Previous Gains and Losses influence Belief Formation in Investment Decisions

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Extended Abstract

Investment decisions ought to be forward looking based on information relevant for future earnings. However, ample research underlines the formative role of past experiences in financial risk taking (e.g. Seru et al., 2010; Malmendier & Nagel, 2011; Linnainmaa, 2011) and context dependencies leading to over- or under-reaction to news (Enke et al., 2020). We provide a conceptual framework of expectation formation which extends a Reinforcement Learning model (Sutton & Barto, 2018) by making the learning rate dependent on the context, conceptualized as two dimensions: first, the direction of the received information (*favorable* or *unfavorable* towards ones investment; Eil & Rao, 2011; Kuhnen, 2015). Second, the current investment position, i.e. the past return of the investment (here called a *gain* or *loss* position; Kuhnen & Knutson, 2011; Kuhnen et al., 2017) or not being invested at all. We propose an interaction between these dimensions, leading investors to hold a belief in buying price reversion (Jiao, 2017). An investor becomes "skeptical" about further increases in their returns when in a gain position but overly optimistic about them when having incurred a loss. This happens by an increased reaction to unfavorable (favorable) information in a gain (loss) position, i.e. the updating magnitude for this information being stronger than would otherwise be the case.

To directly test this conceptual framework we use a pre-registered experimental dynamic investment task (Frydman et al., 2014). In this task, participants invest in a stock with a noisy drift in price whose direction (up or down) would flip with a probability of .2. Thus, the investor has to learn about the state of the asset from the price changes to predict the profitability of an investment. Participants were informed about the nature of the price paths. In each round, they can either hold

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one share of the asset, short one share or choose not to invest at all. In each round we further elicit participants' expectations about a price increase in the subsequent round using a lottery matching task (Trautmann & van de Kuilen, 2015). In a second phase of the study, we aimed at reducing the impact of belief formation on trading behavior. One third of our participants was provided with the true probability of a price increase in each round (*"full information"*), thus revealing the current drift direction. Another third was provided with the probability a Bayesian updater would assign to a price increase (*"partial information"*). The remaining participants served as control group and repeated the task as in the first phase (*"no information"*). In total 192 participants played four blocks with 75 rounds each.

We analyze the updates of the reported beliefs about a price increase by calculating the difference between the reported beliefs in round $t-1$ and t. To investigate the updating magnitudes, we "flip" updates stemming from a price decrease such that the signs of all updates should normatively be positive. Doing this, we find that belief updates for a favorable price move in a loss position are stronger than in a gain position while the contrary holds for unfavorable price moves (both $p < .001$), leading to a significant interaction effect ($p < .001$). We further show that participants do base their investment decisions on their reported beliefs.

To directly test our hypothesis about the learning rates of a Reinforcement Learning model we employ a hierarchical Bayesian model estimation approach. This parameter estimation captures the same interaction as the previous analysis. Here it seems to be mainly driven by a strong difference of learning rates for unfavorable price movements between gain and loss positions. To test this interaction we test whether the difference in learning rates between favorable and unfavorable differs between a gain and a loss position (diff-in-diff). The 90% credibility interval of this value does not include zero (Mean: -0.114, 90% CI: $[-.214, -.0163]$). Comparing our model with a Reinforcement Learning model with a single learning rate yields a Bayes-Factor > 100, indicating very strong evidence for a model using multiple learning rates that differ between contexts.

While providing the Bayesian probability did decrease the variance of reported beliefs (Levene-test, $p < .001$), the interaction effect in the belief updating remains even under this condition. Full information (i.e. providing the true probability of a price increase) was necessary to make a significant difference in investment behavior. Here, the Disposition Effect, the tendency of investors to hold losses too long and sell gains too soon, shifts significantly closer to that of an expected value maximizing Bayesian agent under the full information condition ($p < .001$).

In sum we investigate participants' belief updating in two ways: We directly calculate belief updates and estimate the learning rates of a Reinforcement Learning model. The results of both methods agree that the magnitude of belief updates does in fact depend on the context the participants

find themselves in. The pattern of belief updating also translates to the trading behavior, where we observe a Disposition Effect value above that of a risk neutral Bayesian investor. Our intervention of providing further information in the second experimental phase lead to a decrease in Disposition Effect values and thus improved decision making and profitability of investments. This was however only the case when the information about the probability of a price increase was very precise as was the case in the full information condition.

Preferences such as risk aversion may play an important role for investment decisions. We add to the literature showing that beliefs and expectations are another driving force behind the investment behavior. As preferences are usually assumed to not be very malleable, belief formation provides a clear channel for helping investors to make decisions that are in line with their intended investment strategies. Through the belief in buying price reversion interventions such as hiding the buying price itself (Frydman & Rangel, 2014) can work by reducing the salience of the current loss or gain position, reducing their influence on the belief updating. Our conceptual framework allows one to think of potential further interventions reducing the profit diminishing effects of averse trading patterns. It stresses the role of belief formation and the experimental results underline the importance of providing precise and clear information.

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