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Running Head: DYNAMIC MODEL

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Abstract

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A Dynamic Model of Investor Decision-Making:

How Adaptation to Losses Affects Future Selling Decisions

One of the most intriguing phenomena in decision making under risk, particularly in financial markets, is the disposition effect. Shefrin and Statman (1985) propose that investors tend to hold their losers (depreciated investments) too long and sell their winners (appreciated investments) too early. This proposition has received empirical support both in the laboratory setting (Weber & Camerer, 1998) and in the market place (Odean, 1998). Dhar and Zhu (2006) identify heterogeneity in individual investors' propensity to exhibit the disposition effect. A recent study by Lee, Park, Lee and Wyer (2008) demonstrates that the disposition effect is mostly due to differences in the subjective value that investors attach to possible gains and losses, rather than to differences in their beliefs of how likely gains or losses actually are. Their reasoning is based on prospect theory (Kahneman & Tversky, 1979), which claims that investors do not measure a gain or a loss in absolute terms. Rather, the perceived value of each outcome depends on its distance to the investor's reference point. The reference point can generally be defined as one's current wealth. Any value above (below) the reference point is perceived to be positive (negative) for an individual. Moreover, the asymmetry of the value function around the reference point causes losses to have approximately double the psychological effect of an equally-sized gain. Such a value function implies that realizing a loss is psychologically painful.

Although investors are less inclined to sell losers, many of them eventually do if losses accumulate further. Combining the empirical evidence that investors tend to avoid the realization of losses relative to gains with the phenomenon that many investors eventually do sell their losing investments, leads to the question what are the precise determinants of this capitulation decision. This is particularly interesting in a dynamic setting, in which investors can opt to sell or hold their investment every time they receive new information about the investment's performance.

According to standard finance theories, investors' expected utility of an outcome is a function of (1) their subjective expectation of future increases/decreases of the investment, and (2) the subjective values attached to these objective increases/decreases. We contribute to the literature by proposing a dynamic model for investor decision making. We do not only test the direct effect of these two components of decision making separately, but also examine the interaction effect between subjective expectations and subjective values on investors' capitulation decisions. Our model adopts the standard finance perspective for the first component: it is only rational for investors to sell a losing investment if the expected price increase does not off-set the corresponding risk. Our main contribution focuses on the examination of the second component, i.e. the subjective value, and its interplay with expectation formation.

Subjective values attached to future increases or decreases of an investment depend on the investor's adapted reference point. The adapted reference point is an individual's most recent update of his reference point after internalizing the experienced gains or losses. It adjusts in the direction of a prior outcome: upwards for gains and downwards for losses. If an investor's reference point adapts downwards after a loss, the perceived size of the incurred loss becomes smaller. It takes time, however, for people to come to terms with the losses they incurred. Therefore, both the size of the loss and the time spent in a losing position should affect the adaptation level. Our model disentangles these two effects by combining the different theories in this field. The adaptation of the reference point (from prospect theory) is modelled as a change in the adaptation level (from adaptation level theory), which is influenced by the time and size of each stimulus. We expect that investors who have hardly adapted to their previous losses are more likely to capitulate on a losing investment. The main explanation is that for these non-adapted investors the possible increases in value are not interpreted as attractive enough to off-set the risks involved.

Our analysis builds on and extends the results of the few recently published studies on adaptation to financial losses and gains. Arkes, Hirshleifer, Jiang and Lim (2008) show an investor's reference point shifts following the value change of an investment. Their focus is on a single value change. In practice, however, individuals are faced with a chain of decision moments: the decision to hold on to an investment today may account for the fact that one can reconsider this decision tomorrow. To understand how investors' deal with these multiple decision moments, it is necessary to understand how the reference point adjusts each time new information is received by the decision maker, as is done in the current paper. Lee et al. (2008) find that the disposition effect is mostly due to the different subjective values that investors attach to gains and losses. The authors focus on the comparison between subjective values in the gain and loss domains in a single-decision setting. Again, in reality, investors operate in a dynamic, multi-period setting. None of the above studies investigates the interaction between changing expectations and reference point adaptation. Lee et al. (2008) point out that such an interaction may occur. Our paper contributes to the literature by explicitly testing for the interaction between reference point adaptation and changing expectations. In particular, we concentrate on the effect of investors' dynamically changing reference points and expectations on their capitulation probability in a multiple decisions setting where investors experience a loss.

Our results indicate that, consistent with the standard finance perspective, negative expectations lead to larger capitulation probabilities. Interestingly, however, the effect of expectations on the capitulation of a losing investment is much stronger when the investor's adapted reference point is relatively high than when it is lower. That is, investors who have hardly adapted to prior losses (thus sticking to their high adapted reference point) are more likely to capitulate when their expectation is negative.

Theoretical Framework

Expectation and Capitulation

We adopt in our study the standard finance perspective that it is only rational for an investor to sell a (losing) investment if he does not expect the price going up sufficiently to off-set the investment's risk. We thus hypothesize that

H1: Negative expectations lead to a larger probability of capitulation.

Investors may have positive expectations for stocks that have previously incurred losses. Andreassen (1988) proposes that investors often believe that a losing stock is likely to have bottomed and, therefore, is likely to re-gain some of its previous losses over the next investment period. It is possible that such an effect also plays a role in our dynamic setting. As total losses accumulate, some investors may perceive the stock to have reached its bottom and expect it to bounce back. This negative recency (tendency to predict the opposite of the last event) is also known as the gambler's fallacy (Ayton & Fischer, 2004). The opposite result is also found in the literature. Findings on the hot-hand-fallacy (Ayton & Fischer, 2004) suggest that individuals can expect a positive recency (tendency to predict the same as the last event). This implies that losing investments induce negative expectations about future performance. Morrin, Jacoby, Johar, He, Kuss and Mazursky (2002) discuss that both types of phenomena are exploited by actual investors in the form of momentum (positive recency) and contrarian (negative recency) investment strategies, respectively.

Prospect Theory and Reference Point

Prospect theory postulates that investors evaluate outcomes with regard to a reference point. If the outcome is above (below) this point, it is considered as a gain (loss). Prospect theory also suggests investors experience loss aversion: losses impose approximately double the psychological effect of equal-sized gains. In addition, investors show risk aversion in the gain domain, but risk seeking behaviour in the loss domain. This is reflected in concavity of the value function above the reference point and convexity below this point. Concerning the latter, although selling a losing investment can prevent one from incurring additional losses, actually realizing the loss is psychologically painful. Therefore, investors tend to choose the risky option (holding on to the losing investment, i.e., "paper losses" only) in order to retain the possibility of avoiding pain (i.e., realized losses). Weber and Camerer (1998) and Odean (1998) among many others report empirical support for the tendency of holding on to losing investments.

A fundamental and non-trivial issue in prospect theory concerns the determination of the reference point. Kahneman and Tversky (1979) state that the reference point can be the status quo, but also the expectation or aspiration level, and that it is unclear where the reference point actually lies. In financial decision making, there is no consensus which price determines the reference point. Several prices that have been proposed include the initial purchase price (Weber & Camerer, 1998; Odean, 1998), the historical peak of a stock price (Gneezy, 2005), and the expected value of future outcomes (Köszegi & Rabin, 2006; Yogo, 2008). Baucells, Weber and Welfens (2007) argue that since reference point adaptation is a subjective experience, the alternative reference points tested in previous studies may all be valid. Moreover, these reference point candidates may be highly correlated. This makes it hard to disentangle the effects of alternative reference point candidates. Baucells et al. (2007) also show that in most previous studies on the disposition effect, the reference point definitions could have easily been replaced by an alternative one without substantially changing the findings. In our study, we use the investment goal as a measure of reference point adaptation. Further discussion will be provided in the method section.

Adaptation of the Reference Point

Adaptation is a process in which the effect of a constant or repeated stimulus reduces over time. Kahneman and Tversky (1979) propose that one's current level of perceived wealth is determined by one's adaptation to past and present stimuli in a similar way as the adaptation level (Helson 1964) is affected by past stimuli. The adaptation of a reference point is also sometimes referred to as a shift of the reference point or an updated reference point. All definitions imply that the reference point is not static. As gains (losses) accumulate, in a dynamic process the reference points adapt upwards (downwards). A subsequent price of a security is evaluated relative to this adapted reference point. The difference between the adapted reference point and the current objective value of the investment becomes a major input in the investors' hold or sell decision.

Recent research show that people adapt to their economic status. Chen and Rao (2002) suggest that people immediately but incompletely update their reference point after experiencing an event. They find that by holding the economic outcome constant, the sequence of events (either loss-followed-by-gain or gain-followed-by-loss) affects one's psychological appraisal of the outcome differently. Arkes et al. (2008) show that people adapt to gains faster than to losses of the same magnitude. Although the presence of adaptation to economic gains and losses is supported, the extent of adaptation over time is yet to be tested in a dynamic setting.

Adaptation level theory suggests that the perceived magnitude of a stimulus depends on its relation to an adapted level that is determined by preceding stimuli. According to Helson's formula (1964), the adaptation level (*AL)* is the average of past stimuli levels,

$$AL_t = t^{-1} \cdot \sum_{\tau=0}^{t} X_\tau \tag{1}$$

where X_t represents the current stimulus level, and t represents time. It is unlikely that investors adapt to losses precisely based on Helson's formula. In fact, his theory has been criticized on several grounds. Sarris (1967) argued that extreme stimuli do not affect the adaptation level as much as Helson (1964) suggested. Parducci (1968) suggested that the effect of a stimulus is influenced by the rank of the stimulus within a group of stimuli. Moreover, Eq. (1) does not differentiate how, for example, a loss experienced two years ago and a more recent loss experienced two days ago may affect the adaptation level differently. To account for this temporal component, Hardie, Johnson and Fader (1993) propose to model the adaptation level as

$$AL_t = \alpha X_{t-1} + (1-\alpha)AL_{t-1} \quad (2)$$

Although the parameter α now allows recent stimuli to receive more weight than past stimuli, it still does not allow a full separation of time and stimuli levels.

To allow for a more flexible way of capturing reference point adaptation, we propose to examine the unique effect of time and past stimuli on the adaptation level separately. Eq. (1) implies that the adapted reference point is determined as a recursive average of all preceding stimuli. We therefore expect the adapted reference point to be positively related to the sum of all previous changes in the stock price, and negatively to the number of time points t. The sum of past stimuli in our setting thus collapses to the size of the total price change since $t = 0$, i.e.,$(p_t - p_0)$. As the stock price drops further, the size of total loss becomes larger and the adapted reference point is expected to decrease as well. It is important to note that for a losing investment a higher adapted reference point actually indicates a smaller extent of reference point adaptation. We do not expect that the adaptation process follows the precise dynamics of Eq. (1), but we do expect a significant relationship from the total sum of past stimuli and the elapsed time to the final adapted reference point. We thus hypothesize

H2a: A larger size of total loss predicts a lower adapted reference point.

H2b: A longer time in a losing position predicts a lower adapted reference point.

Therefore, we model the effect of total loss and time on adaptation as:

$$AL_t = \alpha + \beta_1 \cdot t + \beta_2 \cdot TL_t + \beta_{int} \cdot t \cdot TL_t + \varepsilon_t \,, \qquad (3)$$

where AL_t denotes the adapted reference point, t the time in a losing position, and TL_t the size of the total loss. Since it takes time for a loss to accumulate, it is inevitable that there is a correlation between time in a losing position and size of total loss in our study. To measure the direct and unique effect of time and size, we include an interaction term in the equation.

The main thrust of our use of adaptation level theory, however, is that we integrate it with prospect theory. We argue that when an investor experiences a loss, a new adaptation level is created, which can also be seen as an adapted reference point in the framework of prospect theory. The combination of these two helps us to understand more about the investor's capitulation decision in a dynamic setting.

S-shaped versus More Complex Prospect Value Functions

Although prospect theory is the most prominent explanation for the disposition effect, questions have been raised about the limitations of the theory in explaining the disposition effect. One theoretical concern is that people who would hold losers too long and sell winners too early should not have invested in stock markets to start with (Hens & Vlcek, 2005). Another argument is that investors in a losing position are not expected to sell at all, as they are expected to be risk taking according to the convex value function in the loss domain. Empirical evidence, however, clearly shows that investors do sell at losses, although the extent at which this occurs is smaller compared to selling winners.

The apparent limitations of prospect theory as an explanation for the disposition effect stem from the proposition that people are risk taking in the loss domain and risk averse in the gain domain. Though empirical findings are generally supportive of this behaviour for limited bet sizes, alternative specifications have also been put forward in the literature. Markowitz (1952) was the first to suggest that utility is defined on gains and losses rather than on the final wealth level. In contrast to prospect theory, Markowitz (1952) argued in favour of risk seeking preferences in both positive and negative prospects. He proposed a utility function with convex and concave regions in both the gains and the loss domains. Also Kahneman and Tversky (1979), though mostly cited for their S-shape value function, have considered special circumstances and alternative specifications. They suggest that the value function of an individual does not always reflect the pure attitudes toward money, because it can also be influenced by additional consequences associated with specific amounts. Therefore, convex regions in the value function for gains and concave regions in the value function for losses can be readily produced under such circumstance. Moreover, since *large* losses often lead to changes in life style, one may expect that it is more common to find concave regions in the value function for losses. Explicitly allowing for a different behaviour of the value function for small versus larger losses is particularly important in our case where we study the dynamic capitulation decision when losses accumulate further over time.

Another proposition, the quasi-hedonic editing hypothesis, also supports the possibility of risk-averse preferences in part of the loss domain and risk-seeking preferences in part of the gain domain. Thaler and Johnson (1990) find that in some cases prior gains increase people's willingness to accept risks. This is known as the house money effect. By contrast, prior losses may decrease people's willingness to take risk, especially if the risky outcome does not offer any chance to break-even with the situation before the prior loss. One of their empirical findings is that a second loss "hurts" more when experienced after a prior loss than when experienced separately. This suggests that in the prospect theory framework a concave region in the loss domain may exist. Consistent findings were also provided by the work of Sullivan and Kida (1995) that shows that managers were more willing to accept risk after experiencing a prior gain as opposed to a prior loss. Zeelenberg and van Dijk (1997) also find that sunk costs can result in risk avoiding behaviour. The quasi-hedonic editing hypothesis has been typically tested in a two-stage setting: a first certain outcome is realized, and then a subsequent choice between a certain and a risky outcome is made. By contrast, prospect theory is typically applied on single-stage decision problems. Due to this difference, the quasi-hedonic editing hypothesis is particularly relevant to our theoretical framework, because we are interested in investment decisions in a dynamic, multi-stage experiment.

To make prospect theory more applicable to an investor's financial decision making, De Giorgi, Hens and Post (2005) formally proposed a modification of the S-shape value function, namely the piecewise exponential value function, which is depicted in Figure 1. Close to the reference point, the new value function recovers the kinked and convex-concave shape as originally proposed by Kahneman and Tversky (1979). For large losses, however, the piecewise exponential value function exhibits more curvature and thus discourages extreme risk taking.

The remarks of Kahneman and Tversky (1979) as well as the quasi-hedonic editing hypothesis and the piecewise quadratic utility function all suggest that there is a "tipping point" in the loss domain after which concavity (and thus risk aversion) sets in again for large or subsequent losses. The importance of this for our experimental setting and empirical model design is evident. As losses accumulate over time, the values of future prospects by an individual investor crucially depend on both his level of adaptation and his future expectations. For example, conditioning on the same experienced total loss size and the same expectations about possible future outcomes in Figure 1, a non-adapted investor may perceive the current value of the investment to be much closer to the left-hand concave region, whereas a more-adapted investor may perceive that to be closer to the convex region. As a result, the non-adapted investor is more likely to capitulate. Conversely, conditioning on the adaptation level we expect the impact of expectations on the capitulation decision to vary at different possible adaptation levels. We therefore expect the interaction between expectations and adaptation to play a major role in our explanation of capitulation over time when losses accumulate. We summarize this in our third hypothesis

H3: The effect of (negative) expectation on the probability to capitulate is stronger for high adapted reference points (i.e., for the investors who adapted less to their losses).

Figure 2 summarizes our complete dynamic model of an investor's financial decision making.

Methodology

Participants and Procedure

A dynamic experiment was conducted to test the prediction that adaptation to losses affects investors' decisions to hold on to or to capitulate on a losing investment. Respondents were presented with a single stock and had to make multiple decisions of whether to hold or sell their investment. The amounts and timing of losses varied across respondents. In our experiment, 111 students at a Dutch university (72 male, 39 female) participated, with a chance to win a €100 prize by enrolling in a lottery. A better performance in the investment experiment resulted in a higher probability of winning the €100 prize. Around 44% of the subjects claimed to have some general experience in investing in financial markets, while 36% of the overall participants had experience investing in stocks. Participants arrived at the lab and were assigned to individual cubicles. They were presented with the scenario that they recently started investing in a single stock – stock X. The amount invested in stock X was predetermined and equal for every investor. We specified up to 10 investment periods for the experiment. After each period, participants received information on the stock's performance and were asked to hold or sell the stock. They could only choose to sell or to hold the whole invested amount. Before deciding to hold or sell, they answered a short questionnaire.

Price Patterns

Previous studies on the disposition effect usually employed a limited number of predetermined price patterns (Weber & Camerer, 1998; Lee et al., 2008). To increase the generalizability of our current findings, we generated a wide range of loss sizes and intermediate price dynamics over the ten investment periods.

All participants incurred losses with their investment in stock X. To make the price patterns look more realistic and to avoid long runs composed of losses only, some mild upward movements were included in the intermediate stages. In order to avoid having these upward movements too frequently, we divided the (up to) ten investment periods into three unequally sized blocks. With random assignment, participants received a first loss of 5%, 10%, 20% or 40% roughly evenly spread out over the initial 1, 3 or 5 periods in block 1. Then in block 2, prices stayed relatively stable (up or down stock price movements around 1%) for either 2 or 4 periods. After that, a second loss of 5%, 10% or 15% took place in block 3 within 1 period. After this the experiment ended (see Table 1). In total, there were 72 possible combinations of price patterns: 4 (first loss: 5%, 10%, 20% or 40%) x 3 (first losing period: 1 vs. 3 vs. 5 periods) x 2 (flat prices: 2 vs. 4 periods) x 3 (second loss: 5% vs. 10% vs. 15%).

One of the focal points of our study is the relevance of time in a losing position and the total loss incurred for the adapted reference point. Past studies have shown that intermediate prices, such as the historical peak, may play a role in the disposition effect (Gneezy, 2005). However, more recent findings point out that the first and the last price of a time series receive more weights in terms of influencing one’s reference point (Baucells et al., 2007). To limit the impact of intermediate price patterns on our experiments, we randomized the order of presenting each price within blocks 1 and 2. Consequently, the values of potential alternative candidates for a new reference point vary strongly over respondents. Such a procedure is crucial for the fit between our model and real trading data. By eliminating the effect of intermediate prices, our results can be better generalized and applied to real investment markets.

Investment Goals as Measures of Adaptation

In this section, we provide the arguments for our operationalization of the estimate of investors' reference points. Via a repeated questionnaire in our dynamic experiment, we measure how investors adjust their investment goals. From this, we infer adaptation.

Several measures of adaptation levels have been proposed by previous studies. For instance, Baucells et al. (2007) ask subjects to report the selling price for which they would feel "neither happy nor unhappy". A limitation of this measure is that participants have to understand the concept of indifference and be able to express that psychological state in terms of stock prices. Another limitation of former studies such as Baucells et al. (2007) and Chen and Rao (2002) is that a series of outcomes is presented and participants are then asked to report their reference point. The use of this type of retrospective evaluation can be highly biased (Freedman, Thorton, Camburn, Alwin & Young-DeMarco, 1988). Moreover, this methodological approach does not allow researchers to observe how reference points change over the course of the study. In study 1 – 3 of Arkes et al. (2008), participants were asked to report how much an investment has to appreciate (depreciate) further to make them feel as happy (sad) as they were when they learned about a previous gain (loss). The limitation here is that subjects may have difficulty imagining how they would feel about future gains and losses. Affective forecasting studies demonstrate that people's predictions of their own hedonic reactions to future events are susceptible to errors and biases (Wilson & Gilbert, 2005). Although people often predict the valence of their emotional reaction (good vs. bad), or even the specific emotions (e.g. joy, sadness) correctly, they overestimate the intensity and duration of their emotional reactions. Wilson and Gilbert (2005) suggest that in case of negative events, people underestimate how quickly they will cope psychologically with the pain/loss and how that speeds up their recovery.

Assuming the constancy of our prospect value function in Figure 1 over time, it does not make much difference whether we use the price proposals from previous literature or the measure proposed in this paper, i.e., the investment goal. Most reference points generally refer to one's current wealth. However, aspiration levels can also serve as anchoring values (Kahneman & Tversky, 1979). We argue that it is natural in our current context to use investors' goals as an indicator of adapted reference points. The notion that goals energize and direct human behaviour is commonly held by psychologists (Austin & Vancouver, 1996; Elliott & Dweck, 1988). For example, previous studies in the management literature show that the aspiration level is adaptive and is affected by performance feedback (Lant, 1992; Mezias, Chen & Murphy, 2002). Rasmussen, Wrosch, Scheier and Carver (2006) also find that goals serve as reference values for a feedback loop. If a goal is perceived as unattainable, people may disengage from their prior goal and reengage to new ones. Such adjustment is beneficial to their well-being (Wrosch, Miller, Scheier & Brun de Pontet, 2007).

We conjecture that when investors' reference points adapt, this adaptation is reflected in their goals. By comparing the reported goals at multiple points in time, we are able to infer the extent of adaptation. In order to measure investors' goals in our experiment, we ask participants after each new price realization to report at what (next) price level they would feel satisfied and at what (next) price level they would be willing to sell their invested security. We adopt the idea of using selling prices as measures of reference point adaptation from study 5 - 6 of Arkes et al. (2008), but we did not adopt their use of the BDM procedure (Becker, DeGroot & Marschak, 1964). In the BDM procedure, two future prices with equal probabilities are specified. Before one of those prices is randomly chosen, participants may sell the stock by indicating a minimum selling price. One of the two future prices is then randomly drawn. Participants are obliged to sell at the random price if it equals or is higher than their minimum selling price. With this procedure, it is impossible to disentangle one's reference point from the selling decision, as the decision is inherently determined by the minimum selling price. In our experiment, investment goals did not lead to any obligation on the hold/sell decisions. Participants were able to hold or capitulate regardless their previously postulated investment goals.

Our measure of reference point adaptation is more intuitive and requires less cognitive pressure compared to previous studies. As goals generally direct our everyday behaviour, it is natural for one to think in terms of goals. Our questions to elicit investment goals can readily be understood by respondents. Low cognitive pressure is relevant for a dynamic experiment in which subjects have to provide answers on the adapted reference point for multiple points in time.

Questionnaire

We derived four measures based on Arkes et al. (2008) and Ayton and Fischer (2004). The investment goal was reflected by two measures. The first measure assesses the satisfy price of investors: “In the next period, what is the price of stock X that would make you feel satisfied?” (mean = 32.75, *s.d.* = 5.35). The second measure is an estimate of the selling price: “In the next period, if the stock price increases, what is the price you would sell at?” (mean = 35.64, *s.d.* = 6.26). (The initial price of the stock was given at 33.61). The third measure assesses their expectation for the rational system: “How do you think the price of stock X will change in the next period?” Answers to this question were reported on a 9-point scale (1 = surely decrease, 9 = surely increase, mean = 5.68, *s.d.* = 1.66). Our final measure indicates whether participants chose to hold on to or to capitulate their losing investment: “Do you want to hold or sell stock X now?” (frequency of hold = 497, frequency of capitulate = 55).

Our calculation of the adapted reference point requires some additional discussion. The investment goal measures are used to estimate the adapted reference point, as in Arkes et al. (2008). For example, if the adapted reference point at time t_0 is AL_0 and the satisfy price is S_0 , the difference between AL_0 and S_0 should be the same as the difference between AL_1 and S_1 at t_1, assuming that the shape of the prospect theory value function remains unchanged:

$$S_0 - AL_0 = S_1 - AL_1 \rightarrow \Delta AL_t = AL_t - AL_{t-1} = S_t - S_{t-1} \quad (4)$$

For example, if one participant reports a satisfy price at €37 at t_0 and €35 at t_1, the adapted reference point is expected to have adjusted €2 downwards. Although neither the satisfy price nor the selling price is the reference point *per se*, by holding the prospect theory value function constant, any reference point adaptation over time is reflected by the adaptations in satisfy price and selling price over time. Thus, by keeping track of the differences in satisfy price and selling price over the course of the experiment, we capture the movement of the adapted reference point.

Results

Preliminary Results

We tested our three hypotheses using partial least squares regression analyses with SmartPLS 2.0 (M3) beta (Ringle, Wende & Will, 2005). Only the adapted reference point has two measures. The remaining variables have only one measure. This means that reliability and validity tests are not applicable. A total of 552 decisions were pooled and analyzed together. Structural coefficients were computed (see Figures 3 and 4). Standard errors and significance were estimated using the bootstrap method with 500 replications.

Before testing the full model, a preliminary model was estimated based on time in a losing position, the total price change since the initial period (more negative price changes indicating larger total losses) and the most recent price change since the previous period (more negative price changes indicating larger recent losses). These variables were used as explanatory variables for expectation and probability of capitulation (see Figure 3). Results indicated that the size of the total price change is negatively related to expectations (beta = -0.196, t = 4.447, $p < .001$). This implies that participants expect a bounce back (negative recency) in prices as losses accumulate. On the other hand, the size of the most recent price change is positively related to expectations (beta = 0.203, t = 4.226, $p < .001$), implying that participants expect a momentum (positive recency) effect: price movements are positively correlated in the short run. These results are consistent with our expectation that both positive and negative recency effects may occur simultaneously. A positive relation was found between the size of the total price change and the capitulation probability (beta = 0.076, t = 2.387 $p = .017$). This indicates that a larger loss is related to a larger probability to hold on to the losing investment. This is consistent with the notion that people avoid realizing losses. As the total price change becomes more negative, the probability to capitulate decreases. Finally, preliminary support for hypothesis 1 is obtained. A negative expectation relates to a larger probability of capitulation. Such an effect is found to be significant (beta = -0.275, t = 6.808, $p < .001$). The size of recent losses and the time in a losing position do not influence the capitulation probability significantly (beta = -0.036, t = 1.088; $p = .277$; beta = 0.053, t = 1.128, $p = .260$). The time in a losing position does not affect expectation either (beta = -0.073, t = 1.356, $p = .176$). Note that the explanatory power of this preliminary model is very limited ($R^2 = 0.086$).

Results of the Proposed Model

Results of the complete model (including adapted reference point and its interaction term with expectation) are presented in Figure 4. Hypothesis 1 has already received support in the preliminary model. Consistent results are found in the complete model. More negative expectations about the stock's future performance predicts a stronger likelihood to capitulate (beta = -0.220, t = 7.583, $p < .001$). Note that higher values for our expectations measure imply more positive expectations about the investment's future values. Thus, a negative effect implies people with lower expectations are more likely to sell, thus again supporting hypothesis 1.

Statistically significant effects are observed from the time in a losing position and the size of the total loss on reference point adaptation. Participants' adapted reference points adjust downwards stronger when the size of the total price change becomes more negative (beta = 0.368, t =8.465, p < .001) and the time in the losing position increased (beta = -0.085, t = 2.085, p = .038). Positive (negative) beta indicates a higher (lower) adapted reference point, which corresponds to less (more) adaptation to losses. It is important to note is that in our experimental setting, it generally takes time for losses to accumulate. Larger losses are thus inevitably correlated with longer times in a losing position in the experiment. To make sure that the effect of time and size of the total price change is unique, and to disentangle their effects on adapted reference points, our dynamic model includes an interaction term between time and the total price change. This interaction term significantly affects the adapted reference point (beta = -0.125, t = 2.971, p = .003). These results give strong empirical support to our hypotheses 2a and 2b, i.e., larger total losses and a longer time in a losing position are related to lower adapted reference points, i.e., respondents have adapted more to the incurred losses. No direct effect of the adapted reference point on capitulation is found (beta = -0.011, t = 0.554, p = .580). Consistent with theory, such an effect was not hypothesized.

Finally, we test hypothesis 3 to see if the adapted reference point interacts with expectations and affects the capitulation tendency. A significant interaction effect is found (beta = 0.559, t = 10.531, p < .001). To examine the interaction effect more closely, we perform a median split on adapted reference points. Expectations are measured with a 9-point scale. Expectations equal to 6 or above are regarded as positive expectations, otherwise negative expectations apply. Table 2 shows the means of the capitulation probability for positive versus negative expectations and high versus low adapted reference points. The results indicate that for positive expectations, the capitulation probability was small for both high and low adapted reference point groups. However, when the expectation is negative, the capitulation probability is larger for the high adapted reference point group than for the low adapted reference point group. This supports our hypothesis 3.

The effect of the total price change on the selling decision is insignificant (beta = 0.054, t = 1.858, $p = .064$) after including the adapted reference point and its interaction term with expectation in the model. Thus, when we control for the effects of reference point adaptation, the relation between size of total loss and capitulation probability becomes irrelevant. That is, as investors adapt to losses, it is not important to look into the actual loss they have incurred. Instead it is important to know how much the investors have adapted to the loss. To mitigate concerns about the robustness of the results, we also incorporated individual characteristics of respondents as controls in our analysis: age, gender, fields of studies, risk aversion, and investment experience. The results remain robust.

In sum, hypotheses 1, 2a, 2b and 3 were supported. Furthermore, the variance in capitulation probability was much better explained with the complete model in Figure 4 (R^2 = 0.393) than with the preliminary model in Figure 3 (R^2 = 0.086). This implies that the interaction between expectation and adaptation is indeed a powerful explanatory variable for the investor's capitulation decision in a dynamic setting. This is confirmed by a simple numerical experiment: dropping only the interaction term from the full model in Figure 4 reduces the R^2 to a meagre 8.8%. This again underlines that the interaction term between expectations and adaptation is crucial for explaining the dynamic capitulation decision.

The opposite effects of sizes of recent loss and total loss on expectation are worth some attention. When the size of total losses becomes larger, participants report significantly more optimistic expectations (beta = -0.196, t = 4.395, $p < .001$). This reflects the bounce-back effect, i.e., participants expect a depreciated stock to appreciate again in the future. At the same time, when the recent loss is larger, participants report negative expectations (beta = 0.203, t = 4.214, p < .001), implying that participants expect momentum in future stock market prices. These results are in line with both the gambler's fallacy and the hot-hand-fallacy. They also highlight the importance of studying the dynamic role of time and the different impact of timed losses on investors' expectation and decision making.

Conclusion and Discussion

We investigated how individuals eventually come to the painful decision to sell their losing investments. We formulated a conceptual model that integrates prospect theory and adaptation level theory. The model is tested by a laboratory experiment. Previous literature tested subjective expectations and subjective value as two separate determinants of investors' hold/sell decisions. To the best of our knowledge, this is the first effort to investigate the interaction effect of these two determinants on the capitulation probability. Also, we proposed a novel way to model investors' subjective value by means of measuring their adaptation to losses.

Our study confirms previously reported empirical findings and adds to the existing body of knowledge. Our finding that negative expectations lead to larger selling probabilities is consistent with standard economic theories. Lee et al. (2008) found that a participant's subjective expectation does not explain the disposition effect. They investigate whether the difference in subjective expectations between a winner and a loser affects trading decisions. This should be distinguished from the general effect of expectations for price changes on the tendency to capitulate. Our empirical results are consistent with Arkes et al. (2008): investors adapt to losses. We contribute to the literature by demonstrating that a lower adapted reference point is predicted by a larger size of loss and by a longer time span in a losing position. Our empirical results have also added more insight into the separate effects of time in a losing position and the size of losses as we have disentangled the unique effects of past stimuli and time in a losing position. Our findings support the conclusion of Hardie et al. (1993) that the temporal component plays a critical role in (financial) decision-making. Our experimental findings are consistent with those by Chen and Rao (2002). People immediately but incompletely update their reference point after experiencing an event. We also find the adapted reference point depends on the time spent in a losing position. That is, it takes time for investors to fully or at least mostly adapt to a financial loss. Our result is also consistent with findings by Odean (1998) and Weber and Camerer (1998) that the initial purchase price is an appropriate reference point in investors' decision making process. We add to this that the importance of the initial purchase price is greater right after a security is acquired compared to later points in time. Lee et al. (2008) find that investors' subjective values attached to gains and losses affect their hold/sell decisions. We extend their findings by proposing a dynamic model to predict one's subjective value, which is based on investors' expectations and adapted reference points.

Our study has two main contributions. First, we provide insight into reference point adaptation in a dynamic context. We find that over time both the size of the loss and the time in a losing position lead to more downward adjustment of the reference point. Second, we find that adapted reference point interacts with expectation and affects capitulation. Specifically, if expectations are negative, a higher adapted reference point predicts a larger capitulation probability. These two main findings imply a link between reference point adaptation and (financial) decision making.

Our findings are most relevant to decision making research within multiple time points/longitudinal settings. We demonstrated that people's decisions are influenced by how much they have adapted to the size and duration of past stimuli. Such a dynamic setting bears a close resemblance to decision making in reality, where people are faced with repeated decisions on a daily basis. Our findings are relevant to other investment markets as well, for example, the property market. Since home owners usually do not buy or sell frequently, the role of time may be even more influential. In fact, our model may be applicable to any situation in which price changes and continuous decision making are involved. For example, consumers may keep track of prices of products and services over time, which affects their reference point adaptation. Lewis (2006) has suggested that the negative effect of promotions (Blattberg, Briesch & Fox, 1995; Neslin, 2002) on brand equity is potentially explained by adaptation theory. That is, consumer adaptation may imply that deeply discounting initial prices can lead to the formation of lower reference prices. We suggest that adaptation can also have relevance for more non-financial aspects of consumer behaviour. Adaptation may explain why consumers stay with service providers with declining levels of service quality. If the decline is gradual, adaptation may partially explain inertia, next to avoidance of incurring switching costs (De Ruyter, Wetzels & Bloemer, 1998). In further research the dynamic experiment reported in the current paper can be adjusted to such settings for assessing the suggested relevance of adaptation.

We conjecture that there may be correlation between an investor's adapted reference point (inferred from the investment goal) and the person's expectation about the stock's future performance. In fact, Lant (1992) shows that models applied to expectation formation are also useful for describing aspiration formation. Thus, it is possible that adaptation to losses induces more negative expectations about future price performance. In addition, a more negative forecast about stock prices may increase the willingness to sell the stock at a lower price. Our findings indeed show that lower adapted reference points correlates to lower expectations. This is in line with models proposed by Köszegi and Rabin (2006) and Yogo (2008) in which the reference point is one's expectation about future outcomes. To estimate the expected value of the future outcome, one needs to be aware of one's own perceived current state, i.e., adapted reference point. Therefore, it is not surprising that investors' expectation for the stock's future performance relates to their adapted reference point. However, as both variables were measured instead of manipulated in the experimental setting in our study, we cannot conclude any causal relationship. Future research may investigate further such possible relations.

Another limitation of our research is that the experiment was conducted within the short time frame of an experimental setting. In reality investors have more time in between their various decision moments than in a typical experimental setting. Future studies should try to replicate these findings with larger samples and adopt more natural settings. Another potential follow-up study is to test if our model also works in the domain of gains. In addition, our participants were undergraduates and about half do not have actual investment experience. It may raise questions on the generalizability of our results. However, we do not find a significant difference in the capitulation tendency between those who have and those who have no prior investment experience. Nonetheless, further studies with participants recruited outside the population of university undergraduates will increase the validity of our findings.

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Tables

Table 1. Price presented to participants in the 3 blocks for up to 10 periods.

Price change presented in Block 1:

	Price change	-5%	-10%	-20%	-40%
No. of periods	1	-165.06	-337.38	-674.76	-1331.36
	3	-113.95	-193.24	-386.48	-834.24
		-89.56	-178.23	-356.46	-698.46
		38.45	35.36	70.72	201.34
	5	-38.27	-99.21	-198.42	-277.33
		-55.68	-89.43	-178.86	-390.12
		40.36	40.32	80.64	177.45
		-61.49	-109.31	-218.62	-314.05
		-49.98	-78.47	-156.94	-527.31

Price change presented in Block 2:

	Price change	+/- ~ 1%
No. of periods	2	-34.78
		39.32
	4	-34.78
		39.32
		46.18
		-33.20

Price change presented in Block 3:

	Price change	-5%	-10%	-15%
No. of period	1	-177.23	-345.31	-512.89

Notes. Participants were randomly assigned into the conditions of incurring from 5% to 40% loss in block 1, either 2 or 4 periods of flat prices, and from 5% to 15% of second loss. There are 72 possible combinations (Block1:12 conditions x Block2: 2 conditions x Block3: 3 conditions). Besides, the order of presenting each price within Block 1 and 2 was randomized.

Table 2. Probability of capitulation in cases of high vs. low expectation and high vs. low adapted reference point.

Capitulation Probability			
		Adapted reference point	
		Low	High
Expectation	Negative	0.182	0.250
	Positive	0.042	0.031

Notes. Median split was performed on adapted reference point. Expectation equals 6 or above in the 9-point scale is regard as positive expectation, otherwise negative expectation.

Figure 1. Piecewise Exponential Value Function.

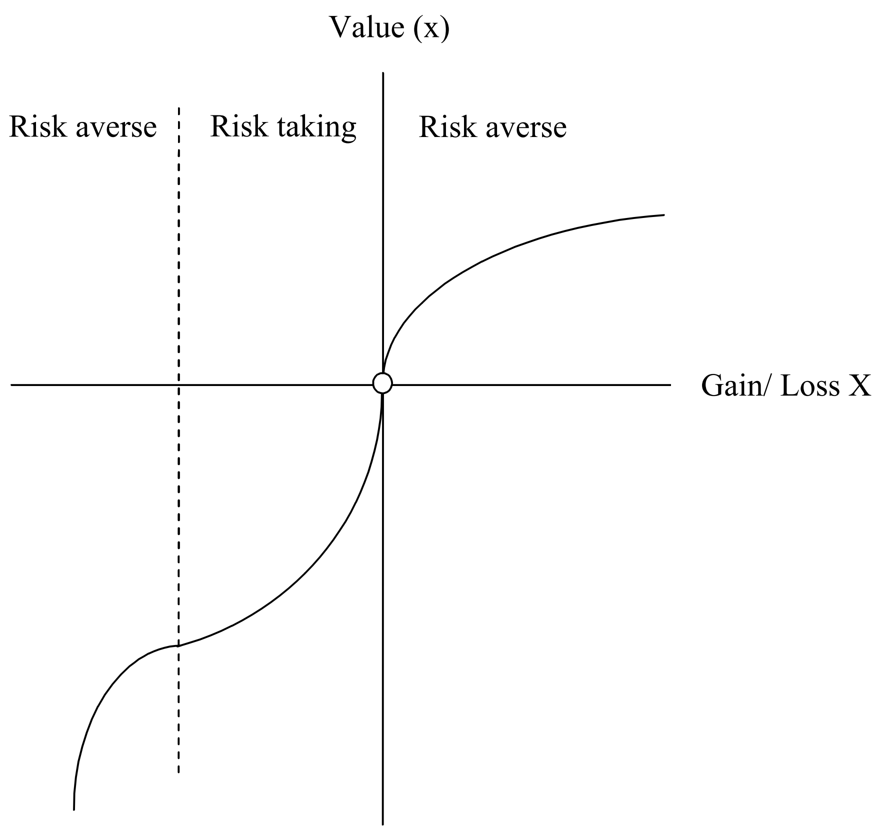


Figure 2. Proposed Model of Decision-making in Holding/Capitulating on Losing Investment.

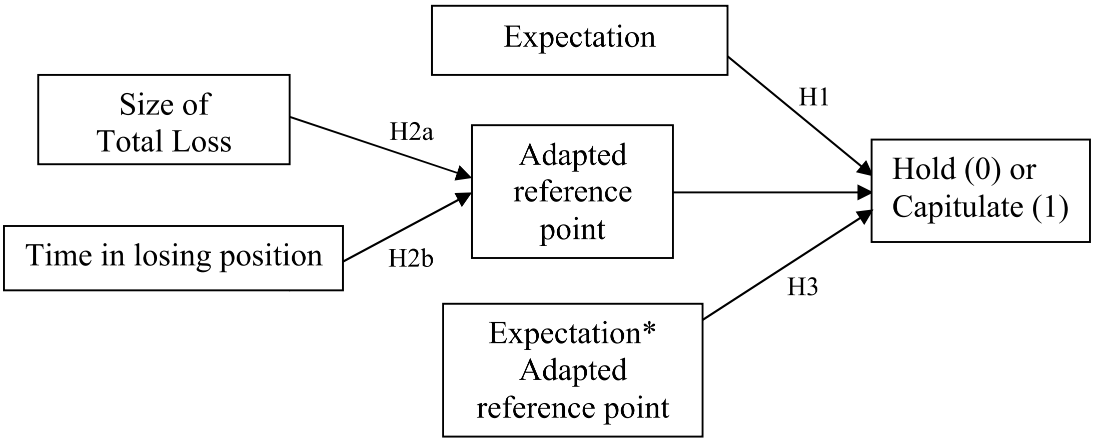
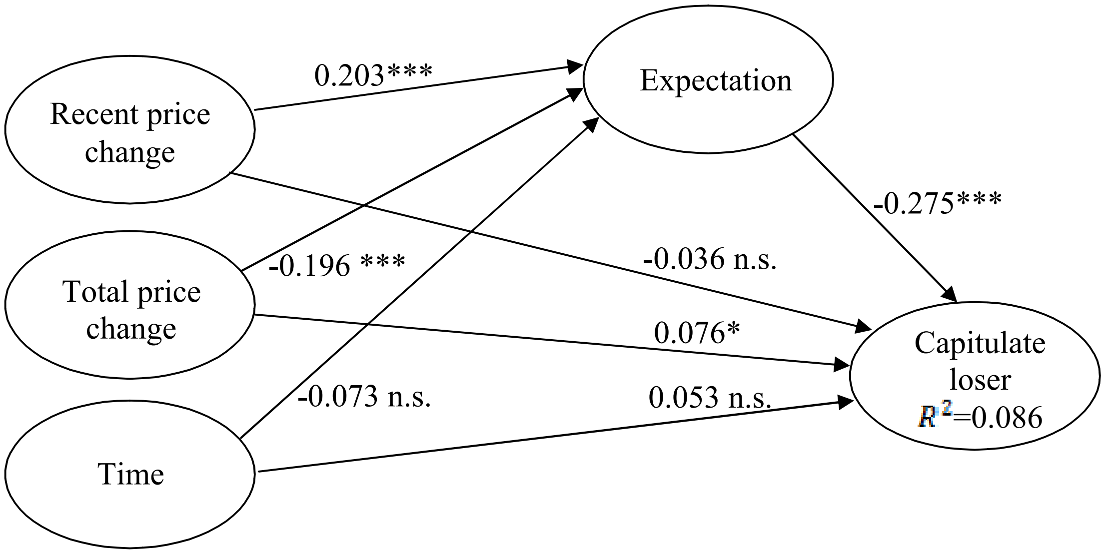
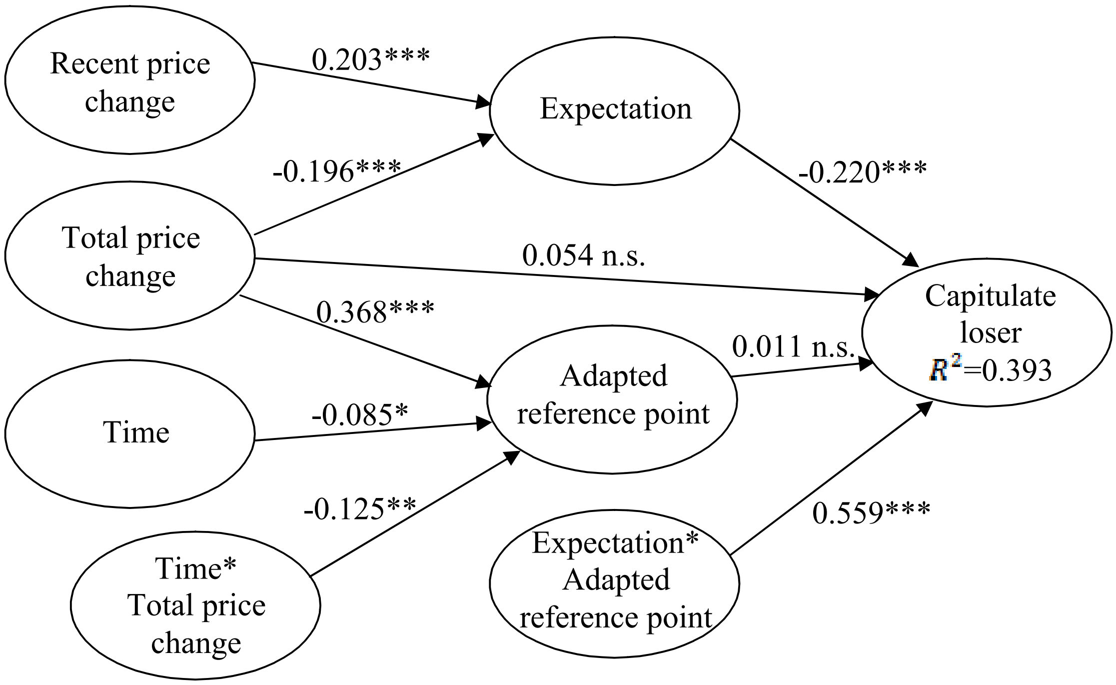


Figure 3. Preliminary PLS Results (Adapted Reference Point Not Included).



Notes: * p < .05; *** p < .001; n.s. = not significant, results based on two-tailed t-test.

Figure 4. Complete PLS Results.



Notes: * p < .05; ** p < .01; *** p < .001; n.s. = not significant, results based on two-tailed t-test. The insignificant relations shown Figure 3, include effects of recent loss size and time in losing position on capitulation tendency; and effect of time in losing position on expectation, remained insignificant in this analysis. For simplicity, these relations are not shown in Figure 4.