En Route Reference Point Updating: Estimating Travel Decisions in the Presence of Unexpected Delays

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Abstract

The defining feature separating (cumulative) prospect theory from expected utility theory is that potential outcomes are measured relative to a reference point as opposed to final asset allocation. Determining the reference point, therefore, is vital to correct analysis. While many theories and assumptions have been proposed concerning reference point updating *between* repeated choices, few papers have looked at reference point updating *within* periods. This paper seeks to find if and when drivers change their reference point in a transportation setting when faced with an unexpected delay *en route*. A novel, yet conservative, approach is proposed to estimate reference point adaption amid data uncertainty. Using this new estimation technique, it is found that drivers are more likely to change their reference point if the unexpected delay occurs near the endpoints of travel.

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Keywords: cumulative prospect theory; transportation; freight; reference point; route choice

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1 Introduction

The seminal paper introducing prospect theory[1] (PT) by Kahneman and Tversky (1979) has been cited "tens of thousands of times" (Barberis, 2013). However, as noted by Barberis (2013), PT has yet to gain universal traction in economics, even after 30 years. Part of the reason for the relative intractability of PT in applied settings is the difficulty in determining the location of the reference point (Barberis, 2013; De Moraes Ramos et al., 2013), i.e., the point that separates desirable outcomes (gains) from those outcomes one hopes to avoid (losses). Kahneman (1992) illustrates the importance of the reference point:

> Consider a man who was given good reason to expect a $5000 raise, but eventually received only $3000. What is the psychological value of that event, as the individual experiences it? Obviously, the raise can be coded either as a gain or as a loss, depending on whether it is compared to zero or to $5000.

Even in this simple example, the location of the reference point determines whether receiving the raise is considered a pleasant or unpleasant experience. Hence, locating the reference point is critical to correct analysis.

While the reference point may be assumed based on the context of the setting or experiment, there is still the added difficulty of determining how the reference point adapts to realized outcomes. This area has been the focus of numerous papers (Arkes et al., 2008; Baucells et al., 2011; Schmidt, 2003; Shi et al., 2015). Applying PT to route choice analysis poses a unique challenge because the outcome is not fully realized until arrival at the destination. As the journey between the origin and destination progresses, the likely position on the pdf is revealed to the driver. The new information shapes expectations, but does this information affect the reference point? That is, does information obtained en route influence drivers to update the reference point employed when they originally chose their preferred route? This paper seeks to answer this question and shed further light on reference point adaption. Using a recent dataset of freight truck drivers in the Pacific Northwest, I calculate reference point adaption given an unexpected delay on the preferred route using a unique, yet conservative approach. Given the vast heterogeneity of driver's PT parameter estimates[2], I employ over 1600 parameter combinations to determine reference point adaption. Drivers tend to update their reference point if the delay occurs near the endpoints of travel.

The rest of the paper is as follows: Section 2 reviews cumulative prospect theory. Section 3 surveys the relevant literature. Section 4 develops the estimation technique, as well as describes the data. Section 5 presents and discuses the results. Section 6 concludes.

2 Cumulative Prospect Theory

There are two fundamental differences between PT (and by extension CPT) and expected utility theory. First, potential outcomes are measured relative to a certain reference point. While expected utility theory is only concerned with final outcomes, the utility derived by PT and CPT is tied to the reference point. Secondly, probability weights are replaced by decision weights, where the latter are not additive. Decision weights are essentially subjectively

[1] Prospect Theory (PT) and Cumulative Prospect Theory (CPT) are used somewhat interchangeably throughout the paper.

[2] For example, see Zhou et al. (2014).

perceived probability weights, "but they do not obey the probability axioms" (Kahneman and Tversky, 1979).

Furthermore, the attitude toward risk for gains and losses relative to the reference point are different. The value function is

$$v(x) = \begin{cases} (x - x_0)^{\alpha}, & \text{if } x \geq x_0 \\ -\lambda (x_0 - x)^{\beta}, & x < x_0 \end{cases} \tag{1}$$

where x is the potential outcome and x_0 is the reference point[3]. The parameters α and β measure the degree of diminishing sensitivity to gains and losses, respectively, while λ denotes the degree of loss aversion. As summarized by Kahneman and Tversky (1979), "the value function is (i) defined on deviations from the reference point; (ii) generally concave for gains and commonly convex for losses; (iii) and steeper for losses than for gains" (see Figure 1).

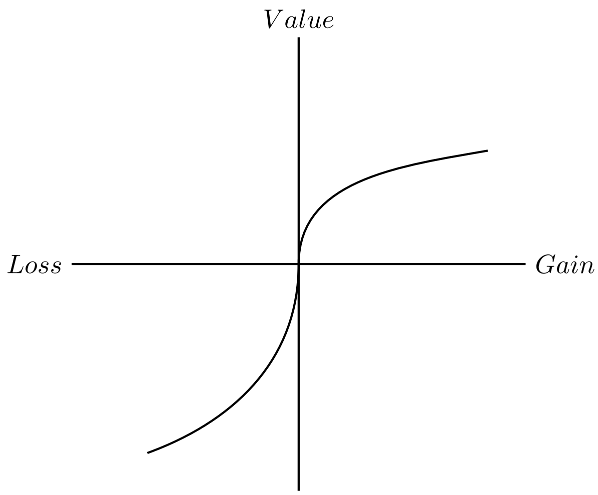

Figure 1. Value function

The decision weights are

$$w^{+}(p) = \frac{p^{\gamma}}{\left[p^{\gamma} + (1-p)^{\gamma}\right]^{1/\gamma}}, \qquad w^{-}(p) = \frac{p^{\delta}}{\left[p^{\delta} + (1-p)^{\delta}\right]^{1/\delta}} \tag{2}$$

where the parameters γ and δ capture the subjective degree of distortion of the true objective probability p. Since both γ and δ are assumed to be less than 1 (by estimation), the weighting functions overweight small probabilities and underweight large probabilities (see Figure 2).

[3] This standard characterization of the value function assumes that larger values of x lead to better outcomes. However, for this paper, larger values of x (i.e. route duration) lead to worse outcomes. Hence, the value function employed is denoted as follows:

$$v(x) = \begin{cases} (x_0 - x)^{\alpha}, & \text{if } x \leq x_0 \\ -\lambda (x - x_0)^{\beta}, & x > x_0 \end{cases}$$

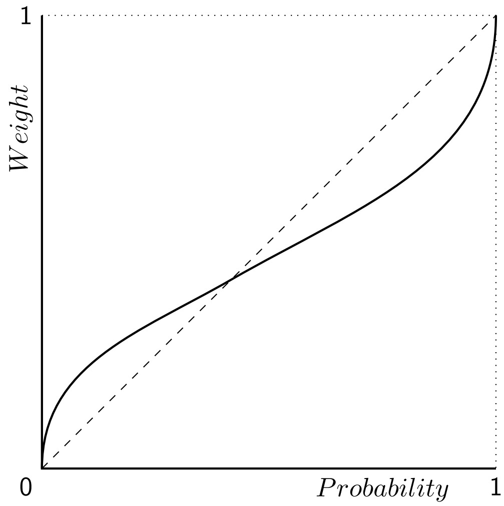

Figure 2. Probability weighting function

Tversky and Kahneman (1992) further refined PT and developed a more robust theory that addresses some of the pitfalls of PT: cumulative prospect theory (CPT). The hallmark feature separating PT from CPT is that the latter employs cumulative weights as opposed to separable decision weights. CPT defines a prospect as

$$U\left(prospect\right)=\sum_{i=0}^{n} v\left(x_i\right)\pi^{+}\left(p_i\right)+\sum_{i=-m}^{0} v\left(x_i\right)\pi^{-}\left(p_i\right) \tag{3}$$

where n outcomes are characterized as gains and m outcomes are characterized as losses. The cumulative decision weights are defined as follows:

$$\pi^{+}\left(p_n\right)=w^{+}\left(p_n\right), \qquad \pi^{-}\left(p_{-m}\right)=w^{-}\left(p_{-m}\right) \tag{4}$$

$$\pi^{+}\left(p_i\right)=w^{+}\left(p_i+\cdots+p_n\right)-w^{+}\left(p_{i+1}+\cdots+p_n\right) \qquad 0\leq i<n \tag{5}$$

$$\pi^{-}\left(p_i\right)=w^{-}\left(p_{-m}+\cdots+p_{-i}\right)-w^{-}\left(p_{-m}+\cdots+p_{-i-1}\right) \qquad -m<i\leq 0 \tag{6}$$

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