What is Loss Aversion?

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Abstract. A behavioral definition of loss aversion is proposed and its implications for original and cumulative prospect theory is analyzed. Original prospect theory is in agreement with the new loss aversion condition, and there utility is capturing all effects of loss aversion. In cumulative prospect theory loss aversion is captured by both, the weighting functions and the utility function. Further, some restrictions apply for the weighting functions involved in the latter model.

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Loss aversion is an important psychological concept which receives increasing attention in economic analysis. It has first been proposed by Kahneman and Tversky (1979) in the framework of prospect theory, and later it has also been defined for choice under certainty by Tversky and Kahneman (1991). The popularity of loss aversion is due to the fact that it can explain many phenomena which remain paradoxes in traditional choice theory. Well-known examples are the endowment effect (Thaler, 1980), the equity premium puzzle (Benartzi and Thaler, 1995), and the status quo bias (Samuelson and Zeckhauser, 1988). In recent years loss aversion has also frequently been applied in behavioral finance (cf. Barberis et al., 2001; Barberis and Huang, 2001; Berkelaar and Kouwenberg, 2000a,b; Roger, 2003; and Gomes, 2003). A further important aspect of loss aversion is the fact that it can resolve the criticism on expected utility put forward by Rabin (2000, p. 1288) and Rabin and Thaler (2001) who showed that reasonable degrees of risk aversion for small and moderate stakes imply unreasonable high degrees of risk aversion for large stakes.

Kahneman and Tversky's (1979, p. 279) view of loss aversion is as follows: An individual is loss averse if she or he dislikes symmetric 50-50 bets and, moreover, the aversiveness to such bets increases with the absolute size of the stakes. This clearly is a behavioral concept defined entirely in terms of preferences. As such, the concept is model independent. Kahneman and Tversky (1979) showed that, in the framework of prospect theory, this definition of loss aversion is equivalent to a utility function which is steeper for losses than for gains. As probability weighting played no role in the derivation of this result, it appears that the effect of loss aversion is captured solely by the utility function. It is, therefore, not surprising that nearly all work on loss aversion employed utility as the carrier of loss aversion. For instance, Tversky and Kahneman (1992, page 303) assume that utility is steeper for losses than for gains. Wakker and Tversky (1993) propose a preference condition based on a cardinal utility index independent of probability weighting. The latter condition has empirically been confirmed in a recent test in Schmidt and Traub (2002). In a review of non-expected utility theories Starmer (2000) highlights the descriptive advantages of rank and sign dependent models, and summarizes loss aversion as utility being steeper for losses than for gains. Benartzi and Thaler (1995) view loss aversion as a property of utility exhibited at the status quo. This view is also adopted in Köbberling and Wakker (2003), where an index of loss aversion is defined as the ratio of the left and right derivative of utility at the status quo. All the previous conditions employ a comparison of utility differences between gains and losses of equal absolute size. In contrast Neilson (2002) suggests stronger conditions by dropping this symmetry requirement.

It can be concluded that, the way loss aversion is currently understood, it is essential to identify utility independent of probability weights prior to any analysis of loss attitudes. Moreover, given that most definitions of loss aversion are not formulated in terms of preferences, it follows that loss aversion is no longer model independent. Since most studies mentioned above do not use original prospect theory but the modern cumulative prospect theory instead, their notion of loss aversion does no longer agree with the behavioral concept proposed by Kahneman and Tversky (1979).

The goal of this note is to analyze loss aversion in more detail, first by showing that the current definitions of loss aversion have different behavioral implications for different decision models, and second by providing model independent definitions of loss aversion. By taking the view that loss aversion is solely an aspect of gain/loss comparisons, and therefore independent of the ranking of outcomes and the likelihood of occurrence, we propose a preference condition which empirically can easily be verified. We then show that, for original prospect theory, this condition is equivalent to the condition proposed by Kahneman and Tversky (1979). For original prospect theory probability weighting has no influence on loss attitudes, and consequently utility being steeper for losses than for gains is equivalent to loss aversion as defined by the new condition. However, when the modern version of prospect theory of Tversky and Kahneman (1992) is assumed, the new condition implies some surprising restrictions for the representing functional. Now utility being steeper for losses than for gains is neither necessary nor sufficient for loss averse behavior. Rather it is the case that the ratio between the utility difference for losses and the utility difference of corresponding gains must exceed the ratio between the gain decision weight and the loss decision weight generated by any common probability. The special case of rank-dependent utility preferences is also discussed, and it is shown that when removing the status quo effects from our behavioral definition, loss aversion comes down to the well-known aversion to mean preserving spreads. Before we provide details of the analysis in Section 2, we introduce the formal framework in the next section.

1 Notation and Definitions

A *lottery* is a finite probability distribution over the set of monetary outcomes (here identified with the set of real numbers, $\mathbb{R}$). It is represented by $P := (p_1, x_1; \ldots; p_n, x_n)$ meaning that probability p_j is assigned to outcome x_j, for $j = 1, \ldots, n$. The probabilities p_j are nonnegative and sum to one. With this notation we implicitly assume that outcomes are ranked in decreasing order, i.e., $x_1 \geqslant \cdots \geqslant x_k \geqslant 0 > x_{k+1} \geqslant \cdots \geqslant x_n$ for some $0 \leqslant k \leqslant n$. Positive outcomes are called *gains* and negative outcomes are *losses*.

Expected Utility (EU) holds if an individual evaluates lotteries according to:

$$EU(p_1, x_1; \ldots; p_n, x_n) = \sum_{i=1}^{n} p_i U(x_i), \tag{1}$$

where U is the utility function. In this paper U is assumed strictly increasing and continuous with $U(0) = 0$. In contrast to the traditional interpretation we assume that U is defined on gains and losses and not on final wealth positions. This allows us to analyze loss attitudes in the EU model.

In the original version of *prospect theory* (OPT) there exists a *weighting function* w (i.e., $w : [0,1] \to [0,1]$, strictly increasing with $w(0) = 0$ and $w(1) = 1$), such that lotteries are evaluated by

$$OPT(p_1, x_1; \ldots; p_n, x_n) = \sum_{i=1}^{n} w(p_i)U(x_i). \tag{2}$$

This formula applies only to lotteries which involve both, gain and loss outcomes. Actually, Kahneman and Tversky (1979) proposed OPT only for lotteries with three outcomes of which one equals zero. Here we use the extension to general lotteries (for instance as used by Fennema and Wakker, 1997). Recall that under OPT the weights involved in the evaluation of a lottery are direct transformations of the probabilities, an aspect that was criticized because it leads to violations of stochastic dominance (e.g., Fishburn, 1978).

The modern version of prospect theory, called *cumulative prospect theory* (CPT), differs from OPT by involving two weighting functions w^+, w^-, and moreover, the weights used in the evaluation of lotteries are differences in decumulative, respectively, cumulative probabilities. All lotteries are evaluated by

$$\begin{aligned} CPT(p_1, x_1; \ldots; p_n, x_n) &= \sum_{i=1}^{k} [w^+(p_1 + \cdots + p_i) - w^+(p_1 + \cdots + p_{i-1})]U(x_i) \quad (3) \\ &+ \sum_{i=k+1}^{n} [w^-(p_i + \cdots + p_n) - w^-(p_{i+1} + \cdots + p_n)]U(x_i). \end{aligned}$$

For the special case that w^+ equals the dual of w^- (i.e., $w^+(p) = 1 - w^-(1 - p)$ for $0 \leqslant p \leqslant 1$), the cumulative prospect theory functional comes down to the *rank-dependent utility* (RDU) functional:

$$RDU(p_1, x_1; \ldots; p_n, x_n) = \sum_{i=1}^{n} [w(p_1 + \cdots + p_i) - w(p_1 + \cdots + p_{i-1})]U(x_i). \tag{4}$$

Note, however, that, similar to EU, general RDU does not require utility to be defined over changes in wealth.

2 Analysis

We start the analysis in this section by contrasting the development of the concept of loss aversion with the development and understanding of the concept of risk aversion. Most of the empirically observed risk aversion is driven by loss aversion, and because loss attitude seems to be an intrinsic component of risk attitudes it is expected that the development of these concepts is analogous. According to Rothschild and Stiglitz (1970), strong risk aversion holds if and only if an individual always dislikes mean-preserving spreads in risk. This is a behavioral concept of risk aversion since it is defined in terms of preferences. It is well-known that this concept of risk aversion is equivalent to the concavity of the utility function in expected utility theory. Under that theory weak risk aversion (i.e., preference for expected value) is also equivalent to a concave utility. Nevertheless, the subsequent literature kept on defining risk aversion in terms of the behavioral concept (e.g., aversion to mean-preserving spreads, weak risk aversion, aversion to monotone mean-preserving spreads (Quiggin, 1991), etc.) and not in terms of properties of the functional representation (e.g., concavity of the utility function).

It is important to make the distinction between choice behavior and properties of utility because in alternative theories the implications for utility may vary. For example, in rank-dependent utility a concave utility function is consistent with strong risk averse behavior (see Chew, Karni, and Safra, 1987), however, weak risk aversion can hold if utility is convex (Chateauneuf and Cohen, 1994). Recently, Chateauneuf, Cohen and Meilijson (2004a) have demonstrated that, under rank-dependent utility, aversion to monotone mean preserving spreads holds if and only if the index of pessimism, which depends solely on the weighting function, exceeds the degree of non-concavity of the utility function, called index of greediness. Hence, nonconcave utility may also coexist with aversion to monotone mean preserving spreads (see also Chateauneuf, Cohen and Meilijson, 2004b, and Abouda and Chateauneuf, 2002). Assuming CPT, Schmidt and Zank (2002), show that strong risk aversion can hold if utility is concave for losses, concave for gains, but convex at the status quo. Therefore, identifying risk aversion with a concave utility means that expected utility is implicitly assumed.

A striking similarity holds for loss aversion: by identifying loss aversion with a utility that is steeper for losses than for gains, one implicitly assumes original prospect theory and not the modern version of cumulative prospect theory (see Propositions 2 and 4 below). To clarify on this point let us now turn to Kahneman and Tversky's (1979) interpretation of loss aversion: individuals dislike symmetric 50-50 bets, and additionally, such bets with higher amounts of prizes are dispreferred. More formally, we state the following definition of loss aversion.

Definition 1 *Loss aversion holds if* $(0.5, x; 0.5, -x) \prec (0.5, y; 0.5, -y)$ *for all* $x > y \geqslant 0$.

As noted above, this is clearly a behavioral concept. It turns out that in the framework of prospect theory or expected utility theory (that is OPT with a linear weighting function for probabilities) loss aversion is equivalent to the fact that the utility function is steeper for losses than for gains, such that we may have a kink at the status quo. This result follows immediately from substitution of the corresponding functional form, and is summarized in Proposition 2.

Proposition 2 *In EU and OPT loss aversion is satisfied if and only if for all* $x > y \geqslant 0$ *it holds that* $U(x) - U(y) < U(-y) - U(-x)$. □

Note that in the definition of loss aversion the restriction to 50-50 symmetric bets is rather arbitrary. Assuming OPT, one can equivalently define loss aversion as aversion to symmetric bets, where the aversion becomes more pronounced if the size of the stakes increases. That is, $(p, x; 1 - 2p, 0; p, -x) \prec (p, y; 1 - 2p, 0; p, -y)$ for all $x > y \geqslant 0$ and any $p \in (0, 1/2]$. The middle payoff in these lotteries does not need to be equal to the status quo, and could be any common outcome. This latter condition has been confirmed in a recent empirical study by Brooks and Zank (2004). The reason we use this simple variation of the definition is to use lotteries that have at most two nonzero outcomes, similar to the framework of OPT in Kahneman and Tversky (1979). Obviously, the size and therefore the rank of the common outcome in the previous preference has no effect on the shape of the utility function. When assuming this latter condition in Proposition 2, the same implications result for utility.

Let us now assume that loss attitudes are independent of the rank of outcomes. Then the following definition of loss aversion is acceptable.

Definition 3 *Strong loss aversion holds if for all* $x > y \geqslant 0$ *and* $0 < \alpha \leqslant 0.5$, *we have*

$$\begin{aligned} & (p_1, z_1; ...; p_{i-1}, z_{i-1}; \alpha, x; p_{i+1}, z_{i+1}; ...; p_{j-1}, z_{j-1}; \alpha, -x; p_{j+1}, z_{j+1}; ...; p_n, z_n) \\ \prec \quad & (p_1, z_1; ...; p_{i-1}, z_{i-1}; \alpha, y; p_{i+1}, z_{i+1}; ...; p_{j-1}, z_{j-1}; \alpha, -y; p_{j+1}, z_{j+1}; ...; p_n, z_n). \end{aligned}$$

The condition says that all that matters for the preference in Definition 3 is that the absolute size of the payoffs with likelihood α are smaller in the second lottery. This condition demands that among two lotteries, for which one can win or lose a given amount with equal probability, that lottery will be preferred for which this amount is smaller. The preference is independent of all other common outcomes, however, with the notation used in this paper, the condition presupposes that the transition from x to y in the second lottery does not change the rank-ordering of outcomes. Note that loss aversion follows from strong loss aversion by requiring $\alpha = 1/2$. If loss aversion is accepted then, intuitively, we do not see any obvious reason for objecting against strong loss aversion. The motivation for strong loss aversion stems from the common belief that loss aversion is reflected only through the utility function. Taking that view, means that the common rank of the outcomes x, y, respectively, $-x, -y$, in the lotteries above should not matter, neither should the magnitude of the common probability α matter.

A closer look at the lotteries in Definition 3 reveals its relationship with aversion to mean preserving spreads. If we define X and Y as

$$\begin{aligned} X &= (p_1, z_1; ...; p_{i-1}, z_{i-1}; \alpha, x; p_{i+1}, z_{i+1}; ...; p_{j-1}, z_{j-1}; \alpha, -x; p_{j+1}, z_{j+1}; ...; p_n, z_n), \\ Y &= (p_1, z_1; ...; p_{i-1}, z_{i-1}; \alpha, y; p_{i+1}, z_{i+1}; ...; p_{j-1}, z_{j-1}; \alpha, -y; p_{j+1}, z_{j+1}; ...; p_n, z_n), \end{aligned}$$

and, by keeping the probability distribution fixed, defining the (not rank-ordered) lottery Z as

$$Z = (p_1, 0; ...; p_{i-1}, 0; \alpha, x - y; p_{i+1}, 0; ...; p_{j-1}, 0; \alpha, -x + y; p_{j+1}, 0; ...; p_n, 0),$$

we can write $X = Y \oplus Z$, where the symbol $\oplus$ means that outcomes are added while keeping the probability distribution fixed. Hence, X results from Y by subtracting $(x-y)$ from $-y$ and adding this amount to y. Obviously, Z has zero expected value. Note, that not all such Z are permitted under strong loss aversion, as the nonzero outcomes in Z need to be added to corresponding outcomes in Y that are of the same sign. Also, the symmetry in the magnitude of the outcomes (i.e., y versus $-y$ in Y and x versus $-x$ in X) needs to be maintained after adding outcomes of Z to those of Y. Strong loss aversion, therefore, does not have any implications for the behavior on the gain domain or the behavior on the loss domain. Permitting the addition of outcomes for general lotteries Z, where the only restriction is that the expected value of Z is zero, which comes down to removing the status quo effects from the definition of strong loss aversion, gives a stronger condition, namely aversion to mean preserving spreads. That strong loss aversion is much weaker than aversion to mean preserving spreads can be inferred from the fact that even under RDU it implies concavity only locally at 0 (see the remarks following Proposition 7 below). Clearly, removing the status quo effects from the definition of strong loss aversion implies that utility under RDU is concave everywhere, in agreement with the results of Chew, Karni and Safra (1987) and Schmidt and Zank (2002).

The next proposition shows that, under OPT (and EU) strong loss aversion has the same implications as loss aversion. Its proof follows immediate from substituting the corresponding functional forms and cancelling the common terms.

PROPOSITION 4 *In EU and OPT strong loss aversion is satisfied if and only if for all $x > y \geqslant 0$ it holds that $U(x) - U(y) < U(-y) - U(-x)$.* □

As pointed out by Starmer (2000) the rank and sign dependent model of CPT combines mathematical tractability and descriptive validity to accommodate most stylized facts from experimental studies. Rank-ordering of outcomes did not play any role in OPT, and it is not surprising that it does not play any role in the result of Propositions 2 and 4. It is probable that by retaining the view that loss aversion is equivalent to a utility that is steeper for losses than for gains, the important development initiated by Quiggin (1982) regarding the ranking of outcomes for the derivation of decision weights has been neglected in the analysis of loss attitudes. This is in contrast to the concept of risk aversion because the subsequent literature did not retain the behavioral definition (aversion to symmetric 50-50 bets) of loss aversion but uses the definition in terms of properties of the utility function. In fact, all recent formal studies concerned with loss aversion we are aware of define loss aversion in terms of the shape of the utility function. In our view this is, however, problematic since most of these papers do not rely on EU or OPT but on CPT.

In the latter model a steeper utility for gains than for losses has rather different behavioral implications than in OPT or EU. To highlight this fact the result of the following proposition, combined with specific CPT preferences shows that a utility function that is steeper for losses than for gains can accommodate *loss seeking* (i.e., for all $x > y \geqslant 0$ we have $(0.5, x; 0.5, -x) \succ (0.5, y; 0.5, -y)$).

Proposition 5 *In CPT loss aversion is satisfied if and only if for all $x > y \geqslant 0$ it holds that*

$$\frac{U(-y) - U(-x)}{U(x) - U(y)} > \frac{w^+(0.5)}{w^-(0.5)}. \tag{5}$$

□

Proposition 5 shows that under CPT utility being steeper for losses than for gains is neither necessary nor sufficient for loss aversion. By considering the parametric weighting functions fitted by Tversky and Kahneman (1992), we get $w^+(0.5)/w^-(0.5) = 0.927$, that is, we may have loss aversion even if utility for gains is steeper than utility for losses. Recent non-parametric estimations of weighting functions for CPT indicate that w^- is above w^+ away from the extreme probabilities (e.g., Abdellaoui, 2000; Abdellaoui, Vossmann, and Weber, 2003). This suggests that loss aversion may be dictated by the shape of the weighting functions rather than that of utility. In the case of general CPT preferences where $w^+(0.5)/w^-(0.5) > 1$, we may therefore observe loss seeking behavior if utility is such that the inequality in Proposition 5 is reversed:

Corollary 6 *In CPT loss seeking can hold even if we have* $U(x)-U(y) < U(-y)-U(-x)$ *for all* $x > y \geqslant 0$. □

Note that Corollary 6 also holds if rank-dependent utility is assumed. Thus, if loss aversion is defined in terms of the slope of the utility function, it has different behavioral implications in different choice theories. A further evidence of this fact is the work of Wakker and Tversky (1993) who develop a behavioral condition which implies a steeper utility for losses than for gains in the framework of CPT. Although this condition differs from the behavioral condition of Kahneman and Tversky (1979), it has nevertheless been termed loss aversion.

Loss aversion captured solely in the curvature of utility cannot be a useful concept for decision analysis if it has different behavioral implications in different choice theories. Therefore, concerning the definition of loss aversion the literature should agree on a behavioral concept defined in terms of preferences. Clearly, the choice of common probability $p = 0.5$ in the behavioral condition of Kahneman and Tversky is motivated by a common intuition regarding loss aversion, and that any behavioral definition of loss aversion will need to allow for more flexibility in the choice of such probabilities. Strong loss aversion does exactly that, and as indicated in Proposition 4, for OPT the implications for utility are identical as those in Kahneman and Tversky (1979) (see also Proposition 2 above).

Let us now analyze the implication of strong loss aversion for CPT preferences. The following result can be derived from substitution of CPT for the preference in Definition 3.

Proposition 7 *Under CPT strong loss aversion is satisfied if and only if for all*

$x > y \geqslant 0$, all $0 < \alpha \leqslant 0.5$, and all $\gamma, \delta \geqslant 0$ with $1 - 2\alpha \geqslant \gamma + \delta$ it holds that

$$\frac{U(-y) - U(-x)}{U(x) - U(y)} > \frac{w^+(\gamma + \alpha) - w^+(\gamma)}{w^-(\delta + \alpha) - w^-(\delta)}. \tag{6}$$

□

By keeping x and y fixed, inequality (6), rewritten as

$$\frac{[w^-(\delta + \alpha) - w^-(\delta)][U(-y) - U(-x)]}{[w^+(\gamma + \alpha) - w^+(\gamma)][U(x) - U(y)]} > 1,$$

clarifies on the consequences of strong loss aversion: the impact of increasing a gain of given size with a given probability by a fixed amount is less than the impact of decreasing a loss of the same size and with the same probability by the same amount. Note, that here impact means the combined effect of decision weight and utility difference. This result supports the view that under CPT loss aversion is captured by both, probability weighting and utility.

The condition in Proposition 7 has strong implications for the shapes of the weighting functions. First, if the gain weighting function is too steep near impossibility (as in the usually proposed inverse S-shape) then the right hand side of inequality (6) can become unreasonably high. For example, in the parametric forms proposed by Lattimore, Baker, and Witte (1992), Tversky and Kahneman (1992), and Prelec (1998), this ratio converges to infinity if $\gamma + \alpha$ converges to 0, as the right derivative of w^+ at impossibility becomes infinity. Therefore, in order to be compatible with strong loss aversion, the weighting function for gains cannot be "too steep" over a given range while, using similar arguments, the weighting function for losses cannot be "too flat."

A second implication of strong loss aversion is that the weighting function w^+ is continuous at impossibility if there exists some $0 < \delta < 1$ such that $w^{-\prime}(\delta)$ is a positive constant.[1] Assuming that this were not the case, let $(q_j)_{j=1}^{\infty}$ be a decreasing sequence of probabilities converging to 0, such that $w^+(q_j)$ is converging to $q^* > 0$. Then, $[w^+(q_j) - w^+(0)]/q_j \to \infty$ for $j \to \infty$, and $[w^-(\delta + q_j) - w^-(\delta)]/q_j \to w^{-\prime}(\delta)$. This implies that the ratio between the decision weights in inequality (6) becomes infinity, contradicting the assumption of boundedness for the utility function in CPT. Consequently, w^+ must be continuous at 0.

Given these implications one immediate question that arises is regarding an upper bound for the ratio of decision weights in inequality (6). For general weighting functions this remains an open question, however, we can give a partial answer to this question, for the special case of continuous and differentiable inverse S-shaped weighting functions, which initially are concave and then convex. In that case the right and left derivative of the weighting functions are well defined. Recall that, under the assumptions of CPT, the right derivative of w^+ at 0 and the left derivative at 1 must be finite, otherwise inequality (6) is violated. Similarly, w^- cannot be too flat (i.e., $w^{-\prime}(\delta) = 0$ for some $0 < \delta < 1$). For this case of weighting functions the supremum of the right hand side of (6) can take two forms, depending on whether w^+ is steepest at 0 (and then w^- is flattest at its inflection point) or w^+ is steeper for larger probabilities relative to w^- for probabilities below its inflection point. So, either the supremum is equal to the ratio $w^{+\prime}(0_+)/w^{-\prime}(p^*)$, where p^* denotes the inflection point of w^-, or it is equal to:

$$\sup_{0 \leqslant p \leqslant 1} \frac{w^{+\prime}(p)}{w^{-\prime}(1-p)}. \tag{7}$$

If these ratios are larger or equal 1 (for example if both weighting functions intersect the 45-degree line from above) then we can retain the statement that utility is steeper for losses than for gains.

A further interesting special case is the following one. Assume that the weighting functions are continuous on $(0, 1)$ and that they intersect in the open interval $(0, 1)$. Then, there exist some probability $p \in (0, 1)$ where the weighting function for gains is steeper than that for losses, implying that utility must be steeper for losses than for gains. In fact if both weighting functions are continuous on $[0, 1]$, then w^+ must be steeper than w^- at some probability p. For noncontinuous weighting functions this must not hold, and utility can be flatter for losses than for gains (e.g., if utility is linear for gains and linear for losses, and the weighting functions are linear and discontinuous at 1, then one can choose utility steeper for gains than for losses and simultaneously w^- sufficiently steeper than w^+ such that inequality (6) above holds). This shows that under reasonable assumptions for the weighting functions utility is required to be steeper for losses than for gains. In particular this shows that under RDU with a continuous weighting function strong loss aversion implies that utility is concave at 0. Whether the degree of loss aversion measured from utility (i.e., the left hand side of inequality (6)) is driven by the corresponding degree measured from the weighting functions (that is the right hand side of inequality (6)) seems to be an empirical question. Strong loss aversion does not imply that the infimum of ratios of symmetric utility differences is equal to the supremum of the ratios of decision weights.

This paper has highlighted the need for a definition of loss aversion in terms of preference conditions, which represents model independent choice behavior. We have introduced the concept of strong loss aversion, and stressed some of its implication for the weighting functions in CPT. We have demonstrated that probability perception plays a key role in the analysis of loss attitudes alongside utility. Whether strong loss aversion is the most appropriate definition of loss aversion can be debated, and empirical tests of the condition can help clarifying this point. We hope that these results generate further theoretical analyses on the important issue of loss attitudes, leading to a satisfactory answer to the question of what is an appropriate model free definition of loss aversion.

Notes:

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1. Note that the weighting functions considered here are strictly increasing on $[0, 1]$, and therefore the derivatives exist almost everywhere. To derive continuity of w^+ at 0 we need to ensure that the derivative of w^- is not everywhere equal to 0.

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