

A Parameter-Free Analysis of the Utility of Money for the General Population under Prospect Theory*

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ABSTRACT. Extensive data have convincingly shown that expected utility, the reigning economic theory of rational decision making, fails descriptively. The descriptive inadequacy of expected utility questions the validity of classical utility measurements. This paper presents the results of an experiment that completely measures the utility function for different positive and negative monetary outcomes, using a representative sample of $N = 1932$ from the general public, in a completely parameter-free way. Hence, the present paper provides a parameter-free measurement of the rational component of risk attitudes from the general population. This information is crucial for policy decisions on important economic problems such as equitable taxation and the cost benefit analysis of education, health care, and retirement. In addition, we obtain individual parameter-free measurements of loss aversion. The results give empirical support to a recent conjecture by Rabin, being that utility curvature is less pronounced than suggested by classical utility measurements, using a large representative sample. Also, females are more risk averse than males, which confirms frequent findings, but our results give more background and show that this finding is primarily driven by utility for gains and loss aversion, and not by utility of losses.

JEL-Classification: D81, C91, C93

KEYWORDS: Prospect Theory; Utility for Gains and Losses; Loss Aversion.

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30 1. Introduction

31 Expected utility is the reigning economic theory of rational decision making under
32 risk. In the classical expected utility framework, outcomes are transformed by a
33 strictly increasing utility function and prospects are evaluated by the probability-
34 weighted average utility. Therefore, risk attitudes are solely explained by utility
35 curvature under expected utility. For example, *risk aversion* (preferring the expected
36 value of a prospect to the prospect itself) holds if and only if the utility function is
37 concave, implying diminishing marginal utility. However, a decade of extensive
38 experimentation has convincingly shown that “risk aversion is more than the
39 psychophysics of money” (Lopes 1987): numerous studies have systematically
40 falsified expected utility as a descriptive theory of decision making (Allais 1953;
41 Kahneman & Tversky 1979). This descriptive inadequacy has been the main
42 inspiration for the development of many new descriptive theories of individual
43 decision making under risk (for a survey, see Starmer 2000). The most prominent of
44 these nonexpected utility models is prospect theory (Kahneman & Tversky 1979;
45 Tversky & Kahneman 1992).

46 Prospect theory entails that besides the transformation of outcomes,
47 probabilities are transformed by a subjective probability weighting function,
48 reflecting sensitivity towards probabilities. In addition, prospect theory entails that
49 outcomes are evaluated relative to a reference point, reflecting sensitivity towards
50 whether outcomes are better or worse than the status quo. Consequently, in the
51 prospect theory framework, the one-to-one relationship between utility curvature and
52 risk attitudes no longer holds: risk attitudes are determined by a combination of utility
53 curvature, subjective probability weighting, and the steepness of the utility function
54 for negative outcomes (*losses*) relative to the steepness of the utility function for
55 positive outcomes (*gains*), i.e. *loss aversion*. Therefore, the validity of classical
56 measurements of risk attitudes can be questioned, which explains why these
57 measurements have often led to preference inconsistencies (Hershey & Schoemaker
58 1985) or theoretical implausibilities (Rabin 2000a).

59 From a policy perspective, it is important to decompose risk attitudes into a
60 utility curvature part, a subjective probability weighting part, and a loss aversion part

61 at the individual level. Choice behavior based on diminishing marginal utility is
62 considered to be rational by most economists in the sense that these choices satisfy
63 the fundamental axioms of expected utility. Choice behavior based on subjective
64 probability weighting for example does not agree with these normatively compelling
65 axioms.

66 This paper presents the results of an experiment that completely measures the
67 utility function for different positive and negative monetary outcomes, using a
68 representative sample of $N = 1932$ respondents from the Dutch population, in a
69 completely parameter-free way. The measurement technique we use is the (gamble-)
70 tradeoff method introduced by Wakker and Deneffe (1996), which is robust against
71 subjective probability distortion and is parameter-free in the sense that a priori
72 assumptions about the true underlying functional form of the utility function are not
73 necessary. Hence, the present paper provides the first parameter-free measurement of
74 the rational component of risk attitudes of the general population, which is important
75 for policy decisions on economic problems such as equitable taxation and the cost
76 benefit analysis of education, health care, and retirement. In addition, we have
77 obtained individual parameter-free measurements of loss aversion under expected
78 utility. The obtained dataset also allows us to test whether utility curvature is more or
79 less pronounced for losses than for gains, whether scaling up monetary outcomes
80 leads to a higher or a lower degree of utility curvature or loss aversion, and to relate
81 the obtained measurements of utility curvature and loss aversion to socio-
82 demographic characteristics.

83 First of all, our results support Rabin's (2000b, p. 202) claim that diminishing
84 marginal utility is an "implausible explanation for appreciable risk aversion, except
85 when the stakes are very large": we confirm that utility curvature is less pronounced
86 than suggested by classical utility measurements. Second, the results show that utility
87 is concave for gains and convex for losses, reflecting *diminishing sensitivity* as
88 predicted by prospect theory but contrary to the classical prediction of universal
89 concavity. In addition, the results confirm the common finding that females are more
90 risk averse than males. Contrary to classical studies that ascribed this gender
91 difference solely to differences in the degree of utility curvature, our results show that
92 this finding is primarily driven by utility for gains and loss aversion, and not by utility

93 of losses. Fourth and finally, we did not find significant evidence for the hypothesis
94 that both the degree of utility curvature and the degree of loss aversion increases with
95 the size of the outcomes involved.

96 The remainder of this paper is organized as follows. Section 2 briefly provides
97 background information about the ongoing debate in the literature about the proper
98 shape of the utility function. Section 3 discusses prospect theory, and Section 4
99 provides an explanation of the measurement techniques we used to obtain parameter-
100 free measurements of utility curvature and loss aversion at the individual level.
101 Section 5 presents the experimental method, followed by the presentation of the
102 results of the experiment in Section 6. Section 7 contains a discussion of the
103 experimental method and the experimental results and Section 8 concludes. Finally,
104 Appendix A presents details of the experimental instructions.

105 2. Background

106 As mentioned in the introduction, measuring risk attitudes and decomposing risk
107 attitudes into a rational and irrational component is crucial from a policy perspective.
108 Consider for example the *equal sacrifice principle* first put forth by Mill (1848).
109 According to this principle, tax rates should be set in such a way that all people
110 paying tax lose the same amount of utility. Hence, information about the utility that
111 people derive from money obtained in isolation, that is, obtained in an environment
112 where confounding effects such as probability weighting did not play a role, is
113 necessary. Young (1990) used historical tax data from the US to derive the utility
114 function of taxpayers under the assumption that the equal sacrifice principle holds.
115 Because the resulting estimates of the utility function are consistent with estimates
116 from the finance literature, Young (1990) justified US tax policy. However, Young
117 (1990) assumed expected utility and, hence, his results may have been distorted by
118 probability weighting.

119 Parametric studies that provide measurements and decompositions of risk
120 attitudes into a rational and irrational part are numerous and, consequently, there is an
121 ongoing debate about the shape of the utility function. For gains, most studies have
122 corroborated that the utility function is concave-shaped reflecting the natural intuition

123 that each new euro brings less utility than the euro before and implying diminishing
124 marginal utility (Wakker & Deneffe 1996). However, the debate regarding the shape
125 of the utility function for losses has not been settled.

126 First of all, there is no consensus at present about the fundamental question
127 whether the utility function for losses is convex or concave. Some studies found
128 concave utility for losses (Davidson, Suppes & Siegel 1957; Laury & Holt 2000 (for
129 real incentives only)), while other studies found convex utility for losses (Currim &
130 Sarin 1989; Tversky & Kahneman 1992; Abdellaoui 2000; Etchart-Vincent 2004).
131 Second, some studies did not only find convex utility for losses but also found more
132 pronounced convexity for losses than concavity for gains (Fishburn & Kochenberger
133 1979; Abdellaoui, Bleichrodt & Paraschiv 2004), and this constitutes another point of
134 debate since other studies found that convexity for losses is less pronounced than
135 concavity for gains (Fennema & van Assen 1999; Köbberling, Schwieren & Wakker
136 2004; Abdellaoui, Vosmann & Weber, 2005). Finally, there is no consensus on
137 whether utility curvature is more (or less) pronounced for larger outcomes. Increasing
138 relative risk aversion has been found, for example, by Kachelmeier & Shehata (1992),
139 Holt & Laury (2002, 2005), and Harrison, Johnson, McInnes & Rustrom (2003),
140 whereas the opposite result, i.e. a decreasing relative risk aversion coefficient, has
141 been found, for example, by Friend & Blume (1979), and Blake (1996).

142 There are four possible confounding factors in the aforementioned studies that
143 are not present in the current study, and that may explain the seemingly contradictory
144 findings. First, some studies assume expected utility and, thus, ignore the important
145 role of probability weighting in risk attitudes. Second, the functional form of the
146 utility (and probability weighting-) function are sometimes assumed beforehand and,
147 therefore, the estimations depend critically on the appropriateness of the assumed
148 functional form: conclusions drawn on the basis of the parameter estimates need no
149 longer be valid if the true functional form differs from the assumed functional form.
150 Third, most of these studies use aggregate data to estimate the different assumed
151 functional forms, ruling out heterogeneity of individual preferences. Fourth and
152 finally, student populations are commonly used as subjects, making the external
153 validity of the results questionable.

154 3. Prospect Theory

155 Let \mathbb{R} be the set of possible monetary outcomes. We consider decision under risk. A
 156 *prospect* is a finite probability distribution over the outcomes. Thus, a prospect
 157 yielding outcome x_i with probability p_i ($i = 1, \dots, n$) is denoted as $(p_1:x_1, \dots, p_n:x_n)$. A
 158 two-outcome prospect $(p:x, 1-p:y)$ is denoted by $(p:x, y)$ and the unit of payment for
 159 outcomes is one euro. In this paper, *prospect theory* refers to the modern (cumulative)
 160 version of prospect theory that corrected a theoretical mistake in the original '79
 161 version, introduced by Tversky & Kahneman (1992). Prospect theory entails that the
 162 value of a prospect with outcomes $x_1 \leq \dots \leq x_k \leq 0 \leq x_{k+1} \leq \dots \leq x_n$ is given by:

$$163 \quad \quad \quad 164 \quad \quad \quad \sum_{i=1}^k \pi_i^- U(x_i) + \sum_{j=k+1}^n \pi_j^+ U(x_j) \quad (3.1)$$

165 Here $U: \mathbb{R} \rightarrow \mathbb{R}$ is a continuous and strictly increasing *utility function* satisfying $U(0)$
 166 $= 0$, and π^+ and π^- are the *decision weights*, for gains and losses respectively, defined
 167 by:

$$168 \quad \quad \quad \pi_i^- = w^-(p_1 + \dots + p_i) - w^-(p_1 + \dots + p_{i-1}) \quad \text{for } i \leq k, \text{ and} \\ 169 \quad \quad \quad \pi_j^+ = w^+(p_j + \dots + p_n) - w^+(p_{j+1} + \dots + p_n) \quad \text{for } j > k \quad (3.2)$$

170 Here w^+ is the *probability weighting function for gains* and w^- is the *probability*
 171 *weighting function for losses*, satisfying $w^+(0) = w^-(0) = 0$ and $w^+(1) = w^-(1) = 1$, and
 172 both strictly increasing and continuous. Thus, the decision weight of a positive
 173 outcome x_i is the marginal w^+ contribution of p_i to the probability of receiving better
 174 outcomes and the decision weight of a negative outcome x_i is the marginal w^-
 175 contribution of p_i to the probability of receiving worse outcomes. Finally note that the
 176 decision weights do not necessary sum to 1 and that prospect theory coincides with
 177 expected utility if people do not distort probabilities, i.e. prospect theory coincides
 178 with expected utility if w^+ and w^- are the identity.

179 4. Measuring The Utility Function

180 This section provides an explanation of the measurement techniques we used to
 181 obtain parameter-free measurements of utility curvature and loss aversion at the
 182 individual level.

183

184 4.1 Measuring Utility Curvature: The Tradeoff Method

185 The (gamble-) tradeoff method, first introduced by Wakker and Deneffe (1996),
 186 draws inferences from a series of indifferences between two-outcome prospects in
 187 order to obtain a so-called *standard sequence of outcomes*, i.e. a series of outcomes
 188 that is equally spaced in utility units. Contrary to other elicitation techniques often
 189 used to measure individual utility functions such as the certainty equivalent method,
 190 the probability equivalent method, and the lottery equivalent method (McCord & de
 191 Neufville 1986), utilities obtained through the tradeoff method are robust to
 192 subjective probability distortion. Hence, besides being valid under expected utility,
 193 the tradeoff method retains validity under prospect theory, rank-dependent utility and
 194 cumulative prospect theory (Wakker & Deneffe 1996).

195 Consider an individual who is indifferent between the prospects $(p:x_1, g)$ and
 196 $(p:x_0, G)$ with $0 \leq g \leq G \leq x_0 \leq x_1$. In most existing laboratory experiments employing
 197 the tradeoff method (as well as in our field experiment) individual indifference is
 198 obtained by eliciting the value of outcome x_1 that makes a person indifferent between
 199 these two prospects while fixing outcomes x_0, G, g , and probability p . Under prospect
 200 theory, indifference between these prospects implies that:

$$201 \quad w^+(p)(U(x_1) - U(x_0)) = (1 - w^+(p))(U(G) - U(g)) \quad (4.1)$$

202 Thus, under prospect theory, the weighted improvement in utility by obtaining
 203 outcome G instead of outcome g is equivalent to the weighted improvement in utility
 204 by obtaining outcome x_1 instead of outcome x_0 . Now suppose that the same person is
 205 also indifferent between the prospects $(p:x_2, g)$ and $(p:x_1, G)$. If we apply the prospect
 206 theory formula to this indifference we find that:

$$207 \quad w^+(p)(U(x_2) - U(x_1)) = (1 - w^+(p))(U(G) - U(g)) \quad (4.2)$$

208 Combining equations 4.1 and 4.2 yields:

$$209 \quad U(x_2) - U(x_1) = U(x_1) - U(x_0) \quad (4.3)$$

210 Thus, the tradeoff in utilities between receiving outcome x_2 instead of outcome x_1 is
 211 equivalent to the tradeoff in utilities between receiving outcome x_1 instead of outcome
 212 x_0 under prospect theory. Or, put differently, x_1 is the utility-midpoint between
 213 outcome x_0 and outcome x_2 and the sequence of outcomes x_0, x_1, x_2 is equally spaced
 214 in terms of utility units. We can continue eliciting individual indifference between
 215 prospects $(p:x_i, g)$ and $(p:x_{i-1}, G)$ in order to obtain an increasing sequence x_0, \dots, x_n of
 216 gains that are equally spaced in utility units. A similar process can be used to
 217 construct a decreasing sequence of equally spaced losses. More specifically,
 218 individual indifference between the prospects $(p:y_i, l)$ and $(p:y_{i-1}, L)$ with $0 \geq l \geq L \geq$
 219 $y_0 \geq y_1 \geq \dots \geq y_n$ implies that the resulting decreasing sequence of losses y_0, \dots, y_n is
 220 equally spaced in utility units under prospect theory. In what follows, we will use the
 221 term *utility increment* to denote the (equal) utility difference between the elements
 222 of the particular standard sequence considered.

223

224 4.2 Measuring Loss Aversion

225 The tradeoff method allows measuring utilities for either gains or losses. Without any
 226 further information these measurements cannot be combined, because they are not on
 227 the same scale. This requires the elicitation of additional indifferences that also
 228 involve mixed prospects, i.e. prospects that yield both gains and losses. This will then
 229 amount to measuring loss aversion and, with the proper use of the obtained standard
 230 sequences, this can be done in a parameter-free way.

231 To measure loss aversion, we first determine the utility-distance of x_0, \dots, x_n to
 232 outcome 0. Indeed, although we know that the sequence is equally spaced in utility
 233 units, we do not know how far their utility is above $U(0) = 0$. This we determine by
 234 obtaining the value of outcome b that makes a person indifferent between the
 235 prospects $(r:b, 0)$ and $(r:x_1, x_0)$, where r is some fixed probability. Under prospect
 236 theory, indifference between these prospects implies:

$$237 \quad U(x_0) - U(0) = \frac{w^+(r)}{1 - w^+(r)} (U(b) - U(x_1)) \quad (4.4)$$

238 If the quantities on the right hand side of this equation are known then, for the
 239 purpose of utility measurement, this equation can be seen as eliciting the location of

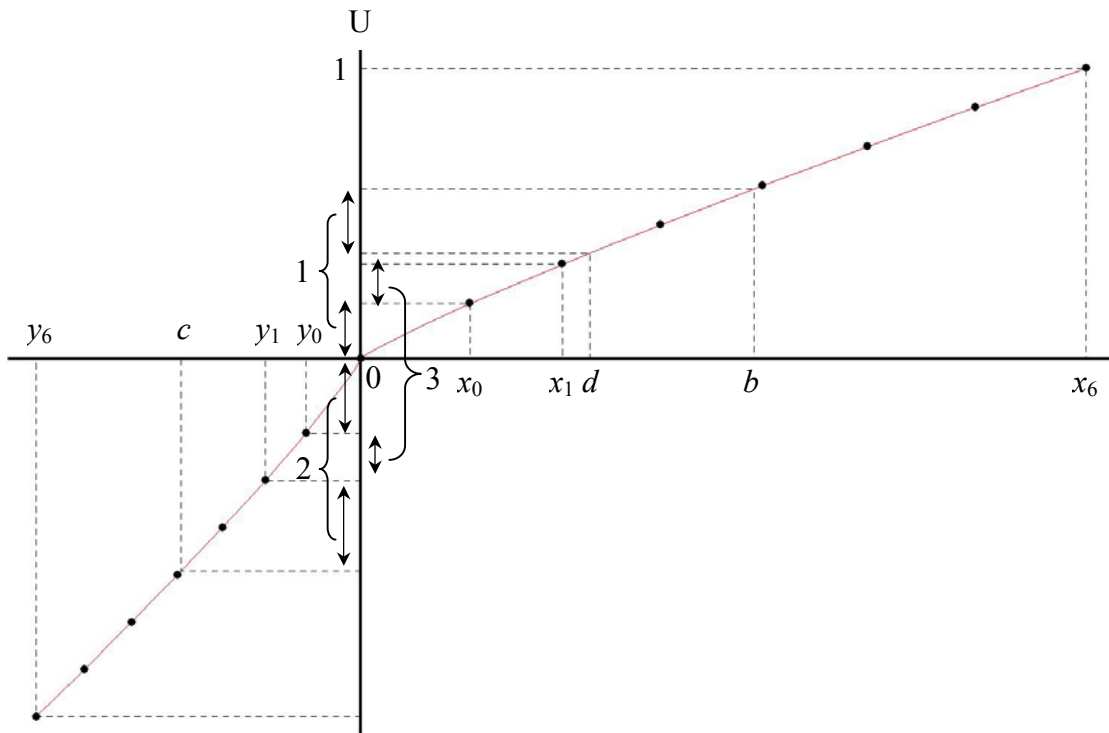
240 the utilities of the standard sequence for gains with respect to the utility 0 that is
 241 attached to outcome 0. Put differently, Equation 4.4 identifies the utility distance
 242 between outcome 0 and the outcomes of the standard sequence for gains. This is
 243 illustrated by brace 1 in Figure 4.1 below.

244

245

FIGURE 4.1 – Linking the Utilities for Gains and Losses

246



247

248

249 Assuming that $w^+(r)$ is known, the right-hand side of Equation 4.4 can be quantified
 250 directly in terms of the number of utility increments of the standard sequence if $b \in$
 251 $\{x_0, \dots, x_n\}$. The indifference outcome b usually is not an element of the obtained
 252 standard sequence of gains. If the obtained indifference outcome b falls within the
 253 range of the standard sequence, i.e. $b \in [x_1, x_n]$, then an estimate of $U(b)$ can be
 254 obtained by using linear interpolation. For example, if $b \in [x_{j-1}, x_j]$, then $U(b)$ can be
 255 approximated by

$$256 \quad \frac{b - x_{j-1}}{x_j - x_{j-1}} (U(x_j) - U(x_{j-1})) + U(x_{j-1}) \quad (4.5)$$

257 This approximation can be justified on the grounds that utility is often found to be
 258 linear over small monetary intervals (Wakker & Deneffe 1996).

259 As a second step in our measurement of loss aversion, we measure the utility
 260 distance between outcome zero and the standard sequence y_0, \dots, y_n of losses. This can
 261 be done by obtaining the outcome c that makes an agent indifferent between the
 262 prospects $(r:0, c)$ and $(r:y_0, y_1)$. Under prospect theory, indifference between these
 263 prospects implies:

$$264 \quad U(y_0) - U(0) = \frac{w^-(1-r)}{1-w^-(1-r)} (U(c) - U(y_1)) \quad (4.6)$$

265 This second step is illustrated by brace 2 in Figure 4.1. Assuming that $w^-(1-r)$ is
 266 known, again only $U(c)$ has to be determined in order to quantify the right-hand side
 267 of Equation 4.6 in terms of the number of utility increments of the standard sequence
 268 of losses. Because indifference outcome c need not be an element of the obtained
 269 standard sequence of losses, the utility of outcome c has to be interpolated from this
 270 sequence again.

271 The first two indifferences measure the utility distances between outcome 0
 272 and the standard sequences of gains and losses respectively. In the third and final step,
 273 the utility function for gains is linked to the utility function for losses by eliciting the
 274 outcome $d > x_0$ that makes the agent indifferent between the mixed prospects $(r:d, y_1)$
 275 and $(r:x_0, y_0)$. This is illustrated by brace 3 in Figure 4.1. Under prospect theory,
 276 indifference between these prospects implies

$$277 \quad U(y_0) - U(y_1) = \frac{w^+(r)}{w^-(1-r)} (U(d) - U(x_0)) \quad (4.7)$$

278 From a measurement perspective this equation amounts to relating the utility
 279 increment of the standard sequence of losses to that of the standard sequence of gains.
 280 The utility of outcome d has to be interpolated from the standard sequence of gains
 281 again.

282 Equations 4.5 – 4.7, the fact that standard sequences are equally spaced in
 283 utility units, and linear interpolation of the utility of indifference outcomes b, c, d ,
 284 fully determine the utilities of the outcomes $\{y_n, \dots, y_0, 0, x_0, \dots, x_n\}$.

285 In the above steps, the probability weights corresponding to the probabilities
 286 used in the elicitation procedure were assumed to be known, while in fact they are
 287 unknown a priori. Several parameter-free techniques to obtain these probability
 288 weights have been proposed in the literature (Abdellaoui 2000, Bleichrodt & Pinto

289 2000). Hence, if combined with these measurement methods, the three indifferences
 290 stated above can in principle be used to measure the utilities of the standard sequences
 291 of gains and losses on the same scale. In the present study, we did not pose additional
 292 questions to obtain the probability weights, and assume either linear probability
 293 weighting as in classical economic analyses or use the empirical estimates of the
 294 probability weights found by Kahneman & Tversky (1992) in the analysis. A different
 295 parameter-free method to measure loss aversion is in Abdellaoui, Bleichrodt &
 296 Paraschiv (2005).

297 5. The Experiment: Method

298 *Participants.* N = 1932 Dutch participated in the experiment which was held in
 299 February 2006. We used the DNB Household survey which is a household panel that
 300 completes a questionnaire every week on the Internet or, if Internet is not available in
 301 the household, by a special box connected to the television. The household panel is a
 302 representative sample of the Dutch population.

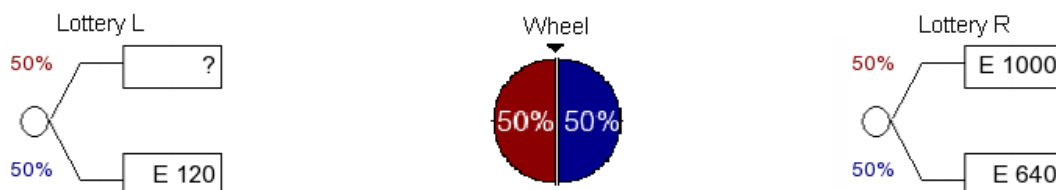
303

304 *Procedure.* Respondents first read experimental instructions (see Appendix A) and
 305 were then asked to answer a practice question to familiarize them with the
 306 experimental setting. In the instructions it was emphasized that there were no right or
 307 wrong answers. In order to obtain indifference between prospects we used direct
 308 matching, that is, respondents were asked to report an outcome of a prospect for
 309 which they would be indifferent between two particular prospects, which were framed
 310 as depicted in Figure 5.1 below.

311

312

FIGURE 5.1 – The Framing of the Prospect Pairs



313

314

315 Respondents were thus simply asked to report the upper prize of the left prospect that
 316 would make them indifferent between both prospects. The wheel in the middle served
 317 to explain probabilities to respondents. Both the probabilities reported in the wheel
 318 and the colors of the wheel corresponded to the probabilities of the prospects. The
 319 prizes of the prospects used were hypothetical (for a discussion see Section 7).

320

321 *Stimuli.* For each respondent we obtained a total of 16 indifferences; see Table 5.1.

322

323

TABLE 5.1 – The Obtained Indifferences

Matching Question	Prospect L		Prospect R
1	(0.5: <u>a</u> , 10)	~	(0.5: 50, 20)
2	(0.5: <u>x₁</u> , g)	~	(0.5: x ₀ , G)
.	.		.
.	.		.
7	(0.5: <u>x₆</u> , g)	~	(0.5: x ₅ , G)
8	(0.5: <u>y₁</u> , l)	~	(0.5: y ₀ , L)
.	.		.
.	.		.
13	(0.5: <u>y₆</u> , l)	~	(0.5: y ₅ , L)
14*	(0.5: <u>b</u> , 0)	~	(0.5: x ₁ , x ₀)
15*	(0.5: 0, <u>c</u>)	~	(0.5: y ₀ , y ₁)
16*	(0.5: <u>d</u> , y ₁)	~	(0.5: x ₀ , y ₀)

324

325

326

Notes: underlined outcomes are the matching outcomes and questions marked with an asterisk were presented in randomized order.

327 Following the first practice question, matching questions 2 to 7 served to obtain an
 328 increasing sequence of gains x_0, \dots, x_6 that are equally spaced in utility units, followed
 329 by six matching questions to obtain a decreasing sequence of losses y_0, \dots, y_6 that are
 330 equally spaced in terms of utility (see Section 4.1). Matching questions 14-16 served
 331 to obtain a parameter-free measurement of the degree of loss aversion at the
 332 individual level, under expected utility (see Section 4.2). As can be seen in Table 5.1,

333 the parameter values of p and r used throughout Section 4 were set at $1/2$, as in
 334 Bleichrodt & Pinto's (2000) experiment.

335

336 *Treatments.* In order to be able to test whether utility curvature is more pronounced
 337 for larger monetary outcomes, respondents were randomly assigned to two different
 338 treatments. These treatments only differed in the parameters values used for G , g , x_0 ,
 339 L , l , and y_0 . In the low-stimuli treatment, these parameters values were set at $G = 64$, g
 340 $= 12$, $x_0 = 100$, $L = -32$, $l = -6$, and $y_0 = -50$. In the high-stimuli treatment, all
 341 parameter values were scaled up by a factor 10, i.e. the parameters values were set at
 342 $G = 640$, $g = 120$, $x_0 = 1000$, $L = -320$, $l = -60$, and $y_0 = -500$.

343 6. The Experiment: Results

344 In the following analyses, the number of observations used varies considerably. The
 345 precise number of observations used in each analysis will be reported separately. The
 346 (sometimes high) rate of dropped observations is mainly determined by an imposed
 347 monotonicity condition (the obtained standard sequence of gains (losses) had to be
 348 strictly increasing (decreasing)), and an imposed completeness condition (each
 349 respondent had to complete all matching questions). Violation of such conditions
 350 suggests that respondents did not understand the questions or were not well
 351 motivated. We also dropped some extreme observations that similarly suggested lack
 352 of understanding.

353 Although dropping observations is unfavorable, it has some advantages
 354 especially when using a large representative sample. Then the performed analysis is
 355 based on data of respondents who had a good understanding of the questions, making
 356 them of better quality. In the same way, some other studies of large representative
 357 samples dropped even more subjects: for determining the relative risk aversion
 358 coefficient (see Section 6.1.2), Guiso & Paiella (2003) and Dohmen, Falk, Huffman,
 359 Sunde, Schupp & Wagner (2005) were even forced to drop 57% and 61% of their
 360 observations, respectively.

361

362 6.1.1 Utility Curvature: Non-Parametric Analysis

363 Table 6.1 summarizes the results regarding the obtained utility function for monetary
 364 gains and losses under the different treatments. As can be seen in the table, the
 365 difference between the successive elements of the average standard sequences is
 366 mostly increasing over all treatments for both gains and losses. This implies concave
 367 utility for gains and convex utility for losses, reflecting *diminishing sensitivity*: people
 368 are more sensitive to changes near the status quo than to changes remote from the
 369 status quo, as predicted by prospect theory but contrary to the classical prediction of
 370 universal concavity. Also, at face value utility curvature seems to be more
 371 pronounced for larger monetary outcomes.

372

373

TABLE 6.1 – Mean Results Utility Curvature

<i>i</i>	GAINS				LOSSES			
	High (N = 383)		Low (N = 431)		High (N = 330)		Low (N = 360)	
	x_i	$x_i - x_{i-1}$	x_i	$x_i - x_{i-1}$	y_i	$y_i - y_{i-1}$	y_i	$y_i - y_{i-1}$
1	1993 (602)	993	205 (94)	105	-851 (231)	350	-86 (36)	36
2	3000 (1131)	1007	319 (184)	114*	-1243 (431)	392*	-126 (59)	40*
3	4060 (1692)	1060*	441 (313)	122*	-1664 (634)	421*	-168 (83)	42*
4	5161 (2311)	1101**	576 (561)	135***	-2075 (856)	411	-211 (106)	43**
5	6283 (2980)	1122**	727 (865)	151*	-2494 (1069)	419	-254 (130)	43
6	7447 (3713)	1164**	893 (1244)	166	-2920 (1297)	426***	-298 (156)	44

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376

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Notes: standard deviations in parenthesis. * significantly higher than its predecessor at the 1% level. ** significantly higher than its predecessor at the 5% level. *** significantly higher than its predecessor at the 10% level.

378 We performed Wilcoxon signed-rank tests to test whether the differences between the
 379 successive elements of the standard sequence for gains and losses are indeed
 380 significantly increasing. As can be seen in Table 6.1, a total of 4 differences between
 381 the obtained successive elements of the standard sequence were significantly
 382 increasing for gains. In the loss domain, 3 differences between the obtained elements
 383 of the standard sequences were significantly increasing in both the low and the high-

384 stimulus treatment. Only one difference was significantly decreasing. Overall, our
 385 results thus suggest the presence of significant diminishing sensitivity, which is
 386 consistent with the findings of other parameter-free studies employing the tradeoff
 387 method to obtain utilities for gains (Wakker & Deneffe 1996; Abdellaoui 2000;
 388 Abdellaoui, Barrios & Wakker 2005) and losses (Fennema & van Assen 1999;
 389 Etchard-Vincent 2004) as well as with results from studies using parametric fittings
 390 (Currim & Sarin 1989; Tversky & Kahneman 1992; Heath, Huddart & Lang 1999;
 391 Davies & Satchell 2003)

392

393

TABLE 6.2 – Classification of Respondents

		LOSSES				Total
		Concave	Linear	Convex	Missing	
GAINS	Convex	50	31	77	58	216
	Linear	25	108	43	59	235
	Concave	49	44	143	121	363
	Missing	35	30	49	–	114
	Total	159	213	318	238	928

394

395 Finally, for each respondent we calculated the area under the normalized utility
 396 function for both gains and losses and we classified a respondent's utility function as
 397 concave (convex; linear) when this area was larger than (smaller than; equal to) 1/2
 398 for gains. For losses, a utility function was classified as concave (convex; linear)
 399 when the area was smaller than (larger than; equal to) 1/2. As Table 6.2 shows, a vast
 400 majority of utility functions exhibited a concave shape for gains combined with a
 401 convex shape for losses, again implying diminishing sensitivity as predicted by
 402 prospect theory.

403

404 6.1.2 Utility Curvature: Parametric Analysis

405 Although we obtained utilities in a parameter-free way using the trade-off method,
 406 we also used parametric methods to analyze the data. For each respondent, we
 407 estimated the *power utility function* with parameter ρ for both treatments. Thus, for
 408 each respondent and for each separate domain (gains and losses) we estimated:

$$409 \quad U(x) = x^\rho \quad \text{for } \rho > 0 \quad (6.1)$$

$$410 \quad U(x) = \ln(x) \quad \text{for } \rho = 0 \quad (6.2)$$

$$411 \quad U(x) = -x^\rho \quad \text{for } \rho < 0 \quad (6.3)$$

412 by minimizing the sum of squared residuals. The power utility function with
 413 parameter ρ is currently the most popular parametric family for fitting utility (Wakker
 414 2006) and is also known as the family of constant relative risk aversion (CRRA)
 415 because the ratio $-xU''(x)/U'(x)$, i.e. the *index of relative risk aversion*, is constant and
 416 equal to $1 - \rho$. We also estimated the *exponential utility function* for both gains and
 417 losses which is defined by:

$$418 \quad U(x) = e^{-\gamma z} - 1 \quad \text{for } \gamma > 0 \quad (6.4)$$

$$419 \quad U(x) = z \quad \text{for } \gamma = 0 \quad (6.5)$$

$$420 \quad U(x) = 1 - e^{-\gamma z} \quad \text{for } \gamma < 0 \quad (6.6)$$

421 where $z = (x - x_0)/(x_6 - x_0)$. This family is also known as the family of constant
 422 absolute risk aversion (CARA) because the ratio $-U''(x)/U'(x)$, i.e. the *Pratt-Arrow*
 423 *measure of risk aversion*, is constant and equal to γ .

424 Finally, we estimated the *expo-power utility function*, introduced by
 425 Abdellaoui, Barrios & Wakker (2005), which is a variation of the two-parameter
 426 family proposed by Saha (1993) and which is defined by:

$$427 \quad U(x) = -\exp(-z^\delta / \delta) \quad \text{for } \delta \neq 0 \quad (6.7)$$

$$428 \quad U(x) = -1/z \quad \text{for } \delta = 0 \quad (6.8)$$

429 where $z = x / x_6$. This particular specification allows for both concave and convex
 430 utility functions and a subset of this specification allows for the combination of
 431 concave utility, a decreasing Pratt-Arrow measure of risk aversion $((1 - \delta)/x + x^{\delta-1})$
 432 and an increasing index of relative risk aversion $(1 - \delta + x^\delta)$, which is a desirable
 433 feature because these phenomena are often found empirically (Abdellaoui, Barrios &
 434 Wakker 2005). As mentioned in the introduction, the one-to-one relationship between
 435 utility curvature and risk attitudes is not valid under nonexpected utility models such
 436 as prospect theory and, thus, we avoid the terms index of relative risk aversion and
 437 Pratt-Arrow measure of risk aversion in what follows.

438 Table 6.3 below summarizes the average optimal parameter estimates for the
 439 different parametric specifications for each specific treatment, found by minimizing
 440 the sum of squared residuals. As can be seen in the table, the average individual

441 parametric estimate of the power coefficient ρ for gains is 0.94 in both the high- and
 442 the low-stimulus treatment. This result seems to be consistent with a mean estimate
 443 for gains based on parameter-free data of 0.91 found by Abdellaoui, Barrios &
 444 Wakker (2005). A two-sided Mann-Whitney test does not reject the null hypothesis
 445 that the ranks of the estimated ρ -parameters for gains are equal across the high- and
 446 the low-stimulus treatment ($z = 0.253$, p -value = 0.8005).

447

448

TABLE 6.3 – Estimation Results

Treatment	ρ	γ	δ
Gains, high N = 378	0.94 (0.40)	0.14 (0.64)	1.36 (0.36)
Gains, low N = 428	0.94 (0.41)	0.19 (0.86)	1.36 (0.38)
Losses, high N = 326	0.90 (0.55)	0.17 (0.66)	1.36 (0.49)
Losses, low N = 356	0.93 (0.55)	0.19 (0.76)	1.39 (0.51)

449

Note: standard deviations in parenthesis.

450

451 Analysis of the individual ρ -parameters on the basis of one-sided Wilcoxon signed
 452 rank sum tests does indicate that the ρ -coefficients for gains are significantly lower
 453 than 1 in both the high- and the low-stimulus treatment (low: $z = -5.009$, p -value =
 454 0.000; high: $z = -4.944$, p -value = 0.000), which implies a significant overall degree
 455 of diminishing marginal utility for gains.

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For losses, the obtained parameter estimates were 0.90 for the high-stimulus
 treatment and 0.93 for the low stimulus treatment respectively, which is in line with a
 trimmed mean estimate of 0.901 based on parameter-free data found by Fennema &
 Van Assen (1999). Again, a two-sided Mann-Whitney test does not reject the null
 hypothesis that the ranks of the estimated ρ -parameters for losses are equal across the
 treatments ($z = 0.141$, p -value = 0.888). In addition, the obtained ρ -coefficients for
 losses proved to be significantly lower than 1 in both the high and the low-stimulus
 treatment based on one-sided Wilcoxon signed rank sum tests (low: $z = -5.662$, p -

464 value = 0.000; high: $z = -5.466$, p-value = 0.000) which suggests diminishing
465 sensitivity, as predicted by prospect theory.

466 Interestingly, an overall two-sided Wilcoxon rank sum test rejects the null-
467 hypothesis that the ranks of the obtained ρ -coefficients are equal between the gain and
468 the loss domain in favor of the hypothesis that the ρ -coefficients are higher in the gain
469 domain compared to the loss domain ($z = 2.159$, p-value = 0.0308). Thus, we have
470 obtained evidence suggesting that utility is concave for gains but is even more convex
471 for losses. This finding supports the results obtained by Abdellaoui, Bleichrodt &
472 Paraschiv (2004) and Fishburn & Kochenberger (1979, p. 511). The parameter
473 estimates of the other functional forms are all highly correlated and, hence, statistical
474 tests based on the other functional families gives very similar results and will not be
475 reported here.

476 The large representative dataset allows us to relate the degree of utility
477 curvature with socio-demographic variables. Therefore, we performed a simple
478 regression analysis with the individual estimators as dependent variables and a
479 treatment dummy and several socio-demographic variables as independent variables.
480 The results of this simple regression are reported in the first three columns of Table
481 6.4. As can be seen in Table 6.4, the estimated coefficient for gains (ρ^+) is
482 significantly lower for females than for males, but a significant negative relation
483 between gender and the estimated coefficient for losses (ρ^-) is not found. This finding
484 is indirectly consistent with the common finding that females are generally more risk
485 averse for gains than males (Barsky 1997; Hartog, Ferrer-i-Carbonell & Jonker 2002;
486 Donkers, Melenberg & van Soest 2000), but contradicts the results of a recent study
487 by Fehr-Duda, de Gennaro & Schubert (2006), who did not find gender differences in
488 the utility functions for both gains and losses based on parametric fittings and using
489 students as subjects.
490

491

TABLE 6.4 – Results Regression

Variable	ρ^+	ρ^-	λ
TrLow	-0.002 (0.029)	0.022 0.043	-0.121 (0.158)
Female	-0.065* (0.030)	0.030 (0.042)	0.340* (0.170)
Income /1000	-0.002 (0.013)	-0.004 0.018	-0.02 (0.07)
Age	0.001 (0.001)	0.002 (0.002)	0.002 (0.005)
Education	-0.0004 (0.006)	0.010 (0.008)	-0.062* (0.031)
N	803	678	437

Notes: standard errors in parentheses. * significant at the 5% level.

492

493

494 Because our method to obtain utilities is robust to subjective probability weighting,
 495 our results suggest that part of the difference in risk attitudes between males and
 496 females is rational: the utility that females obtain from positive monetary outcomes
 497 diminishes quicker compared to males, leading to more risk-averse behavior.
 498 Interestingly, our results suggest that this the difference in the degree of utility
 499 curvature between genders pertains to gains only. Other socio-demographic variables
 500 such as income, age, and education all proved to have no significant effect on the
 501 degree of utility curvature for both gains and losses.

502

503 6.2 Loss Aversion

504 Unfortunately, a commonly accepted definition of loss aversion does not exist in the
 505 literature (Abdellaoui, Bleichrodt & Paraschiv 2005). We define the loss aversion
 506 parameter λ as follows:

507

$$\lambda = \frac{U(y_0) x_0}{U(x_0) y_0} \quad (6.9)$$

508 This definition best approximates the definitions proposed by Tversky & Kahneman
 509 (1992), Wakker & Tversky (1993) and Köbberling & Wakker (2004).¹ Table 6.5
 510 below presents the summary statistics for the different indifference values of
 511 outcomes b , c , and d , and the resulting loss aversion parameter under expected utility,
 512 i.e. $w(1/2) = 1/2$, and prospect theory using the probabilities corresponding to the
 513 subjective probability weighting function found by Kahneman & Tversky (1992),
 514 being $w^-(1/2) = 0.4540$ and $w^+(1/2) = 0.4206$. The mean value of λ under expected
 515 utility, denoted by λ_{EU} , is 1.69 for the high-stimuli treatment and 1.64 for the low
 516 stimuli treatment. Under prospect theory with the parameter estimates found by
 517 Tversky & Kahneman (1992), the mean value of λ , denoted by λ_{PT} , is equal to 1.79
 518 for the high-stimuli treatment and 1.74 for the low stimuli treatment.

519

520

TABLE 6.5 – Mean Results Loss Aversion

	High N = 210	Low N = 229
b	4016 (1604)	386 (150)
c	-1569 (612)	-157 (59.0)
d	1842 (833)	180 (87.6)
λ_{EU}	1.69 (1.10)	1.64 (1.43)
λ_{PT}	1.79 (1.17)	1.74 (1.51)

521

Note: standard deviations in parenthesis.

522

523 This overall decrease in the degree of loss aversion with the size of outcomes is
 524 consistent with the findings of Abdellaoui, Bleichrodt & Paraschiv (2004, p. 27) and

¹ Tversky & Kahneman (1992) implicitly used $\lambda = U(-\$1)/U(\$1)$ as an index of loss aversion. Wakker & Tversky (1993) defined loss aversion as $U'(-x) \geq U'(x)$ for all relevant $x > 0$, which could be translated to a loss aversion coefficient of $\lambda = U'(-x)/U'(x)$ for some proper x (Abdellaoui, Bleichrodt & Paraschiv 2005). Finally, Köbberling & Wakker (2004) proposed defining loss aversion as the ratio between the left and the right derivative of the utility function at the reference point, i.e. $\lambda = U'_1(0)/U'_2(0)$.

525 Bleichrodt & Pinto (2002), who found a decreasing degree of loss aversion with the
 526 size of the outcomes in the health domain. This difference in estimates between the
 527 high-stimulus and the low-stimulus treatment is however not statistically significant
 528 based on a two-sided Mann-Whitney test ($z = -0.054$, $p\text{-value} = 0.9569$). Thus,
 529 generally, our result suggests that on average people weight a particular loss about 1.7
 530 times as heavy as a corresponding gain when making decisions. The obtained λ is
 531 lower than the parametric estimate of $\lambda = 2.25$ obtained by Tversky & Kahneman
 532 (1992), and the non-parametric estimate of $\lambda = 2.15$, based on the definition of loss
 533 aversion proposed by Kahneman & Tversky (1979) and found by Abdellaoui,
 534 Bleichrodt & Paraschiv (2005). Our mean estimate of λ is however more consistent
 535 with a recent study by Johnson, Gaechter & Herrman (2006) who found an average
 536 overall mean λ of 1.85 using a large sample of car buyers.

537 Interestingly, if we regress the obtained measurement of loss aversion with
 538 socio-demographic characteristics, we find that females are significantly more loss
 539 averse than males as the final column of Table 6.4 shows. Thus, on average, females
 540 weight losses about .34 more heavily than males.² In addition, education has a
 541 significant negative effect on the degree of loss aversion. These results are consistent
 542 with the results obtained by Johnson, Gaechter & Herrman (2006).

543 7. Discussion

544 7.1 Discussion of Method

545 We used direct matching to obtain indifferences between prospects. There is evidence
 546 that using direct choice between prospects by using a bisection method (Abdellaoui
 547 2000) or by using a multiple price list (Tversky & Kahneman 1992; Holt & Laury
 548 2002) to obtain indifference between prospects yields more consistent results (Bostic,

² It could be argued that this holds because females and males weight probabilities differently as a recent study by Fehr-Duda, de Gennaro and Schubert (2006) suggests. However, if we use the median obtained parameter estimates from the aforementioned study, being $w^+(\frac{1}{2}) = 0.468$ and $w^-(\frac{1}{2}) = 0.5$ for males and $w^+(\frac{1}{2}) = 0.425$ and $w^-(\frac{1}{2}) = 0.524$ for females, the average obtained λ becomes 1.60 for males and 2.21 for females. Hence, the gender difference in loss aversion becomes even stronger if we correct for gender differences in subjective probability weighting.

549 Herrnstein & Luce 1990; Luce 2000). However, using such methods to obtain
550 indifference is fairly time consuming which was not tractable in this large-scale
551 experiment with the general public.

552 We used hypothetical incentives in our experiment. There is an extensive
553 debate in experimental methodology about whether real or hypothetical incentives
554 yield better or more reliable data. Camerer & Hogarth (1999) and Hertwig & Ortmann
555 (2001) provide excellent summaries of the ongoing debate. In general, real incentives
556 do seem to reduce data variability (Camerer & Hogarth 1999) and increase risk
557 aversion in choice (Holt & Laury 2002, 2005) and direct matching tasks (Kachelmeier
558 & Shehata 1992). We did not use the incentive compatible Becker-DeGroot-Marschak
559 (BDM) rewarding scheme to implement real incentives for the following reasons.
560 First of all, a large part of the experiment concerned substantial losses and, hence, real
561 incentives could not be used for ethical reasons. Second, the BDM scheme is fairly
562 complex (Braga & Starmer 2005) and the BDM scheme is prone to irrational auction
563 strategies (Plott & Zeiler 2005, p. 537). For example, respondents might report a
564 higher matching outcome thinking it is a clever bargaining strategy or respondents
565 might fail to understand that it is a dominant strategy to report their true matching
566 outcome. Because it is important to minimize the burden on respondents in a large-
567 scale experiment, this was another reason for not implementing real incentives. Third,
568 there is evidence that real incentives do not affect results in relatively simple tasks
569 (Camerer & Hogarth 1999). Fourth and finally, due to practical limitations it is
570 virtually impossible to implement real incentives in a large-scale experiment
571 (Donkers, Melenberg & van Soest 2001; Guiso & Paiella 2003; Dohmen et al 2005),
572 although Harrison, Johnson, McInnes & Rutström (2006) did use real incentives in
573 their impressive study.

574

575 **7.2 Discussion of the Results**

576 If we compare our findings with other measurements of risk attitudes using large
577 representative datasets, we find that our estimated relative risk coefficient for gains of
578 0.06 ($= 1 - 0.94$) is relatively small. For example, Harrison et al (2006) found a mean
579 risk aversion coefficient of 0.67, and Barksy, Juster, Kimball & Shapiro (1997) found
580 a mean risk tolerance (the reciprocal of the constant relative risk coefficient) of 0.24

581 which translates into a mean relative risk coefficient of 4.16. The smallest degree of
582 relative risk aversion coefficient found by Hartog et al (2002) was 20. Clearly, the
583 difference between these studies and the present study is that all these studies
584 assumed expected utility and hence ignored the important role of probability
585 weighting in the analysis. Hence, our results give empirical support to the conjecture
586 of Rabin (2000b, p.202) being that diminishing marginal utility is an “implausible
587 explanation for appreciable risk aversion, except when the stakes are very large”:
588 utility curvature is less pronounced than suggested by classical utility measurements.
589 Hence, this suggests that the phenomenon probability weighting is valid outside the
590 laboratory, that is, the results support the external validity of subjective probability
591 weighting.

592 In addition, the results confirm the common finding that females are more risk
593 averse than males. Contrary to classical studies that ascribed this gender difference
594 solely to differences in the degree of utility curvature, we are able to test whether this
595 finding is caused by gender differences in the degree of utility curvature, loss
596 aversion, or subjective probability weighting. The results show that females are more
597 risk averse than males because the utility that females obtain from monetary gains
598 diminishes quicker compared to males, but, more importantly, because females are
599 more loss averse than males.

600 8. Conclusion

601 We have obtained parameter-free measurements of the rational (utility) component of
602 risk attitudes using a representative sample from the Dutch population. Such
603 measurements are of crucial importance for policy decisions on important economic
604 problems such as equitable taxation and the cost-benefit analysis of education, health
605 care, and retirement. The results suggest that utility is concave for gains and convex
606 for losses, implying diminishing sensitivity, as predicted by prospect theory. In
607 addition, our results suggest that classical utility measurements are overly concave,
608 which is possibly caused by the ignoring of probability weighting in these studies. We
609 have also found evidence that utility for gains diminishes quicker for females than for
610 males, which explains the common finding in the literature that females are generally

611 more risk averse than males. Further, we found that the degree of utility curvature is
612 not altered by scaling up monetary outcomes. Finally, we have obtained
613 measurements of loss aversion. The results show that on average the general public
614 weights losses 1.7 times as much as a commensurable gain and that males and higher
615 educated persons are less loss averse.

616 Appendix A. Experimental Instructions

617 [Instructions are translated from Dutch]

618

619 Welcome at this experiment on individual decision making. The experiment is about
620 your risk attitude. Some people like to take risks while other people like to avoid
621 risks. The goal of this experiment is gain additional insight into the risk attitude of
622 people living in the Netherlands. This is very important for both scientists and
623 policymakers. If we get a better understanding of how people react to situations
624 involving risk, policy can be adjusted to take this into account (for example with
625 information provision on insurance and pensions, and advice for saving and
626 investment decisions). Your cooperation at this experiment is thus very important and
627 is highly appreciated.

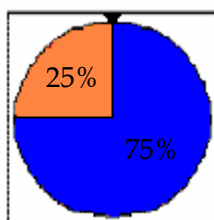
628 The questions that will be posed to you during this experiment will not be
629 easy. We therefore ask you to read the following explanation attentively. In this
630 experiment, there are no right or wrong answers. It is exclusively about your own
631 preferences. In those we are interested.

632 Probabilities (expressed in percentages) play an important role in this
633 experiment. Probabilities indicate the likelihood of certain events. For example, you
634 probably have once heard Erwin Krol say that the probability that it will rain
635 tomorrow is equal to 20 percent (20%). He then means, that rain will fall on 20 out of
636 100 similar days. During this experiment, probabilities will be illustrated using a
637 wheel, as depicted below.

638

639

640



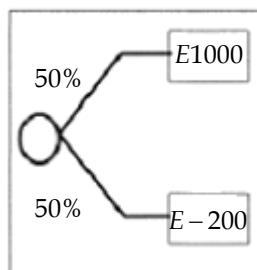
641

642

643

644 Suppose that the wheel depicted in the picture above is a wheel consisting of 100
 645 equal parts. Possibly you have seen such a wheel before in television shows such as
 646 The Wheel of Fortune. Now imagine that 25 out of 100 parts of the wheel are orange and
 647 and that 75 out of 100 parts are blue. The probability that the black indicator on the
 648 top of the wheel points at an orange part after spinning the wheel is equal to 25% in
 649 that case. Similarly, the probability that the black indicator points at an blue part after
 650 spinning the wheel is equal to 75%, because 75 out of 100 parts of the wheel are blue.
 651 The size of the area of a color on the wheel thus determines the probability that the
 652 black indicator will end on a part with that color.

653 Besides probabilities, lotteries play an important role in this experiment.
 654 Perhaps you have participated in a lottery such as the National Postal Code Lottery
 655 yourself before. In this experiment, lotteries yield monetary prizes with certain
 656 probabilities, similar to the National Postal Code Lottery. However, the prizes of the
 657 lotteries in this experiment can also be negative. If a lottery yields a negative prize,
 658 you should imagine yourself that you will have to pay the about amount of money. In
 659 the following explanation we will call a negative prize a loss and a positive prize a
 660 profit. During this experiment, lotteries will be presented like the example presented
 661 below:



662

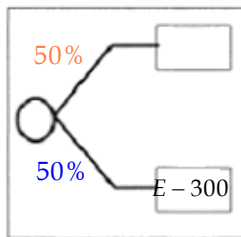
663 In this case, the lottery yields a profit of 1000 Euro with probability 50%. However,
 664 with probability 50%, this lottery yields a loss of 200 Euro. You should image that if
 665 you participated in this lottery, you would get 1000 Euro with probability 50%, and
 666 with probability 50% you would have to pay 200 Euro.

667 During this experiment you will see two lotteries, named Lottery L (Left) and
 668 Lottery R (right), on the top of each page. Between these lotteries you will see a
 669 wheel that serves as an aid to illustrate the probabilities used. You will see an
 670 example of the layout of the screen on the next page.

671

672

Lottery L



673

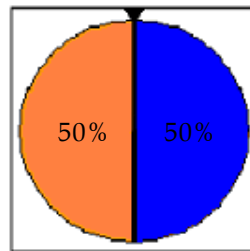
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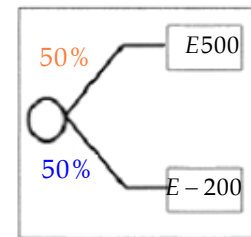
677

Wheel



678

Lottery R



679 In this example, Lottery R yields a profit of 500 Euro with probability 50% and with
 680 probability 50% it yields a loss of 200 Euro. You should imagine that, if we would
 681 spin the wheel once and the black indicator would point at the orange part of the
 682 wheel, Lottery R would yield a profit of 500 Euro. However, if the black marker
 683 would point at the blue part of the wheel, Lottery R would yield a loss of 200 Euro.

684 Similarly, Lottery L yields a loss of 300 Euro with probability 50%. However,
 685 as you can see, the upper prize of Lottery L is missing. During this experiment, we
 686 will repeatedly ask you for the upper prize of Lottery L (in Euro) that makes Lottery
 687 L and Lottery R equally good or bad for you. Thus, we will ask you for the upper
 688 prize of Lottery L for which you value both lotteries equally.

689 You could imagine that most people prefer Lottery L if the upper prize of
 690 Lottery L is very high, say 3000 Euro. However, if this prize is not so high, say 500
 691 Euro, most people would prefer Lottery R. Somewhere between these two prizes there
 692 is a “turnover point” for which you value both lotteries equally. For high prizes you
 693 will prefer Lottery L and for low prizes you will prefer Lottery R. The turnover point
 694 is different for everybody and is determined by your own feeling. To help you a little
 695 bit in the choice process, we will report the range of prizes in which the answer of
 696 most people lies approximately at each question.

697 How this works precisely will become clear in the practice question that will start if
 698 you click on the CONTINUE button below. If something it not clear to you, you can

699 read the explanation of this experiment again by pressing the BACK button below.
 700 [Practice question]
 701 The practice question is now over. The questions you will encounter during this
 702 experiment are very familiar to the practice question. If you click on the BEGIN
 703 button below, the experiment will start. If you want to go through the explanation of
 704 this experiment again, click on the EXPLANATION button. Good luck.

705 References

- 706 Abdellaoui, Mohammed (2000), Parameter-Free Elicitation of Utilities and
 707 Probability Weighting Functions, *Management Science* 46, 1497–1512.
- 708 Abdellaoui, Mohammed, Carolina Barrios & Peter P. Wakker (2005), Reconciling
 709 Introspective Utility With Revealed Preference: Experimental Arguments Based
 710 on Prospect Theory, *Journal of Econometrics*, forthcoming.
- 711 Abdellaoui, Mohammed, Frank Vossman & Martin Weber (2005), Choice-Based
 712 Elicitation and Decomposition of Decision Weights for Gains and Losses under
 713 Uncertainty, *Management Science* 51, 1384–1399.
- 714 Abdellaoui, Mohammed, Han Bleichrodt & Corina Paraschiv (2004), Measuring Loss
 715 Aversion under Prospect Theory: A Parameter-Free Approach, iMTA/iBMG,
 716 Erasmus University, Rotterdam, The Netherlands.
- 717 Allais, Maurice (1953), Le Comportement de l'Homme Rationnel devant le Risque:
 718 Critique des Postulats et Axiomes de l'Ecole Américaine, *Econometrica* 21,
 719 503–546.
- 720 Arkes, Hal R., Robyn M. Dawes & Caryn Christensen (1986), Factors Influencing the
 721 Use of a Decision Rule in a Probabilistic Task, *Organizational Behavior and*
 722 *Human Decision Processes* 37, 93-110.
- 723 Barsky, Robert B., F. Thomas Juster, Miles S. Kimball & Matthew D. Shapiro (1997),
 724 Preference Parameters and Behavioral Heterogeneity: An Experimental Approach
 725 in the Health and Retirement Study, *Quarterly Journal of Economics* 112, 537–
 726 579.

- 727 Blake, David (1996), Efficiency, Risk Aversion and Portfolio Insurance: An Analysis
728 of Financial Asset Portfolios Held by Investors in the United Kingdom, *Economic*
729 *Journal* 106, 1175–1192.
- 730 Bleichrodt, Han & José Luis Pinto (2000), A Parameter-Free Elicitation of the
731 Probability Weighting Function in Medical Decision Analysis, *Management*
732 *Science* 46, 1485–1496.
- 733 Bleichrodt, Han & José Luis Pinto (2002), Loss Aversion and Scale Compatibility in
734 Two-Attribute Trade-Offs, *Journal of Mathematical Psychology* 46, 315–337.
- 735 Braga, Jacinto & Chris Starmer (2005), Preference Anomalies, Preference Elicitation,
736 and the Discovered Preference Hypothesis, *Environmental and Resource*
737 *Economics* 32, 55-89.
- 738 Bostic, Raphael, Richard J. Herrnstein & R. Duncan Luce (1990), The Effect on the
739 Preference-Reversal Phenomenon of Using Choice Indifferences, *Journal of*
740 *Economic Behavior and Organization* 13, 193–212.
- 741 Camerer, Colin F. & Robin M. Hogarth (1999), The Effects of Financial Incentives in
742 Experiments: A Review and Capital-Labor-Production Framework, *Journal of*
743 *Risk and Uncertainty* 19, 7–42.
- 744 Currim, Imran S. & Rakesh K. Sarin (1989), Prospect versus Utility, *Management*
745 *Science* 35, 22–41.
- 746 Davidson, Donald, Patrick Suppes & Sidney Siegel (1957), *Decision Making: An*
747 *Experimental Approach*, Stanford University Press, Stanford, CA.
- 748 Davies, Greg B. & Stephen E. Satchell (2003), Continuous Cumulative Prospect
749 Theory and Individual Asset Allocation, University of Cambridge, UK
- 750 Dohmen, Thomas, Armin Falk, David Huffman, Uwe Sunde, Jürgen Schupp & Gert
751 G. Wagner (2005), Individual Risk Attitudes: New Evidence from a Large,
752 Representative, Experimentally-Validated Survey, Institute for the Study of
753 Labor, Bonn, Germany, Working Paper No.1730.
- 754 Donkers, A.C.D., Bertrand Melenberg & Arthur H.O. van Soest (2001), Estimating
755 Risk Attitudes Using Lotteries; A Large Sample Approach, *Journal of Risk and*
756 *Uncertainty* 22, 165–195.

- 757 Etchart-Vincent, Nathalie (2004), Is Probability Weighting Sensitive to the Magnitude
758 of Consequences? An Experimental Investigation on Losses, *Journal of Risk and*
759 *Uncertainty* 28, 217–235.
- 760 Fennema, Hein & Marcel A.L.M. van Assen (1998), Measuring the Utility of Losses
761 by Means of the Tradeoff Method, *Journal of Risk and Uncertainty* 17, 277–295.
- 762 Fishburn, Peter C. & Gary A. Kochenberger (1979), Two-Piece von Neumann-
763 Morgenstern Utility Functions, *Decision Sciences* 10, 503–518.
- 764 Friend, Irwin & Marshall E. Blume (1975), The Demand for Risky Assets, *American*
765 *Economic Review* 65, 900–922.
- 766 Gneezy, Uri, & Aldo Rustichini (2000), Pay Enough or Don't Pay at All, *Quarterly*
767 *Journal of Economics* 115, 791–810.
- 768 Green, Paul E. (1963), Risk Attitudes and Chemical Investment Decisions, *Chemical*
769 *Engineering Process* 59, pp. 35-40.
- 770 Guiso, Luigi & Monica Paiella (2003), Risk Aversion, Wealth and Background Risk,
771 Bank of Italy Economic Working Paper No.483.
- 772 Harrison, Glen W., Eric Johnson, Melayne M. McInnes, & E. Elisabet Rutström
773 (2003), Risk Aversion and Incentive Effects: Comment, Dept. of Economics,
774 College of Business Administration, University of Central Florida, USA.
- 775 Harrison, Glen W., Eric Johnson, Melayne M. McInnes, & E. Elisabet Rutström
776 (2004), Estimating Risk Attitudes in Denmark: A Field Experiment, Dept. of
777 Economics, College of Business Administration, University of Central Florida,
778 USA.
- 779 Hartog, Joop, Ada Ferrer-i-Carbonell, & Nicole Jonker (2002), Linking Measured
780 Risk Aversion to Individual Characteristics, *Kyklos* 55, 3–26.
- 781 Heath, Chip, Steven Huddart, & Mark Lang (1999), Psychological Factors and Stock
782 Option Exercise, *Quarterly Journal of Economics* 114, 601–627.
- 783 Fehr-Duda, Helga, Manuele de Gennaro & Renate Schubert (2006), Gender, Financial
784 Risk, and Probability Weights, *Theory and Decision* 60, 283-313.
- 785 Hershey, John C. & Paul J.H. Schoemaker (1985), Probability versus Certainty
786 Equivalence Methods in Utility Measurement: Are They Equivalent?,
787 *Management Science* 31, 1213–1231.

- 788 Hertwig, Ralf & Andreas Ortmann (2001), Experimental Practices in Economics: A
789 Challenge for Psychologists?, *Behavioral and Brain Sciences* 24, 383–403.
- 790 Holt, Charles A. & Susan K. Laury (2002), Risk Aversion and Incentive Effects,
791 *American Economic Review* 92, 1644–1655.
- 792 Holt, Charles A. & Susan K. Laury (2005), Risk Aversion and Incentive Effects: New
793 Data without Order Effects, *American Economic Review* 95, 902–904.
- 794 Johnson, Eric, Simon Gaechter & Andreas Herrmann (2006), Exploring the Nature of
795 Loss Aversion, Institute for the Study of Labor, Bonn, Germany, Working Paper
796 No.2015.
- 797 Kachelmeier, Steven J. & Mohamed Shehata (1992), Examining Risk Preferences
798 under High Monetary Incentives: Experimental Evidence from the People’s
799 Republic of China, *American Economic Review* 82, 1120–1141
- 800 Kahneman, Daniel & Amos Tversky (1979), Prospect Theory: An Analysis of
801 Decision under Risk, *Econometrica* 47, 263–291.
- 802 Köbberling, Veronika, Christiane Schwieren & Peter P. Wakker (2006), Prospect-
803 Theory’s Diminishing Sensitivity versus Economic’s Intrinsic Utility of Money:
804 How the Introduction of the Euro Can Be Used to Disentangle the Two
805 Empirically, Dept. of Economics, University of Maastricht, The Netherlands.
- 806 Laury, Susan K. & Charles A. Holt (2000), Further Reflections on Prospect Theory,
807 Dept. of Economics, Georgia State University, Atlanta, GA.
- 808 Loehman, Edna (1998), Testing Risk Aversion and Unexpected Utility Theories,
809 *Journal of Economic Behavior and Organization* 33, 285–302.
- 810 Loewenstein, George F. (1999), Experimental Economics from the Vantage-Point of
811 Behavioural Economics, *Economic Journal* 109, F25–F34.
- 812 Lopes, Lola L. (1987), Between Hope and Fear: The Psychology of Risk, *Advances in*
813 *Experimental Psychology* 20, 255–295.
- 814 Luce, R. Duncan (2000), *Utility of Gains and Losses: Measurement-Theoretical and*
815 *Experimental Approaches*, Lawrence Erlbaum Publishers, London.
- 816 McCord, Mark R. & Richard de Neufville (1986), Lottery Equivalents: Reduction of
817 the Certainty Effect Problem in Utility Assessment, *Management Science* 32,
818 56–60.

- 819 Mill, John S. (1848), *Principles of Political Economy*, London, Longmans Green,
820 1917.
- 821 Plott, Charles R. & Kathryn Zeiler (2005), The Willingness to Pay-Willingness to
822 Accept Gap, the “Endowment Effect,” Subject Misconceptions, and Experimental
823 Procedures for Eliciting Valuations, *American Economic Review* 95, 530–545.
- 824 Rabin, Matthew (2000a), Risk Aversion and Expected-utility Theory: A Calibration
825 Theorem, *Econometrica* 68, 1281–1292.
- 826 Rabin, Matthew (2000b), Diminishing Marginal Utility of Wealth Cannot Explain
827 Risk Aversion. In Daniel Kahneman & Amos Tversky (Eds), *Choices, Values,
828 and Frames*, Chapter 11, 202–208, Cambridge University Press, New York.
- 829 Starmer, Chris (2000), Developments in Non-Expected Utility Theory: The Hunt for a
830 Descriptive Theory of Choice under Risk, *Journal of Economic Literature* 38,
831 332–382.
- 832 Tversky, Amos (1967), Utility Theory and Additivity Analysis of Risky Choices,
833 *Journal of Experimental Psychology* 75, 27–36.
- 834 Tversky, Amos & Daniel Kahneman (1992), Advances in Prospect Theory:
835 Cumulative Representation of Uncertainty, *Journal of Risk and Uncertainty* 5,
836 297–323.
- 837 Wakker, Peter P. (2006), Explaining the Characteristics of the Power (CRRA) Utility
838 Function, Econometric Institute, Erasmus University Rotterdam, The Netherlands
- 839 Wakker, Peter P. & Daniel Deneffe (1996), "Eliciting von Neumann-Morgenstern
840 Utilities when Probabilities Are Distorted or Unknown", *Management Science*
841 42, 1131–1150.
- 842 Young, H. Peyton (1990), Progressive Taxation and Equal Sacrifice, *American
843 Economic Review* 80, 253–266.