

# Investigation of the Stochastic Choice under Risk using Experimental Data

Yudistira Permana<sup>\*a</sup>, Giovanni van Empela<sup>a</sup>, Rimawan Pradiptyoa<sup>a</sup>

<sup>a</sup>Universitas Gadjah Mada, Indonesia

**Abstract:** This paper extends the analysis of the data from the experiment undertaken by Pradiptyo et al. (2015), to help explain the subjects' behaviour when making decisions under risk. This study specifically investigates the relative empirical performance of the two general models of the stochastic choice: the random utility model (RUM) and the random preference model (RPM) where this paper specifies these models using two preference functionals, expected utility (EU) and rank-dependent expected utility (RDEU). The parameters are estimated in each model using a maximum likelihood technique and run a horse-race using the goodness-of-fit between the models. The results show that the RUM better explains the subjects' behaviour in the experiment. Additionally, the RDEU fits better than the EU for modelling the stochastic choice.

**Keywords:** stochastic choice, expected utility, rank-dependent expected utility, maximum likelihood, lab experiment, risk

**JEL Classification:** C91, D81

## Introduction

The decision-making process is arguably the central part of economics. In the managerial context, decision making is a regular and iterative process where executives make decisions about various problems. For instance, decisions considering all the combinations of inputs, or decisions on the business's yearly performance targets are part of every business owner's or executive's tasks. These decisions, however, are made under consideration of the constraints the business has, with the expectation to generate the maximum profit possible in the face of many business uncertainties, including how competitors respond to the decisions, how the market evolves over time, etc. In other words, every decision maker has distinct preferences towards uncertainties.

In the standard economic model, the decision maker (DM) is assumed to evaluate the utility correctly and to choose accordingly (Mas-Colell et al. 1995). The expected utility theory, coined by von-Neumann and Morgenstern (1944), has been widely accepted as the workhorse of the choice theory when faced with risk and uncertainty. This is not always the case, however, for explaining the actual decision; the classic experimental studies which are widely referred to are the Allais paradox and the Ellsberg paradox. These findings have led to the development of the deterministic model, which offers a better explanation of the DM's behaviour under the assumption of maximising utility.<sup>1</sup> One of the prominent models in the non-expected utility theory is the rank-dependent expected utility (RDEU) theory, introduced by Quig-

gin (1982). Apart from utility's maximisation, the intuition of this model is the DM may weigh the probability of the outcomes differently (Diecidue and Wakker 2001).

Experimental studies<sup>2</sup> have been conducted to infer the subjects' true preferences. Most findings have found that decisions are noisy, even though the subjects have well-defined preferences. It is inevitable in many situations, including in a controlled lab-experiment with some restrictive procedures. Due to this, there is a need to accommodate the stochastic process into the model, to have a proper identification given the preference functional. To proceed with this objective, this paper uses the theory to investigate whether or not the hypothesis is true. It, rather technically, is crucial to have the correct specification of the stochastic process. This has been experimentally investigated by Hey (1995), Loomes and Sugden (1998) and Blavatskiy (2007)<sup>3</sup> to name a few. The use of the econometric approach in analysing the experimental data may well motivate this interest. One advantage of this approach is to exteriorise a different explanation of the noise in the experimental data –the fact that it is very rare that a study has perfect data without noise.

As this study strongly hypothesises that the experimental data must be stochastic, the focus is on the two alternative stochastic models to investigate that, namely the random utility model (RUM) and the random preference model (RPM). The idea of the RUM was firstly coined by Manski (1977) and McFadden (1981) in an attempt to characterise the inconsistent patterns of individual behaviour. This, later on, has been extensively

<sup>1</sup>For references see: Kahneman and Tversky (1979) for the prospect theory and its extension (reference-dependent, loss aversion and cumulative prospect theory); Machina (1982) for EU without the independence axiom; Loomes and Sugden (1982) for the regret theory; Quiggin (1982) for the rank-dependent expected utility theory; Gilboa and Schmeidler (1989) for the maxmin expected utility.

<sup>2</sup>See Kahneman and Tversky (1979), Loomes and Sugden (1982), Quiggin (1982), Gilboa and Schmeidler (1989), Cicchetti and Dubin 1994, Hey and Orme 1994, Holt and Laury 2002, Harrison et al. 2007, von Gaudecker et al. 2011, Toubia et al. 2013, *inter alia*.

<sup>3</sup>Blavatskiy (2007) used ten well-known pieces of experimental data for his study.

used to estimate the preference functionals, including risk aversion (Cicchetti and Dubin 1994, Hey and Orme 1994, Holt and Laury 2002, Harrison et al. 2007, von Gaudecker et al. 2011, Toubia et al. 2013). This paper takes the idea of the RPM from Loomes and Sugden (1995) who posited that the DM's preference was represented by some set of functions and the DM acts as if he or she picks one of those randomly. Some literature about the use of this model is by Carbone (1997), Loomes et al. (2002) and Moffatt (2015).

Both models are applied using the dataset from Pradiptyo et al.'s experiment (2015). The main difference between both approaches is in the source of the stochastic process. Within the RUM, the DM calculates his or her utility with noise in the preference function. Hence the utility is evaluated with noise and assumes that the noise is normally distributed. The DM then chooses according to what he or she found from his or her calculations. Within the RPM, the DM draws parameter(s) in the preference function from a distribution. Here the assumption is that the DM randomly draws a parameter in the preference function from the normal distribution and the utility is evaluated without error. This approach explains why the DM may behave differently on different occasions.

This paper aims to answer the main question of which stochastic models, between the RUM and the RPM, are the best-fit for the subjects' behaviour. This study shows that the RDEU is better able, rather than the EU, to model the preference in our stochastic stories. The primary contribution of this study is that our models allow us to characterise and to identify the source of noise in the subjects' preferences. However, it should not be saying anything about whether the population behaves the same way, in accordance

with our estimation. The estimated preferences are only applied to the subjects in the experiment; who are traditional merchants in Yogyakarta and Pontianak. Therefore, one will need to conduct an identical experiment in order to elicit preferences—either using the population in Yogyakarta and Pontianak or using different types of occupation—of a broader sample or population.

This paper is organised as follows: Section 2 discusses the preference functional and its assumption. Sections 3 and 4 explain the preference functionals and the modelling of the stochastic choice, respectively. Results and analyses are presented in Section 5 and the paper's findings are in Section 6.

## The experimental design and the data

This paper used the dataset from Pradiptyo et al.'s (2015) experiment, with 245 subjects but the analyses only use data from 242 subjects, due to the incomplete data from three subjects. All the subjects were traders from traditional markets in Yogyakarta, in Java (122 subjects) and Pontianak, in Kalimantan (120 subjects), Indonesia. The experiment was conducted in two different settings: a laboratory (Yogyakarta, Java) and a lab-in-the-field (Pontianak, Kalimantan), which was a typical on-campus-lab. Charness et al. (2013) referred to this type of experiment as an extra-laboratory experiment. This practice must be an appropriate experiment for Pradiptyo et al. (2015) given the main purpose of the study and the subjects' backgrounds.

The subjects were invited<sup>4</sup> and they were

<sup>4</sup>The common alternative practice in experimental economics research is to invite subjects randomly using a database in which any subject can express their interest in being a participant in experimental research. In Pradiptyo et al. (2015), the subjects were re-

asked to fill in a short questionnaire regarding their personal information prior to the experiment. In addition, they were given written instructions and were shown presentation slides of the instructions before the experiment. All the instructions and presentation slides were in Indonesian. The subjects completed all the tasks using an electronic tablet. Ten assistants were available to aid the subjects if they had difficulties in operating the electronic touchscreen tablet. The assistants' particular task was to minimise any confusion among the participants, as they might not have been familiar with such experiments, or in operating the electronic tablet. The assistants, however, did not assist the subjects in making any decisions during the experiment.

The experiment was constructed for two main purposes: an opinion survey and a decision making in the face of risk and uncertainty experiment. There were four main sessions, with the first two main sessions being the opinion survey, while the other two main sessions were the experiment. There were 75 problems in total. The opinion survey had 39 questions in two sessions, whereas the decision-making sessions had 36 questions spread over the last two sessions. The subjects were given a break after completing the 2nd session and they started the 3rd session together. The subjects were allowed to finish all the questions within sessions 1 and 2, and also within sessions 3 and 4, anytime they wished to. In addition, each main session was preceded by a practice session.

The analysis used the dataset from the decision-making experiment (3rd main session). There were 20 pairwise-choices consisting of 10 positive pairwise-choice problems and another 10 negative pairwise-choice problems—the subjects were asked to choose

between two alternatives (Option A and Option B). The design follows Kahneman and Tversky (1979). Due to the technical specification issue, only six positive pairwise-choices that captured the three axioms in the decision theory were used: common consequence, common ratio and substitution. The pairwise-choice problems used are described in Appendix 1. Furthermore, all the observations were pooled from all the subjects for the purpose of estimation.

A random incentive mechanism was used to determine the subject's payment for this experiment. Every subject picked a random number which corresponded to one of the numbers of the respective questions (in all sessions) as the basis of his or her payment. If a subject got a question in the 3rd session, he or she would play the option for real according to his or her answer. An attendance fee of IDR25,000 was given as an endowment in each of the 3rd and 4th sessions—and an additional IDR125,000 was given when the subjects also faced the negative pairwise-choices.<sup>5</sup> This design ensured that the subjects maximised their preferences in the 3rd session. The payment range that the subjects could earn from the experiment was IDR0 to IDR300,000; the experiment's software was written (mostly by Ali Faiq) in PHP script.

## Modelling the preference functional

This paper focuses on the two different alternative stochastic choice theories in the face of risk to model the subjects' preferences, the RUM and the RPM. The former assumes the DM has a set of fixed parameters in its preference function when making

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cruited manually due to the intended characteristics of the subjects.

<sup>5</sup>Approximately close to USD 2.5 to USD 12.5 as the exchange rate during the experiment was about USD1 = IDR10,000 in 2015.

decisions about all the problems. The DM, however, evaluates the utility with noise. The general assumption is that the noise is normally distributed with the mean 0 and the standard deviation  $\sigma$ . In addition, this study specifies this model with a tremble parameter to capture the subjects' mistakes. The RPM model assumes that the parameter(s) in the DM's preference function is(are) drawn from a distribution. The DM evaluates the utility without noise. This means the subjects may have different parameter scores when making a decision about each problem. The parameter score was drawn from a distribution. Additionally, this study assumed that the other parameter(s) in the preference function remains constant across all the problems. What the parameters mean and how they are specified will be explained in the following section.

The EU and the RDEU were used to model the preference. Both theories are arguably considered to be two of the prominent theories about decision making in the face of risk and uncertainty. The model's construction was as follows:

Recall that there were five basic outcomes for the problems used. The lowest outcome was IDR0 and the highest outcome was IDR100,000. The outcomes were denoted as  $X = \{x_1, \dots, x_5\}$  with  $x_1 > \dots > x_5$ . Then the outcomes were normalised so  $u(x_1) = 1$ ,  $u(x_5) = 0$ , and  $u(x_i) = u$  where  $1 < i < 5$ . An option in a pairwise-choice problem is a probability distribution over those five outcomes where  $\{p_1, \dots, p_5\}$  as the corresponding probabilities of Option A and  $\{q_1, \dots, q_5\}$  as the corresponding probabilities of Option B.

First, this paper looked at the EU specification. The EU has two general properties, a set of true probabilities and a set of utility functions. The key point of the EU is the linearity in the probability and the utility func-

tions satisfies the von Neumann-Morgenstern expected utility function. The general form of the EU is:  $EU(.) = \sum_{i=1}^I z_i u_i$ , where  $EU(.)$  is the EU value of choosing an option,  $z_i$  is a vector of probabilities of the corresponding outcomes (which is a set of the true probabilities), and  $u_i$  is a vector of utility indices of the corresponding outcomes. Essentially, the EU has one key element, which is the utility function.

The RDEU has the identical utility function as interpreted for the EU, however, the key distinct feature of the RDEU is that it is not linear in probability. The DM may not see the set of probabilities ( $z_i$ ) as the true probabilities, hence the DM transforms it in a specific way through the probability weighting function  $w(z_i)$ . This means the RDEU has two key elements: the utility function and the probability weight function.

The general formulation of the RDEU is:  $RDEU(.) = \sum_{i=1}^I Z_i u_i$ , where  $RDEU(.)$  is the RDEU value of choosing an option,  $Z_i$  is a vector of the weighted probabilities, and  $u_i$  is a vector of utility indices of the corresponding outcomes. The weighted probabilities are non-negative values which are adapted to one. The probability transformation function enters  $Z_i$  so the RDEU allows for non-linearity in the probability. A crucial intuition of the RDEU is that the DM ranks the outcomes, in order to weigh the corresponding probabilities. The implication is that  $Z_i$  is not the true probability despite the fact that the probabilities are given in the experiment. Given the setting that  $x_1$  is the best outcome and  $x_5$  is the worst outcome, it is possible to define the weighted probability  $Z_i$  as:  $Z_i = \sum_{j=1}^I w(Z_j) - w(z_{i-1})$ . Hence it is going to be  $Z_i = w(z_i)$ . Note that  $w(z_i)$  is monotonically increasing in the area of  $[0,1]$ , with  $w(0) = 0$  and  $w(1) = 1$ , and the RDEU



reduces to the EU if  $w(z_i) = z_i$  everywhere.

This paper then dug deeper into the specification of the probability weighting function for the RDEU. In particular, two common forms of the probability weighting function were used, namely the power function and the Quiggin function. The functions are written as follows:

$$\text{Power: } w(v) = v^g; g > 0 \quad (1)$$

$$\text{Quiggin: } w(v) = \frac{v^g}{(v^g + (1-v)^g)^{\frac{1}{g}}}; g > g' \quad (2)$$

where  $g$  is the parameter of the probability weighting function and it determines the shape of the indifference curve and explains the behaviour implication (Starmer 2000). Conte et al. (2011) suggested that  $g' = 0.279095$  unless the function is not monotonic. The function is an inverted S-shape for  $g' < g < 1$  and an S-shape for  $g > 1$ .<sup>6</sup> Note that both probability weighting functions lead the RDEU to reduce to the EU when  $g = 1$ .

Now this part turns into the specification of the utility function where two forms of the utility function are specified—the constant relative risk aversion (CRRA) and the constant absolute risk aversion (CARA). The application of CRRA and CARA under normalization therefore is:

$$\text{CRRA: } u(x_i) = \begin{cases} \frac{(x_i/x_1)^{1-r}}{1-r}; r \neq 1 \\ \log(x_i/x_1); r = 1 \end{cases} \quad (3)$$

$$\text{CARA: } u(u_i) = \begin{cases} \frac{1 - \exp(-rx_i)}{1 - \exp(-rx_1)}; r \neq 0 \\ \frac{x_i}{x_1}; r = 0 \end{cases} \quad (4)$$

The CRRA and the CARA specifications

<sup>6</sup>See Starmer (2000) for further implication of an (inverted) S-shape probability weighting function.

can take any value of  $r$  between  $-\infty$  and  $\infty$ . A positive value of  $r$  indicates a risk-averse, a negative  $r$  indicates a risk-seeking, and  $r = 0$  indicates a risk-neutral agent.

## Stochastic specifications

To start our specification, the assumption was that the DM is either the agent of the EU or the RDEU. All models shared an identical assumption, that the DM makes a choice depending on the evaluation of his/her true preference. Let  $V_t(p_i, x_i)$  and  $V_t(q_i, x_i)$  be the utility of Option A and of Option B respectively, referring to the EU or the RDEU in every problem  $t$ . Thus the DM's calculation is  $V_t(A_t, B_t) = V_t(p_i, x_i) - V_t(q_i, x_i) \stackrel{>}{\leq} 0 + A_t \left( \frac{>}{\approx} \right) B_t$  and it is determined by the parameters in the EU ( $r$ ) and in the RDEU ( $r$  and  $g$ ).

## The random utility model (RUM)

This study assumed the parameters in the DM's preference function are constant and the DM evaluates the utility with noise. By this, the stochastic variation  $\epsilon$  is added into  $V_t(A_t, B_t)$  and the DM's choice becomes  $V_t(A_t, B_t) + \epsilon \stackrel{>}{\leq} 0 + A_t \left( \frac{>}{\approx} \right) B_t$  where  $\epsilon \sim N(0, \sigma^2)$ . So the DM prefers Option A if  $V(A) - V(B) + \epsilon > 0$ , otherwise the DM prefers Option B. The DM, however, may make a mistake in expressing his or her preference; therefore this paper involves a *tremble* parameter ( $\omega$ ) to capture the DM's mistake. Hence the DM chooses an optimal choice for every problem  $t$  following  $V_t(A_t, B_t) + \epsilon$  with a probability of  $(1 - \omega)$  and mistakenly chooses a non-optimal choice with a probability of  $\omega$ . The tremble parameter takes any values of  $0 \leq \omega \leq 1$ .

Let  $y_t = 1$  if the DM chooses Option A

and  $y_t = -1$  if the DM chooses Option B for choice problem  $t$ . The likelihood contribution in every problem  $t$  is:

$$(1 - \omega)\Phi\left(y_t[V_t(A, B)]s\right) + \frac{\omega}{2}; y_t \in \{1, -1\} \quad (5)$$

where  $\Phi(\cdot)$  is the cumulative distribution function (*cdf*) of the normal distribution with parameters mean  $\mu$  and precisions  $= 1/\sigma$ . In summary, there are six variations for the RUM from the specifications of the utility function and the probability weighting function. The variations within the EU's specification have estimates of  $r$ ,  $s$ , and  $\omega$ ; and the variations within the RDEU's specification have estimates of  $r$ ,  $s$ ,  $g$ , and  $\omega$ .

#### 4.2. The random preference model (RPM)

This model started by assuming that a parameter, either  $r$  or  $g$  depending on the preference function used, is random and that it is drawn once from a distribution. Unlike the RUM, the utilities in this model were evaluated without noise. Given this, two specifications of this model were used, according to which parameter was random.<sup>7</sup>

The first specification assumed that  $r$  was random and it followed a normal distribution –that  $g$  was constant across all the problems. So the DM had his or her mean of  $r$  at  $\mu$  and standard deviation  $\sigma$  when making the decision for every choice problem. In every  $V_t(A, B)$  there will be an  $r^*$  that indicates the indifference between two options. This obviously happens when  $V_t(A, B) = 0$ . The implication is that if  $r > r^*$  then the DM chooses the riskier option (Option A), or vice versa. Notations  $r_t^*$  and  $r_2^*$  are used to dis-

tinguish the  $r^*$  from the EU and the RDEU specification (for any variations of the utility functions and of the probability weighting functions).

The second specification assumed that  $g$  was random and it followed a lognormal distribution as it was always positive –that  $r$  was constant across all the problems.<sup>8</sup> With this, the assumption was that the DM had his or her mean of  $g$  at  $\ln(M)$  and standard deviation  $\ln(\Sigma)$  when making the decision for every choice problem. Given this, there exists a  $g^*$  when the DM is indifferent between Option A and Option B as the RDEU values for both options are equal –  $V_t(A, B) = 0$ . The implication of this specification is that every preference for Option A will always have  $g > g^*$ , or *vice versa*. It should be noted that this model only works under the RDEU with the Power weighting function. The RDEU specification with the Quiggin weighting function provides no solution for finding  $g^*$  for any given  $r$ .

The econometric specification was as follows. Specifically, the maximum likelihood technique was used to proceed with the estimation. Let  $y_t = 1$  if the DM chooses Option A and  $y_t = -1$  if the DM chooses Option B for every choice problem  $t$ . Within the first specification, the contribution to the likelihood of an observation  $r^*$  in every problem is:

$$\Pr(y_t | \mu, \sigma) = \Phi\left(y_t \frac{\mu - r^*}{\sigma}\right); y_t \in \{1, -1\} \quad (6)$$

where  $\Phi(\cdot)$  is the *cdf* of the normal distribution with parameters mean  $\mu$  and precision  $s = 1/\sigma$ . Note crucially that  $g$  enters the likelihood function in Equation 6 through  $r_2^*$  from the specification of the weighted probability function, as defined in the previous section. Meanwhile, within the second

<sup>7</sup>We can specify that both parameters ( $r$  and  $g$ ) are random within the RDEU specifications. This will need a joint distribution between  $r$  and  $g$ . However we start with a simple specification within the RPM.

<sup>8</sup>One may think, however, of other plausible distributions to account for both specifications. See Drichoutis and Lusk (2014) for a literature survey discussing this matter.

specification, the likelihood contribution of an observation of  $g^*$  in every problem is:

$$\Pr(y_i | \ln(M), \ln(\Sigma)) = \pi\left(y_i, \frac{\ln(M) - \ln(g^*)}{\ln(\Sigma)}\right); y_i \in \{1, -1\} \quad (7)$$

where  $\pi(\cdot)$  is the *cdf* of the lognormal distribution with parameters  $\ln(M)$  and  $\ln(\Sigma)$ . However, this paper reports the non-logarithmic value of  $M$  and  $S = 1/\Sigma$  instead in each model;  $S$  is the precision which is the same as that in the random preference model on  $r$ . In summary, there are eight variations from the specifications for the utility function and the probability weighting function.

## Results and analyses

The paper estimated the parameters using a pooled subject rather than taking them individually. This part shall begin the discussion of which of the two models was best fitted to explain the data. In total, we have fourteen variations from two models—the RUM and the RPM. Then to answer this question, a comparison of the corrected log-likelihood is conducted. This is due to the difference in the number of parameters in each model and can be a formal comparison of our models.

Three alternatives for measuring the goodness-of-fit for the corrected log-likelihood were used: (i) Akaike information criterion (AIC); (ii) Bayesian information criterion (BIC); and (iii) Hannan-Quinn information criterion (HQC).<sup>9</sup> Appendix 2 presents the models' selection according to the corrected log-likelihood. It ranks the best-fitted specification according to each measure of the goodness-of-fit for all the models. It suggested that the RUM specified with RDEU Quig-

<sup>9</sup>AIC =  $2k - 2 \ln(LL)$ , BIC =  $k \ln(n) - 2 \ln(LL)$ , HQC =  $2k \ln(\ln(n)) - 2 \ln(LL)$ ; where  $k$  is the number of estimated parameters,  $n$  is the number of observations and  $LL$  is the maximised log-likelihood. AIC provides a simple approach and is widely used in practice among analysis of complex data but may not perform well if there are too many parameters, whereas BIC and HQC try to reduce the potential bias by imposing a more stringent penalty on the number of parameters than that of AIC (Haggag 2014).

gin using the CARA utility function was the best fit for the data, according to the AIC, the BIC, and the HQC. The RPM on  $r$ , however, varies only slightly with the RUM, according to the BIC measure. The small number of problems could be the main reason why the subjects had a constant preference across the problems. The results in Appendix 2 also show that the use of the RDEU as a core theory was better to model our stochastic story in this paper, in comparison to the EU.

This study delved deeper to investigate the subjects' risk aversion (appendices 3 and 4). Most of the variations suggested that the subjects were risk-averse; with variations within the RPM that showed the subjects had a strong tendency to be risk-averse. Note that this estimate was unique for all the subjects. Secondly, this paper estimated the probability weighting parameter of all the variants using the RDEU, in which it was specified, with the Power and the Quiggin functions (Appendix 5). All the variants using the Power function suggested a convex probability weighting function, and all the variants using the Quiggin function suggested an inverted S-shaped probability weighting function. Both exhibited an identical behaviour implication where the subjects over-weigh the small probabilities and under-weigh the large probabilities. Lastly, this study estimated the tremble within all the variants in the RUM, which appeared to be relatively high. One plausible explanation for this is the subjects had difficulties understanding the nature of the problems during the experiment.

## Conclusions

This paper discusses the modelling of a preference under two stochastic theories: the RUM and the RPM. The results give us a clear message that the RUM can explain the



subjects' behavior in Pradiptyo *et al.*'s (2015) experiment very well. Given this, the subjects often showed a constant preference across the problems. The results of this study also show that the RDEU is more applicable, rather than the EU, for modelling the preference in our stochastic stories. A further extension can be made by extending the choice problems in the experiment for analysis of the decision making in the face of uncertainty.

The advantage of this paper is that it allows us to identify the source of noise in the subjects' preference. This is the primary contribution of this paper. The paper applies the model to capture the stochastic process, since the initial hypothesis is that the data would be noisy, particularly due to the characteristics of the subjects. In addition, regarding the subjects' occupation, it may be a

worthwhile investigation for the policy-makers (and related stakeholders) to gain some knowledge about the economic agent, as a basis for related policy-making. For example, the policy-makers may make a greater effort to prevent stockpiling in their price control policy—knowing that the subjects (traditional merchants) are likely to be risk-averse. Another issue worth raising is that the subjects were found to over-weigh the small probabilities and under-weigh the greater probabilities (an inverse S-shape). This typically shows that the subjects tend to lower their allocation in the risky asset/stock, or *vice versa*, and that the policy-makers should cover the risk of price volatility for some essential items, in order to make them available—at a relatively stable price—for the consumers. However, a further study might be necessary, depending upon the particular context, to explore the subjects' preferences in a specific case.

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## Appendices

### Appendix 1. Pairs of decision problems used in this study

Pair	Riskier option (Option A)	Safer option (Option B)	Problem design
1	33% chance of IDR100,000 66% chance of IDR80,000	Certain money of IDR80,000	Common consequence
2	33% chance of IDR100,000 33% chance of IDR80,000	67% chance of IDR80,000	Common consequence
3	80% chance of IDR100,000	Certain money of IDR75,000	Common ratio
4	40% chance of IDR100,000	50% chance of IDR75,000	Common ratio
5	45% chance of IDR100,000	90% chance of IDR50,000	Substitution
6	1% chance of IDR100,000	2% chance of IDR50,000	Substitution

### Appendix 2. Model selection based on the corrected log-likelihood

Rank	The Corrected Log-Likelihood		
	AIC	BIC	HQC
1	RUM (RDEUQ CARA)	RUM (RDEUQ CARA)	RUM (RDEUQ CARA)
2	RUM (RDEUQ CRRA)	RPM on $r$ (RDEUQ CRRA)	RUM (RDEUQ CRRA)
3	RPM on $r$ (RDEUQ CRRA)	RUM (RDEUQ CRRA)	RPM on $r$ (RDEUQ CRRA)
4	RPM on $r$ (RDEUQ CARA)	RPM on $r$ (RDEUQ CARA)	RPM on $r$ (RDEUQ CARA)
5	RUM (RDEUP CRRA)	RUM (RDEUP CRRA)	RUM (RDEUP CRRA)
6	RUM (RDEUP CARA)	RUM (RDEUP CARA)	RUM (RDEUP CARA)
7	RPM on $r$ (RDEUP CRRA)	RPM on $r$ (RDEUP CRRA)	RPM on $r$ (RDEUP CRRA)
8	RUM (EU CARA)	RUM (EU CARA)	RUM (EU CARA)
9	RUM (EU CRRA)	RUM (EU CRRA)	RUM (EU CRRA)
10	RPM on $g$ (RDEUP CARA)	RPM on $r$ (EU CARA)	RPM on $r$ (EU CARA)
11	RPM on $r$ (RDEUP CARA)	RPM on $r$ (EU CRRA)	RPM on $g$ (RDEUP CARA)
12	RPM on $g$ (RDEUP CRRA)	RPM on $g$ (RDEUP CARA)	RPM on $r$ (RDEUP CARA)
13	RPM on $r$ (EU CARA)	RPM on $g$ (RDEUP CARA)	RPM on $g$ (RDEUP CRRA)
14	RPM on $r$ (EU CRRA)	RPM on $g$ (RDEUP CRRA)	RPM on $r$ (EU CRRA)

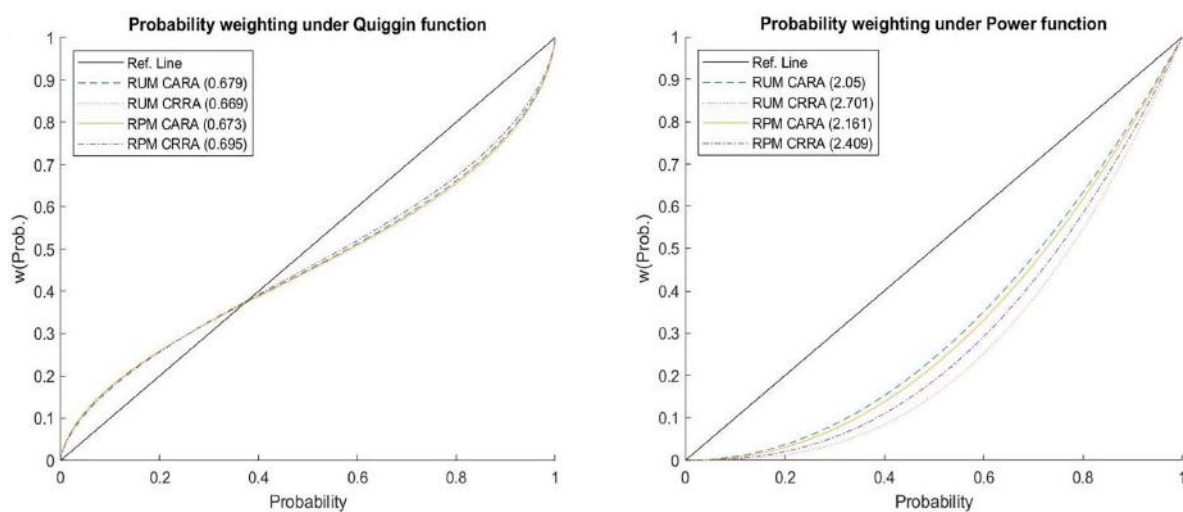
### Appendix 3. Estimate results from the random utility model

Model Specification	$r$	$S$	$\omega$	$g$	$LL$
EU CARA	0.012	88.164	0.665		-978.632
EU CRRA	0.426	20.735	0.668		-978.725
RDEUP CARA	-0.008	38.457	0.648	2.05	-972.337
RDEUP CRRA	-1.016	140.143	0.641	2.701	-965.048
RDEUQ CARA	0.009	27.986	0.598	0.679	-959.208
RDEUQ CRRA	0.296	24.931	0.597	0.669	-959.562

#### Appendix 4. Estimate results from the random preference model

Model Specification	Random on $r$				Random on $g$			
	$\mu$	$s$	$G$	LL	$M$	$S$	$r$	LL
EU CARA	0.018	10.461		-993.135				
EU CRRA	0.451	0.437		-993.976				
RDEUP CARA	-0.008	13.597	2.161	-991.829	1.162	1.458	0.01	-991.342
RDEUP CRRA	-0.46	0.456	2.409	-976.969	1.565	1.597	0.013	-991.66
RDEUQ CARA	0.014	19.241	0.673	-965.774				
RDEUQ CRRA	0.357	0.807	0.695	-962.919				

#### Appendix 5. Probability weighting function



#### Appendix 6. The written instructions for decision making under risk session (in English)

### EXPERIMENT INSTRUCTIONS

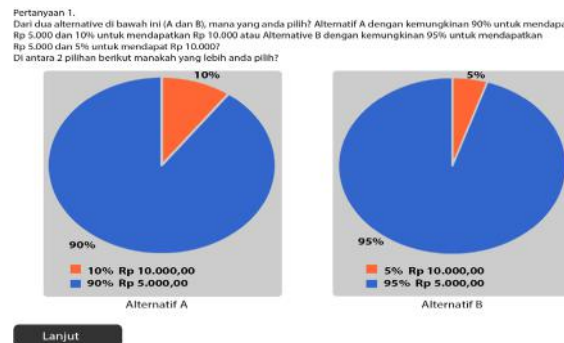
Welcome and thank you for your participation in this experiment. You will take part in a decision making in the face of risk experiment. These instructions will help you to understand this experiment. You will have a chance to win some money (cash) by the end of this experiment depending solely on your answers. Before you go on to the main experiment, you are asked to listen to the PowerPoint presentation. It will appear on the big screen in front of you. Please read and listen to the two sets of instructions so you understand this experiment. There will be a practice session after the PowerPoint presentation.

At the end of the experiment, you will be asked to fill out the personal information form. We will keep your personal information and it will be only used in this experiment. You are also asked to turn-off your mobile phones and not to make any form of communication with other people, unless allowed by the experimenters. Do not hesitate to raise your hand if you have any questions. Either the experimenters or helpers will come to you to answer your questions.

## The Experiment

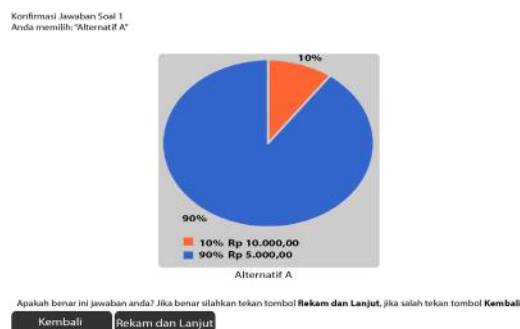
You will be presented with 20 pairwise-choices, all of the same type. For each problem you will have to choose one of the two options that you think you prefer. Your choice will have no impact on anyone else but you. You can finish all the problems in this session anytime you wish to. There is no time limit for you to complete all the problems.

A picture below gives you an example of a problem in this session.



*Translation* – Problem 1. Which one of these two options (Option A and Option B) will you choose, according to your preference? Option A will give you a 90% chance to win IDR5,000 or a 10% chance to win IDR10,000. Option B will give you a 95% chance to win IDR5,000 or a 5% chance win IDR10,000. “Next” button.

If you choose an Option A you will have a 90% chance to win IDR5,000 or a 10% chance to win IDR10,000. If you choose an Option B you will have a 95% chance to win IDR5,000 or a 5% chance win IDR10,000. You have to click the “Next” button and you will be directed to this page:



*Translation* – Confirmation for Problem 1. You have chosen Option A. Is this your true preference? If yes please click the “Save and Continue” button (the right one), otherwise click the “Back” button (the left one).

The picture above is the confirmation screen. If you think you are sure of your answer you should click the “Save and Continue” button. Otherwise click the “Back” button (the left one) to modify your answer. Once the software has saved your answer you cannot modify your answer.



## Appendix 7. Examples of screenshots in the decision making under risk session (in Indonesian)



*Translation* – Question 1: Which one of these two options would you prefer to choose?

Once a subject has made his or her choice by clicking one of the two options, then this screen below will appear:



*Translation* – Confirmation of Question 1. You have chosen “A”. Is this your true answer? Please click the “Record and Continue” button if you think you are sure about your answer otherwise click “Back”.

## Appendix 8. The roulette used in the experiment

