue in experimental economics methodology. While subjects would be risk neutral in theory, much empirical evidence shows that most subjects are risk averse even for small stakes. Thus, if an experimenter uses repetition, controlling the wealth effect through rounds arises as a methodological issue. If most subjects are risk neutral or have CARA, the experimenter may not need to worry about the wealth effect. However, if most

subjects have DARA or IARA (increasing absolute risk aversion), the experimenter should control the wealth effect since it would bias the experimental results. This is ultimately an empirical question. Our second hypothesis deals with this.

We summarise our hypotheses to be tested:

Hypothesis 1) Subjects behave more risk aversely if there is an independent and exogenous background risk to initial wealth. That is, they give up more potential gain under the background risk.

Hypothesis 2) Subjects show DARA as their initial wealth is accumulated, but RRPM could control the wealth effect by DARA preference.

2 Experimental design

This experiment was implemented in a computerised environment using the z-Tree software (Fischbacher 1999) in the EXEC laboratory at the University of York. The participants were undergraduates and postgraduates of the university. In this experiment, there were 48 subjects. Each subject had to choose a number in each of two similar but different tasks at each round through 10 rounds. The first task was an individual decision making problem and the second was a two-person game. We call the former *Task 1* and the latter *Task 2*. The design of the experiment is summarised in Table 1. Using a 2 by 2 treatment design, there were 4 groups with 12 subjects each. The average duration of the experiment for each group was 40 minutes, and subjects’ average earnings were £7.72 for the experiment as a whole.

The basic payoff structure for both tasks follows:

$$p = \begin{cases} c \cdot (m - x) & \text{if } x > y \\ \frac{c}{2} \cdot (m - x) & \text{if } x = y \\ 0 & \text{if } x < y \end{cases} \quad (2)$$

where p denotes the payoff, m is the reference number, $x \in [1, 10]$ is the integer number which the subject decides and $y \in [1, 10]$ is the random integer number from

Table 1 Experimental design

Groups ^a	Subgroups	Number of Subjects	Number of Rounds ^c	Payoff mechanism for Task 1	Payoff mechanism for Task 2	Matching for Task 2
APM group ^b	APM&Partner	12	10	RRPM	APM	Partner
	APM&Stranger	12	10	RRPM	APM	Stranger
RRPM group ^b	RRPM&Partner	12	10	RRPM	RRPM	Partner
	RRPM&Stranger	12	10	RRPM	RRPM	Stranger

^a APM and RRPM represent the accumulated payoff mechanism and the random round payoff mechanism, respectively.

^b For the purpose of this paper, we find that it is natural to pool the data. So, we pool APM&Stranger group and APM&Partner group and call them APM group. We define RRPM group by the same way.

^c Each round consists of two tasks: Task 1 and Task 2.

the uniform distribution (Task 1) or the integer number which the partner chooses (Task 2). The c is a conversion rate. Suppose we set $m=12$ and $c=£1$. Following the logic of our basic model in Section 2, we can easily derive the implications from this set-up: In Task 1, a risk-neutral subject will choose 6 while a risk-averse [risk-loving] subject will choose a number higher [lower] than 6. And, a more risk-averse subject would choose a higher number. Of course, the implications of Proposition 3 and 4 are also valid. In Task 2, the unique Nash equilibrium is that both players choose 10. It can be shown that this equilibrium is dominant solvable by iteratively eliminating weakly dominated strategies. Since subjects' behaviour in Task 1 is of our main concern, we do not present the results in Task 2 which are dealt with in more detail in Lee (2006). In our actual experiment, we used slightly different number sets in order to avoid the flat payoff problem (Harrison 1989). However, the interpretation of the data is not affected by this, and hence we proceed in this paper with the number sets introduced above.⁴

For Task 2, the accumulated payoff mechanism (APM) has been used for half of the subjects and the random round payoff mechanism (RRPM) for the other half.⁵ We call the former the *APM group* and the latter the *RRPM group*. For Task 1, all subjects faced an identical treatment: RRPM.⁶ Hence, in terms of Task 1, there were only two comparable groups of the *APM group* and the *RRPM group*. The only difference between these two groups was the payoff mechanism used for Task 2.

Subjects' total earnings from the experiment were the sum of their cash earnings in Task 1 and Task 2. Note that the earnings in the randomly chosen round are multiplied by 10 when RRPM is used for Task 1 and Task 2. The APM group faced a decision problem for Task 1 in each round with a certain amount of initial wealth from Task 2 which was accumulated through rounds. However, the RRPM group faced Task 1 in each round with a risky initial wealth since RRPM implies that the initial wealth from Task 2 is risky. Since we equated the expected earnings of APM and RRPM for any identical decision, it can be easily seen that RRPM induces a mean preserving spread payoff distribution of APM (Lee 2006). Thus, the RRPM group faced an independent and exogenous background risk to initial wealth while the APM group did not.

The implication of this design is straightforward. In each round, the RRPM group faces Task 1 with the background risk at the earnings from Task 2 while the APM group faces Task 1 with a certain amount of accumulated earnings from Task 2.

⁴ We actually used the set of numbers {2, 4, 5, 6, 7, 8, 16, 21, 24, 27} for x and y , 35 for m , and 40 pence (4 pence multiplied by 10 since the actual earnings for Task 1 are multiplied by 10 as explained below) for c in the actual experiment. In this paper, we need to consider these numbers when we estimate the risk aversion coefficient using a utility functional.

⁵ For Task 2, there was one more treatment related to matching as shown in Table 1: Strangers vs. partners. But, for the purpose of this paper, we find that it is natural to pool the data. So, we pool APM&Strangers and APM&Partners to define the APM group. We define the RRPM group by the same way.

⁶ The real earnings for Task 1 in the actual experiment were decided by the following manner: subjects choose a number x at each round, a round is randomly drawn by each subject after the experiment is completed, a random number y at the round is randomly drawn by the subject, the earnings in the round are computed according to the equation (2) using the actual numbers used in the experiment, and then those are multiplied by 10.

Moreover, the effect of wealth accumulation from Task 2 would be diluted under RRPM. Hence, the experimental version of the hypotheses in Section 1 follows:

Hypothesis 1.1) Choice numbers of the RRPM group are higher than those of the APM group.

Hypothesis 2.1) The wealth effect exists under APM (DARA under APM) while it would be diluted under RRPM.

3 Experimental results

3.1 Categorising risk attitudes

Since the theoretical predictions critically depend on subjects' risk attitude and our main concern is with risk-averse subjects' behaviour, we first need to categorise subjects' risk attitudes. For an illustration, we calculate the interval of the constant absolute risk aversion coefficients for each decision number in Task 1. This is shown in Table 2. It shows that a risk-neutral subject would choose 6 while a risk-averse [risk-loving] subject would choose a number higher [lower] than 6 and that a more risk-averse subject would choose a higher number. This implies that our Propositions 1 and 2 naturally hold as a result of our experimental design.

In principle, we can categorise and get an interval estimate of subjects' risk attitudes directly from the above if subjects' preference is CARA and it is consistent. However, our data shows that subjects' decisions tend to be inconsistent through rounds: that is, most subjects change the choices through rounds.⁷ Of course, it is not surprising for a subject in the APM group to change a decision through rounds because there may be a wealth effect if his or her preference is not CARA. But our data shows that there is a more problematic inconsistency that subjects' preferences oscillate between risk loving and risk aversion. This cannot be explained by the wealth effect. If RRPM is used for Task 2 and a subject's preference is EU, then the independence axiom implies that he or she should make an identical choice through rounds (that is, RRPM controls the wealth effect). Though it is not impossible that the subject makes different decisions at each round under RRPM if his or her preference is not EU and he or she does not separate each decision task, the previous experimental studies do not support this possibility (Hey and Lee 2005a, b; Cubitt, Starmer and Sugden 1998; Starmer and Sugden 1991). Thus, we conjecture that there is a noise when subjects make a decision, and need to incorporate it in categorising subjects' risk attitudes (Hey and Orme 1994; Harless and Camerer 1994; Loomes, Moffatt and Sugden 2002).

⁷ It is well known that subjects' choices in experiments are in general not constant when they repeatedly make a choice for the same risky decision problems (Isaac and James 2000).

Table 2 Relationship between decision numbers and risk attitudes

Decision numbers for Task 1	R_A (i.e., q)	Risk attitudes
1	Stochastically dominated	–
2	$q < -1.73$	Extreme risk loving
3	$-1.73 < q < -1.01$	Very risk loving
4	$-1.01 < q < -0.72$	Moderate risk loving
5	$-0.72 < q < -0.55$	Slight risk loving
6	$-0.55 < q < 0.16$	Risk neutral
7	$0.16 < q < 0.23$	Slight risk averse
8	$0.23 < q < 0.26$	Moderate risk averse
9	$0.26 < q < 0.53$	Very risk averse
10	$q > 0.53$	Extreme risk averse

Each interval has been computed with the CARA functional, $U(x) = \frac{-e^{-qx}}{q}$ using the number sets which actually were used in the experiment: {2, 4, 5, 6, 7, 8, 16, 21, 24, 27} for x and y , 35 for m , and 40 pence for c .

One way to incorporate the noise is to fit a flexible utility function to our data. Suppose that subjects’ utility function follows an expo-power type (Saha 1993):

$$u(w) = \frac{1 - \exp(-\alpha w^{1-\gamma})}{\alpha} \tag{3}$$

where w includes the accumulated initial wealth until the previous round (w_0) and the possible payoffs at the current round for the option i (p_i), i.e. $w = w_0 + p_i$. It can be easily shown that this utility function implies CARA as γ goes to 0 while it implies CRRA as α goes to 0. Moreover, this utility function can represent various types of risk aversion according to the relationship of the signs of α and γ . For example, the utility functional implies DARA and IRRRA (increasing relative risk aversion) if both α and γ are positive while it implies IARA (increasing absolute risk aversion) and IRRRA if α is positive and γ is negative. It is possible to estimate the parameters incorporating a noise by using the error response model suggested by Holt and Laury (2002). This model implies that the probability of choosing option i among our 10 possible options is

$$Pr(\text{choosing option } i) = \frac{EU(w_0 + p_i)^{1/\mu}}{\sum_{j=1}^{10} EU(w_0 + p_j)^{1/\mu}} \tag{4}$$

where $i, j=1, 2, \dots, 10$ and the parameter μ represents a noise: the choices will be random among 10 options as μ goes to infinity while an option with the highest expected utility is chosen as μ goes to 0.⁸ We estimated three parameters for each subject by applying maximum likelihood estimation subject by subject. However, our data (i.e., 10 observations for each subject) was insufficient to get a robust result. This implies that categorising subjects’ risk attitudes only by this method would not be convincing enough.

⁸ For the estimation, we calculated the payoff p_i using the actually used decision numbers in the experiment: $x=\{2, 4, 5, 6, 7, 8, 16, 21, 24, 27\}$, $m=35$ and $c=40$ pence.

The second way to incorporate the noise is to run interval estimation for the risk aversion coefficients shown in Table 1 assuming that subjects' preference is CARA. This is possible since each decision number can represent the interval of the CARA coefficient. Thus if we denote the exact value of the CARA coefficient by α^* , the probability that α^* lies in the interval $(a_j, a_{j+1}]$ is derived as follows:

$$\Pr(a_j < \alpha^* < a_{j+1}) = F^*(a_{j+1}) - F^*(a_j) \quad (5)$$

where $F(\cdot)$ denotes the cumulative distribution function of α^* , $j=0, 1, \dots, 8$. Note that $a_0=-\infty$ and $a_8=\infty$. Assuming that the errors are normally distributed and excluding the stochastically dominated decision ($x=1$), we can derive the log-likelihood function and get the estimation results for each subject by using the maximum likelihood method. However, as the case of the estimation of the expo-power utility function, the data is not enough and thus using only this method would not provide a credible categorisation. While this method is more directive in categorising risk attitudes, we cannot directly estimate whether subjects' preference is CARA or not in both the individual level and the aggregate level since we presume CARA.

We add a supplementary third categorisation method which we call a modified mode method since we do not have enough data. By this method, we categorise each subject's risk attitude by the modified mode. That is, through 10 rounds, a subject who chooses the number 6 most frequently is categorised as *risk neutral*, and a subject who chooses a number greater [less] than that number most frequently is categorised as *risk averse* [*risk loving*]. Some would argue that this method would be biased since only the number 6 allows risk neutrality while any integer number between 7 and 10 allows risk aversion. However, it should be noted that a risk-neutral preference has a strong robustness because it is only concerned with the first moment while the degree of risk aversion (or risk loving) is easily affected by the change of the higher moments: DARA preference is an example. It is also possible that a subject has preferences with a random variation (Loomes, Moffatt and Sugden 2002). In that case, a risk-neutral subject is not affected by such a preference variation, but a risk-averse [risk-loving] subject is affected by it so that his or her degree of risk aversion [risk loving] could change. We believe that this would be sufficient to justify the validity of the modified mode for the categorisation.

As a result, we categorised subjects' risk attitudes by the following two steps. First, we estimated each subject's risk aversion by the expo-power utility estimation or the interval estimation. If the estimation results were significant, then we categorised his or her risk attitude following the results. Then, we used the modified mode method for subjects on which the estimation did not provide a significant result. We believe that this strategy would lead to a satisfying categorisation of risk attitudes though it is difficult to estimate each individual's risk aversion types (i.e. whether each subject's preference is CARA or not). Table 3 summarises the categorisation results. We in this paper use the categorisation using Method I (the expo-power utility estimation supplemented by the modified method). Note that using the other categorisation methods presented in Table 3 hardly changes the qualitative results. By Method I, there are 29 risk-averse subjects and 16 risk-neutral subjects.⁹

⁹ There was one risk-loving subject and two subjects' risk attitude was indecisive.

Table 3 Categorisation of subjects’ risk attitudes

Risk attitudes	Method I	Method II	Method III
Risk averse	29	28	26
Risk neutral	16	15	19
Risk loving	1	4	1
Indecisive	2	1	2
Total	48	48	48

Method I uses the expo-power utility estimation and the modified mode. Method II uses the interval estimation and the modified mode. Method III uses the modified mode.

Before we tested the hypotheses, we ran an estimation of the expo-power utility parameters using the aggregate data of risk-averse subjects. The estimation results are shown in Table 4. Recall from equations (3) and (4) that the value of μ decides the degree of noise and the values of α and γ decide the type of risk aversion. The second column shows the estimation results for all the rounds. We can find that there is a significant noise ($\mu=0.205$) and subjects show IARA and IRRA preference since α is positive and γ is negative. These results are contrary to our intuition. We suspect that the noise crucially affects these results. Thus, we use subjects’ answers on the post-experiment questionnaire: the average round in which the learning process was completed was 2.292 according to their report. Accordingly, we estimated the parameters by excluding the data up to the second round. The results are presented in the third column. Most of all, the noise parameter ($\mu=0.073$) is remarkably reduced as consistent with the subjects’ reports. The estimation results are also changed. Since both α and γ are positive, we find that risk-averse subjects show DARA and IRRA consistent with the results of Holt and Laury (2002).

3.2 Analysis on hypothesis 1

Our first hypothesis indicates that risk-averse subjects would choose a higher number under RRPM than under APM and that risk-neutral subjects’ behaviour would not be different between RRPM and APM. The number of risk-averse subjects is 14 in the RRPM group and 15 in the APM group. Their choices for Task 1 in each round are shown in Table 5 and Figure 1. For most rounds, there is a clear difference of chosen numbers between the RRPM group and the APM group: the mean chosen numbers of the RRPM group are clearly higher than those of the APM group. This difference is significant by the Mann–Whitney test ($p=0.022$). The result is qualitatively the same even if we exclude the decisions in the sixth round which looks like an outlier.¹⁰ Hence, this result supports our first hypothesis: risk-averse subjects in the RRPM group give up more (i.e., behave more risk aversely) than those in the APM group do. Recalling that the difference of payoff mechanisms

¹⁰ At this round, the abrupt decrease of the mean chosen number in the APM group is not a result of one or two subjects’ choice. Most subjects in the APM group decreased the number accidentally. So, it is more appropriate to exclude all data in the sixth round if we consider it as an outlier. In this case, the difference is still significant ($p=0.089$). If we exclude the data up to the second round as we did in the previous subsection, the qualitative results do not change but the statistical significances are improved: $p=0.004$ in the case including the sixth round, and $p=0.021$ in the case excluding the sixth round.

Table 4 The expo-power utility estimation results for risk-averse subjects

Risk-averse subjects		
	Whole round (Obs.=290)	Round ≥ 3 (Obs. =232)
μ	0.205 ^a (0.031)	0.073 ^a (0.017)
α	0.125 ^a (0.034)	0.487 ^a (0.091)
γ	-0.369 ^b (0.183)	0.482 ^a (0.130)
Log-likelihood	-559.81	-443.49

Standard deviation in parentheses. Parameters are estimated using the expo-power utility functional, $u(w) = \frac{1 - \exp(-aw^{1-\gamma})}{1-\gamma}$, and μ is a noise parameter. Note that the value of μ decides the degree of noise and the values of α and γ decide the type of risk aversion. The utility function implies CARA as γ goes to 0 while it implies CRRA as α goes to 0. Moreover, this utility function can represent various types of risk aversion according to the relationship of the signs of α and γ . For example, the utility functional implies DARA and IRRA (increasing relative risk aversion) if both α and γ are positive while it implies IARA (increasing absolute risk aversion) and IRRA if α is positive and γ is negative. There is no noise if μ is 0, and the noise becomes larger as μ increases.

For the estimation, we used the actual decision numbers of $x=\{2, 4, 5, 6, 7, 8, 16, 21, 24, 27\}$, $m=35$ and $c=40$ pence.

^a Significant at 1% significance level.

^b Significant at 5% significance level.

is only in Task 2 (i.e., RRPM has been used for Task 1 in all sessions), this result implies that the existence of an exogenous risk at initial wealth imposed by RRPM could make people behave more risk aversely.

For purposes of comparison, the numbers chosen by risk-neutral subjects can be compared between the RRPM group (n=8) and the APM group (n=8). This is shown in Figure 2. Since the riskier environment induced by RRPM is not relevant to risk-neutral subjects, it is predicted that there is no difference between the RRPM group and the APM group. As predicted, the null hypothesis that there is no difference between them cannot be rejected (p=0.797).

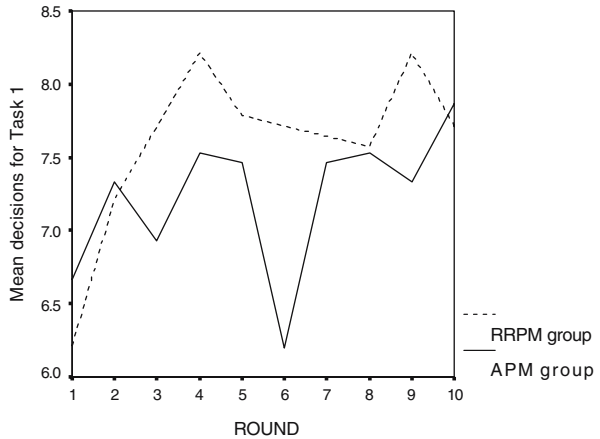
The implication of this result seems to be clear. Risk-averse people tend to behave more risk aversely if their exogenous initial wealth faces a risk. For example, a risk-averse company, which is to merge with another firm and take its debt, would try to take more debt to increase the chances of a successful merger if it were to face a background risk to its wealth. A risk-averse job seeker who confronts a background risk to his or her

Table 5 Risk-averse subjects' average chosen numbers for Task 1

Groups	Round									
	1	2	3	4	5	6	7	8	9	10
APM	6.67	7.33	6.93	7.53	7.47	6.20	7.47	7.53	7.33	7.87
group	(1.18)	(1.29)	(1.03)	(0.99)	(1.41)	(1.97)	(1.41)	(1.30)	(2.19)	(1.51)
RRPM	6.21	7.21	7.71	8.21	7.79	7.71	7.64	7.57	8.21	7.71
group	(2.12)	(1.12)	(2.43)	(1.81)	(1.81)	(1.98)	(1.98)	(1.99)	(1.42)	(2.16)

Standard deviation in parentheses. APM and RRPM represent the accumulated payoff mechanism and the random round payoff mechanism, respectively.

Fig. 1 Risk-averse subjects' choice for Task 1. Note: APM and RRPM represent the accumulated payoff mechanism and the random round payoff mechanism, respectively. The decision for Task 1 is an integer $x \in [1, 10]$



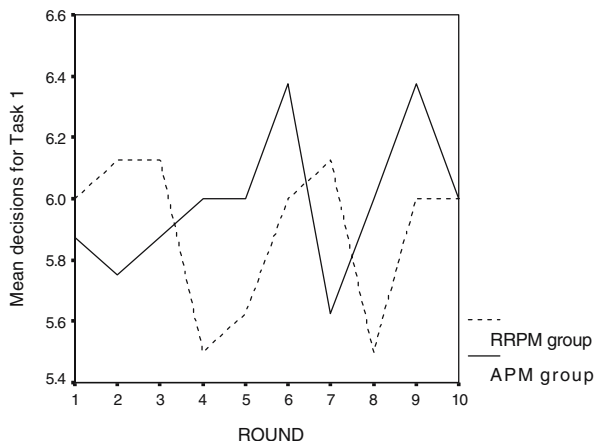
wealth would reduce his or her willingness-to-accept wage. An investor who has real estate as initial wealth would behave more conservatively in a risky stock market if the price of his real estate were at risk. Of course, it should be noted that this result is subject to our strong restriction on $p(x)$. In fact, McGuire, Pratt and Zeckhauser (1991) show that a $p(x)$, which would lead to a contrary result to ours, could exist. Still, we believe that our results contribute to the literature in that we first (to our knowledge) suggest the evidence supporting the theoretical prediction on the relationship between a chance improving behaviour and a background risk.

3.3 Analysis on hypothesis 2

Now, we test our second hypothesis using a simple regression analysis. That is, we test that there could exist a wealth effect under APM (especially, DARA) while RRPM could control or mitigate it.

The relationship between subjects' risk attitudes and an initial wealth effect has been one of the topics of debate in experimental economics literature. Do we need to

Fig. 2 Risk-neutral subjects' choice for Task 1. Note: APM and RRPM represent the accumulated payoff mechanism and the random round payoff mechanism, respectively. The decision for Task 1 is an integer $x \in [1, 10]$



control for the wealth effect in a laboratory experiment where a modest payoff is typically used? Many experimenters argue *no*, since subjects must be approximately risk neutral for such a modest payoff (e.g., see Friedman and Cassar 2004). However, many experimental studies report that a high proportion of subjects are risk averse even for such low stakes (Holt and Laury 2002; Laury 2005; Harrison et al. 2005; Binswanger 1980). Of course, if subjects' risk aversion is constant with initial wealth, then we still do not need to control the wealth effect.¹¹ However, this is an empirical question: that is, we do not know whether subjects' preference is increasing or decreasing with initial wealth. If we allow the possibility that a subject's risk aversion is decreasing with initial wealth for low stakes, then the wealth effect could exist for such low stakes, and hence we need to control it.

Our experiment could give us a clue to the answer to this question. We already found that more than half of the subjects in our experiment could be categorised as *risk averse* for the small payoffs used in our experiment. We also found evidence suggesting that the risk-averse subjects as a whole would show DARA preference. In this section, what we want to know is whether these risk-averse subjects' behaviour is affected by accumulated wealth during an experiment under a more articulate definition of the wealth effect. That is, we want to isolate the pure effect of the accumulated wealth up to a particular round from the effects of the concern with the future opportunities for accumulating wealth and of a learning process. *This basically can be done by investigating the relationship between subjects' choices for Task 1 in each round and the accumulated earnings from Task 2 up to that round.* Hence, APM for Task 2 represents a situation where the wealth effect is not controlled (i.e. the accumulation of certain amounts of initial wealth through rounds) while RRPM for Task 2 represents a situation where it is controlled (i.e. no accumulation of certain amounts of initial wealth through rounds).

Our prediction is that under the APM treatment for Task 2, if the wealth effect exists, then subjects' chosen numbers for Task 1 will decrease as their accumulated initial wealth from Task 2 increases, implying that their preferences show DARA for an initial wealth level. However, the RRPM treatment for Task 2 could control such a wealth effect, and hence subjects' choices for Task 1 will not be affected by the increase of initial wealth from Task 2.¹²

We can construct a linear regression model to test the wealth effect as below:

$$z_i = \beta_0 + \beta_1 r_i + \beta_2 w_i + \beta_3 p_i + \beta_4 g_i + \beta_5 d_i + u_i \quad (6)$$

where z_i is the subject i 's choice number in each round for Task 1, r_i is the round in which the subject chooses the number for Task 1, w_i is subject i 's pounds value of accumulated earnings (from Task 2) up to that round, and p_i , g_i and d_i are dummy variables for experience (experience=1), gender (male=1) and major (economics and PEP=1), respectively. Here, the variable r_i is a proxy variable representing the round

¹¹ For example, see Cox and Grether (1996). They report that there is no significant wealth effect in their experiment on preference reversal.

¹² It should be noted that we are here investigating whether the *increase* of wealth from Task 2 affects subjects' decisions for Task 1. Thus this is a different question from our first hypothesis which is related to the effect of riskiness in an initial wealth level between APM and RRPM.

effect including the effects of learning and of subjects' perception on future earning opportunities.

We cannot completely exclude a learning process through rounds though Task 1 is, we believe, quite easy to understand and there is no feedback (e.g. Loomes and Sugden 1998). We call this the *learning effect*. Moreover, a subject's perception at each round on future earning opportunities could affect her current decision, and we call this the *opportunity effect* (Lee and Lima 2004). That is, making decisions round after round would imply the decrease of remaining earning opportunities. Consider a subject in the APM group. The subject could earn deterministic wealth from Task 2 as rounds proceed. However, at the same time, the fact that rounds proceed also implies that his or her remaining opportunities to increase wealth decrease. Suppose that the subject is to make a decision for Task 1 in the first round. He or she does not have any initial wealth at the moment but has 10 opportunities for future earnings from Task 2 by which he or she could increase wealth.¹³ Hence, if his or her risk aversion is decreasing with wealth, the zero initial wealth may lead him or her to behave more risk aversely while the ten future earning opportunities decrease his or her risk aversion toward any risky choice. Given that RRPM has been used for Task 1 regardless of the payoff treatments used for Task 2, the choice behaviour for Task 1 must represent subjects' risk attitudes after subjects contemplate both the initial wealth and the chance for future earnings from Task 2. Related arguments in terms of experimental methodology can be found in Holt and Davis (1993, pp.84–85), and in Gollier (1996) in terms of theoretical economic applications. But, the effect of the perception related to the future opportunities must be diluted under RRPM since only the choice(s) in the randomly chosen round(s) would decide a subject's final payoff. Thus, RRPM would control the opportunity effect as well as the wealth effect.

This argument suggests that we need to consider both the opportunity effect and the wealth effect. Moreover, we need to isolate the opportunity effect from a learning effect in the round effect. In order to do this, we used subjects' answers for the questionnaire on when they learned the structure of Task 1, which was given after they completed the experiment. We used the average number of rounds in which subjects answered that they completed learning about Task 1. According to their reports, this average was 2.292. Hence, we conjecture that learning for Task 1 was completed after the second round on average, and as a result the learning effect would not exist from the third round. If we run a regression for the samples only from the third to the final round, then the round effect would represent only the opportunity effect excluding the learning effect. Therefore, if our hypothesis is right, then there will be a significant positive round effect under APM while the round effect will not be significant under RRPM.

There were 15 risk-averse subjects in the APM group and 14 in the RRPM group. We separately ran a simple linear regression for each group. The regression results

¹³ It should be noted that there is no possibility that subjects lose money in future rounds and subjects know that in advance. In fact, most experiments are not allowed to make subjects lose money. Of course, money for initial wealth may be given by an experimenter before the experimental session in that case. However, this could also bring up an empirical question called the "house money effect": a tendency that subjects may behave less risk aversely (e.g., higher marginal propensity to consume or more risky investment) with such a given endowment than with their own endowment (Clark 2002; Thaler and Johnson 1990).

Table 6 Regression results for Task 1 (from third round)

Coefficients	Risk-averse Subjects		Risk-neutral Subjects	
	APM group (<i>n</i> =120)	RRPM group ^a (<i>n</i> =112)	APM group (<i>n</i> =64)	RRPM group ^a (<i>n</i> =64)
Constant ^b	7.53 ^c (0.512)	8.48 ^c (0.579)	5.43 (0.623)	5.72 (0.436)
Round	0.211 ^c (0.078)	0.003 (0.091)	0.006 (0.059)	0.008 (0.046)
Accumulated earnings	-0.442 ^d (0.176)	-0.049 (0.216)	0.062 (0.097)	0.042 (0.107)
Experience (Experienced=1)	-0.386 (0.313)	-0.134 (0.371)	-0.063 (0.380)	0.344 ^c (0.200)
Gender (Male=1)	-0.977 ^c (0.326)	-0.098 (0.389)	0.204 (0.409)	-0.275 (0.349)
Major (Economics&PEP=1)	-0.594 ^c (0.346)	-1.445 ^c (0.412)	0.335 (0.376)	0.187 (0.222)
<i>R</i> ²	0.13	0.14	0.02	0.09

Standard errors in parentheses. APM and RRPM represent the accumulated payoff mechanism and the random round payoff mechanism, respectively.

^a Corrected for autocorrelation

^b Constants have been tested for the alternative hypothesis H_1 : Constant >6 against the null hypothesis H_0 : Constant=6 which implies risk neutrality.

^c Significant at 1% significance level.

^d Significant at 5% significance level.

^e Significant at 10% significance level.

Dependent variable = the chosen numbers for Task 1

are summarised in Table 6. We also include the regression results for risk-neutral subjects in the APM group and the RRPM group for the purpose of comparison.

In the APM group, risk-averse subjects' choices for Task 1 significantly decrease as accumulated earnings increase, which implies that there is a significant wealth effect. As accumulated earnings increase by £1, the number chosen for Task 1 decreases by 0.442 and it is significant. Recalling Proposition 3, we can conclude that subjects' choice behaviour becomes less risk averse as their initial wealth is accumulated. The round effect is also significant, indicating that the number for Task 1 increases by 0.211 as rounds proceed which means that subjects become more risk averse as the number of remaining rounds decreases. Because we isolated the opportunity effect from the learning effect in the round effect, this seems to support that the negative opportunity effect exists under APM.

In the RRPM group, risk-averse subjects' choices for Task 1 also decrease as accumulated wealth increases, but it is not significant implying that we cannot reject the null hypothesis that the wealth effect does not exist.¹⁴ Moreover, we find that for risk-averse subjects, the round effect is not significant under RRPM. Since we can regard this round effect as the opportunity effect, we may conclude that there is the opportunity effect under APM, but RRPM controls it. This result is in accordance with our hypothesis and supports the idea that subjects may separate each task under

¹⁴ One would argue that subjects' decisions in the RRPM group are affected by the potential earnings even if they are not influenced by the accumulated earnings: under RRPM, the potential earnings would be cognitively more relevant than the accumulated earnings. We ran a regression using the potential earnings for the RRPM group, and the results do not change qualitatively: RRPM controls the effect of the potential earnings too. We also ran a regression including both the accumulated earnings and the potential earnings for each group, and the results were qualitatively identical to those which we present here.

RRPM: at least, subjects may not consider future earning opportunities when they face a current decision under RRPM. The results also partially support Gollier (1996)'s theoretical prediction that a risk-averse EU maximiser will behave less risk aversely if there are remaining opportunities for identical and independent risky gambles.¹⁵

The accumulated wealth effect is insignificant for risk-neutral subjects regardless of the payoff mechanisms. Moreover, our prediction that the opportunity effect would be insignificant for risk-neutral subjects is supported.

Hence, we conclude that only risk-averse subjects under APM sessions are affected by initial wealth accumulation through rounds (specifically, they show DARA), and that RRPM could control the initial wealth effect for risk-averse subjects. Thus, our *Hypothesis 2* is supported.

4 Conclusion

In this paper, we attempted to fill the gap between many theoretical studies and the little empirical evidence on the effect of the independent and exogenous background risk to wealth. Moreover, we tackled an important issue in the experimental economics methodology: whether subjects show DARA in laboratory experiments and whether RRPM can control the wealth effect.

We found that the background risk makes subjects behave more risk aversely in our very simple chance improving decision situation. While our set-up of the probability distribution of outcomes may be quite restrictive, the test result is clear: it unambiguously supports the theoretical prediction on the effect of the background risk given the particular probability distribution. This result becomes more robust with findings that subjects tend to show DARA as their initial wealth is accumulated. It is a little striking in the theoretical sense that subjects show DARA in a laboratory experiment where a moderate stake is used. However, it was already striking that many experimental studies have found that most subjects were risk averse in the same environment. In fact, this issue is ultimately an empirical one which could be settled after evidence is accumulated. In the meantime, it would be a better strategy for an experimenter to control the possible wealth effect. We in this paper found that RRPM would work well for this purpose. Our result suggests with the previous experimental studies on the effect of RRPM (Hey and Lee 2005a, b; Cubitt, Starmer and Sugden 1998; Starmer and Sugden 1991) that RRPM could be a valid and better payoff mechanism under repetition in individual decision making experiments.

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¹⁵ If the remaining opportunities (e.g. lotteries) are not identical while those are independent, the answer could be the opposite since such remaining lotteries could be regarded as a background risk. For analysis on the background risk, see Gollier (2001), Eeckhoudt, Gollier, and Schlesinger (1996), and Pratt and Zeckhauser (1987).

Appendix

Appendix A: Proofs of propositions

(Proof of Proposition 1) First we show that $x_N=M/2$. Define $D(x) = u(w_0 + M - x) - u(w_0) - x \cdot u'(w_0 + M - x)$. For a risk-neutral person, $(u(w_0 + M - x) - u(w_0))/(M - x) = u'(w_0 + M - x)$. Hence, $D_N(x_N) = u(w_0 + M - x_N) - u(w_0) - x_N \cdot (u(w_0 + M - x_N) - u(w_0))/(M - x_N) = 0$. Solving this gives $x_N=M/2$. Now we show that $x_A>M/2$. Since $x_N=M/2$, we need to check $D_A(x_N)$. Note that for a risk-averse person, $(u(w_0 + M - x) - u(w_0))/(M - x) > u'(w_0 + M - x)$. Hence, $D_A(x_N) - D_N(x_N) = D_A(M/2) = u(w_0 + M/2) - u(w_0) - M/2 \cdot u'(w_0 + M/2) > 0$. But, $dD_A/dx < 0$ by SOC. Hence, To satisfy $D_A(x_A)=0$, x_A should be higher than $x_N = M/2$. Thus, $x_A>M/2$. (Q.E.D.)

(Proof of Proposition 2) Define $v=k(u(\cdot))$ where k is a concave transformation of $u(\cdot)$, i.e., $k(\cdot)>0$, $k'(\cdot)>0$, and $k''(\cdot)<0$. Hence, $k(u)/u > k'(u) \Leftrightarrow k(u) > u \cdot k'(u)$. Then, v is more risk averse than u at every initial wealth level. If we show that v gives up more than u does, we are done. Solving v 's optimization problem generates FOC as following: $H(x) = k(u(w_0 + M - x)) - x \cdot k'(u(w_0 + M - x)) \cdot u'(w_0 + M - x) - k(u(w_0)) = 0$. Suppose $x=x_A$ which was the solution of $D_A(x_A)=0$ which implies $x_A \cdot u'(w_0 + M - x_A) = u(w_0 + M - x_A) - u(w_0)$. Denote $u(w_0 + M - x_A) = u_A$, $u(w_0) = u_0$ and $H(x_A) = H_A$ where $u_A > u_0 > 0$. Then, by a simple calculation, we can show $H_A = k(u_A) - k(u_0) - (u_A - u_0)k'(u_A)$. Note that since $k'(u) > 0$, $k''(u) < 0$, and $u_A > u_0 > 0$, $(k(u_A) - k(u_0))/(u_A - u_0) > k'(u_A)$. That is, $k(u_A) - k(u_0) - (u_A - u_0)k'(u_A) > 0$. Thus, $H_A > 0$ while $D_A=0$. Since it is easily seen that $dH_A/dx < 0$, we find that x_A' which satisfies $H_A=0$ should be higher than x_A . Thus, $x_A' > x_A$. In other words, a more risk-averse person v chooses a higher x than u does. (Q.E.D.)

(Proof of Proposition 3) By totally differentiating FOC, we get $dx_A/dw_0 = (u'(w_0 + M - x_A) - u'(w_0) - x_A \cdot u''(w_0 + M - x_A))/(2u'(w_0 + M - x_A) - x_A u''(w_0 + M - x_A))$. Since $u' > 0$, $u'' < 0$, $\text{sgn}(dx_A/dw_0) = \text{sgn}(u'(w_0 + M - x_A) - u'(w_0) - x_A \cdot u''(w_0 + M - x_A))$. Thus $u'(w_0 + M - x_A) - u'(w_0) - x_A u''(w_0 + M - x_A) < 0$ would imply $dx_A/dw_0 < 0$. But note that DARA preference implies that $v = -u'$ is a concave transformation of u where $v' > 0$ and $v'' < 0$ (Eeckhoudt, Gollier and Schlesinger 2005). That is, DARA implies that v is more risk averse than u . If we solve the maximisation problem of v , then we get the FOC, $I(x_A') = -\{u'(w_0 + M - x_A') - u'(w_0) - x_A' \cdot u''(w_0 + M - x_A')\} = 0$ where x_A' is a giving-up amount satisfying FOC, $I(x_A')=0$. From Proposition 2, we know $x_A' > x_A$ since v is more risk averse than u . This implies that $I(x_A) > 0$ since x_A' , which is higher than x_A , should satisfy $I(x_A')=0$ and by SOC, $dI(x_A)/dx_A < 0$ if and only if v is concave.

Note that $I(x_A) = -(u'(w_0 + M - x_A) - u'(w_0) - x_A \cdot u''(w_0 + M - x_A)) = -dx_A/dw_0$. Thus, $I(x_A) > 0$ implies $dx_A/dw_0 < 0$. (Q.E.D.)

(Proof of Proposition 4) We here mainly follow Gollier and Pratt (1996). Note from Proposition 2 that if a person is more risk averse at any wealth level, then he or she would choose a higher x . Hence, if we show that a risk-averse person who faces an independent and exogenous background risk to initial wealth would be more risk

averse than one who does not face the background risk to initial wealth, then we are done. Denote $v(w_0 + M - x) = Eu(w_\varepsilon + M - x)$. If we denote $z = w_0 + M - x$, then $v(z) = Eu(z + \varepsilon)$. Since we know that $-v''(z)/v'(z) > -u''(z)/u'(z)$ implies $x_v > x_u$ at any z , we only need to show $-v''(z)/v'(z) > -u''(z)/u'(z)$. Rearranging $-v''(z)/v'(z) = -Eu''(z + \varepsilon)/Eu'(z + \varepsilon) > -u''(z)/u'(z)$, the condition implies $Eg(z, \varepsilon) = Eu''(z + \varepsilon) \cdot u'(z) - Eu'(z + \varepsilon) \cdot u''(z) < 0$. By noting $g(z, E(\varepsilon)) = 0$ since $E(\varepsilon) = 0$, we find the condition implies that $g(z, \varepsilon)$ should be concave in ε at any z , that is, $g_{22}(z, \varepsilon) < 0$. This implies $-u''(z)/u'(z) < -u''''(z)/u'''(z)$ when evaluated at $\varepsilon = 0$. By our assumptions of $u''' > 0$ and $u'''' < 0$, this could be satisfied. So this is the necessary condition. In fact, it is easily shown that $u''' > 0$ and $u'''' < 0$ are sufficient for $-v''(z)/v'(z) > -u''(z)/u'(z)$ by using the implied relationship of $-Eu''(z + \varepsilon) = E[A(z + \varepsilon) \cdot u'(z + \varepsilon)] > EA(z + \varepsilon) \cdot u'(z + \varepsilon) > A(z) \cdot u'(z + \varepsilon)$ where $A(\cdot)$ denotes the absolute risk aversion coefficient. (Q.E.D.)

Appendix B: Instructions

These instructions have been used for the RRPM&Stranger group. The instructions for the other treatments are almost identical to this except only a few sentences to explain Partner treatment and/or APM treatment.

Instructions

This is an experiment in the economics of decision-making. If you follow the instructions carefully and make good decisions you may earn a considerable amount of money. You will be paid in private and in cash at the end of the whole session. It is important that you remain silent and do not communicate with the other participants. If you have any questions, please raise your hand and an experimenter will answer your question in private.

Overview

This experiment consists of **10 Rounds**. Each *Round* consists of two *Tasks*, **Task 1 and Task 2 in that order**. In each task, your decision problem is to choose *your number*, which we call x . In each task, *another number*, which we call y , will be determined. Your *potential earnings* for each task and for each round will depend on x and y . Your *final cash earnings from this experiment* will depend on your *potential earnings* in each round and in each task.

Choosing your number x In each Task of each Round, you have to choose one number from the set of numbers **2, 4, 5, 6, 7, 8, 16, 21, 24, and 27**.

How the other number y will be determined In **Task 1**, the other number y will be chosen **at random** from the same set of numbers 2, 4, 5, 6, 7, 8, 16, 21, 24, and 27.

In **Task 2**, the other number y will be chosen from the same set of numbers by **some other participant** in the experiment, who we call your *partner* for that Round.

Your partner will be changed in each Round. Hence, you will never meet the same partner more than once through the 10 Rounds. Your partner will face exactly the same decision task as you, and you and your partner will not know the identity of each other.

How your potential earnings are determined In every Round and in both Tasks, your *potential earnings* will depend on x and y in the following way:

If x is greater than y then your *potential earnings* will be $(35 - x)$ times 4 pence.

If x is equal to y then your *potential earnings* will be $(35 - x)$ times 2 pence.

If x is less than y then your *potential earnings* will be zero.

Tables 1 and 2, which are provided on separate sheets, show you the calculated *potential earnings* for Task 1 and for Task 2 corresponding to your various choices, respectively. Please see the tables and read the examples on those sheets now.

What feedback is given to you after each Task in each Round **For Task 1**, a history table for Task 1 on the screen will present you with only the number x you chose for Task 1.

For Task 2, a history table for Task 2 on the screen will present you with the following: the number x you chose in Task 2, the number y your partner chose in Task 2, and your *potential earnings* for Task 2.

How your cash earnings will be determined

Your cash earnings for Task 1 will be **10 times your potential earnings for Task 1 from a randomly chosen Round**: that is, after you completed all the ten Rounds, one of the ten Rounds will be selected at random and the number x , which you choose for Task 1 in that Round, will be recalled. Then, y will be chosen at random. Your *potential earnings* for Task 1 in that Round are calculated by Table 1 with the x and y , and your *cash earnings* for Task 1 will be 10 times your *potential earnings* for Task 1 in that Round.

Your cash earnings for Task 2 will be **10 times your potential earnings for Task 2 from a randomly chosen Round**: that is, after you completed all the ten Rounds, one of the ten Rounds will be selected at random, and your *potential earnings* for Task 2 in that Round will be recalled. Your *cash earnings* for Task 2 will be 10 times your *potential earnings* for Task 2 of that randomly selected Round.

Your cash earnings for the experiment as a whole will be the **sum of your cash earnings for Task 1 and your cash earnings for Task 2**.

An Example

Your cash earnings from Task 1 Suppose that Round 2 is randomly selected after you completed all the ten Rounds and that you chose 4 in Task 1 in that Round. That number will be recalled from your history table for Task 1. Then, the other number y is randomly chosen. For example, if the randomly chosen y is 2, then your *potential*

earnings from Task 1 will be $124p$ as shown in Table 1 (with $x=4$, $y=2$). Hence, your *cash earnings from Task 1* will be £12.40 (= 10 times $124p$). Similarly, if the randomly chosen y is 4, then your *potential earnings* are $62p$ as shown in Table 1 (with $x=4$ and $y=4$) and so your *cash earnings from Task 1* will be £6.20 (= 10 times $62p$). If the randomly chosen y is 7, then your *potential earnings* will be $0p$ as shown in Table 1 (with $x=4$ and $y=7$) and so your *cash earnings from Task 1* will be £0 (10 times $0p$).

Your cash earnings from Task 2 Suppose that Round 5 is randomly selected for Task 2 after you completed all the ten Rounds. Your *potential earnings* in Task 2 in that Round will be recalled from your history table for Task 2. For example, if your *potential earnings* for Task 2 in that Round was $124p$, then your *cash earnings from Task 2* will be £12.40 (=10 times $124p$). Similarly, if your *potential earnings* for Task 2 in that Round was $44p$, then your *cash earnings from Task 2* will be £4.40 (=10 times $44p$), and if your *potential earnings* for Task 2 in that Round was $0p$, then your *cash earnings from Task 2* will be £0 (=10 times $0p$).

Your final cash earnings for the experiment as a whole For example, if your *cash earnings from Task 1 and Task 2* are £5.00 and £3.50 respectively, then your **final cash earnings for this experiment** will be £8.50 (=£5.00+£3.50).

Some details

Throughout this experiment, the Round number and the Remaining time for the Task will appear on the upper-left part and the upper right part of the screen, respectively. The Task number will be on the center of the screen. **Each Round begins with Task 1 and ends with Task 2.**

In each Task, please put the number that you choose in the box on the screen, and then click the OK button.

After each Task of each Round, you will have feedback about your choice in that task of that Round, and your *history tables* for Task 1 and Task 2 will be in the bottom of the feedback screen.

After you finish the 10th Round, an experimenter will come over to you. You will pick one coin at random from an opaque bag (labeled with ‘Round for Task 1’) containing 10 coins numbered from 1 to 10: the number on it determines the Round in which your chosen number x for Task 1 will be recalled. Then, you will pick one coin at random from an opaque bag (labeled with ‘ y for Task 1’) containing 10 coins numbered from the set 2, 4, 5, 6, 7, 8, 16, 21, 24 and 27 to decide y for Task 1. As explained above, **your cash earnings from Task 1 will be 10 times the potential earnings determined by these x and y .** After doing this, you will pick one coin at random again from an opaque bag (labeled with ‘Round for Task 2’) containing 10 coins numbered from 1 to 10 to decide the Round in which your *potential earnings* for Task 2 will be recalled, and as explained above, **your cash earnings from Task 2 will be 10 times the potential earnings for Task 2 of that Round. Your final cash earnings from this experiment will be the sum of your cash earnings from Task 1 and Task 2** as already explained.

The experiment will be finished after you have answered a brief *questionnaire* and you have been paid your *final cash earnings*.

Many thanks for taking part.

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