ABSTRACT

"Reflections on Gains and Losses: A 2×2×7 Experiment"

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What determines risk attraction or aversion? We experimentally examine three factors: the gain-loss dichotomy, the probabilities (0.2 vs. 0.8), and the money at risk (7 amounts).

We find that, for both gains and losses and for low and high probabilities, the majority display risk attraction for small amounts of money, and risk aversion for larger amounts. Thus, when examining the risk attitudes of the majority, what matters is the amount of money at risk (the *amount effect*) and not the gain-loss dichotomy, or the probabilities.

Yet the frequency of risk-attraction behavior does vary according to the gain-loss dichotomy and to the probabilities involved. Since Kahneman and Tversky, the literature has studied gain-loss *reflections*. We submit that a reflection can be decomposed into a *translation* and a probability *switch*. We find that both the translation effect and the switch effect are significant, and of comparable magnitude, a result that is equidistant from the diverging implications of two popular views, namely the gain-loss asymmetry view, and Kahneman and Tversky's fourfold pattern. We also argue that the translation effect implies a deeper violation of preference theory than the amount and switch effects, because it requires "multiple-selves" preferences.

Keywords: Reflection Effect, Risk Attraction, Risk Aversion, Gains, Losses, Experiments, House Money,Single self, Multiple-selves preferences.

JEL Classification Numbers: C91, D81

Reflections on Gains and Losses: A 2×2×7 Experiment[1]

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1. Introduction

What determines risk attraction or aversion? Present conventional wisdom, no doubt inspired by the pioneer work of Nobel laureate Daniel Kahneman and his late coauthor Amos Tversky, views individuals as risk averse for gains and risk seeking for losses. They asked "What happens when the signs of the outcomes are reversed so that gains are replaced by losses?" (Kahneman and Tversky, 1979, p. 268), and answered,

> "… the preference between negative prospects is the mirror image of the preference between positive prospects. Thus the reflection of prospects around 0 reverses the preference order. We label this pattern the *reflection effect*."

And they continued,

> "…the reflection effect implies that risk aversion in the positive domain is accompanied by risk seeking in the negative domain."

The present paper experimentally examines not only Kahneman and Tversky's gain-loss dichotomy, but also the role of probabilities (0.2 vs. 0.8) and of the amount of money at stake (seven amounts, from \$3 to a relatively substantial \$100). This yields a 2×2×7 experimental design, implemented in four treatments named *G*, *G'*, *L* and *L'*, each dealing with the seven amounts of money at stake. Our participants (or "subjects") make real, not hypothetical, choices between simple uncertain money prospects and their expected money values.

A first result is that the majority of our participants display risk attraction for small amounts of money and risk aversion for larger amounts. The implications are noteworthy: when examining

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the risk attitudes of the majority, *what matters is the amount of money at risk*, and not the gain-loss dichotomy, or the probabilities. In fact, this "amount effect" is extremely robust, and it already appears in our 1999 and in press papers.

Following Kahneman and Tversky's path, the study of the gain-loss dichotomy has been largely confined to "reflected" choices where all the money amounts of a positive prospect are multiplied by minus one. We submit that such a reflection has two components: a *translation* (or change of origin) of the probability distributions of the money outcomes, which naturally captures the gain-loss asymmetry, and a *switch* of probabilities between the good and the bad outcomes. (See Section 2 below for precise definitions.)

Our Treatments *G* and *L* differ only by a translation from gains to losses, and so do Treatments *G*' and *L*'. Treatments *G* and *G'*, on the contrary, differ only in the switch of the probabilities of the favorable and unfavorable outcomes, and so do Treatments *L* and *L*'. (Thus, Treatments *G* and *L*' differ by a reflection, as do *G*' and *L*.) Taken together, they explore the effects of the two components, "translation" (gain vs. loss) and "probability switch" (0.2 vs. 0.8), on risk attraction, so permitting a better understanding of any gain-loss asymmetry for each amount of money at stake. In a nutshell, we find:

* Translating gains into losses increases the frequency of choices that display risk attraction, both when the probability of the bad outcome is low (0.2) and when it is high (0.8). We call this increase in risk attraction a *translation effect*.

* Increasing the probability of the bad outcome from 0.2 to 0.8 increases the frequency of risk attraction, both when choices involve gains and when choices involve losses. We call this increase in risk attraction a *switch effect*.

* The translation and switch effects are of comparable magnitude.

Accordingly, we confirm the previously observed reflection effect for high probabilities of gains and losses, i.e., risk attraction increases when moving from a high probability of gain (which entails a low probability of the bad outcome "no gain") to a high probability of loss (i.e., high probability of the bad outcome). But we observe no significant change in risk attitudes when moving from a low probability of gain (which entails a high probability of the bad outcome) to a low probability of loss (i.e., low probability of the bad outcome).

The design of Treatments *L* and *L*' (see Sections 3.2 and 3.4 below) addresses a basic difficulty in real-money experiments with losses and gains, namely the need for the experimenter and the participants to agree on their perceptions of *what is a loss and what is a gain*.

Because participants cannot legally lose relative to their pre-experiment wealth, all real-money experiments with losses require that participants previously receive, or earn, from the experimenter the money that they may eventually lose. Therefore, in the experiments with losses, either losses are hypothetical or participants play with "house money," which seems to increase their willingness to accept risk. In order to mitigate these difficulties, our participants make their choices between certain and uncertain losses several months after earning some income by taking a quiz. This delay made a majority of participants feel that they had fully spent the earned cash by the time they made their decisions.[3]

Section 5 below compares our results with those reported in the literature, while Appendix 3 comments on their theoretical implications. Perhaps surprisingly, the translation effect has more severe implications than the amount and the switch effects, requiring a deeper departure from standard preference theory.

Mainstream economics has taken individual preferences as having both positive and normative meaning. From the positive viewpoint, we use individual preferences to explain and predict behavior. Normatively, we take the individual to be the definitive judge of his or her welfare. But this requires the individual to have consistent preferences: what we call "single-self preferences."

It turns out that single-self preferences are ruled out by the translation effect, which requires "multiple selves," in conflict with each other, one self for each possible level of wealth. This feature of the translation effect contrasts with the switch effect and the amount effect which, jointly or in isolation, allow for a single self.

The just discussed difference between the translation effect, on the one hand, and the amount and switch effects, on the other, concerns their compatibility, or lack of it, with *single-self preferences*, rather than with *expected utility theory*. In fact, all three effects behave alike with respect to expected utility: they all violate the canonical expected utility model, where "prizes" are final wealth levels, while they are all compatible with a wealth-dependent expected utility formulation, where, instead of a single von Neumann-Morgernstern (vNM) utility function defined

[3] See footnotes 7 and 8 below for details.

on final wealth levels, we have a family of vNM utility functions, one for each level of initial wealth, defined on wealth changes.

2. What is the "corresponding choice involving losses"?

As noted in the introduction, Kahneman and Tversky replaced gains by losses through a "reflection," i.e., the multiplication by minus one of all money amounts. But it is important to observe that, as long as the probabilities are not 50-50, this reflection involves two distinct operations: a *switch* of the probability masses of the good and bad money outcomes, and a *translation* by which a gain becomes the absence of a loss. The distinction can be illustrated as follows.

Denote by < *z*, *p*> the choice between the positive (gain) or negative (loss) amount of money *z* with probability *p* (and zero with probability 1 – *p*) and the certain positive or negative amount of money *pz*. Let *z* > 0, and consider first the following choice.

Choice G ≡ <*z*, 0.8>. *A person with given wealth w has to choose between a certain gain of* \$0.8*z vs. an uncertain gain of* \$*z with probability* 0.8.

If she chooses the certain gain, her *ex post* money balance is $x = w + 0.8\,z$, whereas if she chooses the uncertain gain, then her *ex post* money balance is $x = w + z$ with probability 0.8, and $x = w$ with probability 0.2. Thus, she is choosing between the two discrete probability density functions of the NW cell in Figure 1. The certain choice is the degenerate pdf, depicted as a solid (green) bar, whereas the two hollow (red) bars depict the uncertain choice.

Now assume that she is not making choice *G*, but the following one.

Choice G′ ≡ <*z*, 0.2>. *A person with given wealth w has to choose between a certain gain of* \$0.2*z vs. an uncertain gain of* \$*z with probability* 0.2.

Choice *G′* is depicted in the SW cell of Figure 1. Note that Choice *G′* is obtained from Choice *G* by *switching the probabilities* of the good and bad outcomes, while preserving actuarial fairness. More generally, consider the *probability switch operator s* defined by *s*(< *z*, *p*>) = < *z*, 1 – *p*>. Of course, there is no reason why the person could not choose the certain gain in *G* and the uncertain gain in *G′*.

Assume next that she does choose the certain gain in *G*, thus displaying risk aversion in that choice. Would she actually choose the uncertain loss, and hence display risk attraction, in the "corresponding choice involving losses"? Both Kahneman and Tversky's reflection and our translation create choices involving losses that in some way "correspond" to *G*: translation gives choice *L* depicted in the NE cell of Figure 1, while reflection gives *L′* in the SE cell.

Choice L $\equiv < -z, 0.2>$. *A person with given wealth w has to choose between a certain loss of* \$0.2*z vs. an uncertain loss of* \$*z with probability* 0.2.

Note that choice *L*, involving losses, can be derived from choice *G,* involving gains, by a leftward translation of the discrete probability density functions along the money axis, so that the good outcome is now *w* (no loss) instead of $w + z$ (a gain), whereas the bad outcome is now $w - z$ (a loss), instead of *w* (no gain). As a result, a translation keeps unchanged the probabilities of the good and bad outcomes.

More generally, define the *translation operator t* by $t(< z, p>) = < -z, 1 - p>$.

Choice L′ $\equiv < -z, 0.8 >$. *A person with given wealth w has to choose between a certain loss of* \$0.8*z vs. an uncertain loss of* \$*z with probability* 0.8.

Note that choice *L′* can be derived from choice *G* by applying a switch and a translation, in any order. More generally, define the *reflection operator r* as the composite transformation:

$$r(< z, p>) \equiv s(t(< z, p>)) = t(s(< z, p>)) = < -z, p>,$$

i.e., **Reflection = Translation + Switch.**

Which one of the two loss choices, *L* or *L′* is the more natural counterpart to the gain choice *G*? Choice *L* involves a minimal transformation of *G*. After all, what makes an *ex post* money balance the result of a gain or a loss is the starting point: an *ex post* balance of 900 is due to a gain if you start at 800, but it is due to a loss if you start at 1000. Choice *L* is a choice involving losses obtained by simply moving the reference point in *G*, from the outcome *w* meaning "unluckily, I did not gain" to meaning "luckily, I did not lose," without altering the probability of being unlucky. Accordingly, we view *L* as the more appropriate counterpart to *G*.

Our experiment targets the effect of both translations and probability switches on risk attitudes. The treatments are named after the type of choices that the participants are asked to make.

The comparison of the risk attitudes displayed in type *G* vs. *L* choices, or in type *G*' vs. *L*' choices, enables us to test for asymmetries when gains are translated into losses, and nothing else is changed. The comparison of *G* vs. *G′* choices, or *L* vs. *L′* choices throws light on the effect of switching the probabilities between the good and the bad outcome while maintaining the sign of the prospects and keeping choices fair. Last, the comparison of *G* vs. *L'* choices, or *G'* vs. *L* choices, tests for reflection effects.

3. The experiment

3.1. Treatment *G*: gains at low probability of the bad outcome

Our four treatments share a basic design. As with the rest of them, we performed Treatment *G* in a single session (no preliminary pilot sessions) with students from the *Universitat Pompeu Fabra* who volunteered. We only selected students who had not taken courses in economics or business and tried to maintain an equal proportion of sexes. In Treatment *G* we used twenty-one participants, but we ended up with a ratio of males to females of 6/15. Participants were told that they would be randomly assigned, without replacement, to one of seven classes corresponding to the seven money amounts, in *pesetas*, 500, 1000, 2000, 5000, 7500, 10000 and 15000 (i.e., approximately, US$ 3, 7, 13, 33, 50, 67 and 100). A participant was asked to choose, for each of the seven classes and before knowing to which class she would eventually belong, between the certain gain of 0.8 times the money amount of the class and the uncertain prospect giving the money amount of the class with probability 0.8 and nothing with probability 0.2. In what follows we say that a participant displays *risk attraction* (resp. *risk aversion*) in a particular choice if she chooses the uncertain (resp. certain) alternative.[4]

Participants were given a 7-page folder to record their decisions, one page for each class. Every page had five boxes arranged vertically. The certain gain was printed in the first box, and the amount of money of the uncertain prospect in the second one, with the statement that the probability of winning was 0.8. The third box contained two check cells, one for choosing the certain gain, and another one for choosing the uncertain prospect.[5] Below a separating horizontal line, two more boxes were later used to record the random outcome and the take-home amount. In order to facilitate decisions, a matrix on the back of the page showed all the amounts of money involved. The information was given to the participants as written instructions (available on request), which were read aloud by the experimenter. The treatment began after all questions were privately answered. Once all participants had registered their seven decisions (under no time constraint: nobody used more than 15 minutes), their pages were collected. Participants were then called one by one to an office with an urn that initially contained twenty-one pieces of paper: each piece indicated one class,

[4] A risk-neutral participant could choose either the certain or the uncertain prospect, his or her choice being at random. But the likelihood that the results of our experiments consist of random variation is statistically indistinguishable from zero.

[5] Note that there is no default, i.e., "doing nothing" is not an option.

and each of the seven classes occurred three times. A piece of paper was randomly drawn (without replacement): the experimenter and the participant then checked her (i.e., his or her) choice for that particular class. If her choice was the certain gain, she would take home 0.8 times the amount of money of her class. If, on the contrary, she chose the uncertain prospect, then a number from one to five was randomly drawn from another urn. If the number one was drawn, then the participant would take nothing home. Otherwise, she would take home the amount of money of her class. The participant was then paid and dismissed, and the next participant was escorted into the office.

The experimental data are presented in Table A1 of Appendix 1.

3.2. Treatment *L*: losses at low probability of the bad outcome

Since experimenters should not earn money from their participants, any experiment with losses must involve either hypothetical losses or the provision of sufficient initial cash. Doubts have been raised about the reliability of the results from experiments with hypothetical losses (see Charles Holt and Susan Laury, 2002). But providing money to the participants has its pitfalls too. First, if participants do not earn the cash, then the cash provision will easily be interpreted as a windfall gain. Second, even if participants earn the necessary cash through their own skills and effort, they will still be playing with "house money." There are grounds for suspecting that playing with windfall gains or house money increases risk attraction.[6]

Our Treatment *L* implements a design that we believe avoids to a large measure both the *windfall-gains effect* and the *house-money effect*. The treatment consists of two temporally separated parts: first, a cash-earning quiz, and, second, the decision-making on certain vs. uncertain losses. In order to counteract the windfall-gains effect, twenty four participants took a quiz on general education in the first part of the treatment and earned cash according to the number of correct answers: 15000 *pesetas* to the participants ranked one to six, 10000 *pesetas* to the next six, 7500 *pesetas* to the third group of six, while the last group received 5000 *pesetas*.

To alleviate the house-money effect, the two parts of the treatment were separated by four months and a semester break. Because we guaranteed that the losses would never exceed the cash received in the quiz, the participants could admittedly feel that they were playing with house money.

[6] See, e.g., Martin Weber and Heiko Zuchel (2001), Scott Boylan and Geoffrey Sprinkle (2001), Kevin Keasy and Philip Moon (1996) and Richard Thaler and Eric Johnson (1990). According to Thaler and Johnson (1990), p. 657, "… after a gain, subsequent losses that are smaller than the original gain can be integrated with the prior gain, mitigating the influence of loss-aversion and facilitating risk-seeking." But see Jeremy Clark (2002) for small sums of money.

But we hoped to reduce this effect by the temporal separation of the treatment's two parts. It is hard to know to what extent we managed this, but some evidence indicates that we mostly succeeded.[7] The answers to some questions asked to a different group of people also indicated the importance of the time lag for the perception of loss.[8]

In the second part of the treatment, participants were told that they would be randomly assigned to one of seven classes corresponding to the seven money amounts to *lose* (500, 1000, 2000, 5000, 7500, 10000 and 15000 *pesetas*). In any event, a participant could not be assigned to a class with an amount of money exceeding the amount earned in the quiz. Now, a participant was asked to choose, for each of the possible classes and before knowing to which class she would eventually belong, between the certain loss of 0.2 times the money amount of the class and the uncertain prospect of losing the money amount of the class with probability 0.2 and nothing with probability 0.8. To record their decisions, participants were given a 7-page folder that contained one page for each class. In each page, they were required to register, under no time constraint, their choice between the certain loss and the uncertain prospect. Participants were then called one by one to an office where the participant's class was randomly drawn. Next, the experimenter and the participant checked the participant's choice for that particular class. If her choice was the certain loss, she would pay 0.2 times the amount of money of her class. If, on the contrary, she chose the uncertain prospect, then a number from one to five was randomly drawn from an urn. If the number one was drawn, then the participant would pay the amount of money of her class. Otherwise, she would pay nothing.

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[7] After registering their choices, participants answered a questionnaire about the prospective pain of losing money in the experiment. The majority (59%) agreed that it would be very painful to lose money because "the money was theirs," 9% accepted that they would feel some pain since it was "as if the money was theirs," 21% claimed to no pain since the money "was not actually theirs," and 11% gave other answers. Post-experiment personal interviews showed similar results.

[8] The questions concerned hypothetical gains and losses, as well as different time lags. In one situation, a Mr. A and a Mr. B gained and lost the same amounts of money, but while Mr. A experienced the gain and the loss on the same day, Mr. B's loss occurred several weeks later. Respondents were asked to compare the happiness of Mr. A. and Mr. B after losing the money. Of the 107 respondents, 71 considered Mr. A the happier one, whereas 27 thought it was Mr. B and 9 said that both were equally happy. In another situation, we asked to compare Mr. C, who won and lost some money on the same day, and Mr. D, who earned an amount equal to the difference between Mr. C's gain and loss. The response was overwhelmingly in favor of Mr. D being happier (87), with 4 favoring Mr. C and 15 voting for indifference. Taken at face value, the answers to this questionnaire indicate that individuals feel more pain if a loss does not coincide in time with a gain, suggesting that their capability of integrating the loss with a previous gain is limited (even when the loss and the gain are presented together as in the examples described), when time separates the moment of the gain from the moment of the loss.

Twenty-one participants took part in the second part of the treatment.[9] The male/female ratio ended up being 10/11. The experimental data are presented in Table A2 of Appendix 1.

3.3. Treatment *G*': gains at high probability of the bad outcome

The treatment was identical to Treatment *G*, except that the probability of the uncertain gain was now 0.2, instead of 0.8. Twenty-four students participated, with a male/female ratio of 9/15. The experimental data are displayed in Table A3 of Appendix 1.

3.4. Treatment *L*': losses at high probability of the bad outcome

Treatment *L'* was performed with thirty-four students, with a male/female ratio of 18/16.[10] The treatment had exactly the same format as Treatment *L*, except that the probability of the loss was now 0.8, instead of 0.2. The experimental data are displayed in Table A4 of Appendix 1.

4. Results

4.1. Statistical analysis

We proceed to obtain a quantitative estimate of the impact of the three effects that we have called the amount effect, the switch effect and the translation effect on the probability that a participant chooses the certain prospect. To this end, our statistical model has as independent variables the "amount of money at risk" plus two dummies that capture the two remaining effects. The first dummy separates the treatments with a probability of the bad outcome of 0.2 (Treatments *G* and *L*) and the treatments with a probability of the bad outcome of 0.8 (Treatments *G*' and *L*') and, consequently captures the switch effect. The second one separates the treatments with gains (*G*, *G*' Treatments) and the treatments with losses (Treatments *L* and *L*') and, consequently, portrays the translation effect.

We estimate the following logit regression model with random intercept[11]

$$\ln \frac{p_{ij}}{1-p_{ij}} = \alpha + u_i + \delta_1 d_1 + \delta_2 d_2 + b z_j ,$$

[9] Twenty-four participants had taken the quiz, but three did not show up for the second part of the *L* experiment.
[10] Thirty-six participants had taken the quiz, but two did not show up for the second part of the *L*' experiment.
[11] Note that we assume a common slope *b* in the four different regimes: we had previously estimated the model $\alpha + u_i + \delta_1 d_1 + \delta_2 d_2 + \delta_3 d_1 d_2 + (b + \delta_4 d_1 + \delta_5 d_2)\, z_j$, and found that the estimates for δ_3, δ_4 and δ_5 were statistically insignificant. Accordingly, we estimated the more parsimonious model described.

$i \in \{1,\ldots, I\}$,where I is the number of participants.

$j \in \{1, \ldots, 7\}$, the seven levels of money, $z_j \in \{0.5, 1, 2, 5, 7.5, 10, 15\}$,

$d_1 = 0$ if the probability of the bad outcome is 0.2 (Treatments *G*, *L*),

$d_1 = 1$ if the probability of the bad outcome is 0.8 (Treatments *G*', *L*'),

$d_2 = 0$ if gains (Treatments *G*, *G*'),

$d_2 = 1$ if losses (Treatments *L*, *L*'),

i.e., a change of the value of d_1 indicates a probability switch, whereas one of d_2 indicates a translation.

The variable p_{ij} is the probability that participant i chooses the certain alternative (and thus displays risk aversion) when the amount of money at stake is z_j (or - z_j) in thousands of pesetas (so as to avoid too many decimals in the estimates of the regression coefficients) for the four regimes described by the values of the dummy variables. The individual effect u_i allows for heterogeneous individual tastes, assumed to be normally distributed with mean zero and standard deviation σ_u, so that $\alpha + u_i$ is the random intercept.

Recall that with the purpose of mitigating the "windfall-gains" and "house money" effects, we designed our loss treatments so that participants *earned* different amounts of money that they could eventually lose months later. Consequently, while all the participants in the gains treatments had to make seven choices, corresponding to all seven amounts of money at risk, only some participants in the loss treatments, namely those who earned the largest amounts of money, had to make the choices corresponding to all seven situations. Since having to make a larger or smaller number of choices may affect how the choices are made, in the regression we only take into account data from the participants who had to make all seven decisions.[12] This still means 98 observations in the loss treatments, out of an overall number of observations of 406.

The estimation results appear in Table 1.

A first observation is that the hypothesis of no individual effect ($\rho = 0$) is rejected by the χ^2 test. More interestingly, all estimates are highly significant.

[12] Observing the results in Tables A1-A4 of Appendix 1, it appears that most participants chose the certain prospect for the largest amounts of money while taking risks for the smallest amounts. Since, in the loss treatments, the largest amounts of money at risk were not the same for all participants, choices involving medium range amounts of 5,000 or 7,500 pesetas were more risk averse for those participants who did not choose in situations involving larger sums than for those who did.

The magnitudes of the parameter estimates show that the odds of choosing the safe prospect increase 97% when the money at risk increases by 1000 pesetas (about US$ 7), while the odds fall by 99% when the probability of the bad outcome goes from 0.2 to 0.8 and also by 99% when gains are translated into losses.[13] Thus, the switch and translation effects appear to be of similar magnitude.

4.2. The fundamental role of the amount of money at stake

Figure 2 below displays, in the manner of Figure 1, the raw data of our four treatments, as detailed in Appendix 1. Each row in each of the four panels corresponds to a participant, whereas the columns correspond to the amounts of money at risk. A letter *c* indicates choosing the certain gain or loss (thus displaying risk aversion, color green), while the letters *un* indicate choosing the uncertain gain or loss (thus displaying risk attraction, color red). In each panel participants have been ordered to help reading the table: the bottom ones violate the "standard pattern" (see Result 2 below), whereas the other participants are ordered by increasing risk attraction. The statistical analysis above, the visual inspection of the panels of Figure 2, and the percentages calculated in Table 2, allow us to state the following results.

Result 1. Diversity. The majority of participants display risk attraction for choices involving some amounts of money, and risk aversion for some others, the number of safe choices varying across individuals.

Result 2. Standard pattern. Most individuals (85%) follow the *standard pattern*, defined as follows: whenever risk attraction is displayed in a choice involving a given money amount, risk attraction is also displayed for any smaller (in absolute value) amount of money.[14]

Result 3. Amount effect**.** The proportion of participants who display risk aversion in a particular choice increases with the amount of money at stake.

Result 4. Risk aversion by the majority for large amounts of money at stake. For both gains and losses, and for low and high probabilities, a majority of our participants display risk attraction for low amounts of money at stake (the red area in Figure 2 and Table 2), but risk aversion for large amounts (the green area in Figure 2 and Table 2).

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[13] By the classical transformation of the regression coefficients we obtain the percentage change on the dependent variable, namely 100[exp (.6777454) - 1] = 97%, 100[exp (-4.413035) – 1] = 99%, 100[exp (-4.491003) – 1] = 99%.

[14] This was also observed and reported in Bosch-Domènech and Silvestre (1999, in press).

Result 4, which states that, when examining the risk attitudes of the majority, *what matters is the amount of money at stake*, and not whether the choices are on gains or on losses, or whether the probabilities are high or small (for our nonextreme values of 0.2 and 0.8), is justified by Table 2. The key to this observation, the most surprising of the present paper, was designing an experiment that involved relatively substantial losses.

4.3. Translations, switches and reflections

Again, the visual inspection of the panels of Figure 2, together with the percentages collected in Table 2, suggest the following statements, which are consistent with our statistical analysis.

Result 5. Translation effect. For all amounts of money at stake, if gains and losses are related by a translation, then participants are more likely to display risk attraction with losses than with gains. In other words, risk attraction becomes more frequent as we move right in Figures 1 and 2, both along to top row (probability of bad outcome = 0.2) and along the bottom row (probability of bad outcome = 0.8).

Result 6. Switch effect. Both for gains and for losses, and for all amounts of money at stake**,** participants display more risk attraction when the probability of the bad outcome is high. In detail, participants are more likely to display risk attraction when the probabilities of the uncertain gain are low than when they are high. In fact, at a low probability of gains, and for small amounts of money, a substantial majority of individuals show risk attraction, even though all choices involve gains. And for losses, participants are more likely to display risk attraction when the probabilities of the uncertain loss are high than when they are low.

Result 7. Equal strength of the translation and switch effect. As shown in Table 1 by the estimated coefficients of the dummy variables capturing the translation and switch effects, which are of similar magnitude (- 4.49 and – 4.41, respectively).

Next, Results 8 and 9 refer to the "reflection effect" as defined by Kahneman and Tversky (1979, see the first paragraph of this paper). Recall that this reflection effect occurs if risk attraction increases when all the money amounts of a positive prospect are multiplied by minus one, i.e., when gains are translated into losses, and the probabilities of the bad and good outcomes are switched. Because "*reflection = translation + switch*," Results 8 and 9 agree with Results 5-7.

Result 8. Large reflection effect for high probability of gains and losses. The frequency of risky choices substantially increases when moving from a prospect with a high probability of gain (low probability of the bad outcome) to a prospect to a high probability of loss, i.e., along the main diagonal of Figure 1. Indeed, along the main diagonal, the translation and switch effects reinforce each other, and hence this result is in line with Results 5 and 6 above.

Result 9. Negligible reflection effect for low probability gains and losses. The frequency of risky choices is essentially unchanged when moving from a prospect with a low probability of loss to one with a low probability of gain, i.e., along the skew diagonal of Figure 1. This is consistent with Result 7 above, and is also suggested by the comparison of the second and third rows (Treatments *L* and *G*') of Table 2.

5. Relation to the literature

A summary of the features of our approach will help the comparison with other experiments reported in the literature. First, we deal with real money, and our participants' losses are designed to be more real than in previous experiments. Second, the elicitation method consists of choices between uncertain prospects and their expected value.[15] Third, we consider seven amounts of money at stake, with substantial quantities at the higher end. Fourth, we choose the probabilities 0.2 and 0.8 away from the zero and one extremes. Last, we study asymmetries in risk attitudes when the choices faced by the agents are transformed by a reflection, but also when they are separately transformed by the two components of a reflection, namely a translation and a probability switch.

5.1. The gain-loss asymmetry and the Tversky-Kahneman fourfold pattern

Kahneman and Tversky (1979) inspired what may be called the *gain-loss asymmetry view,* according to which people tend to display risk aversion for gains and risk attraction for losses. This view is illustrated in Table 3: the risk attitudes in the rows are identical, i.e., they are independent of the probability of the bad outcome, but we keep two rows to facilitate the comparison with Table 4 below. The arrows indicate directions of increasing risk attraction, with the labels defined above. But the same authors later posited the more complex view of a *fourfold pattern of risk attitudes* (Tversky and Kahneman, 1992), here summarized in Table 4, where, one should note, only the

[15] See William Harbaugh *et al.* (2002b) for results on different elicitation methods.

entries of the main diagonal are justified by the assumptions of prospect theory (see Appendix 2 below).[16]

In a sense, our experiment *contradicts* both the gain-loss asymmetry view and the Tversky-Kahneman fourfold pattern because of the amount effect that we verify: as stated in Result 4 above, the risk attitude of the majority of our participants is essentially risk attraction for low amounts of money at risk, and risk aversion for large amounts, irrespective of whether they face gains or losses, and whether the probability is 0.2 or 0.8.[17] But, leaving aside this fundamental discrepancy, we can compare the translation, switch and reflection effects that we observe with those evoked by Tables 3 and 4.

Both the gain-loss asymmetry and the four-fold pattern entail a reflection effect along the main diagonal of Figure 1 and Tables 3-4: risk attraction increases when moving from high-probability gains to high-probability losses, in agreement with our findings as well as those of the early experimental literature.[18]

But the gain-loss asymmetry view and the fourfold pattern disagree on the off-main-diagonal entries. The gain-loss asymmetry view does not distinguish between the two <u>rows</u> of Table 3, and, thus, from its perspective, the reflection effect among the main diagonal is *purely due to a translation effect*. In fact, the gain-loss asymmetry view also predicts a conventional reflection effect along the skew diagonal, because it maintains that any move from gains to losses increases risk aversion, even one from low probability gains to low-probability losses. The fourfold pattern, on the contrary, predicts a decrease in risk attraction in that move, i.e., a reverse reflection effect along the skew diagonal. And, more generally, the fourfold pattern sees the same risk attitudes in

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[16] Tversky and Kahneman base the skew-diagonal entries of their four-fold pattern on "empirical regularities" rather than on theoretical considerations. The (perhaps unconventional) arrangement of the fourfold pattern in Table 4 agrees with our Figures 1-2.

[17] Of course, the appropriateness of our discussion to the Tversky-Kahneman fourfold pattern is in any event contingent on interpreting the probabilities that we deal with (0.8 and 0.2,) as sufficiently "high" and "low" for their pattern. Because of the related probability weighting (see Appendix 2 below), Figures 3.3 in Tversky and Kahneman (1992) do suggest that 0.2 is "low" and 0.8 is "high," whereas the earlier Figure 2.4 in Kahneman and Tversky (1979) suggests that 0.2 is not low enough.

[18] Kahneman and Tversky (1979, Table 1, Problem 3) provide one instance of "reflection" corresponding to the main diagonal of our Figure 1 above. Table 3.3 in Tversky and Kahneman (1992) has more instances (all the experiment pairs in the 6th column, where the probability of gain or loss is 0.75, and in the 7th column, where the probability is 0.90). John Hershey and Paul Shoemaker (1980) critically examine the reflection effects submitted by Kahneman and Tversky's (1979), yet their only experiment with a probability close to our 0.80 yields a strong and significant reflection effect (Table 3, Experiment 11). Gains and losses are hypothetical in all these experiments.

the two columns of Table 4, hence granting *the switch effect the main role* in the changes in risk attitudes.[19]

Our experimental results concerning the translation, switch and reflection effects (Results 5-9 above) are right midway between the extremes implied by the gain-loss asymmetry view and the fourfold pattern. Indeed, we observe both a significant translation effect (as in the gain-loss view, but contrary to the fourfold pattern), and a significant switch effect (as in the fourfold-pattern, but contrary to the gain loss-view). Moreover, our translation and switch effects are of similar strength: thus, they *add up* to a major reflection effect along the main diagonal (in agreement with both the gain-loss view and the fourfold pattern), but essentially *cancel each other out* along the skew diagonal, resulting in a null reflection effect there (thus contradicting both the conventional reflection effect of the gain-loss view, and the reverse one of the fourfold pattern).

5.2. Experiments with real money

How do our results compare with the newer experimental literature that uses real money? Robin Hogarth and Hillel Einhorn (1990) run one experiment with real gains and losses (together with two with hypothetical ones). It covers three probability values, namely 0.1, 0.5 and 0.9 (vs. our 0.2 and 0.8) and two amounts of money, namely a very low $0.1 and a low $10 (versus our seven amounts, ranging from $3 to $100). Their $10 treatment lies between our $7 and $13 treatments. Some of their results agree with ours. In particular, the increases in the percentages of risk-attracted choices induced by an increase in the probability of the bad outcome are similar to ours.[20] But because they do not deal with money amounts higher than $10, it is not possible to compare their work with our high-money results.

Laury and Holt (2000) investigate the reflection effect under both hypothetical and real gains and losses: indeed one of their objectives is to unearth discrepancies in hypothetical vs. real money, which is the main theme of Holt and Laury (2002). The methodology of these two papers is quite different from ours. Instead of actuarially fair choices, their participants face pairs of

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[19] The data in Tversky and Kahneman (1992), Table 3.3, systematically show what we call a switch effect, while most of the examples in the table fail to evidence what we call a translation effect. An exception is provided by rows three and four for the probabilities 0.25 and 0.75 (4^{th} and 6^{th} columns). There they report risk aversion for a 0.75 probability of a gain of $100, but risk attraction for a 0.25 probability of a loss of $100.

[20] Although not the levels: the fractions of their participants displaying risk attraction are systematically smaller than ours.

sequences, one for losses and one for gains, of ten binary choices, each choice involving an "*S*" (for safe) and an "*R*" (for risky) alternative. Loss choices are reflected from gain choices by multiplying all money amounts by minus one. The difference "expected $*S* minus expected $*R*" increases along the ten-choice loss sequence, and a risk-neutral individual would choose the pattern *RRRRR*/*SSSSS* for losses. It follows that the difference in expected money amounts decreases along the gain sequence, and that risk neutrality requires the pattern *SSSSS*/*RRRRR* for gains. Thus, a participant choosing *RRRRR*/*RRSSS* in the loss sequence displays risk attraction in losses, and, if she chooses *SSSSS*/*SSRRR* in the gain sequence, then she displays risk aversion in gains, a combination that exhibits a reflection effect. The main result in Laury and Holt (2000) is that the conventional reflection effect is widespread in the experiments with hypothetical gains and losses, but becomes substantially less frequent with real money. In Holt and Laury (2002) participants tend to display more risk aversion for higher than for lower amounts. None of these conclusions contradicts our finding that participants become risk averse for high amounts of money at stake.

Harbaugh *et al*. (2002a) conduct a series of experiments with participants from age 5 to 64, using a range of payoffs from $10 to $90 for adults and $1 to $9 for children, and varying the probabilities from 0.02 to 0.98. Choices of adults seem consistent with the use of objective probabilities, especially when evaluating a gamble over a gain, and are, on average, risk neutral. Unfortunately Harbaugh *et al*. (2002a) do not provide a disaggregation of choice data in terms of payoffs.[21] Without it, we can only speculate that the stated risk neutrality may be an average of more risk attraction for low payoffs and more risk aversion for high payoffs, in agreement with our observations; and that their results may be, in any case, biased towards a more risky behavior as a result of their participants gambling with house money.

Harbaugh *et al*. (2002b) use real payoffs and vary the probabilities, while keeping the amount of money at stake a constant $20. One of their objectives is to discover discrepancies in risk attitudes due to the elicitation method: the certainty equivalent of a lottery (as in Tversky and Kahneman, 1992) vs. the choice between a lottery and its expected value (as we do). We limit the comparison between our results and the ones in Harbaugh *et al.* (2002b) for the latter elicitation method. Their results seem to contradict Tversky and Kahneman fourfold pattern: notably, they

[21] While they disaggregate choices by age, by probability, by gains and losses, they do not provide data showing how choices evolve as payoffs change.

show a reverse reflection effect along the main diagonal of our Figures 1-2 and Tables 3-4. Contrary to the findings of the present paper, they report what we call a reverse switch effect. However, none of these observations is statistically different from risk neutrality: their only statistically significant result is what we call a translation effect along the top row of Figures 1-2 and Tables 3-4, in agreement with our Result 5.

5.3. Implications for preference theory

We have observed, as previous researchers had before us, a rich variety of behavior among individuals: for instance, some display risk attraction in all the choices. Here we wish to focus on some qualitative patterns, namely the *amount*, *translation* and *switch* effects. Without being universal, they are well represented in our findings: We view them as plausible, and conjecture that individuals would display them even if their wealth changed.

We shall say that a person exhibits an *amount effect* if she displays risk attraction when the amounts z of money at risk are small (positive or negative, but small in absolute value) but risk aversion for large ones, *at all levels of wealth, or, at least, for a wide interval of wealth values w*. This, we submit, is a realistic phenomenon, as our Results 2 and 3 of Section 3.2 above show. Moreover, our in press paper supports its extrapolation to various levels of wealth.

Similarly, a person exhibits a *switch effect* if she displays risk aversion for choice $< z, p>$ (as in the NW cell of Figure 1 above), but risk attraction for choice $< z, 1 - p>$ (SW), *for a wide range of initial wealth values w and of gain values z.* And she exhibits a *translation* effect if she displays risk aversion for the choice $<z, p>$ (as in the NW cell of Figure 1 above), but risk attraction for choice $< -z, 1 - p>$ (NE cell), also *for a wide range of initial wealth values w*.

Appendix 3 spells out a fundamental difference between the amount and switch effects, on the one hand, and the translation effect: the former turn out to be compatible with single-self preferences, whereas the translation effect does not. Thus, the translation effect (or a reflection involving translation) is in the same category as inconsistencies due to addiction or myopia. They do occur, yet they imply a departure from full individual rationality, and raise issues on the positive and normative relevance of an individual's evaluation of her welfare.[22]

[22] See Mark Machina (1982).

Interestingly, the just discussed difference between the translation effect, on the one hand, and the amount and switch effects, on the other, concerns their compatibility, or lack of it, with *single-self preferences*, rather than with *expected utility theory*. In fact, all three effects behave alike with respect to expected utility: they all violate the canonical, single-self expected utility model, where "prizes" are final wealth levels (as in Daniel Bernoulli, 1738, and Milton Friedman and Leonard Savage, 1948), while they are all compatible with a wealth-dependent "expected utility" formulation, with a family of vNM utility functions, one for each level of initial wealth, defined on wealth changes, as in Harry Markowitz (1952) and in James Cox and Vjolica Sadiraj (2001).

5.4. Large vs. small decisions: The amount effect and the Rabin critique

Recall that our experimental observations contradict single-self expected utility theory. In particular, our extremely robust findings of an amount effect (i.e., risk attraction for small deviations of current wealth, together with risk aversion for larger deviations) contradict single-self expected utility in a fundamental manner, because risk attraction for small risks in a range of wealth levels would then mean that $u'' > 0$ there, implying risk attraction for all risks with final outcomes in that range.

In other words, single-self expected utility implies this minimal consistency between behavior in the small and in the large. Rabin's critique of expected utility theory (Matthew Rabin, 2000) is also based on a required consistency between behavior in the small and in the large, and hence shows a formal parallelism with the implications of our amount effect. In a nutshell, Rabin's critique is of the form:

(a) The avoidance of small, slightly favorable risks at an interval of wealth is plausible;[23]

It follows from (a) that, under single-self expected utility:

(b) Large, greatly favorable risks must be avoided.

But this is ridiculous.

On the other hand, our amount-effect-based negation of single-self expected utility runs as follows.

(a') We observe attraction to small, fair risks at an interval of wealth;

[23] This is not uncontroversial: Ignacio Palacios-Huerta, Roberto Serrano and Oscar Volij (2001) argue that the "avoidance of small slightly favorable risks at an interval of wealth" (which Rabin finds plausible) implies unrealistically high degrees of risk aversion, contradicted by empirical evidence.

It follows from (a') that, under single-self expected utility:

(b') There must be attraction to large, fair risks.

But this is not what we observe: we find generalized risk aversion to large, fair risks.

Besides the formal parallelism, Rabin's critique and our negation of single-self expected utility share an underlying theme: plausible or observed behavior in the small implies, under single-self expected utility, a behavior in the large that contradicts common sense or observation. It is true that, in the small, what we observe is risk attraction, whereas Rabin posits risk aversion. But what Rabin calls "small" involves gambles with hypothetical amounts of money closer to what we call large (around $100). In addition, his gambles are two-sided, combining gains and losses, which may favor risk aversion.

6. Conclusions

Historically, there are three main views on money risk attitudes. The oldest one (Bernoulli, 1738) sees most people as risk averse most of the time. By positing a fundamental gain-loss asymmetry, Kahneman and Tversky subverted in 1979 this then dominant wisdom, advancing the now popular view that risk attraction is the norm for losses, whereas risk aversion is the norm for gains. Later developments focused on the role of probabilities, leading Tversky and Kahneman in 1992 to propose a fourfold pattern, where the risk attitude depends on both the probabilities and the gain-loss dichotomy.

Our paper experimentally tests these views while including an important third factor: the amount of money of risk. Methodologically, we address a basic difficulty in real-money experiments with losses and design a treatment to alleviate the "house money" effect that pervades real-money experiments with losses.

A main result is that, contrary to the recent views, and as Bernoulli thought, risk aversion is the majority attitude when substantial amounts of money are at stake, both for gains and for losses. Much of the previous experimental evidence of risk taking in the face of losses is confined either to hypothetical losses or the loss of small amounts, limitations that our experimental design avoids. To paraphrase Kahneman and Tversky, the relevant distinction appears to be, not the domain of gains vs. domain of losses, as they claim, but between the domains of large vs. small money amounts. In particular, when studying decisions in the face of uncertainty, behavior observed for small money amounts cannot be extrapolated to large amounts.

The claim should not be construed as negating the presence of risk-attitude patterns based on the gain-loss dichotomy or the probabilities involved. On the contrary, the body of this paper is also devoted to the analysis of such patterns.

Kahneman and Tversky formulated the gain-loss asymmetry in terms of a reflection. We propose the decomposition "*reflection* = *translation* + *switch*," which throws new light on the risk-attitude patterns, and we submit that translations, rather than reflections, capture the gain-loss dichotomy in a natural and parsimonious manner. Our experimental findings on risk-attitude patterns shows the presence of both a translation effect and a switch effect, of comparable magnitude. When moving from high probability gains to high probability losses, the translation and switch effects move in the same direction, adding up to a strong reflection effect. But when moving from low probability gains to low probability losses, the translation and switch effects move in opposite direction, basically canceling each other. This result evenly splits the differences between the gain-loss asymmetry view (which implies that only the translation effect counts) and Kahneman and Tversky's fourfold pattern (which can be interpreted purely in terms of a switch effect).

The distinction between the translation and the switch effects helps clarify the implications of the observed behavior on preference theory. We argue that, contrary to the switch effect (and to the amount effect), the translation effect negates the existence of single-self preferences, and, accordingly, has deeper implications.

With our 2×2×7 experimental design, we have attempted systematically to approach a central issue in the analysis of risk attitudes. But our work is subject to the limitations inherent to the experimental method in the social sciences, first and foremost the non-randomness and small size of the samples. Accordingly, our results have the character of initial discoveries that require the scientific test of replication. While experimenting with substantial money losses can be a difficult endeavor, the study of risk attitudes is a keystone in the understanding of choice, and demands additional efforts.

Appendix 1. Experimental data

	Amount of Money (*pesetas*)						
	500	1000	2000	5000	7500	10000	15000
Participant AG	c	c	c	c	c	c	c
Participant BG	c	c	c	c	c	c	c
Participant CG	c	c	c	c	c	c	c
Participant DG	c	c	c	c	c	c	c
Participant EG	c	c	c	c	c	c	c
Participant FG	c	c	c	c	c	c	c
Participant GG	c	c	c	c	c	c	c
Participant HG	c	c	c	c	c	c	c
Participant IG	un	c	c	c	c	c	c
Participant JG	un	un	c	c	c	c	c
Participant KG	un	un	c	c	c	c	c
Participant LG	un	un	c	c	c	c	c
Participant MG	un	un	c	c	c	c	c
Participant NG	un	un	c	c	c	c	c
Participant OG	un	un	un	c	c	c	c
Participant PG	un	un	un	c	c	c	c
Participant QG	un	un	un	c	c	c	c
Participant RG	un	un	un	un	un	c	c
Participant SG	c	un	un	c	c	c	c
Participant TG	un	un	un	c	c	un	c
Participant UG	un	un	c	c	un	un	un

Table A1. Treatment *G*. A letter *c* (green cell) indicates choosing the certain gain (thus displaying risk aversion), while the letters *un* (red cell) indicate choosing the uncertain gain (thus displaying risk attraction). In this table, as in similar tables below, participants have been ordered to help reading the table.

	Amount of Money (*pesetas*)						
	500	1000	2000	5000	7500	10000	15000
Participant AL	c	c	c	c	c	c	c
Participant BL	c	c	c	c	-	-	-
Participant CL	ur	c	c	c	c	c	-
Participant DL	ur	c	c	c	c	-	-
Participant EL	ur	un	c	c	c	-	-
Participant FL	ur	un	c	c	-	-	-
Participant GL	ur	un	c	c	-	-	-
Participant HL	ur	un	un	c	c	c	c
Participant IL	ur	un	un	c	c	c	-
Participant JL	ur	un	un	c	c	c	-
Participant KL	ur	un	un	c	c	-	-
Participant LL	ur	un	un	c	c	-	-
Participant ML	ur	un	un	c	c	-	-
Participant NL	ur	un	un	c	-	-	-
Participant OL	ur	un	un	un	un	-	-
Participant PL	ur	un	un	un	un	un	-
Participant QL	ur	un	un	un	un	un	un
Participant RL	c	c	c	un	un	c	-
Participant SL	ur	c	un	un	c	c	c
Participant TL	ur	un	un	c	c	c	un
Participant UL	ur	un	un	un	c	un	c

Table A2. Treatment *L*. A letter *c* (green cell) indicates choosing the certain loss (thus displaying risk aversion), while the letters *un* (red cell) indicate choosing the uncertain loss (thus displaying risk attraction). The dashes indicate that the participant was not asked to make the corresponding choice.

	Amount of Money (*pesetas*)						
	500	1000	2000	5000	7500	10000	15000
Participant AG’	c	c	c	c	c	c	c
Participant BG’	c	c	c	c	c	c	c
Participant CG’	un	un	c	c	c	c	c
Participant DG’	un	un	c	c	c	c	c
Participant EG’	un	un	c	c	c	c	c
Participant FG’	un	un	un	c	c	c	c
Participant GG’	un	un	un	c	c	c	c
Participant HG’	un	un	un	c	c	c	c
Participant IG’	un	un	un	c	c	c	c
Participant JG’	un	un	un	c	c	c	c
Participant KG’	un	un	un	un	c	c	c
Participant LG’	un	un	un	un	c	c	c
Participant MG’	un	un	un	un	un	c	c
Participant NG’	un	un	un	un	un	c	c
Participant OG’	un	un	un	un	un	c	c
Participant PG’	un	un	un	un	un	c	c
Participant QG’	un	un	un	un	un	c	c
Participant RG’	un	un	un	un	un	c	c
Participant SG’	un	un	un	un	un	un	un
Participant TG’	un	un	un	un	un	un	un
Participant UG’	un	un	un	un	un	un	un
Participant VG’	un	un	un	c	un	c	c
Participant WG’	un	un	un	c	un	un	c
Participant XG’	un	un	un	c	un	c	un

Table A3. Treatment *G′*. A letter *c* (green cell) indicates choosing the certain gain (thus displaying risk aversion), while the letters *un* (red cell) indicate choosing the uncertain gain (thus displaying risk attraction).

	Amount of Money (*pesetas*)						
	500	1000	2000	5000	7500	10000	15000
Participant AL'	un	c	c	c	c	-	-
Participant BL'	un	un	c	c	-	-	-
Participant CL'	un	un	c	c	-	-	-
Participant DL'	un	un	c	c	-	-	-
Participant EL'	un	un	c	c	c	-	-
Participant FL'	un	un	c	c	c	c	-
Participant GL'	un	un	c	c	c	c	c
Participant HL'	un	un	c	c	c	c	c
Participant IL'	un	un	un	c	-	-	-
Participant JL'	un	un	un	c	-	-	-
Participant KL'	un	un	un	c	c	-	-
Participant LL'	un	un	un	c	c	-	-
Participant ML'	un	un	un	c	c	c	-
Participant NL'	un	un	un	c	c	c	-
Participant OL'	un	un	un	c	c	c	-
Participant PL'	un	un	un	c	c	c	c
Participant QL'	un	un	un	un	-	-	-
Participant RL'	un	un	un	un	c	c	-
Participant SL'	un	un	un	un	un	-	-
Participant TL'	un	un	un	un	un	-	-
Participant UL'	un	un	un	un	un	-	-
Participant VL'	un	un	un	un	un	c	-
Participant WL'	un	un	un	un	un	c	-
Participant XL'	un	un	un	un	un	c	c
Participant YL'	un	un	un	un	un	un	-
Participant ZL'	un	un	un	un	un	un	-
Participant AAL'	un	un	un	un	un	un	c
Participant BBL'	un	un	un	un	un	un	un
Participant CCL'	un	un	un	un	un	un	un
Participant DDL'	un	un	un	un	un	un	un
Participant EEL'	c	un	un	c	-	-	-
Participant FFL'	un	un	c	un	c	-	-
Participant GGL'	c	un	c	c	un	-	-
Participant HHL'	c	un	un	un	-	-	-

Table A4. Treatment *L´*. A letter *c* (green cell) indicates choosing the certain gain (thus displaying risk aversion), while the letters *un* (red cell) indicate choosing the uncertain gain (thus displaying risk attraction).

Appendix 2. Prospect theory and the fourfold pattern

Prospect Theory (Kahneman and Tversky, 1979, Tversky and Kahneman, 1992) postulates that, when deciding between the uncertain gain or loss z with probability p (and zero with probability $1 - p$) and the certain gain or loss pz, the individual chooses the uncertain (resp. the certain) gain or loss, thus displaying risk attraction (resp. aversion) if and only if

$$\pi(p \mid \text{sign } z)v(z) - v(pz) > 0 \text{ (resp. } < 0), \tag{1}$$

where $v: \Re \rightarrow \Re$ is her "value function," which can be normalized so that $v(0) = 0$, and $\pi:[0, 1] \rightarrow [0, 1]$ is a "weighting function" that transform probabilities into decision weights.[24] The following assumptions are standard.

A.1 (Convexity-concavity). The function v is increasing on $\Re$, strictly concave on $\Re_+$ and strictly convex on $\Re_-$.

A.2 (Weak distortion of probabilities). If p is small, then $\pi(p \mid .) \geq p$; if p is large, then $\pi(p \mid .) \leq p$.

Lemma. Under A.1 and A.2, if p is large, then the individual displays: (i) risk aversion for all $z > 0$, and (ii) risk attraction for all $z < 0$.

The proof is immediate. By strict concavity, $v(pz) > pv(z)$, and hence $\pi(p \mid .)\, v(z) - v(pz) < \pi(p \mid .)\, v(z) - pv(z) \leq 0$, by A.2, proving (i). A similar argument proves (ii). ■

But the model has no theoretical implications on risk attitudes when the probability of the uncertain gain or loss is small. Indeed, A.2 implies that $\pi(p \mid .) \geq p$, whereas, by A.1, $pv(z)/v(pz) < 1$, and the sign of

$$\pi(p \mid .)\, v(z) - v(pz) = v(pz)\left[\frac{\pi(p|.)}{p}\frac{pv(z)}{v(pz)} - 1\right] \tag{2}$$

depends on the functional forms of π and v.

Tversky and Kahneman (1992, Section 2.3) propose the following form for the value function, which in particular implies A.1.

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[24] The dependence of π on the sign of z means that the weighting may be different for gains and for losses, see Tversky and Kahneman (1992). Gains and losses are defined relative to a reference point, which can be current assets or some subjective aspiration level. Kahneman and Tversky's (1979) notation does not cover changes in the reference point. In fact, they believe that any such changes can be ignored: in their words (1979, p. 277) "the preference order of prospects is not greatly altered by small or even moderate variations in asset positions." Bosch-Domènech and Silvestre (in press) suggest, on the contrary, an important role for wealth.

A.3 ("homogeneous preferences"). $v(z) = \begin{cases} z^{\gamma}, \gamma \in (0,1), \text{ } if \text{ } z \geq 0 \\ -\lambda(-z)^{\beta}, \lambda > 0, \beta \in (0,1), \text{ } if \text{ } z < 0 \end{cases}.$

Expression (2) becomes, under assumption A.3,

$$(pz)^{\gamma}\left[\frac{\pi(p|+1)}{p}p^{1-\gamma} - 1\right], \qquad \text{for } z > 0,$$

$$-\lambda(-pz)^{\beta}\left[\frac{\pi(p|-1)}{p}p^{1-\beta} - 1\right], \text{ for } z < 0,$$

still of indefinite sign for small p under A.2, because $\frac{\pi(p|.)}{p} \geq 1$, but $p^{1-\gamma}$ and $p^{1-\beta}$ are less than one. Thus, while the Lemma justifies the main diagonal of the fourfold pattern of Table 4 in the text, the theory has no prediction for its skew-diagonal cells.

Appendix 3. Preferences, and the amount, switch and translation effects

A.3.1. The translation effect violates single-self preferences

Economists often base their policy recommendations on the premise that an individual is the ultimate judge of her welfare, assuming that she has a single self, so that her judgment does not vary with the circumstances in which she judges. Whether this is a realistic assumption or not largely depends on the issue at hand: Modern behavioral economics has uncovered a variety of instances where individuals act as if they have multiple selves, depending on, say, the presence or absence of previous consumption (addiction), on the distance in time between the decision and its outcome (myopia with respect to the future), or on their endowment or reference points (reference dependence).

We now argue that an individual who displays a translation effect in her decisions facing uncertainty cannot have single-self preferences. Consider the following instance of translation effect. At two different wealth levels (\$1000 and \$1100), our consumer displays risk aversion in the choice $<z, p> = <100, 0.8>$ (NW cell of Figure 1, with the bad event being "not winning \$100," which occurs with probability 0.2), yet risk attraction in the choice $<-z, 1-p> = <-100, 0.2>$ (NE cell of Figure 1, with the bad event being "losing \$100," also occurring with probability 0.2).[25]

[25] Note that the attitude reversal is assumed to occur for a range of initial wealth values. There would be no problem with single-self preferences if the reversal only occurred for a single w, in which case we could have single-self, expected utility preferences, with a vNM utility function convex in the interval $(w - z, w)$ and concave in $(w, w + z)$.

We consider the space of contingent money balances first. There are two states, with the interpretation that the first state is the bad one: the number x_s denotes an amount of money available to the individual in the contingency that state s occurs. A vector $x = (x_1, x_2) \in \Re^2_+$ is interpreted as a point of contingent money balances, see Figure A.1. If the initial wealth is certain w, then we can view (w, w) as the decision maker's endowment point. For the initial wealth w and for $z > 0$, choice $<z, p>$ is the choice between the uncertain point of contingent money balances $(w, w + z)$ and the certain point $(w + pz, w + pz)$, whereas, for $z < 0$, the choice is between $(w + z, w)$ and $(w + pz, w + pz)$. In Figure A1, the decision maker of this example prefers S to C when her endowment point is C', but C to S if it is C''.[26] Thus, no single set of indifference curves on the space of contingent money balances can rationalize her behavior.

Alternatively, we can represent her preferences in lottery space. Let there be three possible final money balances $\{x_1, x_2, x_3\}$. We call a point (p_1, p_2, p_3) in the 2-standard simplex a *lottery*, interpreted as the vector of the probabilities of ending up with the various possible money balances. If she is initially endowed with a certain wealth w, then her endowment lottery is degenerate.

For our example, let $\{x_1, x_2, x_3\} = \{1000, 1080, 1100\}$. A wealth of 1000 is then the lottery (1, 0, 0) as endowment, represented as point C'' in the Marschak-Machina triangle of Figure A2, whereas a wealth of 1100 is the lottery (0, 0, 1), represented as point C'.[27] Points C and S have an expected money value of 1080.[28] When her wealth is 1000, she prefers a sure gain of 80 to a gain of 100 with probability 0.8, i.e., when her endowment point is C'', she prefers point C (a certain gain of 80 added to 1000) to point S (the gain of 100 with probability 0.8). But when her wealth is 1100, she prefers a loss of 100 with probability 0.2 to a certain loss of 20, i. e., when the endowment point is C', she prefers the uncertain point S to the certain point C. Thus, no single set of indifference curves in the simplex can rationalize her behavior.

We can say that she has two different selves. Her "poor" self, relevant when her wealth is \$1000, prefers a certain total wealth of \$1080 to a 0.8 probability of a total wealth of \$1100 coupled to a 0.2 probability of a total wealth of \$1000. But her "wealthy" self, relevant when her initial wealth is \$1100, reverses her preference. This raises positive and normative issues. From the

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[26] The line of slope – 1/4 through point C in Figure A1 is a fair-odds (or iso-expected-money) line.

[27] The Marschak-Machina triangle is a 2-dimensional Cartesian representation of the standard 2-simplex $\{(p_1, p_2, p_3) \in \Re^3_+ : p_1 + p_2 + p_3 = 1\}$ where we read p_1 as the abscissa, p_3 as the ordinate, and p_2 as $1 - p_1 - p_3$.

[28] The expected money balances are 1080 along any points of the line of slope 4 through C in Figure A2.

positive viewpoint, knowing the preferences of both her "poor" and her "wealthy" selves does not suffice to predict her choice in the following situation.[29] Her initial wealth is $1000, and she has to choose between a certain loss of $20 and a loss of $100 with probability 0.2. But just before making her choice, she is given $100. Does she see this $100 as being added to her initial wealth, so that her wealthy self takes over, displaying risk attraction? (preferring a loss of $100 with probability 0.2 to a certain loss of $20.) Or, on the contrary, does she see this $100 as being part of the changes in her wealth, and, thus, her poor self takes over, preferring to increase her wealth by a certain $80 (100 – 20), rather than by an uncertain $100 with probability 0.80? Or does she actually have a third, "nouveau riche" self, which resolves this particular conflict between her two previous selves?

A.3.2. The amount and switch effects do not violate single-self preferences

It turns out that, contrary to the translation effect, the other two effects that we emphasize, namely the amount effect and the switch effect, are consistent with single-self preferences. Thus, an individual who displays both an amount effect and a switch effect, but not a translation effect, may well have single self preferences, which can then be used in the standard manner both to explain her behavior and to evaluate her *ex ante* welfare by her own preferences. This is consistent with the gain-loss asymmetry of a reflection effect as long as it is solely due to the switch effect.

As an hypothetical example of single-self preferences displaying an amount and a switch effect, consider

$U : \Re^2_+ \times \{(p_1, p_2) \in \Re^2_+ : p_1 + p_2 = 1\} \to \Re :$

$$U(x_1, x_2, p_1, p_2) = \frac{\sqrt{p_1}}{\sqrt{p_1} + \sqrt{p_2}} \sqrt{x_1} + \frac{\sqrt{p_2}}{\sqrt{p_1} + \sqrt{p_2}} \sqrt{x_2} \,. \tag{3}$$

A decision maker with these preferences and wealth w displays risk attraction in choice $< z, p>$ if and only if

$$\frac{\sqrt{1-p}}{\sqrt{1-p} + \sqrt{p}} \sqrt{w} + \frac{\sqrt{p}}{\sqrt{1-p} + \sqrt{p}} \sqrt{w+z} - \sqrt{(1-p)w + p(w+z)} > 0 \,. \tag{4}$$

Defining $\mu \equiv \frac{w+z}{w}$, the inequality can be written, after dividing through by $\sqrt{w}$, as

$$\sqrt{1-p} + \sqrt{p}\sqrt{\mu} > (\sqrt{1-p} + \sqrt{p})\sqrt{1-p+p\mu} \,,$$

[29] This point is raised by Ariel Rubinstein (2001).

which is impossible if $p = 0.5$, and (by squaring both sides and then repeatedly rewriting the inequality along the steps of the usual completion of the square) is otherwise equivalent to

$$\text{* either } p < 0.5 \text{ and } 1 < \mu < \left(\frac{1-p}{p}\right)^2$$

$$\text{* or } p > 0.5 \text{ and } \left(\frac{1-p}{p}\right)^2 < \mu < 1 \ ,$$

which can also be written

$$\text{* either } p < 0.5 \text{ and } 0 < z < \left[\left(\frac{1-p}{p}\right)^2 - 1\right] w \tag{5}$$

$$\text{* or } p > 0.5 \text{ and } \left[\left(\frac{1-p}{p}\right)^2 - 1\right] w < z < 0 . \tag{6}$$

It is clear from (5) that these preferences generate an amount effect for gains whenever the probability of the gain is less than 0.5: the decision maker chooses the risky alternative if *z* is less than a given positive fraction of wealth. Similarly, (6) implies an amount effect for losses whenever the probability of the loss is greater than 0.5.

For low enough positive *z*, a switch effect in gains occurs when moving from a probability of gain $p^0 > 0.5$ to a probability $p^1 \equiv 1 - p^0 < 0.5$ (as when moving from the NW to the SW of Figure 1). Indeed, because $p^0 > 0.5$, (5) indicates risk aversion for all gains, whereas, because $p^1 < 0.5$, (5) implies risk attraction as long as $0 < z < \left[\left(\frac{1-p^1}{p^1}\right)^2 - 1\right] w$. Similarly, for *z* negative and low enough in absolute value, a switch effect in losses occurs when moving from $p^1 < 0.5$ to $p^0 \equiv 1 - p^1 > 0.5$ (from NE to SE in Figure 1). Indeed, for $p^1 < 0.5$, (6) requires risk aversion for all losses, whereas, because $p^0 > 0.5$, (6) implies risk attraction as long as $\left[\left(\frac{1-p^0}{p^0}\right)^2 - 1\right] w < z < 0$.

From these observations, we also deduce the presence of a reflection effect both along the main diagonal and the skew diagonal of Figure 1. For the main diagonal, consider choice

<z, p^0> for $p^0 > 0.5$ and $z \in (0, \left[1-\left(\frac{1-p^0}{p^0}\right)^2\right]w)$ (NW cell of Figure 1). As just argued, (5) implies risk aversion, whereas (6) requires risk attraction in the (SE) choice <- z, p^0>. For the skew diagonal, consider choice <z, p^1> for $p^1 < 0.5$ and $z \in (\left[1-\left(\frac{1-p^1}{p^1}\right)^2\right]w, 0)$ (NE), where (6) requires risk aversion, and choice <- z, p^1> (SW), where (5) implies risk attraction.

Remark 1. One should resist the temptation to interpret (4) as a special case of expression (1) of Prospect Theory (see Appendix 2 above): a fundamental difference is that the arguments in (4) are probabilities and final money balances, whereas those appearing in Prospect Theory's (1) are probabilities and changes in money balances. In other words, (3) represents single-self preferences, whereas Prospect Theory's preferences are of the multiple-selves variety.

Remark 2. As noted in Section A.3.1 above, the translation effect violates single-self preferences. It follows that no translation effect can occur with (3), as we can directly check. Given $\overline{w}$, assume risk aversion for some <z, p>, $z > 0$, yet risk attraction in choice <- z, 1- p>, which by (5) implies that $p^0 \equiv 1\text{-}\, p > 0.5$, i. e., $\left(\frac{1-p^0}{p^0}\right)^2 < 1$. But consider a w satisfying

$0 < w < \frac{z}{1-\left(\frac{1-p^0}{p^0}\right)^2}$, i.e., $0 < \left[1-\left(\frac{1-p^0}{p^0}\right)^2\right]w < z$, or $-z < \left[\left(\frac{1-p^0}{p^0}\right)^2 - 1\right]w < 0$, which by (6) implies risk aversion in the choice <- z, p^0> given w. Thus risk attraction for <- z, 1- p> cannot occur for a wide range of wealth values, and hence (3) does not display a translation effect.

A.3.3. Single-self, multiple selves and expected utility

In our context of lotteries over two possible outcomes, we define Single-Self Expected Utility Preferences as those being representable by a function of the form

$$p\, u(x_1) + (1\text{-}\, p)\, u(x_2) \qquad (\text{or } p\, u(w + z_1) + (1\text{-}\, p)\, u(w + z_2)\,),$$

where the function $u(x)$, defined on the amounts of final wealth x, is called her von Neumann-Morgenstern (vNM) function.[30]

[30] Of course, understood as a function of the probabilities p and 1- p, the function $p\, u(x_1) + (1\text{-}\, p)\, u(x_2)$ is linear, with $u(x_1)$ as the coefficient of p and $u(x_2)$ as the coefficient of $1 - p$.

This view goes back to Bernoulli (1738), who postulated risk aversion for all choices. Two centuries later, and in order to accommodate some extent of risk attraction, Friedman and Savage (1948) assumed that u was concave (risk aversion) for low wealth levels, convex (risk attraction) for intermediate ones and concave again for high wealth levels. It is by now generally recognized that the Friedman-Savage model fails to realistically integrate risk aversion and risk attraction. Markowitz (1952) was an early critic. He submitted that the argument of the utility function should not be total wealth $w + z$, but the deviations z from the reference wealth w (which he called "customary wealth"). One can visualize the individual as being endowed with a family of utility functions $u_w(z)$, one for each possible wealth level w, leading to the following notion.

Multiple-Selves, Expected Utility Preferences. When her wealth is w, the objective of the individual is to maximize $p\, u_w(z_1) + (1- p)\, u_w(z_2)$, where $u_w(z)$ is the vNM utility function corresponding to her "self" with wealth w, defined on gains or losses z, so that her final wealth is $w + z$.[31] The multiplicity of selves occurs when $u_{\overline{w}}(x-\overline{w}) \neq u_{\overline{\overline{w}}}(x-\overline{\overline{w}})$ for some $(x, \overline{w}, \overline{\overline{w}})$.

Should we apply the label "expected utility" to such preferences? The usage is not unanimous: Rabin (2000), or Palacios-Huertas, Serrano and Volij (2001), would not, whereas Cox and Sadiraj (2001) and Rubinstein (2001) would: let us adopt the loosest usage of the term "expected utility" and admit both single-self and multiple-selves preferences.[32]

We now argue that the amount, switch and translation effects violate single-self expected utility. Let us start with the amount effect. If the reversal of risk attitude occurred at a single level of wealth, then preferences could well be of the single self, expected utility variety, as in those of Friedman and Savage (1948). But single-self, expected utility preferences require the vNM utility function u(x) to be locally convex (u"(x) > 0) on the interval where the individual is attracted to small risks, and thus $u(x)$ must be convex on that interval. This contradicts the aversion to large risks involving quantities within this interval. Thus, amount-dependent attitudes are incompatible with single-self, expected utility preferences.

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[31] Two comments. First, there is still linearity in the probabilities, where the coefficients of the probabilities are the values of $u_w(z)$, which depend on both w and z (or w and x) This contrasts with Kahneman and Tversky's nonlinear "weighting functions" π, see Appendix 2 above. Second, writing z instead of x as the argument in $u_w(z)$ is just a convention: we could as well use functions $\hat{u}_w(x)$ by defining $\hat{u}_w(x) = u_w(x - w)$.

[32] Thus applying the term "expected utility" to any preferences that can be represented by functions that are linear in the probabilities, independently of the number of selves.

For the switch effect, again there would be no problem if the attitude change only took place for a single w and z, in which case the single self, expected utility hypothesis could be maintained, with a vNM utility function u that is convex in the interval (w, $w + 0.5z$) and concave in ($w + 0.5\, z$, $w + z$). But it is not difficult to show that if the switch effect changes the risk attitude over a range of wealth levels, then single-self, expected utility (continuous) preferences must be ruled out. [33]

Last, as seen in A.3.1 above, the translation effect violates single-self preferences and, hence, *a fortiori* single-self, expected-utility preferences

A.3.4. The amount, switch and translation effects are consistent with multiple-selves, expected utility preferences

The consistency is illustrated by the $u_w(z)$ function of Figure A3. First, because the curve is convex close to $z = 0$, and concave away from zero, it entails an <u>amount effect</u>.

In addition, there is risk aversion for gains at low probability of the bad state, because $u_w(80) > 0.8\, u_w(100)$. If we switch the probabilities, then we get risk attraction, because $u_w(20) < 0.2\, u_w(100)$. Thus, there is a <u>switch effect</u> for gains.

But if we translate gains into losses, at the low probability of the bad state, we get $u_w(-20) < 0.2\, u_w(-100)$, i.e., risk attraction. Thus, there is a <u>translation effect</u> when the probability of the bad state is 0.2.

A.3.6. Summary

To sum up, all three effects contradict single-self, expected utility theory, and none contradicts multiple-selves, expected utility theory. But the translation effect implies a deeper departure from standard theory because, contrary to the switch effect and to the amount effect, it

[33] Assume that, for any $w \in [1000, 1100]$ and any $z \in [0, 100]$, (a) the individual prefers the uncertain gain of z with probability 0.2 to the certain gain of $0.2z$; but (b) she prefers the certain gain of $0.8z$ to the uncertain gain of z with probability 0.8. Under the expected utility hypothesis we can set $u(1000) = 0$, and $u(1100) = 100$. Then (a) implies that $u(1020) < 20$, and (b) that $u(1080) > 80$, which, as long as u is continuous, imply that there is a z' in (20, 80) and a z'' in (80, 100] such that

(i) $u(1000 + z') = z'$,

(ii) $u(1000 + z'') = z''$, and

(iii) $u(1000 + z) > z$, $\forall\, z \in (z', z'')$.

Consider $w \equiv 1000 + z'$ and $z = z'' - z'$. By (a), the individual prefers the uncertain gain of z with probability 0.2 to the certain gain of $0.2\, z$, i.e., $0.8\, u(1000 + z') + 0.2\, u(1000 + z' + z'' - z') > u(1000 + z' + 0.2(z'' - z'))$, or, using (i)-(ii), $0.8\, z' + 0.2\, z'' > u(1000 + 0.8\, z' + 0.2\, z'')$, contradicting (iii), because $0.8\, z' + 0.2\, z'' \in (z', z'')$.

Thus, (a) and (b) are incompatible with the expected utility hypothesis with single-self, continuous preferences.

negates the existence of single-self preferences. Table A5 displays the results of our discussion in Appendix 3.

	Single-Self Expected Utility (Canonical Eu)	Single-Self Nonexpected Utility	Multiple-Selves "Expected Utility"
Amount Effect	Contradiction	OK	OK
Switch Effect (or reflection due to switch)	Contradiction	OK	OK
Translation Effect (or reflection due to translation)	Contradiction	Contradiction	OK

Table A5. The amount, switch and translation effects vs. single self and expected utility: Summary.

var	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
d1	-4.413035	.8182728	-5.39	0.000	-6.016821	-2.80925
d2	-4.491003	.9849294	-4.56	0.000	-6.421429	-2.560577
z	.677745	.0923447	7.34	0.000	.496753	.8587377
_cons	.387533	.4822355	0.80	0.422	-.557631	1.332698
ln σ2u	3.066563	.3329171			2.414058	3.719069
σu	4.633356	.7712618			3.343535	6.420746
ρ	.867118	.0383601			.772628	.926097

Likelihood-ratio test of ρ = 0: χ2(1) = 96.09 Prob >= χ2 = 0.000

Table 1: ML estimation

	Amount of Money (in *pesetas* and in US$ rounded off to the nearest dollar)						
	500 **$3**	**1000** **$7**	**2000** **$13**	**5000** **$33**	**7500** **$50**	**10000** **$67**	**15000** **$100**
Treatment *G* (gains with prob. = 0.8) (i.e., prob. of bad outcome = 0.2)	0.57	0.57	0.29	0.05	0.10	0.10	0.05
Treatment *L* (losses with prob. = 0.2)	0.83	0.66	0.83	0.50	0.24	0.27	0.33
Treatment *G´* (gains with prob. = 0.2) (i.e., prob. of bad out. = 0.8)	0.92	0.92	0.79	0.46	0.50	0.17	0.17
Treatment *L´* (losses with prob. = 0.8)	1.00	1.00	0.75	0.62	0.62	0.50	0.37

Table 2. Fraction of participants, in Treatments *G, L*, *G´* and *L´*, facing choices on the seven possible amounts of money, who display risk attraction (by choosing the uncertain alternative) for the various amounts of money a stake. The color red highlights a majority of participants displaying risk attraction. The color green, a majority displaying risk aversion.

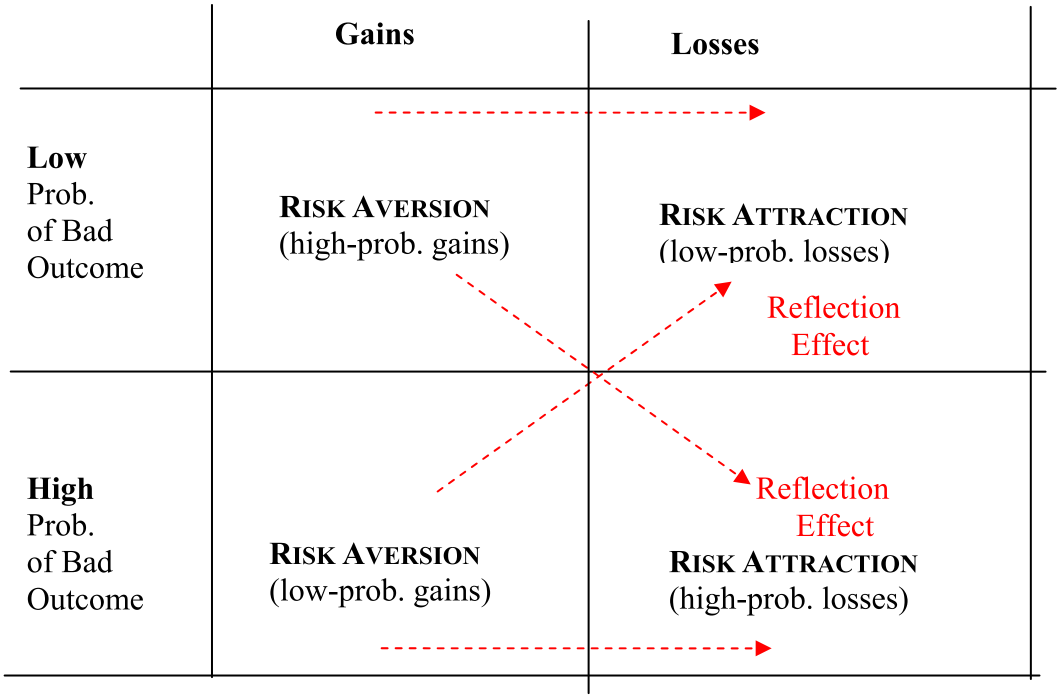

Table 3. The gain-loss asymmetry view

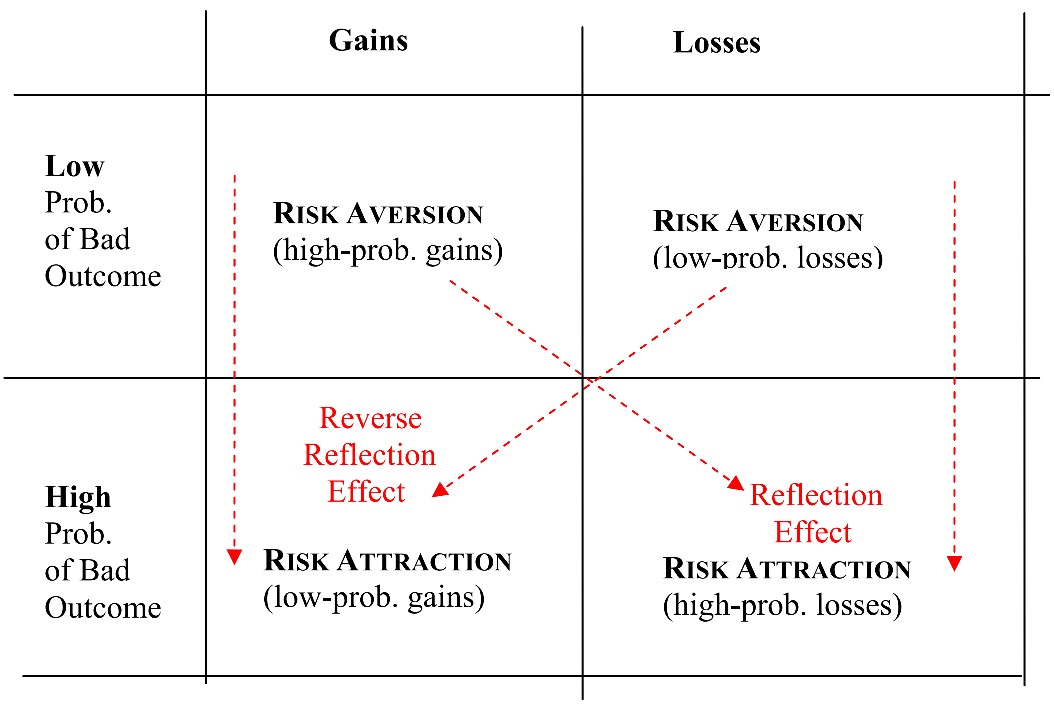

Table 4. Tversky-Kahneman (1992) fourfold pattern of risk attitudes

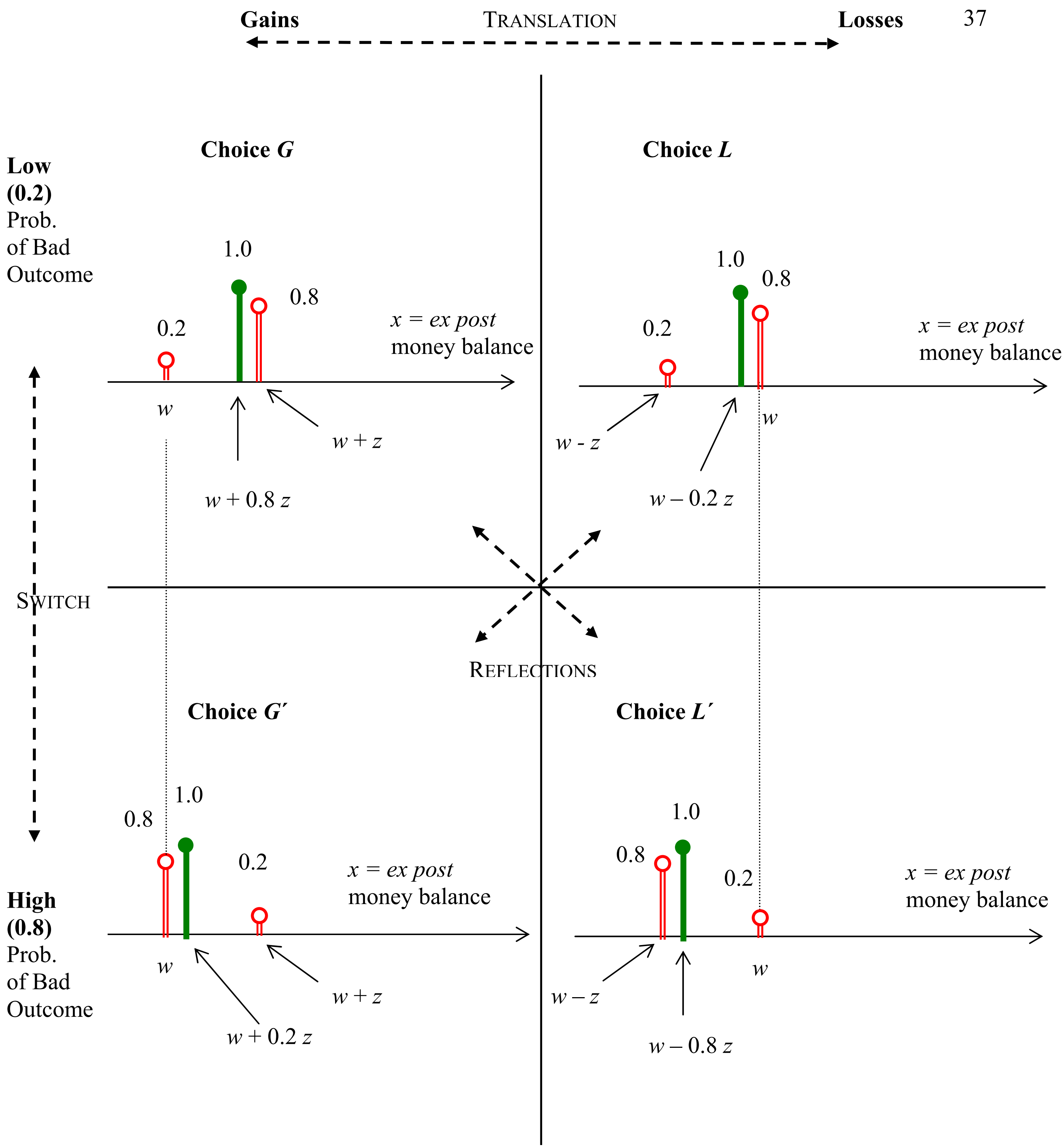

Figure 1

Reflection = Translation + Switch

$G \leftrightarrow L$: translation

$G' \leftrightarrow L'$: translation

$G \leftrightarrow G'$: switch

$L \leftrightarrow L'$: switch

$G \leftrightarrow L'$: reflection (main diagonal)

$G' \leftrightarrow L$: reflection (skew diagonal)

$z > 0$, probabilities are measured vertically

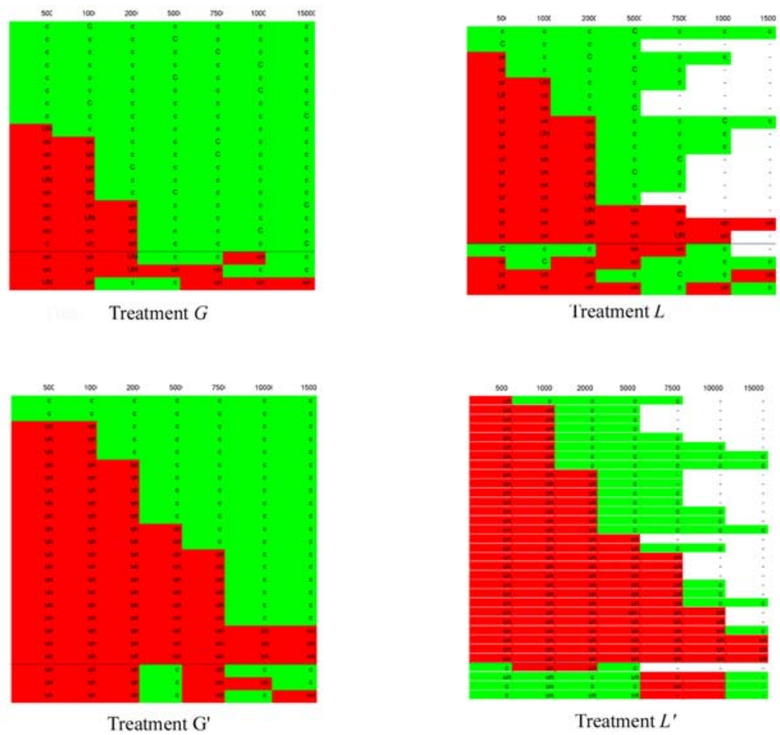

Figure 2. Raw data of the four treatments, G, L, G' and L'. The color green indicates risk aversion and the color red risk attraction. Each row corresponds to the decisions of a single subject for each of the seven money amounts.

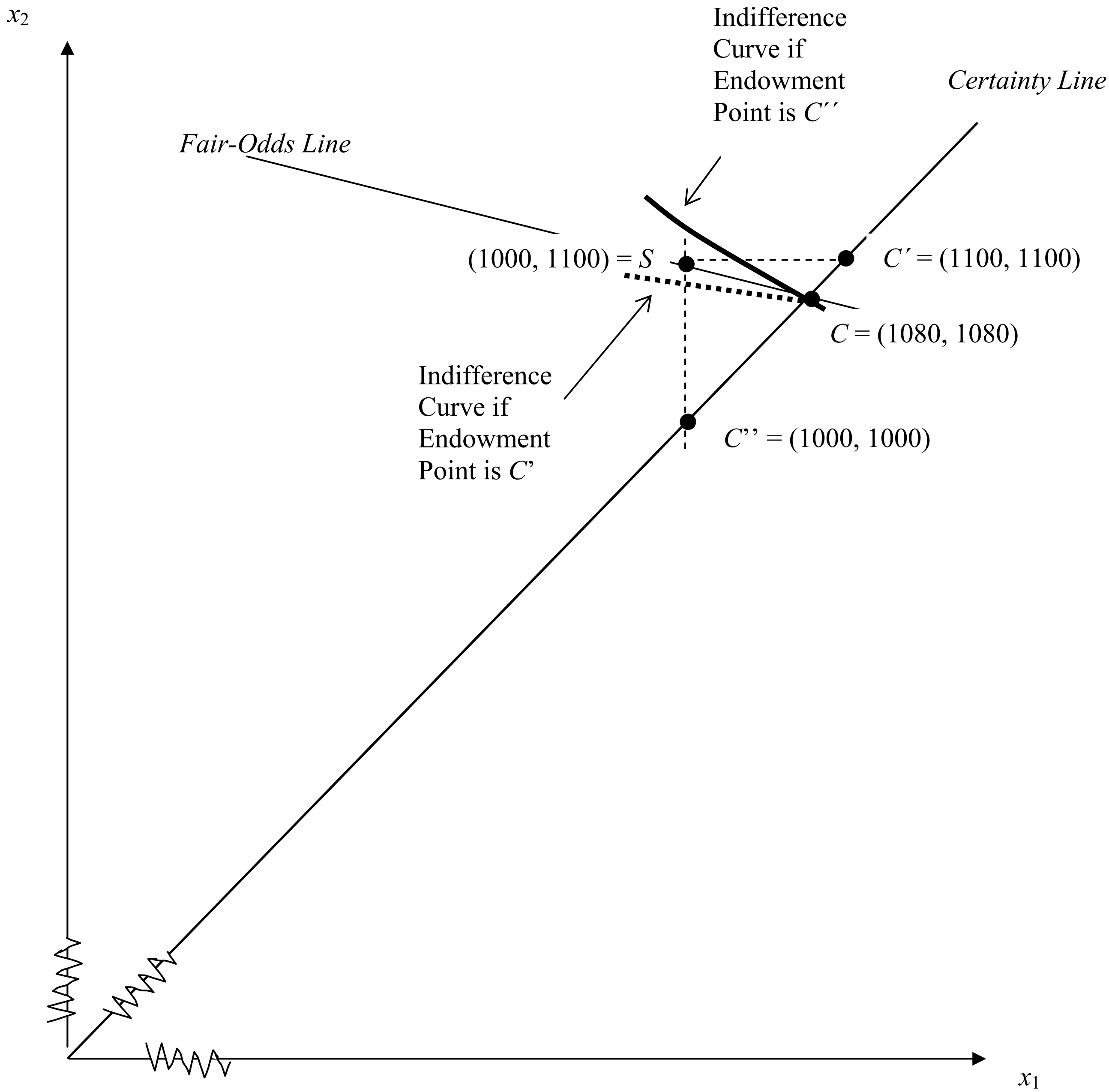

Figure A1. Translation-dependent risk attitudes do not allow for single-self preferences on the space of contingent money balances.

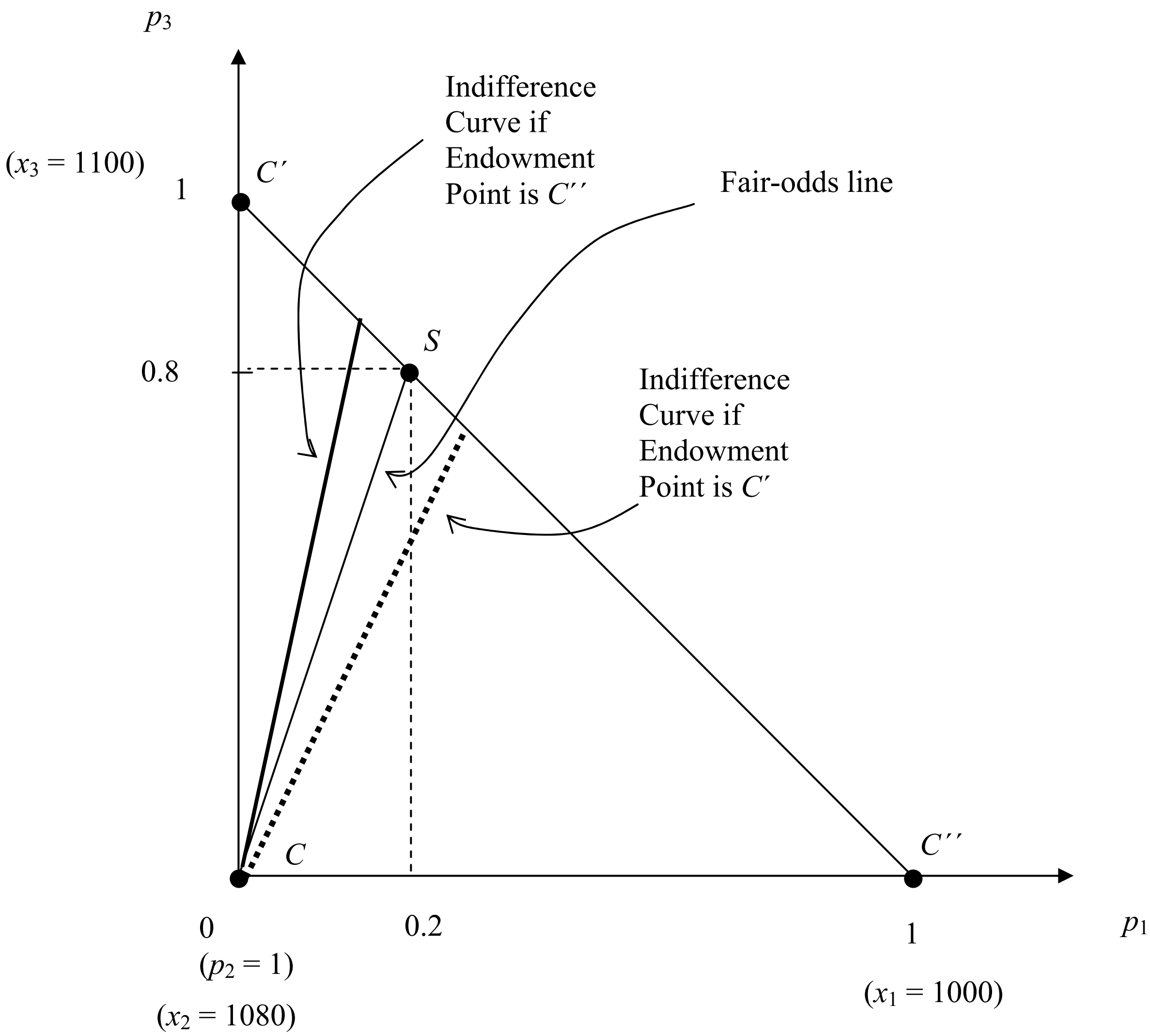

Figure A2. Translation-dependent risk attitudes do not allow for single-self preferences on the space of lotteries.

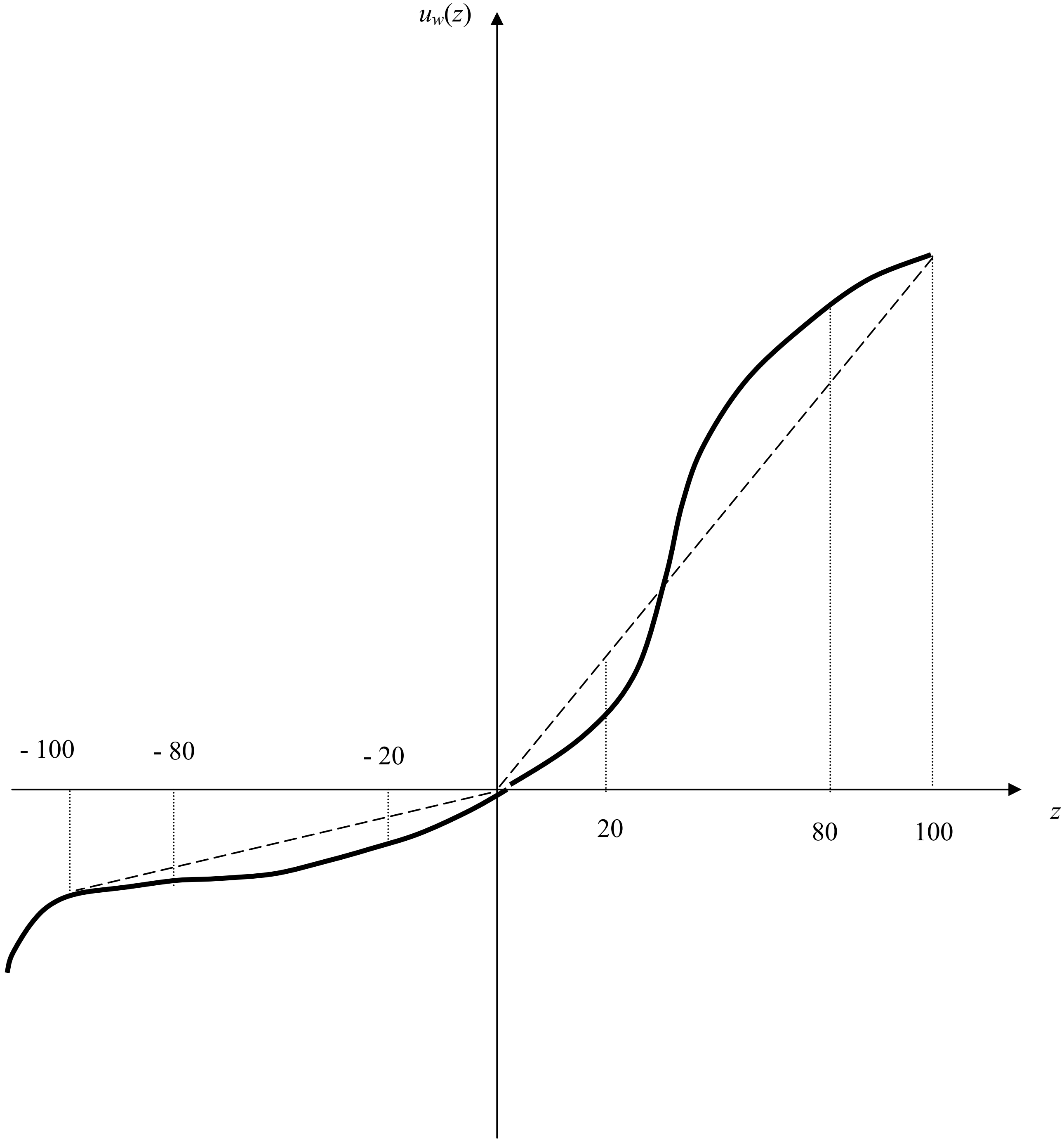

Figure A3.
The amount, switch and translation effects are consistent
with multiple-selves, "expected utility" preferences.

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