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Time is money: Costing the impact of duration misperception in market prices

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ABSTRACT

We explore whether, and to what extent, traders in a real world financial market, where participants' judgements are reportedly well calibrated, are subject to duration misperception. To achieve this, we examine duration misperception in the horserace betting market. We develop a two-stage algorithm to predict horses' winning probabilities that account for a duration-related factor that is known to affect horses' winning prospects. The algorithm adapts survival analysis and combines it with the conditional logit model. Using a dataset of 4736 horseraces and the lifetime career statistics of the 53,295 horses running in these races, we demonstrate that prices fail to discount fully information related to duration since a horse's last win. We show that this failure is extremely costly, since a betting strategy based on the predictions arising from the model shows substantial profits (932.5 percent and 16.27 percent, with and without reinvestment of winnings, respectively). We discuss the important implications of duration neglect in the wider economy.

1. Introduction

Sterman (2000, p. 26) observed that "faced with the overwhelming complexity of the real-world, time pressure, and limited cognitive capabilities, we are forced to fall back on rote procedures, habits, rules of thumb, and simple mental models to make decisions." One of the consequences is duration neglect, where the human brain reduces experiences to "peak-and-end" events "…as if duration did not matter" (Frederickson & Kahneman, 1993, p. 54).

In many fields, overlooking or incorrectly interpreting duration can lead decision makers to incorrect choices. In fact, the consequences of duration misperception in experimental studies are well known. For example, subjects have been found to underestimate the time-delay in repeated scheduling tasks (Sterman, 1989) and to underperform in tasks because of confusion linked to time delays and feedback loops (Sterman & Diehl, 1993). Even experienced decision-makers have been shown to misallocate resources because they consistently confuse stock and flow variables, and misperceive how these relate to each other over time (Moxnes, 1998; Sweeney & Sterman, 2000). The latter study, which involved mathematically trained MBA students, concluded that subjects misperceived time delays. Ossimitz (2002) found that duration-based stock-flow confusion resulted in subjects being no better at forecasting than a random coin-toss and Cronin and Gonzales (2007) attributed the stock-flow confusion phenomenon to overly-simple heuristics. Furthermore, Fu and Gonzales (2006) showed that including irrelevant information further adversely affected subjects' ability to estimate duration. The conclusion to emerge from these experimental studies is that subjects fail to account fully for duration information when making decisions. However, to our knowledge, whether individuals engaged in *real world* activities are subject to duration misperception and, if so, the *impact* it might have, has not been addressed. This, therefore, may have led decision makers to pay less attention to duration misperception than they should.

We examine a real world setting where one might expect duration to be considered carefully, namely, where there are large financial penalties associated with duration misperception. Clearly, if we discover duration misperception in such a setting it suggests this phenomenon is more widely prevalent and may cause significant pecuniary loss.

To achieve our objective, we search for duration misperception in an apparently efficient financial market. The semi-strong form of the Efficient Market Hypothesis (EMH) (Fama, 1970, 1991) states that, if a market is fully efficient, it should be impossible to find any publicly available information that can be systematically exploited for pecuniary gain. This is widely held by financial economists and Jensen (1978) claims that "there is no other

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proposition in economics which has more solid empirical evidence supporting it." Clearly, therefore, all publicly available information, including that related to duration, should be fully discounted in market prices. If this is not the case, this will represent an important discovery.

We focus on a speculative market, which previous studies have demonstrated incorporates efficiently a range of complex information (e.g., Bruce & Johnson, 2000). and where large sums are traded; namely, the horserace betting market ($134 billion per annum bet worldwide: International Federation of Horseracing Authorities, 2013). Speculative markets associated with sports, and the events on which they are based, have a definitive endpoint where all uncertainty is resolved. For example, at the end of a horserace, the winner is declared and uncertainty regarding the 'correct' prices (odds) is fully resolved (Peel, 2009). Consequently, speculative markets associated with sports events, and the events themselves, provide an ideal setting in which to measure the impact of biases (Law & Peel, 2002). For example, Hwang and Kim (2015) analyzed betting market data related to volleyball to test the degree to which bettors underestimate probabilities corresponding to extreme ends of the distribution and learning behaviour. Marginson (2010) examined the extent to which horserace bettors fully discount information held by insiders and Flores, Forrest, and Tena (2012) showed that professional sport managers might make biased decisions due to public pressure.

We conducted interviews with training and breeding experts in the racing industry to discover what they believed might be the most important duration factor that the betting public undervalues. This turned out to be the time that horses need to recover from *winning* performances. They argued that the betting public are likely to understand that horses need time to recover between races, as this is given considerable attention in the media. However, they believed that the betting public might not appreciate the significantly greater recovery time that is needed when horses have exerted maximum effort. Jockeys often do not push horses to their limits should they believe, as the race unfolds, that they do not have a clear winning chance. Therefore, the interviewees argued that the exertion of maximum effort by a horse is most reliably captured by focussing on winning performances and that the betting public are likely to fail to account for the time between a horse's winning performances. The interviews also revealed that a range of factors influence speed of recovery following winning performances, including, the horse's age, gender, length-of-distance-run, ability and general health. An individual horse's recovery state after a race is, therefore, a combination of the degree to which it exerted maximum effort in that race, its own speed of recovery and the time since that race. Based on our interviews, it is this complex cocktail of duration-based information for all competitors in a race that we suspect the betting public might struggle to estimate correctly.

Previous studies examining the forecasting accuracy of horserace betting markets suggest that market prices generally incorporate available information (e.g., Law & Peel 2002, Vaughan Williams & Paton, 1997). The few studies that generate forecasts of winning probabilities that can be used to earn abnormal returns only do so by combining a number of complex derivatives of raw variables associated with each horse and/or by capturing the complex non-linear relationships (Lessmann, Sung, & Johnson, 2010) or interactions between several variables (see Sung & Johnson, 2008 for a review), including, for example, published forecasts from racing experts. However, individuals have been shown to be influenced by irrelevant factors when assessing the reliability of forecasts (e.g., Goodwin, 2005). Supplying additional information (e.g. prediction intervals) does not improve the quality of resulting decisions (Goodwin, Önkal, & Thomson, 2010) unless, in the case of prediction intervals, they are employed in the correct circumstances (Savelli & Joslyn, 2013; Ramos et al., 2013). This clearly cannot always be relied upon in any uncontrolled situation such as a horserace betting market. It has also been shown that judgemental adjustments to statistical forecasts can damage accuracy (Fildes, Goodwin, Lawrence, & Nikolopoulos, 2008). Horse race bettors' forecasts are largely based on judgement and it is conceivable, we believe, that bettors may fail to fully employ duration-based information; specifically, the duration between a horse's winning performances (we refer to this period subsequently as, 'days between wins' (DBW).

Consequently, we explore to what extent information concerning DBW can significantly improve upon market-generated forecasts of winning probabilities. To achieve this we adapt survival analysis (SA), a statistical technique for analysing the time to the occurrence of an event, to the task of predicting winners of horseraces. Our adaptation captures the competitive relationship between horses in a race by developing a two-stage SA/conditional logit (CL) model. A horse's wins occur at well-defined points in time, and it is therefore possible, in stage one, to adopt SA to model the relationship between the individual horse's characteristics (e.g., gender and age), and the time to the occurrence of its next win. Conventional statistical methods, such as logistic regression, can only include time related information by incorporating suitable independent variables. Consequently, they are unable to incorporate information concerning time between events (e.g. DBW) directly within the underlying model using probabilities conditional on time. Logistic regression, therefore, does not use time-related information in the most efficient manner. On the other hand, survival models directly estimate the probability of $P(T \geq t)$, which can be interpreted as the probability that the time until an event occurs is larger than time t. The hazard rate in survival models allows the investigation of the probability distribution of the event's occurrence at time t given it did not occur before time t.

In addition, logistic regression gives a discrete probability of the event occurring, regardless of the time of the event's occurrence, and these models do not have the capability of handling partial information. For example, logistic regression has no mechanism for directly using information concerning an event that has not yet occurred (e.g., the time since the last win of a horse until the end of the period covered by the dataset). Whereas, the Cox model would be able to use such partial information by using censoring techniques.

The transformation of event-based information for use in a SA model is complex and non-intuitive and we believe that it is beyond the ability of most bettors to interpret this information fully and correctly.

The second stage of our model employs CL to account explicitly for competitors' relative strengths when estimating winning probabilities (e.g. Bolton & Chapman, 1986). To the best of our knowledge, our two-stage model is the first attempt to combine SA with CL. It captures the impact of an individual competitor's characteristics on the time before they achieve their next win, as well as accounting for competition. This enables us to measure the impact of bettors failing to account for duration-based information, via the abnormal returns that predictions from such a model produce.

2. Hypotheses and data

2.1. Hypotheses

The key aim of this paper is to identify whether, and to what extent, duration misperception occurs in a real-world financial market. To achieve this we examine the degree to which the DBW is not fully discounted in the prices in what are widely regarded as efficient horserace betting markets. Sterman (1989) observes that individuals are particularly bad at interpreting information with a