Available online at www.sciencedirect.com

ScienceDirect

Journal of Economic Theory 178 (2018) 360–397

JOURNAL OF Economic Theory

www.elsevier.com/locate/jet

# Probability weighting, stop-loss and the disposition effect

Vicky Henderson [a,*], David Hobson [a], Alex S.L. Tse [b,1]

[a] *University of Warwick, Coventry, CV4 7AL, UK*
[b] *Judge Business School, University of Cambridge, CB2 1AG, UK*

Received 8 January 2018; final version received 2 October 2018; accepted 7 October 2018
Available online 10 October 2018

**Abstract**

In this paper we study a continuous-time, optimal stopping model of an asset sale with prospect theory preferences under pre-commitment. We show for a wide range of value and probability weighting functions, including those of Tversky and Kahneman (1992), that the optimal prospect takes the form of a stop-loss threshold and a distribution over gains. It is skewed with a long right tail. This is consistent with both the widespread use of stop-loss strategies in financial markets, and recent experimental evidence. Moreover, our model with probability weighting in tandem with the $S$-shaped value function makes predictions for the disposition effect which match in magnitude that calculated by Odean (1998).


*JEL classification:* D81; G19; G39

*Keywords:* Prospect theory; Behavioral economics; Disposition effect; Investor trading behavior; Probability weighting

## 1. Introduction

There is a growing body of work which shows that individual investors do not always act as maximizers of expected utility. One of the most prominent alternative explanations of individual

* Corresponding author.
*E-mail addresses:* vicky.henderson@warwick.ac.uk (V. Henderson), d.hobson@warwick.ac.uk (D. Hobson), a.tse@imperial.ac.uk (A.S.L. Tse).
[1] Present address: Department of Mathematics, Imperial College, London, SW7 2AZ, UK.

https://doi.org/10.1016/j.jet.2018.10.002
0022-0531/

decision making is Tversky and Kahneman's (1979, 1992) prospect theory (PT). PT has several innovations relative to expected utility, including reference levels, risk seeking behavior on losses and probability weighting.[2] Probability weighting has been successfully linked, both theoretically and empirically, to a wide range of financial phenomena.[3] In this paper, we contribute to this broad agenda by showing that in the setting of dynamic models of trading, PT can generate realistic behavior including the use of stop-loss strategies and the desire for right skewness and can match empirically observed levels of the disposition effect. Probability weighting plays a crucial role in our conclusions and we cannot obtain our main results from the reference level, loss aversion and risk-seeking on losses features of prospect theory alone.

We study the behavior of an investor with PT preferences who chooses when to sell an asset. The inclusion of probability weighting introduces new challenges, and to our knowledge this is the first paper to solve a dynamic liquidation model in continuous time for a pre-committing investor under a complete specification of realistic PT preferences which include all the features of Tversky and Kahneman (1992). Our model nests the models of Kyle et al. (2006) and Henderson (2012) which consider an optimal sale problem for an investor with PT value function but no probability weighting, and is a continuous time version of the discrete time binomial model of Barberis (2012).

Our theoretical contribution is to determine the optimal prospect. For a class of preference structures and asset price dynamics, including many popular specifications from the literature, we determine the optimal prospect for an agent who can commit to an optimal sale strategy. Our analysis leads to several predictions which closely match empirical and laboratory findings.

Our first prediction, unique to the literature, is that PT investors should employ trading strategies which are of threshold type on losses, but not on gains.[4] Consider first the behavior on losses. Stop-loss strategies are in widespread use in financial markets and are also found desirable in the laboratory experiments of Fischbacher et al. (2017). Existing theories, both EU and non-EU alike have struggled to justify stop-loss strategies — often they predict that assets are never sold voluntarily at a loss, but rather sales are deferred indefinitely. In contrast, we find that overweighting of extreme losses encourages the investor to stop at a threshold, and sooner than might be predicted in a model without probability weighting.

Now consider the behavior on gains. The vast majority of trading models — including those based on expected utility and those based purely on the $S$ shaped utility function of prospect theory (Henderson, 2012, Barberis and Xiong, 2012, Ingersoll and Jin, 2013 and

[2] Many experimental and empirical studies (Tversky and Kahneman, 1992, Camerer and Ho, 1994, Wu and Gonzalez, 1996, and Polkovnichenko and Zhao, 2013) have found strong support for probability weighting. These studies confirm the inverse-S shape of the weighting function identified by Tversky and Kahneman (1992) which is associated with individuals overweighting the tails of the distribution.

[3] An overview can be found in Barberis (2013). Barberis and Huang (2008) show that, in a financial market where investors evaluate risk according to prospect theory, probability weighting leads to the prediction that the skewness will be priced. This idea has been used to explain low average returns of IPO stocks (Green and Hwang, 2012), the apparent overpricing of out-of-the-money options and the variance premium (Polkovnichenko and Zhao, 2013; Baele et al., 2017), the lack of diversification in household portfolios (Polkovnichenko, 2005) and many other puzzles. On an aggregate scale, De Giorgi and Legg (2012) show that probability weighting is useful in generating a large equity premium — and can do so independently of loss aversion (Benartzi and Thaler, 1995). Probability weighting has also been helpful in understanding the popularity of casino gambling (Barberis, 2012).

[4] As PT distinguishes between gains and losses relative to a reference point, and treats them differently, we expect asymmetric treatment of gains and losses, and potentially skew in the optimal prospect and a disposition (or reverse disposition) effect. The claim here is not merely that investor treatment of gains and losses is different, but rather that it is different in character: on one side it is a stop-loss threshold strategy, whereas on the other it is much more sophisticated.