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Reflections on gains and losses: A 2 × 2 × 7 experiment

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Abstract 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 the majority display risk attraction for small amounts of money, and risk aversion for larger amounts. Yet the frequency of risk attraction varies according to the gain-loss dichotomy and the probabilities. Kahneman and Tversky studied gain-loss *reflections*. We submit that a reflection can be decomposed into a *translation* and a probability *switch*. We find significant translation and switch effects, which are of comparable magnitude, a result that is equidistant from the diverging two popular views inspired by Prospect Theory: the gain-loss asymmetry, and the fourfold pattern.

Keywords Reflection effect · Risk attraction · Risk aversion · Gains · Losses · Experiments · Prospect theory · Fourfold pattern

JEL Classification C91 · D81

What determines risk attraction or aversion? In its crudest version, the conventional wisdom inspired by the pioneer work of Kahneman and Tversky views individuals as risk averse for gains and risk seeking for losses: what we call the *gain-loss asymmetry* view. 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*."

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And they continued,

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

Later, Tversky and Kahneman (1992) advocated a fourfold pattern of risk attitudes where the magnitude of the probabilities played a decisive role.

The present paper experimentally examines not only Kahneman and Tversky's gain-loss dichotomy, and the role of probabilities (0.2 vs. 0.8), but also the amount of money at stake (seven amounts, from €3 to a relatively substantial €90). If we combine the loss treatments L and L' reported in Bosch-Domènech and Silvestre (2006b) and the present gain treatments G and G', each dealing with seven amounts of money at stake, then we obtain a $2 \times 2 \times 7$ experimental design. Our participants (or "subjects") make real, not hypothetical, choices between simple uncertain money prospects and their expected money values. Hence, all choices involve pairs of prospects with the same expected value.

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 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 also appears in our 1999 and 2006a,b,c papers.

Following Kahneman and Tversky's path, the study of the gain-loss dichotomy has emphasized "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 1 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 from gains to losses, 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).

Section 4 below relates our results to the literature. We discuss the implications of our results for Prospect Theory, which postulates an *S*-shaped value function plus an inverse-*S*-shaped weighting function. If the curvature of the value function dominates, then we get risk aversion for gains and risk attraction for losses, as in the gain-loss asymmetry view. This is also the pattern implied by our translation effect, if it operated in isolation. But if the curvature of the weighting function dominates, then we get risk aversion (resp. attraction) for low (resp. high) probabilities of the bad outcome. This yields the fourfold pattern, and corresponds to the influence of our switch effect.

Our result that the translation and switch effects are of comparable magnitude confirms the predictions of the gain-loss asymmetry view and the fourfold pattern in the cases when these predictions coincide, and splits the difference between them when they mutually disagree. For instance, when moving from low probability gains to low probability losses, the gain-loss asymmetry view predicts an *increase* in the frequency of risk attraction (i.e., a reflection effect), whereas the fourfold pattern predicts a *decrease* in that frequency (i. e., a *reverse* reflection effect). In line with our findings of the equal magnitude of the translation and switch effects, we find no clear change in the frequency of risk attraction for that move.

We also comment on the compatibility of the translation effect, on the one hand, and the amount and switch effects, on the other, with *single-self preferences*, and with *expected utility theory*. In addition, we compare Rabin's (2000) critique of (single-self) expected utility theory with our amount effect.

1 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 $\langle z, p\rangle$ 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 $G \equiv \langle z, 0.8\rangle$. A person with given wealth w has to choose between a certain gain of €$0.8z$ vs. an uncertain gain of €z with probability 0.8.

If she chooses the certain gain, her *ex post* money balance is $x = w + 0.8z$, 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 upper left cell in Figure 1. The certain choice is the degenerate pdf, depicted as a solid bar, whereas the two hollow bars depict the uncertain choice.

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

Choice $G' \equiv \langle z, 0.2\rangle$. A person with given wealth w has to choose between a certain gain of €$0.2z$ vs. an uncertain gain of €z with probability 0.2.

Choice G' is depicted in the lower left 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

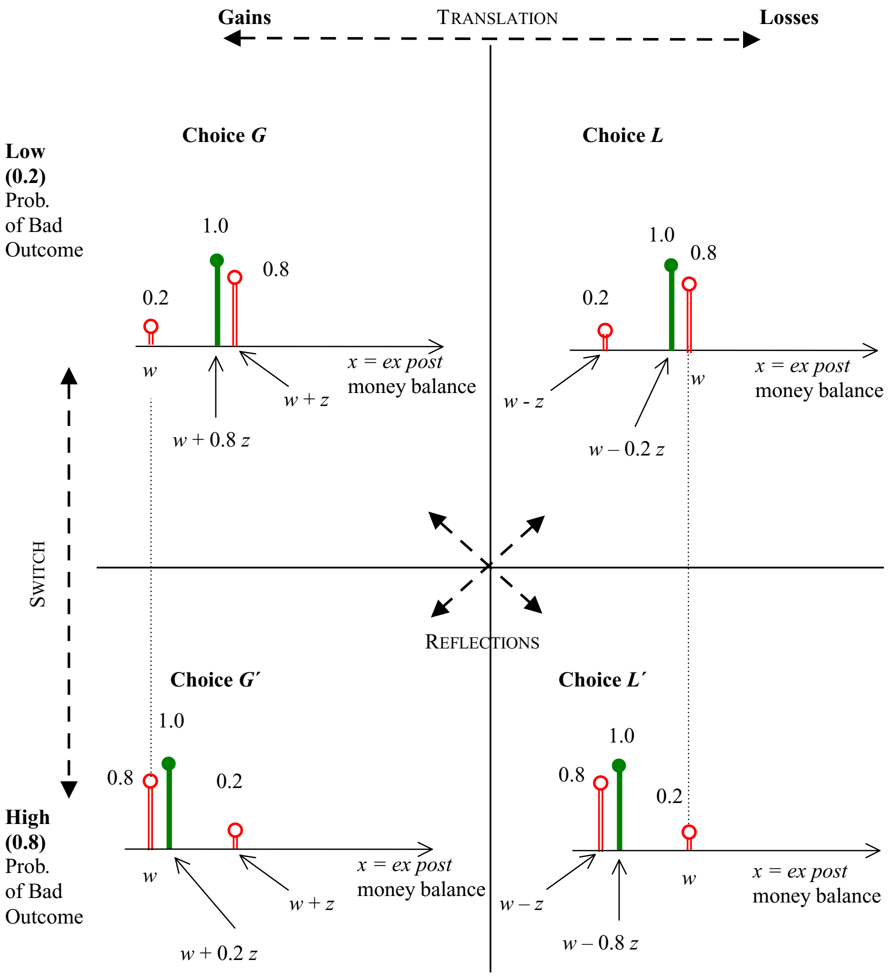


Fig. 1 Reflection = Translation + Switch, $G \leftrightarrow L$: translation, $G' \leftrightarrow L'$: translation, $G \leftrightarrow G'$: switch, $L \leftrightarrow L'$: switch, $G \leftrightarrow L'$: reflection (main diagonal), $G' \leftrightarrow L$: reflection (skew diagonal), $z > 0$, probabilities are measured vertically

$s(\langle z, p\rangle) = \langle z, 1 - p\rangle$. Of course, there is no reason why the person could not choose the certain gain in G and the uncertain gain in G'.

Assume 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 upper right cell of Figure 1, while reflection gives L' in the lower right cell.

Choice $L \equiv \langle -z, 0.2\rangle$. A person with given wealth w has to choose between a certain loss of €$0.2z$ 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 $t(\langle z, p\rangle) = \langle -z, 1 - p\rangle$.

Choice $L' \equiv \langle -z, 0.8\rangle$. A person with given wealth w has to choose between a certain loss of €$0.8z$ 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:

$$r(\langle z, p\rangle) \equiv s(t(\langle z, p\rangle)) = t(s(\langle z, p\rangle)) = \langle -z, p\rangle,$$

i.e., Reflection = Translation + Switch.[1]

Both a translation and a reflection turn a choice involving gains into a choice involving losses. But 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 sheds 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. Finally, the comparison of G vs. L' choices, or G' vs. L choices, tests for reflection effects.

2 The experiment

2.1 Treatment G: Gains at low probability of the bad outcome

Our experiment is between subjects, and the four treatments share a basic design. As with the rest of treatments, we performed Treatment G in a single session (no preliminary pilot sessions) with students from the *Universitat Pompeu Fabra* who volunteered, and we 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 euros, 3, 6, 12, 30, 45, 60 and 90. 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*

[1] Also Translation = Switch + Reflection, and Switch = Reflection + Translation. The three operators together with the identity form the Klein-4 group.

attraction (resp. *risk aversion*) in a particular choice if she chooses the uncertain (resp. certain) alternative.[2]

Participants were given a seven-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.[3] 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 min), 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, 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 depicted in the top left panel of Figure 2: The figure has been arranged in the manner of Figure 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 light shade indicates choosing the certain gain or loss (thus displaying risk aversion), while the dark shade indicates choosing the uncertain gain or loss (thus displaying risk attraction). 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.

2.2 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 depicted in the bottom left panel of Figure 2.

2.3 Treatments L and L'

As reported in our 2006b paper, Treatments L and L' implement a design that we believe avoids to a large measure both the windfall-gains bias and the house-money bias which pervade experiments with losses in real money. In a nutshell, each treatment consists of two sessions: a first one, in which the participants receive various amounts of cash (€30, €45,

[2] A risk-neutral participant could choose either the certain or the uncertain prospect, his or her choice being at random. But the hypothesis that the results are generated at random can be rejected with a p-value practically equal to zero.

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

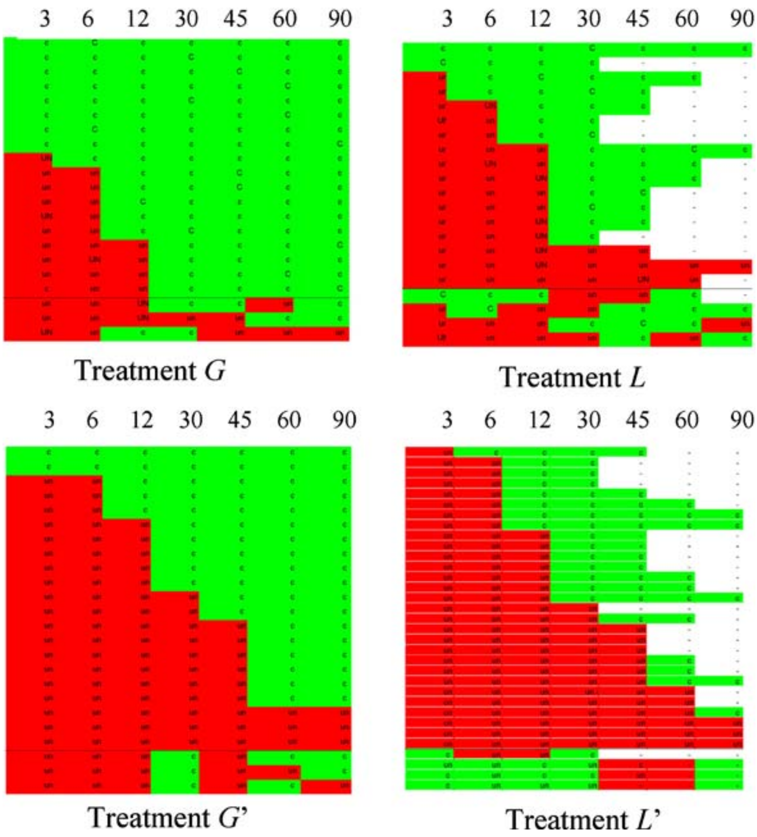


Fig. 2 Raw data of the four treatments G, L, G' and L'. A light shade indicates risk aversion, and a dark shade risk attraction. Each row corresponds to the decision of a single subject for each of the seven money amounts

€60, €90) depending on their performance in a quiz, and a second one, several months later, where they make their decisions.

In the second session no participant can be assigned to a class in which she could lose an amount of money exceeding her earnings in the quiz. A participant in Treatment L (resp. L') is 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 (resp. 0.8) times the money amount of the class, and the uncertain prospect of losing the money amount of the class with probability 0.2 (resp. 0.8) and nothing with probability 0.8 (resp. 0.2).

We reproduce the data for Treatments L and L' in the second column of Figure 2.

3 Results

3.1 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

Table 1 Maximum likelihood estimation

Variables	Coefficients	Standard errors	Exp (Coeff.)	$P > \|z\|$
Dummy for the probabilities, d_1	−4.413	.818	.0118	0.000
Dummy for the sign of the amount of money, d_2	−4.491	.985	.0112	0.000
Amount of money, z	.678	.092	1.9699	0.000
Constant	.387	.482		0.422

Likelihood-ratio test of $\rho = 0$: $\chi^2(1) = 96.09$ $P \geq \chi^2 = 0.000$.

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 (G and L) from the treatments with a probability of the bad outcome of 0.8 (G' and L') and, consequently captures the switch effect. The second one separates the treatments with gains (G and G') from the treatments with losses (L and L') and, consequently, portrays the translation effect.

We estimate the following logit regression model with random intercept[4]

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

$i \in \{1, \ldots, I\}$, where I is the number of participants, $j \in \{1, \ldots, 7\}$, the seven levels of money, $z_j \in \{0.5, 1, 2, 5, 7.5, 10, 15\}$,[5] $d_1 = 0$ 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 $-z_j$) for the four regimes described by the values of the dummy variables. The individual effect u_i allows for individual specificity in overall risk attitude. It is assumed to be normally distributed with mean zero and standard deviation σ_u, so that $\alpha + u_i$ is the random intercept.

Recall that 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 (€90) had to make the choices corresponding to all seven situations. Since having to make a larger or smaller number of choices could in principle affect the choices,[6] in the regression we only use data from the participants who made all seven decisions. 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.

[4] 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 not statistically significant. Accordingly, we estimated the more parsimonious model described. On the other hand, replacing z by $\ln z$ does not result in any qualitative change.

[5] In the regression, the unit of money is 1000 *pesetas*, which equals €6.

[6] Our 2006c paper addresses this issue, see next section.

Table 2 Fraction of participants, in Treatments G, L, G' and L', who display risk attraction (by choosing the uncertain alternative) for the various amounts of money a stake

	Amount of Money						
	€3	**€6**	**€12**	**€30**	**€45**	**€60**	**€90**
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)	0.86	0.71	0.62	0.29	0.23	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)	0.91	0.97	0.71	0.47	0.50	0.35	0.37

The dark shade highlights a majority of participants displaying risk attraction. The light shade, a majority displaying risk aversion.

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.

The magnitudes of the parameter estimates show that the odds of choosing the safe prospect increase 97% when the money at risk increases by €6, 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. From column 4 in Table 1 it follows that the odds of choosing the safe prospect are multiplied by 1.97 when the money at risk increases by €6, while the odds are multiplied by 0.012 when the probability of the bad outcome goes from 0.2 to 0.8 and by 0.011 when gains are translated into losses. Thus, the switch and translation effects appear to be of similar magnitude.

3.2 The fundamental role of the amount of money at stake

The statistical analysis, the visual inspection of the four panels of Figure 2, and the percentages computed 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.*

Result 3 (Amount effect). *The proportion of participants who display risk aversion in a particular choice increases with the amount of money at stake.*[7]

[7] Results 1, 2 and 3 are also obtained in Bosch-Domènech and Silvestre (1999, 2006a,b,c).

Result 4 (Risk attraction by the majority for small 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 dark areas in Figure 2 and Table 2).*[8]

Result 5 (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 aversion for large amounts (the lighter areas in Figure 2 and Table 2).*

Results 3, 4 and 5 assert that "*when it matters*" *the majority are risk averse*, vindicating Bernoulli. Any unusual findings may raise doubts about its robustness, and what we discover often appears to be at odds with previous studies in the literature. Results 4 and 5 are a case in point: for instance, it may surprise that 92% of participants in Treatment G' display risk attraction for small gains (€3 and €6) with a 0.2 probability. But we find fault neither in the sample of participants nor in the procedure. First, in order to test whether the participants in Treatment G' had extreme risk attitudes, we subjected them to a control treatment of gains with probability 0.8, obtaining frequencies similar to the ones reported in Table 2 for Treatment G. This indicates that the frequencies obtained in Treatment G' were not due to sample bias.

Second, one may be concerned with possible biases due to the elicitation procedure. Indeed, most experiments in the literature rely on asking participants either their willingness to pay for a lottery, or their choice between two (nondegenerate) lotteries. Harbaugh et al. (2002a,b) state that these two procedures may well elicit significantly different risk attitudes from the ones obtained by asking participants to make the more natural and direct choice between a lottery and a certain outcome (as we do).

Third, our elicitation method asks participants to make up to seven decisions involving different amounts of money. Conceivably, our participants could be viewing the seven decisions as a whole and trying to balance safer decisions at one end with riskier decisions at the other. Concerned with this potential "embedding" bias, we did not give the participants a single list of all the decisions, but, instead, each decision was explained and recorded on a different page in the folder. Granted, participants could shift from page to page and revise previous decisions in light of the subsequent ones. But we observed very few erasures or changes. More importantly, our 2006c paper addresses the issue of embedding bias (i. e., whether the choice made for a particular amount of money varied when the decision was embedded in a list of four, five, six or seven decisions), and finds no such bias in our procedure.

Fourth, a possible order effect of the questions can be safely dismissed. Both in our 1999 and 2006a papers as well as in the G experiment reported here, participants were allowed, after the particular amount of money to be paid was drawn from the urn, to change their choice. In other words, participants were now confronted with a single decision instead of the seven decisions that they had previously made. If the order, or the embedding, or other group-type effects had been important, we would have observed a large number of participants switching their choice. Instead, out of 94 subjects (21 in the 1999 paper, 42 in the 2006a paper and 31 in the G experiment), only three switched, one in each experiment, all of them moving from an initial choice of the uncertain prospect to prefer the certain one. It appears, therefore, that

[8] Prelec and Loewenstein (1991) coined the expression "peanuts effect" to describe risk taking for small gains and risk aversion for small losses (p. 773). Result 4 shows the prevalence of the so-called peanuts effect for gains, but not for losses. Our result may suggest that people enjoy gambling, and prefer to gamble when "peanuts" are at stake. If so, it would seem more appropriate to define a "peanuts effect" in the sense of our Result 4 rather than as in Prelec and Loewenstein.

if there is an order effect in our results it is very small and, if anything, it favors a riskier behavior.

Last, but most important, many of the results in the literature depend on hypothetical-money experiments. But, according to Holt and Laury (2002) and Laury and Holt (2000), this systematically yields results at variance with those using real money (which is our method).[9]

3.3 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 6 (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).*

This effect shows the increase in risk attraction due to a pure change from gains to losses, without any shift in the probabilities of the bad (and good) outcomes. But statements on individuals being "risk averse for gains and risk taking for losses" often have in mind a reflection effect that also involves a switch in these probabilities.

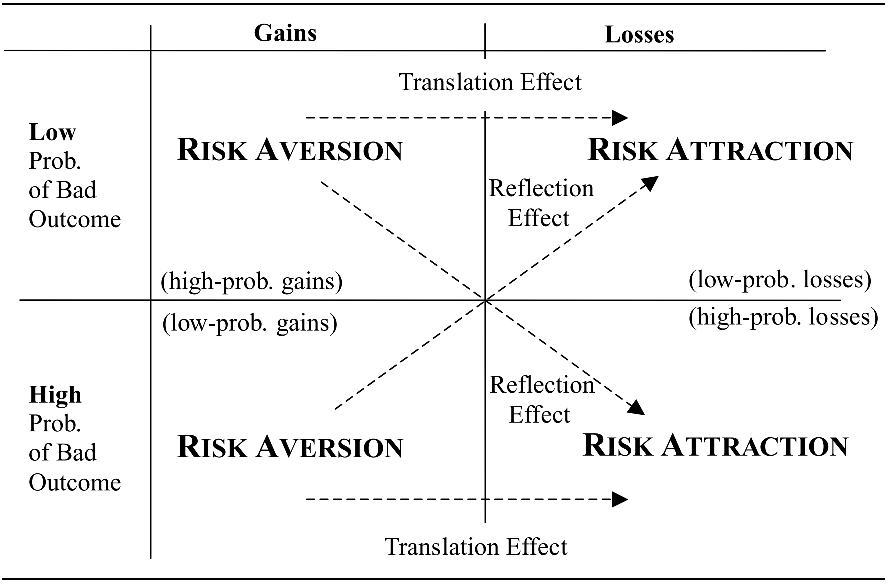
Result 7 (Switch effect). *Both for gains and for losses, and for all amounts of money at stake, participants are more likely to display risk attraction when the probability of the bad outcome is high, in particular when the probabilities of an uncertain gain are low. In fact, at a low probability of 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 8 (Equal strength of the translation and switch effect). *Table 1 shows that the estimated coefficients of the dummy variables capturing the translation and switch effects are of similar magnitude (−4.49 and −4.41, respectively).*

Next, Results 9 and 10 refer to the "reflection effect" as defined by Kahneman and Tversky (1979). 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 9 and 10 agree with Results 6–8.

[9] See Bosch-Domènech and Silvestre (2006b). If emotions play a significant role in decision making (see, e.g., Loewenstein et al., 2001, or Slovic et al., 2002) one should expect to observe different behavior when choices involve hypothetical vs. real gains and losses. It is not surprising that economists, trained to value incentives, only reluctantly have come to accept that hypothetical choices may provide insights into real decision making. What is more surprising is that psychologists, trained to value emotions, have gingerly embraced hypothetical choices as valuable to understanding decision making, when it is hard to imagine a more emotion-barren choice than a hypothetical one.

Table 3 The gain-loss asymmetry view, the role of the value function, and the translation effect (Arrows indicate increasing risk attraction)



Result 9 (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., down the main diagonal of Figure 1. Indeed, the translation and switch effects reinforce each other down the main diagonal, and hence this result is in line with Results 6 and 7 above.*

Result 10 (Negligible reflection effect for low probability gains and losses). *The frequency of risky choices is essentially unchanged when moving between a prospect with a low probability of loss and one with a low probability of gain, i.e., along the skew diagonal of Figure 1. This is consistent with Result 8 above, and is also suggested by the comparison of the second and third rows (Treatments L and G′) of Table 2.*

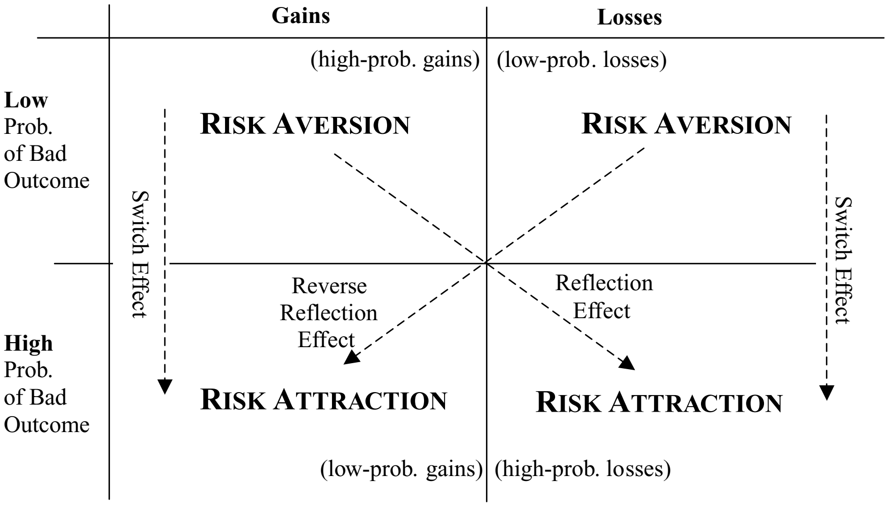
4 Relation to the literature

4.1 Prospect theory, the gain-loss asymmetry view and the fourfold pattern

Prospect Theory originated in Kahneman and Tversky's (1979) path-breaking article. As noted in the introduction above, they inspired the *gain-loss asymmetry view*. The view asserts reflection effects along both diagonals in Figure 1, i.e., the frequency of risk attraction increases as we move either from the upper left to the lower right of Figure 1 (main diagonal), or from its lower left to its upper right (skew diagonal). This pattern is expressed in Table 3, arranged in conformity with Figure 1.

They later posited the more complex view of a *fourfold pattern of risk attitudes* (Tversky and Kahneman, 1992, p. 306–309), here summarized in Table 4. Note that the fourfold pattern agrees with the gain-loss asymmetry view in the upper left and lower right corners. But they

Table 4 The fourfold pattern, the role of the probability weighting function and the switch effect (Arrows indicate increasing risk attraction)



disagree in the upper right and in the lower left corners. In particular, the fourfold pattern predicts a *reverse reflection effect* along the skew diagonal in Figure 1 and Table 4.

Interestingly, the areas of agreement between the two correspond to the cases when the theoretical predictions of the *S*-shaped value function and the inverse-*S*-shaped probability weighting function—which are the formal ingredients of Prospect Theory—coincide, whereas the shapes of these functions pull risk attitudes in opposite directions for the areas where the gain-loss asymmetry view and the fourfold pattern disagree. The following paragraphs make these ideas precise.

Formally, Prospect Theory postulates that, in choice $\langle z, p\rangle$, the decision maker chooses the uncertain (resp. the certain) gain or loss, thus displaying risk attraction (resp. aversion) if and only if $\pi(p|\text{sgn}\, z)v(z) - v(pz) > 0$(resp. < 0), where $v : \mathbf{R} \to \mathbf{R}$ is her *value function*, which can be normalized so that $v(0) = 0$, and π is a *weighting function* that transforms probabilities into decision weights.[10]

Assumption 1 (*S*-shaped value function). The function v is increasing on $\mathbf{R}$, strictly concave on $\mathbf{R}_+$ and strictly convex on $\mathbf{R}_-$.

Assumption 2 (Inverse-*S*-shaped weighting function). If p is small, then $\pi(p|.) \geq p$; if p is large, then $\pi(p|.) \leq p$.

It is clear that, under Assumptions 1 and 2, if p is large, then an individual facing choice $\langle z, p\rangle$ displays (i) risk aversion for $z > 0$, and (ii) risk attraction for $z < 0$. Indeed, we can

[10] 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 (2006a) suggests, on the contrary, an important role for wealth.

compute

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

Assumption 1 yields $0 < pv(z) < v(pz)$, when $z > 0$, and $v(pz) < pv(z) < 0$ when $z < 0$, i.e.,

$$0 < \frac{pv(z)}{v(pz)} < 1 \tag{2}$$

in either case. For p large, Assumption 2 yields $\frac{\pi(p|.)}{p} \leq 1$, which together with (2) implies that the bracketed term in (1) is negative. It follows that, if $z > 0$, then $v(pz) > 0$, and hence (1) is negative, proving (i). If, on the other hand, $z < 0$, then $v(pz) < 0$, and (1) is positive, proving (ii).

But Assumptions 1 and 2 yield no implication on risk attitude when p is small.

Assumption 2 then implies that $\frac{\pi(p|.)}{p} \geq 1$, for small p. Hence, because of (2), the bracketed term in (1) is of indeterminate sign.

Tversky and Kahneman (1992, Section 2.3) propose the following form for the value function ("homogeneous preferences"):

$$v(z) = \begin{cases} z^{\gamma}, \gamma \in (0, 1), & \text{if } z \geq 0 \\ -\lambda(-z)^{\beta}, \lambda > 0, \beta \in (0, 1), & \text{if } z < 0 \end{cases},$$

expression (1) becoming $(pz)^{\gamma}[\frac{\pi(p|+1)}{p}p^{1-\gamma} - 1]$, for $z > 0$, and $-\lambda(-pz)^{\beta}[\frac{\pi(p|-1)}{p} p^{1-\beta} - 1]$, for $z < 0$, still of indefinite sign for small p under Assumption 2, because $\frac{\pi(p|.)}{p} \geq 1$, but $p^{1-\gamma}$ and $p^{1-\beta}$ are less than one.

Thus, Assumptions 1 and 2 justify the main diagonal of both the gain-loss asymmetry view (Table 3) and the fourfold pattern (Table 4), but they offer no prediction for the skew diagonal cells. In fact, Tversky and Kahneman (1992) justify the fourfold pattern on empirical grounds. In their words (p. 307): "The fourfold pattern of risk attitudes emerges as a major generalization about choice under risk."

It is instructive to visualize the separate implications of Assumptions 1 and 2 on risk attitude.[11] First, assume that the weighting function is the identity function (i.e., $\pi(p|.)/p = 1$), in which case risk attraction or aversion is determined by the value function. Assumption 1 then yields risk aversion for gains and risk attraction for losses (the bracketed term in (1) is negative), as in the gain-loss asymmetry view. This would also be the outcome of what we call a translation effect if it operated in isolation. Thus, we can associate the translation effect with the influence of the curvature of the value function on risk attitudes. The gain-loss asymmetry view is therefore supported within Prospect Theory by the prevalence of the curvature of the value function, and in our terminology by the dominance of the translation effect.

Conversely, let the value function be the identity function (i.e., $pv(z)/v(pz) = 1$), and assume that the weighting function is strictly *S*-shaped (i.e., $\pi(p|.)/p > 1$ for low p): hence, the bracketed term in (1) is positive. This implies risk attraction to low-probability gains ($v(pz) > 0$), and risk aversion for low-probability losses ($v(pz) < 0$), producing the

[11] We are indebted to the referee for this suggestion.

fourfold pattern of Table 4. It would also be the outcome of what we call a switch effect if it operated in isolation. Thus, we can associate the switch effect with the influence of the curvature of the weighting function on risk attitudes. The fourfold pattern is therefore supported within Prospect Theory by the prevalence of the curvature of the value function, and in our terminology by the dominance of the switch effect.

In a sense, our experiments contradict both the gain-loss asymmetry view and the fourfold pattern because of the amount effect: as stated in Results 4 and 5 above, the risk attitude of the majority of our participants is essentially risk attraction for small 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. In particular, both views agree in predicting risk attraction for large probability losses (lower right cell of Tables 3 and 4), contrary to what the majority of our participants do. But our experimental results about the translation, switch and reflection effects (Results 6–10 above) concerning the direction of the changes in risk attraction frequencies are right midway between the extremes implied by the gain-loss asymmetry view and the fourfold: they are consistent with these two views in the areas where they mutually agree, whereas they split the difference when they mutually disagree.

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.[12] Thus, they *add up* to a major reflection effect down the main diagonal, in agreement with both the gain-loss view and the fourfold pattern.[13] But they 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 reflection effect of the fourfold pattern).

4.2 Single self, multiple selves, and expected utility

Consider the following instance of translation effect. At two different wealth levels ($1000 and $1100), the consumer displays risk aversion in the choice $\langle z, p\rangle = \langle 100, 0.8\rangle$, yet risk attraction in the choice $\langle -z, 1-p\rangle = \langle -100, 0.2\rangle$.[14] Consider lotteries where the prizes are the final wealth levels $\{x_1, x_2, x_3\} = \{1000, 1080, 1100\}$. A wealth of 1000 is then the lottery (1, 0, 0), represented as point C'' in the Marschak-Machina triangle of Figure 3, whereas a

[12] This is at variance with the data in Tversky and Kahneman (1992), where 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 (4th and 6th 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.

[13] They are also in agreement with the earlier experimental literature. 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). Hershey and Shoemaker (1980) critically examine the reflection effects submitted by Kahneman and Tversky (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.

[14] 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 $(w, w + z)$.

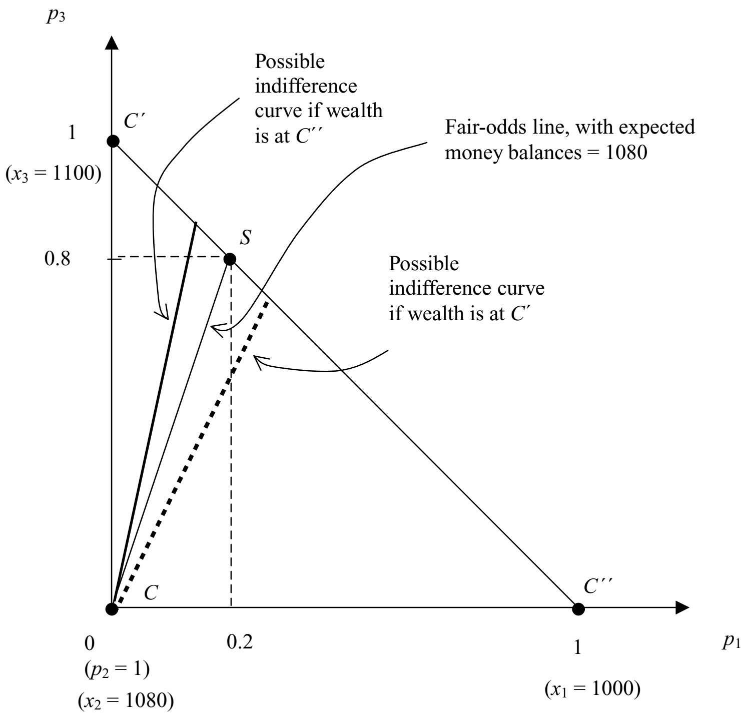


Fig. 3 Translation-dependent risk attitudes do not allow for single-self preferences

wealth of 1100 is represented as point C'.[15] Points C and S have an expected money value of 1080. When her wealth 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 C', she prefers the uncertain point S to the certain point C. Thus, no single set of indifference curves can rationalize her behavior. This is a more fundamental issue than whether the indifference curves are parallel straight lines (as required by expected utility theory) or not.[16]

We can then say that she has *multiple 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.

As is the case with other instances of multiplicity of selves documented in the behavioral literature (due, e.g., to myopia or addiction), this raises positive and normative issues. From the positive viewpoint, knowing the preferences of both her "poor" and her "wealthy" selves does not suffice to predict her choice in the following situation.[17] 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

[15] The Marschak-Machina triangle is a 2-dimensional Cartesian representation of the standard 2-simplex $\{(p_1, p_2, p_3) \in \mathbf{R}^3_+ : p_1 + p_2 + p_3 = 1\}$ where we read p_1 (the probability of x_1) as the abscissa, p_3 (the probability of x_2) as the ordinate, and p_2 (the probability of x_2) as $1 - p_1 - p_3$.

[16] See Machina (1982).

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

to her initial wealth, so that her wealthy self takes over, displaying risk attraction? 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?

We show in Bosch-Domènech and Silvestre (2006d) that, contrary to the translation effect, both the amount effect (defined as risk attraction for small amounts of money at stake and risk aversion for large amounts at a range of initial wealth levels) and the switch effect (defined as risk aversion for low probabilities of the bad outcome and risk attraction for high probabilities, also at a range of wealth levels) are compatible with single-self preferences, i.e., with a single, nonintersecting family of indifference curves. We emphasize that this 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, we show in our 2006d paper that 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 Bernoulli, 1738; Friedman and Savage, 1948), while they are all compatible with a wealth-dependent "expected utility" formulation, with a family of von Neumann-Morgenstern (vNM) utility functions, one for each level of initial wealth, defined on wealth changes, as in Markowitz (1952) and in Cox and Sadiraj (2001).

4.3 Large vs. small decisions: The critique of single-self expected utility theory based on the amount effect and the Rabin critique

Our robust finding of an amount effect contradicts single-self expected utility in a fundamental manner, because risk attraction for small risks in a range of wealth levels means that the von Neumann-Morgenstern utility function is locally convex there, implying risk attraction for all risks with final outcomes in that range.

Rabin's (2000) critique of expected utility theory is also based on a required consistency between behavior in the small and in the large, and hence it shows a formal parallelism with the implications of our amount effect.

(1) Rabin's critique is of the form:

(a) The avoidance of small, slightly favorable risks at an interval of wealth is plausible;[18]
It follows from (a) that, under single-self expected utility:
(b) Large, greatly favorable risks must be avoided.
But this is ridiculous.

(2) Our negation of single-self expected utility, based on the amount effect, runs as follows.

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

Rabin's critique and the implications of our amount effect share an underlying theme: *plausible* (in his case) or *observed* (in our case) behavior in the small implies, under single-self

[18] This is not uncontroversial: Palacios-Huerta, Serrano and 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.

expected utility, a behavior in the large that contradicts *common sense* (in his case) or *observation* (in ours).[19]

5 Conclusions

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 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 show the presence of both a translation effect and a switch effect, and interestingly they are of comparable strength.

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 difference between the gain-loss asymmetry view (which can be viewed as embodying only a translation effect) 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 observed behavior on preference theory. It turns out that, contrary to the switch effect (and also to the amount effect), the translation effect negates the existence of single-self preferences, and, accordingly, has deeper theoretical implications.

Finally, the prevalence of the amount effect (risk attraction for small amounts of money and risk aversion for large amounts) implies that, for a majority, what matters is the amount of money at risk and not the gain-loss dichotomy or the probabilities.

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[19] Note that, in the small, what we observe is risk attraction, whereas Rabin posits risk aversion. But what Rabin calls "small" involves figures of hypothetical money closer to our "large" figures of real money (we wish there was a way to translate hypothetical money into real money). In addition, his gambles are two-sided, combining gains and losses, which may favor risk aversion.

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