Prospect Theory

Prospect theory was developed as a descriptive model of how humans make decisions, based data collected in questionnaires (Kahneman and Tversky 1979; Kahneman 2011). A simplistic way of viewing prospect theory is as an extension of expected utility theory. In the same way as utility theory adds the concept of nonlinear utility to expected cost theory, prospect theory adds moving parts to utility theory. However, prospect theory has fundamental differences with utility theory, and perhaps a better perspective is that prospect theory is a psychology-based description of how actual decisions are made, rather than a foundation for rational engineering decisions. Regardless, important lessons about loss aversion can be learned from applying prospect theory in an engineering context.

The key concepts in prospect theory are a reference point and aversion to losses from that reference point. For most decision-makers, the reference point changes from decision to decision. For example, experiencing a success shifts the reference point for the next decision. Prospect theory postulates that decisions are made based on changes in wealth relative to the reference point. While losses and gains in utility theory are measured by going from point to point on the utility curve, prospect theory allows different utilities to be assigned to a loss and a win, even when the loss and the win are of equal nominal value. In other words, prospect theory focuses on changes in utility rather than particular states of utility. Figure 1 epitomizes prospect theory and shows how the same amount lost generates a stronger negative experience than the positive experience of winning the same amount.

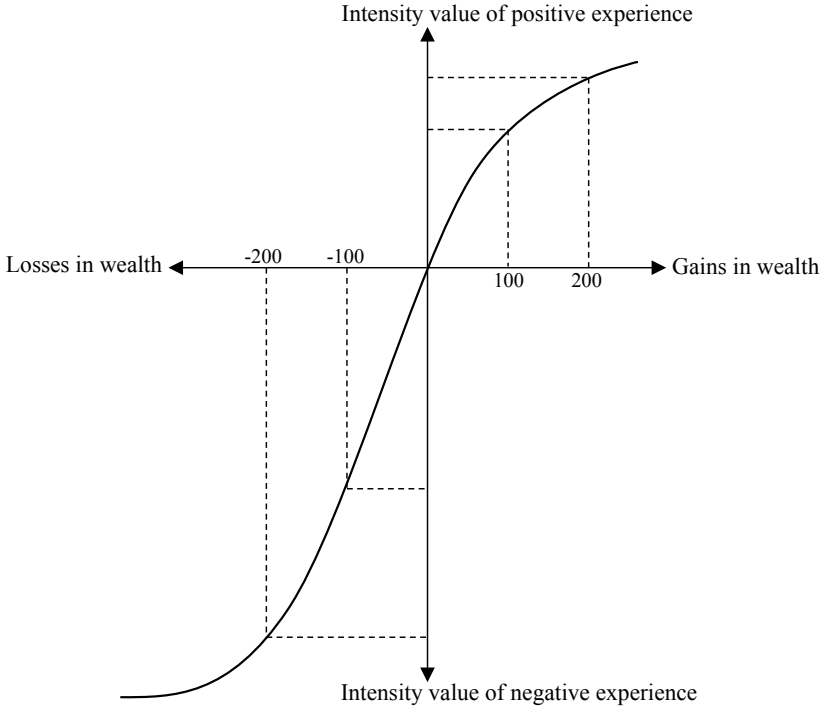

Figure 1: Value function in prospect theory (Kahneman 2011).

In utility theory, the expected utility is

$$E[u] = p_1 \cdot u_1 + p_2 \cdot u_2 + \cdots + p_n \cdot u_n \quad (1)$$

where p_i are probabilities, u_i are outcome utilities, and $p_1+p_2+\ldots+p_n=1$. In prospect theory, the probabilities are replaced by decision weights $\pi(p)$ and the utilities are replaced by values $v(u)$ defined relative to a reference point (Kahneman and Tversky 1979). Figure 1 shows a schematic example of a value function and Figure 2 shows a schematic example of a weighing function. The decision weights, π, need not add to unity, and the prospect value

$$V = \pi(p_1) \cdot v(u_1) + \pi(p_2) \cdot v(u_2) + \cdots + \pi(p_n) \cdot v(u_n) \quad (2)$$

can be interpreted as a relaxation of the expectation principle of utility theory.

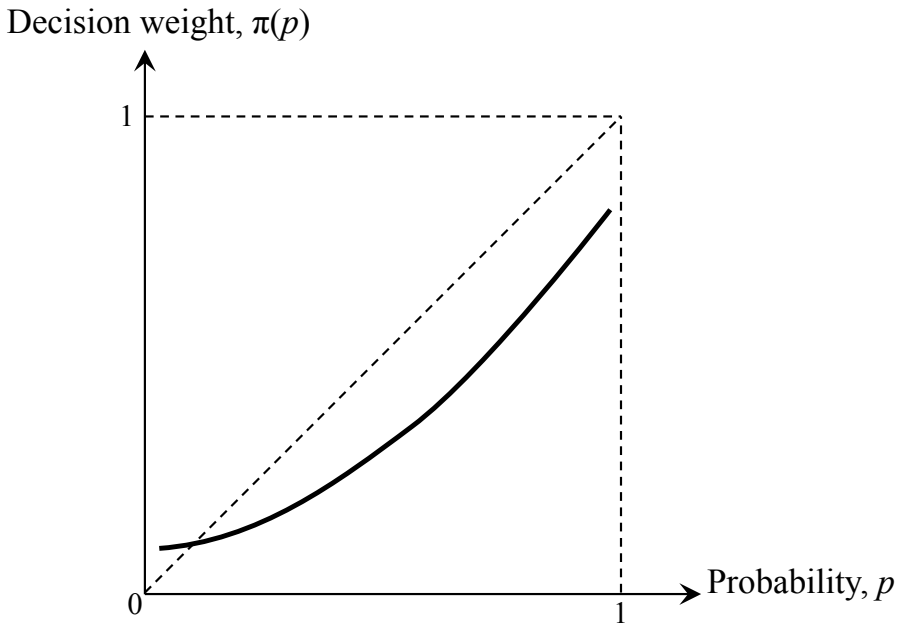

Figure 2: Weighting function (solid line) in prospect theory (Kahneman and Tversky 1979).

An extension of the theory outlined above is called cumulative prospect theory (Tversky and Kahneman 1992). This decision-making model has been employed to seismic risk problems (Goda and Hong 2008) and to general infrastructure exposed to low-probability high-consequence events (Cha and Ellingwood 2012).

References

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