# The Disposition Effect: Explanations, Experimental Evidence, and Implications for Asset Pricing

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## Symbols in Chapter 1

| | |
|---|---|
| $u(\cdot)$ | Utility function |
| $x$ | Final wealth |
| $y$ | Foregone assets |
| $g(\cdot)$ | Function used in the preference function in regret theory |
| $f(\cdot)$ | Function used in the preference function in regret theory; "regret function" |
| $P_t$ | Price of a risky asset at time $t$ |
| $E[\cdot]$ | Expected value of a random variable |
| $n$ | Number of units of a risky asset |

## Symbols in Chapter 2

| | |
|---|---|
| $X_t$ | Demand for the risky asset at time $t$ |
| $P_t$ | Price of the risky asset at time $t$ |

| | |
|---|---|
| $D_t$ | Dividend of the risky asset at time $t$ |
| $r$ | Rate of return of the riskless asset |
| $R$ | $1 + r$ |
| $Q_t$ | Excess return of the risky asset at time $t$: $Q_t = P_t + D_t - RP_t$ |
| $E_t[\cdot]$ | Expected value conditional on information at time $t$ |
| $Var_t[\cdot]$ | Variance conditional on information at time $t$ |
| $C_t$ | Reference point a time $t$; the index $t$ is suppressed if the reference point is time-invariant |
| $\bar{X}$ | Fixed supply of the risky asset |
| $Cov[\cdot, \cdot]$ | Covariance of two random variables |
| $E[\cdot]$ | Expected value of a random variable |
| $\theta_t$ | Residual random variable |
| $T$ | Number of trading periods |
| $F$ | Final dividend of the risky asset in period $T + 1$ |
| $\varepsilon_t$ | In the model with finite (infinite) trading: News about the final (current) dividend |
| $\mu_0$ | Parameter of the distribution of $F$ |
| $\sigma^2$, $\sigma_\varepsilon^2$ | Variance of $\varepsilon_t$ |
| $a$, $b$ | Positive constants |
| $\gamma$ | Parameter of the demand function for the risky asset |

| | |
|---|---|
| $Z_t$ | Measure of prior gains: $Z_t = P_t - C_t$ |
| $\alpha_0,\ \alpha_1$ | Positive constants |
| $P_t^*$ | Fundamental solution |
| $B_t$ | Bubble |
| $\eta_t$ | Bubble innovation at time $t$ |
| $\sigma_\eta^2$ | Variance of bubble innovations |
| $\sigma_{\varepsilon\eta}$ | Covariance between bubble and dividend innovations |
| $\beta_0,\ \beta_1$ | Positive constants |
| $\delta$ | Positive constant measuring the degree of belief in mean reversion |
| $f(t)$ | Deterministic function of time |
| $c(t)$ | Deterministic function of time |
| $m(t)$ | Deterministic function of time |

# Symbols in Chapter 3

| | |
|---|---|
| $X_{j,t}^d$ | Demand for the risky asset by disposition investor $j$ at time $t$ |
| $P_t$ | Price of the risky asset at time $t$ |
| $D_t$ | Dividend of the risky asset at time $t$ |
| $r$ | Rate of return of the riskless asset |
| $R$ | $1 + r$ |

| | |
|---|---|
| $Q_t$ | Excess return of the risky asset at time $t$: $Q_t = P_t + D_t - RP_t$ |
| $C_{j,t}$ | Reference point of investor $j$ at time $t$ |
| $E_t[\cdot]$ | Expected value conditional on information at time $t$ |
| $Var_t[\cdot]$ | Variance conditional on information at time $t$ |
| $G^d$ | Distribution function of disposition investors |
| $X^s_{k,t}$ | Demand for the risky asset by smart investor $k$ at time $t$ |
| $\tau$ | Parameter of the demand of a smart investor |
| $G^s$ | Distribution function of smart investors |
| $X_t$ | Aggregate demand for the risky asset |
| $F$ | Final dividend of the risky asset in period 3 |
| $\varepsilon_t$ | News about the final dividend $F$ at time $t$ |
| $\mu_0$ | Parameter of the distribution of $F$ |
| $\bar{X}$ | Fixed supply of the risky asset |
| $S_t$ | Risk-adjusted expected (excess) return: $S_t = \frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ |
| $V_t$ | Volume in period $t$ |

# Symbols in Chapter 4

| | |
|---|---|
| $v(\cdot)$ | Prospect theory value function |
| $\alpha$ | Constant; $0 < \alpha < 1$ |

$x$ Number of units

$p$ Two-sided significance level

# Preface

Many financial economists used to think that stock returns, much like coin flips, are essentially unpredictable. This is the random walk hypothesis of stock prices. The popularity of the random walk hypothesis derived from both theory and empirical evidence: Samuelson (1965) established that equilibrium returns are unpredictable if expectations of future dividends are unbiased *and* the required rate of return is constant, and the data seemed to support the random walk hypothesis (Fama (1970)). While there has always been evidence of slight predictability of returns, this predictability appeared so small that it was deemed not exploitable after transaction costs, or it was considered a statistical artifact which would surely disappear out of sample.

Today, it is widely accepted that stock returns have significant predictable components (Cochrane (1999a)). At long time horizons, variables such as the dividend yield (dividend/price) or the price-earnings ratio can predict substantial amounts of return variation (see, for example, Fama and French (1988)). Even past returns alone have predictive power. There is evidence of long-term reversals, i.e. negative autocorrelation of short-term returns separated by long lags, both for individual stocks and the market as a whole (De Bondt and Thaler (1985), Poterba and Summers (1988), Lakonishok, Shleifer and Vishny (1994)). And there is evidence of short-term positive autocorrelation of returns, again for individual stocks and the market as a whole (Cutler, Poterba and Summers (1991), Jegadeesh and Titman

(1993)). See Fama (1998) and Hawawini and Keim (1995) for surveys of these and other kinds of predictability (e.g. event-based predictability).

The evidence of return predictability is a driving factor behind the growth of the literature on behavioral finance, i.e. finance that considers explanations based on imperfect rationality. To be sure, the evidence on predictability can be explained using standard preferences. One possibility is that predictability reflects time-varying required rates of return. Samuelson's (1965) unpredictability result is based on the assumption of a constant required rate of return. But efforts to link predictability to (rational) time-varying required rates of return have not been successful (e.g. MacKinlay (1995)).[1] Another possibility is that returns are actually unpredictable and the apparent predictability reflects mere chance deviations (Fama (1998)). But this explanation appears to be disproved by the fact that many of the patterns in returns are stable across time and across different markets (Hawawini and Keim (1995)).

There are two main branches in the literature on behavioral finance.[2] A first branch attempts to link theoretically the observed patterns in asset returns to specific departures from standard assumptions about behavior. This literature is based on the assumption that arbitrage is limited, i.e. the assumption that smart investors or "arbitrageurs" (investors with standard preferences) fail to eliminate the price impact of not-so-smart investors (investors with non-standard preferences).[3] It is also—typically less explicitly—based on the assumption that agents do not learn

[1] According to Cochrane (1999b), roughly half of the academic studies interpret predictability as time-varying premia for holding real and economically meaningful risks. The other half interpret them as evidence that investors are systematically irrational.

[2] There are other branches, e.g. the empirical literature on patterns in asset returns ("anomalies") or the literature on corporate finance under imperfect rationality. See Hirshleifer (2001) for a survey of the literature on behavioral finance.

[3] Barberis and Thaler (2001) discuss in detail why arbitrage may be limited. Crucial conditions are risk aversion together with short time horizons on the part of the arbitrageurs.

to overcome their biases and errors. A second main branch of behavioral finance is empirical and studies investor behavior. Odean (1998a), for example, examines the investment behavior of holders of accounts in a discount brokerage.

There is not much of a link between the two branches. Hardly ever does the theoretical branch make use of the patterns in observed behavior documented in the empirical branch. A notable exception is the early model of positive feedback trading by De Long, Shleifer, Summers and Waldmann (1990) that was apparently motivated by the observation of the behavior of "portfolio insurers." Rather, departures from standard assumptions about behavior are typically motivated by experimental evidence from the literature on individual decision making (e.g. Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer and Subrahmanyam (1998)), or mere plausibility (e.g. Abel (2001), Hong and Stein (1999)).

In the present dissertation I attempt to establish a link between a documented pattern of investor behavior, the disposition effect, and a documented pattern of stock returns, momentum. I also discuss explanations for the disposition effect and, in an experiment, study factors that influence whether individuals exhibit the disposition effect. Before previewing the results of this dissertation in more detail in Subsection 0.3, it is important to articulate the reason for studying the disposition effect in the first place. The reason is simply the substantial amount of evidence that investors do exhibit the disposition effect. This evidence is surveyed in Subsection 0.1. I go on to briefly discuss the evidence on momentum and the various existing explanations for it in Subsection 0.2.

## 0.1 The Disposition Effect

The term "disposition effect" was coined by Shefrin and Statman (1985) to describe the tendency to "sell winners too early and ride losers too long" (p. 778) relative to normative theory of investor behavior. The term "winner" in this definition refers to a stock with capital gains, i.e. a stock with a current price that is higher than the initial purchase price. Conversely, a "loser" is a stock with a current price that is lower than the initial purchase price. According to Shefrin and Statman (1985) the disposition effect belongs to the "general folklore about investing" (p. 778). Shefrin and Statman provide some weak evidence of the disposition effect based on data on mutual fund redemptions. Their paper started a large literature on the subject.

The original definition by Shefrin and Statman as quoted above defines the disposition effect as a difference in the length of the holding period of winners and losers relative to a normative benchmark. This is not what is studied in most of the empirical literature on the subject. Most empirical work—including the empirical part in Shefrin and Statman (1985)—focuses not on the length of the holding period but rather on the difference in behavior for winners and losers at a *given point in time*. According to this interpretation, the disposition effect means that, at any point in time, winners are sold more readily than losers. This interpretation is more meaningful from a theoretical perspective also, because the length of the holding period is typically not thought of as a direct choice variable. Rather, the length of holding period results indirectly from a sequence of decisions to buy, to hold or to purchase additional shares, or to sell.

There are two kinds of empirical studies on the disposition effect. There are studies, such as Shefrin and Statman (1985), that offer indirect evidence from aggregate data. In a study of trading volume of U.S. stocks, Lakonishok and Smidt (1986) find that abnormal turnover (shares traded divided by shares outstanding corrected for market-wide changes in turnover) is positively correlated with past price changes. Such a correlation is consistent with the disposition effect. Interestingly, the positive correlation between abnormal turnover and past price changes exhibits a seasonality. In December the correlation is weaker, a finding which is interpreted by Lakonishok and Smidt as evidence of tax-related trading at year-end. Ferris, Haugen and Makhija (1988) demonstrate for a set of very small U.S. stocks that contemporary volume can be predicted with historic volume at differential price levels: If there was high volume at higher than current prices in the past, i.e. there are many investors holding paper losses, current volume is low. The opposite is true if there was high volume at lower prices in the past.

Most work, however, offers direct evidence from observations of individual behavior. Odean (1998a) documents the disposition effect in the actual trading of 10,000 U.S. holders of discount brokerage accounts in the period 1987 to 1993. He demonstrates that investors sell winners more readily than losers in the sense that they realize gains relatively more frequently than losses.[4] This finding remains intact after controlling for factors that might affect trading decisions such as portfolio rebalancing considerations or the (relatively) higher costs of trading low-priced stocks. The disposition effect is present in every calendar month except December, where, possibly for tax reasons, losers are sold relatively more frequently than winners. Grinblatt and Keloharju (2001) study the trading behavior of different groups of investors on the Finnish stock market in 1995 and 1996. They estimate logit models of the probability to sell or to hold. In line with the disposition effect, capital losses lower the propensity to sell significantly. Shapira and Venezia (2001) document the disposition effect for (non-professional and professional) Israeli stock investors. Ranguelova (2000) finds evidence of the disposition effect using a dataset similar to Odean's (1998a). A different set of papers studies the trading behavior of futures traders. Coval and Shumway (2000) study the behavior of market makers in Treasury bond futures on the Chicago Board of Trade. They find strong evidence of the disposition effect. Locke and Mann (1999) find weak evidence of the disposition

[4] Moreover, Odean finds that if investors purchase additional shares of stocks they already hold, they purchase losers relatively more often rather than winners.

effect in the behavior of professional futures traders on the Chicago Mercantile Exchange. Heisler (1994) documents the disposition effect for small Treasury futures speculators on the Chicago Board of Trade. There is also evidence of the disposition effect in the real estate market. Genovese and Mayer (2001) study the market for condominiums in downtown Boston in the period 1990-97. They find that owners subject to nominal losses set higher asking prices and sell less frequently than other owners (see also Shiller and Case (1988)). Finally, there is experimental evidence of the disposition effect. Weber and Camerer (1998) study the trading behavior of subjects confronted with exogenous price sequences with a fixed drift that is unknown to subjects. They find that subjects tend to sell winners rather than losers, even though learning from the previous gain or loss about the unknown fixed drift would imply the opposite behavior.

So there is by now a substantial body of evidence that some investors do display the disposition effect. Explanations for the disposition effect will be the subject of Chapter 1 of this dissertation. Chapter 4 reports results on the disposition effect from an experiment on the influence of prior outcomes on risky choice.

## 0.2 Momentum

A momentum strategy is a trading strategy that buys a portfolio of past winners (stocks with very good performance, e.g. those in the top performance decile) and shorts a portfolio of past losers (stocks with very bad performance, e.g. those in the bottom performance decile).[5] It appears that momentum strategies using performance over the past three to twelve months to select winners and losers are profitable over the subsequent three to twelve months. This fact is termed "momentum."

[5] Note the difference in the use of the terms winners and losers. In the literature on the disposition these terms refer to assets with capital gains or losses relative to some reference point. In the literature on momentum these terms refer to assets with very good or bad past performance.

Momentum is widely interpreted as evidence of positive autocorrelation of stock returns. Daniel, Hirshleifer and Subrahmanyam (1998), for example, define momentum as "positive short-term autocorrelation of stock returns, for individual stocks and the market as a whole" (p. 1839) and then quote studies on the profitability of momentum strategies as evidence of positive autocorrelations. There are, however, alternative interpretations. Conrad and Kaul (1998) point out that the profitability of momentum strategies could simply be a consequence of cross-sectional variation in unconditional expected returns. Suppose that stock prices follow random walks with drifts, so that returns are uncorrelated, and that different stocks have different drifts. In such a case, momentum strategies work because the winner portfolio on average selects stocks with high unconditional expected return and the loser portfolio on average selects stocks with low unconditional expected return. Momentum profits would then simply reflect this difference in unconditional expected return. But this hypothesis is contradicted by the data. As Jegadeesh and Titman (1999) show, momentum portfolios earn *negative* returns from about one year after the portfolio formation on. This rejects the Conrad and Kaul hypothesis which implies that winners on average outperform losers in any subsequent time period.

In another interpretation of the profitability of momentum strategies, Lewellen (2000) argues that momentum could reflect negative cross-autocorrelations between different stocks rather than positive autocorrelation for individual stocks.

In the present dissertation I follow the dominant view in the literature and use momentum as a synonym for positive autocorrelation of excess returns of individual stocks.[6] Cochrane (1999a) argues that momentum can be seen as a new way of looking at an old phenomenon, the small positive autocorrelation of monthly excess stock returns (Fama (1965)), together with the wide dispersion of individual stock

[6] Positive autocorrelations of *index* returns of various asset classes (e.g. stocks, bonds, real estate) have been documented by Cutler, Poterba and Summers (1991).

returns. Since the winner stocks used in momentum strategies typically went up dramatically in the ranking period, and the loser stocks went down dramatically, just a small autocorrelation of excess returns can generate an expected excess return of a few percent for the momentum strategy over the subsequent few months.

### 0.2.1 Empirical Evidence

That momentum strategies are profitable has been demonstrated in a number of studies for different stock markets and periods of time. In their seminal paper, Jegadeesh and Titman (1993) document that, in a broad sample of U.S. stocks over the period 1965 to 1989, a momentum strategy using past six-month winners and losers earns roughly one percent per month over the following six months. Their results have been confirmed most recently by Grundy and Martin (2001) who study momentum profits for U.S. stocks in the period 1926 to 1995. Rouwenhorst (1998) finds that the U.S. results carry over to European markets. He documents momentum in a sample of stocks from 12 different European markets in the period 1978 to 1995. Schiereck, De Bondt and Weber (2000), using a sample of major German stocks in the period 1961 to 1991, find momentum of a similar magnitude as in the U.S.

A number of empirical studies have attempted to link momentum profits to sorting variables in addition to prior performance. One natural sorting variable is firm size (market capitalization). Hong, Lim and Stein (2000) report a relation between size and momentum profits that has an inverse U-shape: Momentum profits are low for the smallest stocks, high for small to medium-size stocks, and low again for large stocks. Hong, Lim and Stein (2000) also report that momentum strategies are particularly profitable for stocks with low "residual analyst coverage", i.e. a low residual from a regression of analyst coverage on firm size. Lee and Swaminathan (2000) study the link between momentum profits and turnover (number of shares traded divided by the number of shares outstanding). They find that momentum is more pronounced for high-turnover stocks. In addition they find a strong asymmetry in that the effect of turnover on momentum is present only for stocks in the loser portfolio; for past winners there is hardly any effect of turnover on momentum. Moskowitz and Grinblatt (1999) study the relation between momentum and industry affiliation. They argue that momentum profits are primarily due to industry effects. Their results are challenged, however, by Grundy and Martin (2001) who find that industry effects are not the primary cause of momentum. Finally, Grundy and Martin (2001) find that momentum profits are not due to exposure to the Fama-French factors.

### 0.2.2 Existing Explanations for Momentum

The apparent positive autocorrelation of returns at time horizons of three to twelve months has motivated a number of models based on imperfect rationality. This section provides a limited overview of these models. The overview is limited in that it does not contain a complete description of all aspects of the respective models. I focus only on the aspects that pertain to momentum. Also, there are probably many other explanations for positive autocorrelations of returns that I do not mention. I discuss only those models that were designed (at least in part) to address momentum, i.e. positive autocorrelations at time horizons of three to twelve months.

In De Long, Shleifer, Summers and Waldmann (1990) momentum stems from the fact that some risk-averse investors ("informed rational speculators") receive private information ahead of other investors, who fail to learn this private information from the market price. Their model has three trading periods. There is a public signal about terminal (fundamental) value in the third trading period. In the second trading period, informed speculators receive a noisy private signal about the public signal in period three. Since the private signal is noisy, the second period price reflects uncertainty about demand in the third period. And since informed speculators are risk-averse the second period price is lower than the expected third period price which implies positive correlation of returns, or momentum.

Cutler, Poterba and Summers (1990) discuss different explanations for momentum. They model the market for a finitely-lived asset. There are three types of traders: "Rational traders" whose demand is a linear function of expected return over the next period, "fundamentals traders" whose demand is a linear function of the difference between price and perceived terminal value of the asset, and "feedback traders" whose demand is a linear function of current and past returns. The model can generate positive autocorrelation of returns in three ways. First, if fundamentals traders learn about the true terminal value with a lag relative to rational traders. The mechanism is similar to the one discussed in De Long, Shleifer, Summers and Waldmann (1990). Second, if there is negative feedback trading, i.e. feedback traders sell following positive returns and buy following negative returns. For rational traders to be willing to take offsetting positions, returns must on average be high following positive returns and low following negative returns, so there is positive autocorrelation. Third and finally, momentum can result from slowly adjusting feedback traders. If feedback traders demand long (short) positions over long periods of time, expected return has to be below (above) the long-run average for long periods of time, i.e. returns are positively correlated.

Barberis, Shleifer and Vishny (1998) model how momentum can arise from biased expectations. In their model, prices are determined by a representative investor who discounts expected dividends at a constant rate. Positive autocorrelation obtains because expectations of future dividends are biased. The investor thinks—and forms his expectations of future dividends accordingly—that dividends follow a mean-reverting process, while dividends actually follow a random walk. Put differently, the investor thinks changes in dividends have a temporary component, while in fact they are permanent. This means that prices underreact to new information relative to the case of unbiased expectations. Barberis, Shleifer and Vishny (1998) view their model as a crude way of capturing the psychological evidence on the conservatism bias (Edwards (1968)). Conservatism means that individuals update their probability distributions only insufficiently in the face of new information. They put too little weight on new information and too much weight on the prior distribution compared with a Bayesian individual.

Daniel, Hirshleifer and Subrahmanyam (1998) also focus on biased expectations to explain momentum. In their model, it is a risk-neutral overconfident investor who determines prices. Overconfidence is modeled as an overestimation of the precision of private signals about fundamental value. There is hence an overreaction of prices to new private information relative to the case of unbiased expectations. The investor is assumed to update his confidence over time in an asymmetric manner. If later signals confirm the initial private signal (e.g. good news arrives after a buy signal), confidence rises, but if the initial signal is not confirmed, confidence is not reduced. This asymmetric updating of confidence, termed biased self-attribution, leads on average to a delayed further overreaction to the initial private signal. Daniel, Hirshleifer and Subrahmanyam (1998) show that such continuing overreaction causes momentum. Overconfidence and biased self-attribution are biases that are well-documented in the psychology literature.

In Hong and Stein (1999), momentum stems from the fact that investors ignore information: Investors form their demand based on their private information alone, they do not take into account the information conveyed by the asset price itself. Hong and Stein assume that different investors receive different signals at any point in time but they also learn about other investors' earlier signals, a process which they call slow information diffusion. Together with the assumption that investors fail to learn from prices this means that prices underreact to news and that this initial underreaction is corrected over time so that there is momentum. The mechanism is very similar to the one discussed by Cutler, Poterba and Summers (1990), based on fundamentals traders reacting to fundamental news only with a lag.

## 0.3 Outline of the Dissertation

The theme of this dissertation is the disposition effect. Given the substantial amount of evidence for the disposition effect (Subsection 0.1), it is natural to ask why investors tend to behave this way. This question is addressed in Chapter 1. The existing literature has attributed the disposition effect to biases in return expectations, time-varying risk-aversion based on the value function of prospect theory, and regret theory. I review these explanations and argue that none of them is satisfactory because they either fail to capture the disposition effect or because they are not supported by empirical evidence. I point out that there is a large psychological literature on entrapment, escalation of commitment, and sunk cost, that studies phenomena that are very similar to the disposition effect. This literature suggests an explanation of the disposition effect based on cognitive dissonance theory.

Chapter 2 deals with the question how market prices are affected by the disposition effect. I study the time series of equilibrium returns in a model with a representative investor. Through the disposition effect, current demand is affected by past prices. This link between past prices and demand translates into a patterns in equilibrium returns. The main result is that the disposition effect implies trend continuation: Prior gains are on average followed by high returns, prior losses are on average followed by low returns. This general conclusion stems from the negative feedback nature of the disposition effect. If investors like to hold losers and do not like to hold winners, then—in equilibrium—there has to be a reward (a higher expected return) for holding winners and selling losers. Under certain assumptions this trend continuation translates into a positive autocorrelation of excess returns, i.e. momentum. In contrast to other recent explanations, this momentum result does not rely on biases in the expectation of fundamentals. It is consequently independent of whether price changes are driven by news about fundamentals or something else (price bubbles, noise) and it is consistent with prices over- or underreacting to news about fundamentals.

The result that the disposition effect leads to trend continuation is a straightforward application of equilibrium logic. Nevertheless, there appears to be some confusion about this issue in the literature. Klein (2001) and Lo and MacKinlay (1990) state that the disposition effect can be seen as a cause of reversals, i.e. a negative relationship between past and expected returns. Conversely, Grinblatt and Moskowitz (2000) and Hvidkjaer (2000) both attribute momentum to tax-loss selling. Tax-loss selling is behavior that is opposite to the disposition effect. By turning the logic behind the momentum result based on the disposition effect on its head, it is easy to see that tax-loss selling implies reversals rather than momentum (Klein (2001)).

In Chapter 3 I study trading volume under the assumption of the disposition effect. By linking current asset demand to prior gains or losses the disposition effect motivates trade and brings about patterns in equilibrium returns. There are three cases in which the disposition effect leads to trade: Profit taking, i.e. selling to realize capital gains, escalation of commitment, i.e. buying after losses, and re-investment of realized gains. In equilibrium, profit taking increases expected return whereas escalation of commitment and re-investment of the proceeds from profit-taking decrease expected return. I argue that the patterns in trade and returns generated by the disposition effect are broadly consistent with the evidence on momentum and trading volume (Lee and Swaminathan (2000)): The disposition effect gives rise to a positive relation between current and future returns (momentum). It implies that high volume indicates strong momentum, and that this link between volume and momentum is more pronounced for losers. The intuition for this result is that, if investors are reluctant to realize losses, then any trading of losers indicates buying pressure and consequently reduced expected return.

Chapter 4 studies the influence of prior gains or losses on risk taking in an experiment. I contrast two competing hypotheses: The hypothesis of anticyclical risk taking, i.e. reduced risk taking following a gain and increased risk taking following a loss, as the disposition effect would imply, and the hypothesis of procyclical risk taking, i.e. increased risk taking following a gain—the "house-money effect" (Thaler and Johnson (1990))—and decreased risk taking following a loss. The hypothesis of procyclical risk taking is at the heart of Barberis, Huang and Santos' (2001) and Barberis and Huang's (2001) theory of investor behavior that explains many empirical regularities in aggregate and individual stock returns. Contrary to this hypothesis, I find that in a simple dynamic portfolio choice experiment a prior gain leads to a slight decrease in risk taking and a prior loss leads to a great increase in risk taking - consistent with the disposition effect. Moreover, I demonstrate a strong framing effect: The influence of prior outcomes on risky choice is affected by the presentation format of the decision problem. It is also (weakly) affected by whether the prior outcome results from free choice or an assigned choice. By manipulating the presentation format and assigning initial choices it is possible to induce behavior along the lines of Barberis, Huang and Santos, i.e. increased risk taking following a gain and decreased risk taking following a loss.

# Chapter 1

# What Drives the Disposition Effect?

## 1.1 Introduction

From simple observation of friends, colleagues, and maybe ourselves, it is evident that individual investment behavior is often at odds with the assumptions typically made in finance. It is also evident that there are large individual differences in the way investors behave. Recently, some effort has been made to find out how behavior differs *systematically* from the normative models of standard finance theory. One of the better documented behavioral patterns emerging from this research is the disposition effect. The disposition effect describes the tendency to "sell winners too early and ride losers too long" relative to the prescriptions of normative theory (Shefrin and Statman (1985)) where the terms "winners" and "losers" refer to assets that have appreciated or depreciated since purchase. That such behavior is relevant for some investors has been documented in a number of studies. See Odean (1998) and Weber and Camerer (1998) for evidence and overviews of the literature. There are of course many good reasons why prior performance and portfolio choices should influence current investment decision such as portfolio rebalancing, transaction costs, capital gains taxes, etc. This is not what the disposition effect is about. The disposition effect describes a tendency to sell winners and hold losers *over and above* what is implied by normative theory.

While the question *whether* there is a disposition effect (for some investors) arguably has been settled, the question *why* there is such an effect in the first place has received only little attention. This is unfortunate for at least two reasons. The disposition effect describes sell decisions only and is thus only a partial description of investor behavior. Understanding the driving factors behind it might help us in understanding other aspects of investor behavior, such as how initial buy decisions are made. Also, knowing what drives the disposition effect might help us in determining factors that encourage or discourage it. Such information may be useful to help individual investors avoid the disposition effect.

The existing literature has attributed the disposition effect to biases in return expectations, time-varying risk aversion based on the value function of prospect theory, and regret theory. I assess these explanations according to two criteria. First, does the explanation really capture the disposition effect, i.e. does it link current portfolio choice to prior returns (whether the asset is a winner or a loser) and prior portfolio choice (whether the asset is held or not)? Second, is there any empirical evidence (other than the fact that there is a disposition effect) that supports the explanation? As it turns out, none of the extant explanations for the disposition effect is satisfactory according to these criteria.

After having established the insufficiencies of existing explanations, I go on to point out that the disposition effect is a special case of entrapment, a phenomenon that has been studied extensively by psychologists over the past 25 years (e.g. Staw (1997)). The psychological literature on entrapment suggests a different explanation for the disposition effect based on cognitive dissonance theory. According to this theory, motivational factors such as self justification are the driving force behind the disposition effect.

## 1.2 Extant Theories

The disposition effect describes the influence of prior performance (winners and losers are treated differently) and prior portfolio decisions (it makes a difference whether a stock is held or not) on current portfolio choice. How can there be such an influence? At the simplest level, standard economic theory implies that investment decisions are driven by expected return, risk, and the trade-off between these two arguments, i.e. risk aversion. From this perspective, the disposition effect can arise if any of these factors is affected by whether the asset is a winner or a loser. Two of the extant theories are based on such an argument. Unjustified belief in mean reversion implies that investors expect lower returns for winners and, conversely, higher returns for losers. The value function of prospect theory together with the assumption that investors integrate or "merge" the outcomes of successive investment periods implies that risk aversion depends on prior returns, so that investors can have high risk aversion after gains and low risk aversion after losses.[1]

Another possibility to obtain the disposition effect is to posit that investors do not care exclusively about risk and return but also about other things that are in turn affected by prior performance and portfolio choice. This is how the third extant explanation, regret theory, works. According to regret theory, individuals care not only about monetary outcomes but also about how these outcomes make them feel about the decision they made (e.g., the decision to buy or to hold a stock). The

[1] I am not aware of any discussion in the literature of the third possibility - that investors prefer to sell winners and hold losers because they think that losers are less risky than winners.

disposition effect arises if anticipated regret leads to a preference for selling winners rather than losers.

Supposing preferences over investment decisions can be described by some utility function, the disposition effect can arise, if prior performance and prior portfolio composition affect the arguments of the utility function or if they enter the utility function as distinct arguments. In the former case the disposition effect links current decisions *indirectly* to prior performance and portfolio. All of the mentioned theories of the disposition effect are based on such an indirect link. In the latter case utility and hence decisions would be *directly* affected by prior performance and portfolio decisions. It is not easy to come up with reasons why utility should depend directly on past performance or decisions. There is consequently only one explanation for the disposition effect along these lines. If investors care only about *realized* returns current decisions are directly influenced by past choices and returns. I briefly discuss this rationale for the disposition effect in Subsection 1.2.3.

### 1.2.1 Unjustified Belief in Mean Reversion

Consider an explanation for the disposition effect that is based on biased expectations of future returns. Investors might choose to sell winners and hold losers simply because they believe that winners have systematically lower future returns than losers. One reason for such a belief is that investors expect prices to mean revert.

Mean reversion means negative autocorrelation of returns: Above average returns in one period imply that the expected value of returns in subsequent periods are below the long-run average. If there is in fact no such mean reversion, i.e. the investor falsely believes returns to be negatively autocorrelated, such a pattern in returns motivates the disposition effect: After high returns, an investor expects lower returns inducing him to sell and after low returns, he expects higher returns inducing him to hold on to the asset or even purchase additional shares. Hence, as was pointed out by Odean (1998) and Weber and Camerer (1998), an unjustified or irrational belief in mean reversion can cause the disposition effect.[2] Is there any evidence of this particular bias outside the literature on the disposition effect?

The extent to which individuals form accurate expectations of asset prices has been studied experimentally. Andreassen (1987, 1988) has subjects make predictions of future returns based on historical prices. He studies whether forecasts are extrapolating, i.e. whether recent price trends are expected to continue, or regressive, i.e. whether recent trends are expected to reverse. If individuals believe in mean reversion, they will make regressive predictions. The evidence on whether predictions are extrapolative or regressive is mixed. While there seems to be some tendency for individuals to make regressive predictions, possibly motivated by a belief in mean reversion, this tendency is fragile. Andreassen (1987) finds that whether or not predictions are regressive or extrapolative depends crucially on whether or not investors attribute price movements to fundamental news. If price movements are news-related, investors expect a continuation of the trend, if there are no fundamental news investors expect a reversal. Maybe more important concerning the disposition effect are the findings in Andreassen (1988). Whether expectations are regressive or extrapolative depends on whether investors focus on price *levels* (leading to regressive predictions) or price *changes* (leading to extrapolative predictions). This observation is particularly damaging to the mean-reversion explanation since the disposition effect stresses the importance of prior price changes not levels. In a survey of individual and institutional investors, Shiller (1998) finds evidence of ex-

[2] Note that so far this is not an explanation in the true sense of the word. After all, why do people believe in mean reversion? One way to motivate a belief in mean reversion are the cognitive processes underlying the so-called gambler's fallacy. Just as roulette gamblers display a tendency to assume that red is more likely than black following a black number and vice versa, investors might feel that up-moves are more likely following down-moves.

trapolative expectations. In a questionnaire study of MBA students, Siebenmorgen and Weber (2000) find evidence of regressive expectations.

Whether investors believe in mean reversion seems to depend on a variety of factors whose relevance in practice is unclear. There is hence only weak empirical support for the hypothesis that belief in mean reversion explains the disposition effect but, conversely, also no strong evidence that investors do not believe in mean reversion. But there is a more fundamental concern about explaining the disposition effect through belief in mean reversion. As was stressed in the introduction the disposition effect links current demand to past returns *and* past portfolio choices. While belief in mean reversion provides a rationale for the tendency to sell winners and hold losers, it does not explain why this tendency applies only for stocks that are held. Under belief in mean reversion the desire to sell winners and hold losers is completely independent of whether or not the investor already holds the asset or not!

To summarize, belief in mean reversion does not explain the disposition effect unless one makes additional assumptions about why the belief in mean reversion translates into behavior only for those stocks that are in the portfolio. It remains unclear why investors should consistently overestimate the expected return for losers and underestimate the expected return for winners and there is only weak evidence that they actually do.

Unjustified belief in mean reversion is of course only one reason why investors might have biased expectations of future returns. Another reason that gets around the criticisms just discussed is that investors have a strong (and unjustified) belief in their stock picking skills: Suppose an investor believes he can successfully spot mispriced assets in the market. Such an investor would buy assets that he perceives to be undervalued. He would sell assets where he thinks the undervaluation that made him purchase the asset has been eliminated through a subsequent price rise (a winner asset) or through deterioration of his expectations for the asset. He would hold on to assets that have not appreciated or even depreciated (losers) because he thinks the initial undervaluation has not yet been corrected by the market. The disposition effect would thus be a simple consequence of the belief in one's stock picking skills. While it seems likely that many market participants are overly confident in their stock picking skills there is no systematic evidence on such behavior. In addition, exaggerated belief in stock picking cannot plausibly account for the disposition effect in experimental settings where subjects' expectations can, to some extent, be controlled. Finally, Weber and Camerer (1998) have demonstrated that the disposition effect can be greatly reduced when losses are automatically realized and investors are given the opportunity to re-invest. If one assumes that the formation of expectations is independent of whether there is automatic selling or not, this observation contradicts *any* explanation of the disposition effect based on biased expectations.

### 1.2.2 The S-Shape of the Value Function

The second explanation posits that prior returns change an investors preference for bearing risk, i.e. her risk aversion (Shefrin and Statman (1985), Odean (1998), Weber and Camerer (1998)).[3] It is argued that having made a gain on an investment in a stock increases risk aversion and having made a loss decreases risk aversion. Hence prior gains lower current demand for the asset, and prior losses increase it, so that investors might want to sell winners and hold or even escalate their commitment to

[3] Here, risk aversion does not refer to the local definition $-\frac{u''}{u'}$ but rather to the global definition: An investor is risk-averse, if his certainty equivalent for a lottery is lower than the expected payoff from the lottery, i.e. when there is a positive risk premium. Higher (lower) risk aversion refers to a higher (lower) risk premium. Note that this definition of risk aversion depends on the lottery in question. I.e. cases are possible where an individual is risk-averse for some lottery $A$ but not for some other lottery $B$.

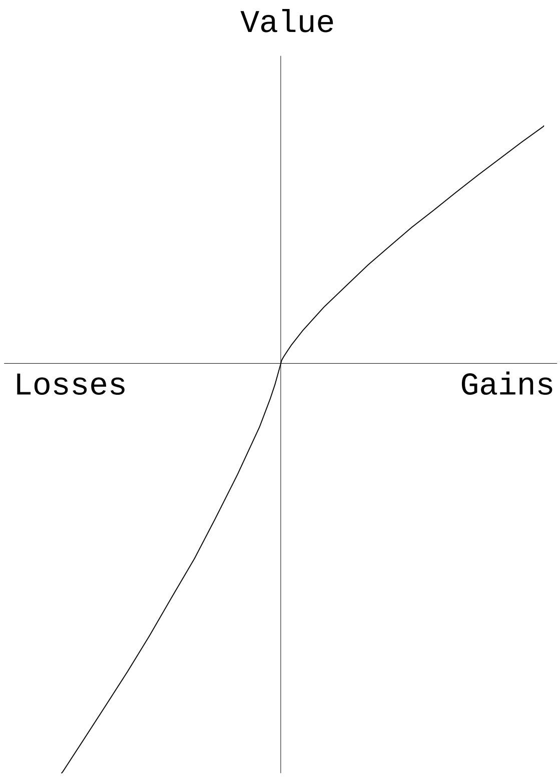


Figure 1.1: Prospect theory value function

losers.

This explanation for the disposition effect is typically loosely based on prospect theory.[4] Kahneman and Tversky (1979) observed in an experiment the reflection effect, the phenomenon of "risk seeking over losses and risk aversion over gains." They formalized this observation through a utility or value function that is defined over gains and losses relative to a reference point and that is concave over gains and convex over losses as in Figure 1.1.

The reference point turns out to be crucial for the disposition effect. It is argued that investors who hold a stock and those who do not use different reference points,

[4] Cf. Shefrin and Statman (1985), Odean (1998), Weber and Camerer (1998).

or, in the language of prospect theory, "frame" their investment decisions differently. For an investor who does not hold the stock the reference point for her investment decision is simply the current stock price. For an investor who holds the stock, the reference point is instead the initial purchase price.[5] The idea behind this distinction is that investors, once they purchase a stock, open a mental account for that stock and then "keep a running score on this account indicating gains or losses relative to the purchase price" (Shefrin and Statman (1985, p. 780)).

To see how the disposition effect can emerge in this framework, consider an investor who has made some losses on a particular stock. For such an investor the decision sell, hold, or to buy the stock is associated with choosing between lotteries whose payoffs are to a large part in the convex portion of his value function. Conversely, for an investor who has made some gains on an investment in a stock, possible payoffs associated with the decision to buy, sell, or to hold are to a large part in the concave portion of his value function. Consequently, the investor will be more risk-averse if she has prior gains than if she has prior losses. This explanation is based on two arguments: Investors integrate prior and future returns and they make portfolio choices so as to maximize the expectation of an S-shaped value function.[6]

Explaining the disposition effect with time-varying risk aversion is not really explaining it. It just begs the question why risk aversion changes over time. If one accepts that investors integrate past and future returns, this question boils down to why the value function has its characteristic S-form. Kahneman and Tversky (1979) attribute the shape of the value function to *decreasing sensitivity* to monetary

[5] There are alternative hypotheses about the setting of reference points. Gneezy (1998) finds evidence that investors use the highest historic price as reference point. Weber and Camerer (1998) find evidence of the use of multiple reference points (purchase prices *and* other previous prices).

[6] Gomes (2000) thoroughly discusses asset demand under these assumptions with only slight modifications. He shows that complex behavior arises, some of which is consistent, some of which is inconsistent with the disposition effect.

stimuli.

> "Many sensory and perceptual dimensions share the property that the psychological response is a concave function of the magnitude of physical change. For example, it is easier to discriminate between a change of 3° and a change of 6° in room temperature, than it is to discriminate between a change of 13° and 16°. We propose that this principle applies in particular to the evaluation of monetary changes. Thus, the difference in value between a gain of 100 and gain of 200 appears to be greater than the difference between a gain of 1,100 and a gain of 1,200. Similarly, the difference between a gain of 100 and a gain of 200 appears to be greater than the difference between a gain of 1,100 and a gain of 1,200." (p. 278)

This is a psychophysical explanation of risk preference. It proposes that the same psychological properties that underlie the perception of physical stimuli (e.g. temperature) underlie the evaluation of monetary stimuli (gains or losses). Decreasing sensitivity means that large gains do not add much more to overall enjoyment and large losses do not diminish overall enjoyment much more than do small losses. The value function is concave for gains and convex for losses. Translated into the context of the disposition effect this means that investors hold on to losers because they are not very sensitive to further losses and eager to sell winners because they are not very sensitive to further gains.

The popularity of the prospect-theory based explanation for the disposition effect—it is the explanation that is most frequently invoked—derives to a large part from the popularity of prospect theory itself. This popularity notwithstanding, the evidence on the S-shaped value function is actually quite mixed (see Hershey and Shoemaker (1980), Schneider and Lopes (1986), and more recently Laury and Holt (2000) and Stocké (2001)). Even more importantly, however, the claim that risk aversion decreases after losses and increases after gains is not derived from prospect theory. Prospect theory is a theory of one-shot decision making. The disposition effect is a phenomenon of sequential decision making. Hence any empirical evidence in favor of the S-shaped value function of prospect theory cannot be seen as evidence of this explanation for the disposition effect.

The relevant issue for the disposition effect is the influence of prior investment returns on subsequent risk taking behavior, an issue on which there is little evidence. The little evidence we have is completely contrary to the explanation for the disposition effect based on the value function of prospect theory. Thaler and Johnson (1990) investigate "the effect of prior outcomes on risky choice." In the context of choices between two-outcome gambles their results indicate behavior that contradicts the disposition effect: They find that prior gains lead to risk-seeking behavior and prior losses lead to risk-averse behavior! See also Barberis, Huang and Santos (2001) for a formalization of the results of Thaler and Johnson (1990) and a discussion of further evidence.

Based on the experimental results of Thaler and Johnson (1990), the presumed link between prior outcomes and current risk preferences that generates the disposition effect is hence rejected. One interpretation of this result is that individuals are actually more sensitive to losses that come on the heels of prior losses rather than less as implied by the joint assumption of decreasing sensitivity and integration of successive returns. It is hence useful to reconsider the rationale behind the S-shape of the value function: decreasing sensitivity, i.e. the assumption that the psychological intensity of an outcome diminishes with its magnitude. While this is plausible for comparisons between changes in outcomes of one-shot gambles, its plausibility in the context of sequential decision making is less clear. Kahneman and Snell (1990) investigate the distinction between one-shot and sequential decision making for gambles involving losses in a different context. Subjects were asked whether some stimulus such as a severe headache was getting better or worse over several days. Most subjects thought that the headache was getting worse, i.e. that a day of headache was more painful following days with headache than following days without headache. Note that this is a question about a sequence of losses (days of headache). In contrast, in one-shot gambles involving "days of headache" as payoffs, subjects gave risk-seeking responses, consistent with decreasing sensitivity. The analogy to the case of an investment situation is straightforward. Investors display decreasing sensitivity to payoffs in one-shot gambles. They do also display increasing sensitivity to incremental losses following prior losses in a sequence of decisions. Since the disposition effect arises in the context of sequential decisions, Kahneman and Snell's results cast doubt on the validity of prospect-theory based explanation for the disposition effect.

To summarize, the assumption that investors integrate past and future returns and maximize an S-shaped value function as in prospect theory can mean that risk aversion is higher following gains than following losses, which would imply the disposition effect. The most powerful element of this explanation is that investors who hold the asset frame their investment decisions differently, and hence act differently, compared with the case if they did not hold the asset. It seems plausible that investors think about the price of an asset in their portfolio in relation to historical prices such as the initial purchase price. The idea that the initial purchase price serves as point of comparison for subsequent prices is an appealing rationale for why it makes a difference whether the investor already holds the asset or not. The contention that risk aversion following gains is higher than following losses is, however, not supported by the experimental evidence in Thaler and Johnson (1990) and Kahneman and Snell (1990).

### 1.2.3 Regret Theory

Shefrin and Statman (1985) put forward regret, "an emotional feeling associated with the ex post knowledge that a different past decision would have fared better than the one chosen" (p. 781), as one of the factors leading to the disposition effect. Shiller (1999) argued that "Regret theory may apparently help explain the fact that investors defer the selling of stocks that have gone down in value and accelerate the selling of stocks that have gone up in value" (p. 1313).

Regret theory is a motivational theory of decision making. Its basic assumption is that individuals are concerned with how the outcome of the decision is going to make them feel *about the decision itself.* In contrast, the traditional expectancy value theories such as prospect theory or expected utility theory emphasize that decisions are a function of probabilities and values or utilities of outcomes alone. How regret can be incorporated into the expected utility framework was suggested by Bell (1982) and Loomes and Sugden (1982). To capture regret, a two-attribute utility function $u(x, y)$ is used, where $x$ denotes final assets and, this is the novel feature, $y$ denotes foregone assets. Regret then stems from the particular shape of the utility function. As an example consider the functional form suggested by Bell (1982)

$$u(x, y) = g(x) + f(g(x) - g(y))$$

where $g$ and $f$ are increasing functions. Now, and this is the crucial point, what is actually meant by the term foregone assets. Bell (1982) and Loomes and Sugden (1982) stated their theories for choice between two gambles. In that case, foregone assets simply means the level of assets in a given state of the world that would have obtained had the individual chosen the foregone gamble. It is not clear how to generalize this to the case of choices between more than two alternatives, which is the case confronting an investor contemplating adjustments of her portfolio. But suppose an investor who holds an asset is simply considering the two alternatives to hold or to sell (and hold the cash). Does regret theory imply the disposition effect under any circumstances?

The answer is emphatically no! To obtain the disposition effect current decisions need to be in some way linked to whether there are prior gains or losses. Under regret theory there is no such link and consequently no disposition effect. To see this more formally, suppose the investor holds $n$ units of a risky asset with current price $P_t$ and risky future price $P_{t+1}$, and suppose the investor uses mental accounting, i.e. she thinks about her investments at the level of the individual asset rather than at the portfolio level. Maximization of expected utility then implies that the investor will continue to hold the asset whenever $E\left[u\left(nP_{t+1}, nP_t\right)\right] > E\left[u\left(nP_t, nP_{t+1}\right)\right]$ and sell when $E\left[u\left(nP_{t+1}, nP_t\right)\right] < E\left[u\left(nP_t, nP_{t+1}\right)\right]$. Assuming no autocorrelation of asset returns, these inequalities, and hence behavior, are simply unaffected by past prices so there is no scope for the disposition effect. Thus expected regret does not explain the disposition effect.

In a different sense, suggested by Shefrin and Statman (1985), regret is sometimes put forward as an explanation for the disposition effect: Investors might feel regret when they *realize* a loss, and, conversely, feel pride when they *realize* a paper gain. So it is not losses per se, but rather the realization of losses that brings about regret. Conversely, it is not gains, but the realization of gains that brings about pride. In this case, investors might display the disposition effect. They might sell winners to rejoice over their past decision and they might refrain from selling losers to avoid feeling the regret over their initial purchase. The disposition effect here stems not so much from regret and pride but rather from the failure to understand that paper gains and losses are as real as realized gains or losses. Why realizing a loss should cause regret is unclear.[7] After all any gain or loss is there irrespective of whether

[7] There are studies that show that decision makers protect their self-image by avoiding feedback

or not it is realized. The only difference selling makes is in the resulting portfolio composition (ignoring transaction costs and taxes). According to the definition by Shefrin and Statman (1985) quoted above regret is caused by *the knowledge* that a different past decision would have fared better, not by the act of realizing a loss.

This is not to argue that there are no investors who fail to understand that paper gains and losses are just as real as realized gains and losses, but simply that such a failure may not be relevant for all investors who display the disposition effect. For example, it seems unlikely that the professional futures traders whose livelihood depends on their trading successes should fail to take unrealized gains or losses for real. Nevertheless, such investors do display the disposition effect (Coval and Shumway (2000), Locke and Mann (1999), Heisler (1994)).

## 1.3 Entrapment, Escalation of Commitment, and Sunk Cost

Extant theories of the disposition effect are unsatisfactory. In this section I try to make the case for an alternative explanation for the disposition effect based on the (motivational) notion that investors prefer to hold losers so as to justify the initial purchase decisions. Such an explanation is suggested by the psychological literature on "entrapment", "escalation of commitment", and "sunk cost." In this literature, psychologists have studied phenomena that are very similar to the disposition effect.[8]

on foregone alternatives (see Larrick (1993) for a discussion of such studies and other studies that have found a contrary pattern). To the extent that realizing a loss creates a more vivid feedback on the initial purchase decision than simply seeing the loss on the account statement, the tendency to avoid feedback is a possible reason why realization can increase regret.

[8] This link has been suggested at least twice in the literature on the disposition effect. Shefrin and Statman (1985) and Weber and Camerer (1998) suggest looking into the psychological literature on the sunk-cost fallacy as an avenue for future research.

The parallels are clear from the definition of entrapment research by Schulz-Hardt and Frey (1998): "Research on «entrapment», «escalation of commitment» and «sunk cost» [...] deals with the question why and under what conditions people irrationally stick to or even intensify losing courses of action" (p. 487).

Entrapment research has used experiments, case studies, as well as field studies to show that entrapment occurs in such diverse contexts as capital budgeting decisions, professional sports, loan decisions in banks, policy decisions, and queuing. See Schulz-Hardt and Frey (1998) and Staw (1997) for overviews of the literature.

An entrapment situation is characterized by repeated (rather than one-shot) decision making under uncertainty, in the face of negative feedback about prior decisions, and choice about whether to continue. The fact that according to the disposition effect, investors irrationally stick to a losing investment neatly fits the definition of an entrapment situation. Staw (1997) explicitly refers to investment decisions as an example of an entrapment situation. "When people have lost money in common stocks or mutual funds, they often face a dilemma. Should they stick with their losing investments, increase their stake (perhaps through dollar cost averaging), or move to an entirely different investment vehicle?" (p. 191) So the research on entrapment, escalation of commitment, and sunk cost (collectively referred to henceforth as entrapment research) may provide some insights as to why investors are reluctant to realize losses.

How do psychologists explain entrapment? The major explanation for entrapment is the *self-justification hypothesis* (Staw (1976), Brockner (1992)).[9] According to this hypothesis individuals stick to a course of action because they feel the need to justify or rationalize their earlier decisions.

[9] There is also a strand in the psychology literature that tries to explain entrapment with the S-shaped value function of prospect theory (e.g. Whyte (1993)). Whatever the merits of this explanation in more general entrapment situations, as was shown in section 1.2.2 it is only a weak explanation of the disposition effect.

> "Decision makers become entrapped in a previous course of action because of their unwillingness to admit—to themselves or others—that the prior resources were allocated in vain. Put simply, people do not like to admit that their past decisions were incorrect, what better way to (re)affirm the correctness of those earlier decisions than by becoming even more committed to them." (Brockner (1992, p. 41))[10]

In the context of the disposition effect the self-justification hypothesis implies that investors are reluctant to realize losses. Investors hold a losing stock because they do not want to admit to themselves that the initial purchase was—with the benefit of hindsight—a mistake. Holding the stock apparently justifies both the initial purchase decision and the losses already endured. This raises two immediate questions: Why do individuals feel the need to justify their initial decision in the face of negative feedback (e.g. losses on an investment), and how does sticking with their initial decision justify the initial decision? The need to justify past decisions can be derived from cognitive dissonance theory. Making a loss on an investment creates the cognition "my investment is losing" that is dissonant with other cognitions such as "I invest to make a profit" or "I am a skillful investor." According to the self-justification hypothesis, the discomfort caused by cognitive dissonance creates the desire to rationalize ex post the initial action, possibly so as to protect a positive self-image.[11] This rationalization works through the creation of new cognitions such as "my investment will come back" or "the loss is only temporary." These cognitions reflect biased estimates of the future outlook of the investment. It is important to

[10] Some authors emphasize the need to distinguish between internal self-justification, i.e. justification toward oneself, and external justification or self-presentation, i.e. self justification tendencies towards others (e.g. Bobocel and Mayer (1994)). Self-presentation tendencies can often be explained by standard agency arguments (Kanodia, Bushman, and Dickhaut (1989)).

[11] Cognitive dissonance could of course be reduced in many other ways that do not imply entrapment.

stress, however, that it is not biased expectations that cause entrapment but rather entrapment that causes biased expectations (Arkes and Hutzel (2000)).[12]

Note that cognitive dissonance (and hence the desire to reduce it) is reinforced by certain characteristics of investment situations. The intensity of cognitive dissonance depends upon commitment and responsibility (Gilad, Kaish, and Loeb (1987)). Commitment to a course of action creates ego-involvement, in the sense that the decision maker cannot deny the significance of his or her behavior to the occurrence of subsequent events. Responsibility means that there is a free choice and the possibility of adverse consequences can be foreseen. Both conditions are clearly met in the context of sequential investment decisions. Moreover, an investor typically receives frequent feedback about the initial action.

The major supporting evidence for the self justification hypothesis is described in Staw (1976) and Brockner (1992). Entrapment occurs more frequently for individuals who were responsible for the initial decision to pursue the course of action. Translated to the context of investment decisions, this means that an investor would be most likely to display the disposition effect if he was responsible for the initial purchase decision.[13]

At a more general level, as suggested by Larrick (1993), individuals focus on two goals when they make a decisions. One goal is to maximize their expected outcomes (i.e. the expected utility of wealth or wealth changes) the other goal is to maintain a positive self image. Consistent with this hypothesis, psychologists

[12] Arkes and Hutzel (2000) emphasize this difference using the bonmot by J.P. Morgan that "man has always two reasons for doing anything - a good reason and a real reason." In the case of the disposition effect, an overly optimistic stance on the future outlook of an investment serves as a "good reason" to rationalize the decision, while the "real reason" is the desire to justify the initial purchase decision.

[13] See, however, Schulz-Hardt, Thurow-Kröning and Frey (2000) for a critical assessment of the evidence.

have identified a number of factors that encourage or discourage entrapment. In addition to economic factors (expected return, transaction costs, etc.) these factors are (translated to the context of the disposition effect from Schulz-Hardt and Frey (1998)): responsibility for the initial purchase of the asset, having invested a large share of one's resources, high external pressure to justify the initial investment, ego-relevance of losses. Factors that discourage the disposition effect are frequent and accurate feedback about the losses, salient opportunity costs, existence of alternative investment opportunities, and the possibility to attribute responsibility for the losses to others. It is worth emphasizing that, in the context of financial investments, the continuation of losing investments does not require any out-of-pocket expenditure.[14]

To summarize, the self-justification hypothesis is a robust explanation for the disposition effect with some empirical evidence to back it up. It provides a clear explanation for why investor behavior differs depending on whether investors hold the stock already or not. Entrapment describes behavior in the face of losses and consequently does not imply any direct tendency towards profit taking. A preference for profit taking, i.e. for selling winners can be an indirect consequence of entrapment, only if the investor has a general tendency to sell some of his assets from time to time, be it for the purchase of other assets (e.g. to escalate his commitment to losers) or consumption goods. In this case, selling winners is simply the converse of not selling losers.

## 1.4 Conclusion

Traditional theories of the disposition effect—belief in mean reversion, the S-shaped value function, and regret theory—either do not capture the disposition effect adequately or are not supported by empirical evidence. The large psychological liter-

[14] An exception is the investment in derivatives (e.g. futures) that are marked to market.

ature on entrapment points to motivational factors such as self justification as the driving force behind the disposition effect. Of course the disposition effect lends itself to more than one explanation, and the explanations reviewed are not mutually exclusive.[15]

To the extent that one considers the disposition effect a central feature, these results indicate that motivational concerns, such as the desire for self-justification, are important determinants of investor behavior. Unfortunately, motivational factors are ignored in recent attempts to model investor behavior, perhaps because decision theories based mostly on psychophysical and cognitive processes such as prospect theory are more elegant, precise, and lend themselves more easily to modeling. Examples are Gomes (2000) and Barberis. Huang and Santos (2001) who study asset demand using some features of prospect theory. Motivational theories have, to my knowledge, so far not been considered. There are formal models of cognitive dissonance (Gilad, Kaish, and Loeb (1987), Rabin (1994)) in abstract decision situations, which (with some changes) could be applied to investment contexts.

It seems difficult to draw conclusions from the self-justification hypothesis regarding aspects of investor behavior not described by the disposition effect, e.g. how buy decisions are made. This is in contrast to some of the traditional theories which make precise predictions on all aspects of investor behavior. Gomes (2000), for example, derives a complete description of investor behavior under the assumption that investors maximize the expectation of a (modified) value function of prospect theory. The self-justification hypothesis does, however, provide some

[15]This point is stressed by Shiller (1999): "[...] each anomaly in finance typically has more than one possible explanation in terms of [...] theories from the other social sciences. The anomalies are observed in complex real world settings, where many possible factors are at work, not in the experimental psychologist's laboratory. Each of their theories contributes a little to our understanding of the anomalies, and there is typically no way to quantify or prove the relevance of any one theory" (p. 1307).

additional insight in that it suggests factors that encourage or discourage the disposition effect. Some of theses factors have already been confirmed in empirical research on entrapment. As an example, consider the following corollary of the self-justification hypothesis: Psychologists have shown that providing individuals with positive information about themselves (raising their self-esteem) can reduce the desire for self-justification (Steele (1988)). So reminding an investor of something good about him- or herself might reduce the disposition effect.

This paper stresses that the psychological literature on entrapment contains results that are relevant to economists studying the disposition effect. It should also be mentioned, that, conversely, the economics literature contains some results of relevance for psychologists. Psychologists have so far studied entrapment situations where there are no similar alternative investment options available should the decision maker decide to discontinue the course of action. The disposition effect suggests that this condition is not necessary. The stock market provides a plethora of alternative investment opportunities and individuals still stick to losing stocks. Second, the question whether entrapment can be explained "rationally" is still not settled in the psychological literature (e.g. Schulz-Hardt and Frey (1998)). The disposition effect provides a clear-cut example of "irrational" entrapment.

# Chapter 2

# The Disposition Effect and Momentum

## 2.1 Introduction

Recent research has shown that individual investors exhibit the disposition effect, i.e. they are too reluctant to realize losses and too eager to realize gains relative to normative theory of investor behavior (Odean (1998), Weber and Camerer (1998)). The question how such a behavioral pattern may affect market prices has so far been neglected.[1] We address this question and show that the disposition effect—if present in aggregate—can help explain positive autocorrelation of returns, i.e. the momentum effect.

In essence, we posit that the disposition effect implies a tendency towards negative feedback behavior, i.e. a tendency to sell on price increases and hold or buy on price declines. Since equilibrium requires market clearing, this tendency towards

[1] Odean (1998) discusses briefly and informally how the disposition effect may contribute to the positive relationship between price change and volume and the phenomenon of "market stability near prices at which substantial trading has previously taken place" (p. 1795).

negative feedback behavior needs to be offset by momentum in asset returns: If investors like to hold losers and do not like to hold winners, then—in equilibrium—there has to be a reward for holding winners and selling losers.

Our model is similar to the recent theoretical literature on momentum (Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer and Subrahmanyam (1998), and Hong and Stein (1999)) in that we relate momentum to a plausible bias in investor behavior. There are, however, two major differences: First, we do not consider a bias that is merely plausible, like Hong and Stein (1999), or that has been shown to exist in non-financial situations, like Daniel, Hirshleifer, and Subrahmanyam (1998) and Barberis, Shleifer, and Vishny (1998). Rather, we employ a bias that is demonstrably relevant for some investors in both actual investment decisions (Odean (1998), Grinblatt and Keloharju (2001)) and experimental asset markets (Weber and Camerer (1998)). We therefore establish a possible link between two well-established pieces of anomalous behavior: the disposition effect as a description of anomalous investor behavior and the momentum effect as a pricing anomaly. Second, while Daniel, Hirshleifer, and Subrahmanyam (1998), and Barberis, Shleifer, and Vishny (1998), and Hong and Stein (1999) use biases in the expectations of future fundamentals, our model generates momentum as a reaction to past prices. This means that our momentum result obtains regardless of whether price changes are driven by the arrival of new information or something else and, consequently, that our momentum result is consistent with both under- and overreaction to news about fundamentals.

*Related Literature*

The term disposition effect was coined by Shefrin and Statman (1985) to describe the tendency to "sell winners too early and ride losers too long" (p. 778) relative to a normative theory of investor behavior. As they point out the disposition effect is part of the "general folklore about investing" (p. 778). The term profit-taking, defined by Barron's Dictionary of Finance and Investment Terms as "action by short-term securities or commodity traders to cash in on gains earned on a sharp market rise", refers to disposition-effect-like behavior. There is strong empirical evidence in favor of the disposition effect.

The early empirical literature on the disposition effect looks at consequences of the disposition effect in aggregate data. Lakonishok and Smidt (1986) find that current trading volume is positively correlated with past price changes in line with the disposition effect. Ferris, Haugen and Makhija (1988) demonstrate for small stocks that contemporary volume can be predicted with historic volume at differential price levels: If there was high volume at higher than current prices in the past, i.e. there are many investors sitting on a loss, current volume is low. The opposite is true if there was high volume at lower prices in the past.

These studies are important because they suggest that the consequences of the disposition effect may be relevant not only at the individual level, but also for the market as a whole. However, they necessarily constitute only weak evidence for the existence of the disposition effect since there are many competing explanations for the price-volume relationship: One alternative explanation is that investors rebalance their portfolios so as to keep the weights put on each individual asset constant across time which would be optimal under the assumption of expected utility maximization with constant relative risk aversion and normal log-returns. Such behavior implies the selling of stocks with returns above the portfolio average and the purchase of stocks with returns below average.

To be able to distinguish among alternative explanations of behavior the more recent studies use disaggregate data. Odean (1998) demonstrates that on average investors sell winners more readily than losers using data on individual discount brokerage accounts. Investors realize 15 percent of their gains and only 10 percent of their losses. Moreover, Odean shows that this behavior is not justified by subsequent portfolio performance, which makes it difficult (though not impossible) to argue that the preference for realizing gains rather than losses is in accordance with some normative theory of investor behavior. Similarly, Heisler (1994) documents the disposition effect for a sample of small Treasury futures speculators on the Chicago Board of Trade. Locke and Mann (1999) find weak supporting evidence for the disposition effect in a sample of professional futures traders on the Chicago Mercantile Exchange. Coval and Shumway (2000) study the behavior of full-time proprietary traders futures traders. They find strong evidence that traders take more risk following losses and, conversely, that they take less risk following gains. Moreover, they find that this behavior affects prices.

Weber and Camerer (1998) find evidence for the disposition effect in an experimental asset market. They have participants in an experiment trade risky assets at exogenously determined prices. Even though participants are (correctly) told that the price process for each risky asset has a fixed trend, and that price changes are independent across time and assets, participants on average prefer to sell winners rather than losers.

The momentum effect is equally well documented. Empirical research has produced evidence of unconditional positive autocorrelation of (excess) returns over horizons between three to twelve months. Cutler, Poterba, and Summers (1990) find momentum in excess returns of stock, bonds, foreign exchange, and real estate markets. There is also a large literature on positive serial correlation in cross sections of individual stock returns (e.g. Jegadeesh and Titman (1993) for the U.S., and Rouwenhorst (1998) for Europe).

In trying to link the disposition effect to asset returns, our model is related to the large literature on how departures from expected utility maximization at the individual level translate into market outcomes. Since the disposition effect links the preference for holding an asset to prior performance, our approach is particularly related to Cutler, Poterba, and Summers (1990) and De Long, Shleifer, Summers, and Waldmann (1990) who discuss the role of feedback traders, i.e. traders whose demand is determined entirely by past returns.

Fama and French (1996) remark that the momentum findings of Jegadeesh and Titman (1993) constitute the "main embarrassment" (p. 81) for their three-factor model. The difficulty in reconciling the momentum effect with traditional theories of asset pricing has given rise to a number of behavioral models. Daniel, Hirshleifer, and Subrahmanyam (1998) focus on a risk-neutral representative investor who is prone to the overconfidence and biased self-attribution biases. Overconfidence leads to initial overreaction to news about fundamentals that is on average followed by even more overreaction due to biased self-attribution which implies momentum. Barberis, Shleifer, and Vishny (1998) also assume that prices are driven by a representative agent, who, in their case, suffers from conservatism bias, i.e. the representative investor updates his priors only insufficiently when new information about a stock becomes available. If this underreaction is corrected over time, it implies momentum. Hong and Stein (1999) use Copeland's (1976) idea that sequential information arrival together with the failure to extract information from observed prices creates underreaction and momentum. Their approach differs from Daniel, Hirshleifer, and Subrahmanyam (1998) and Barberis, Shleifer, and Vishny (1998) in that they appeal to plausibility rather than psychology to justify their assumptions.

Finally, there are two very recent papers that study behavior that is just the opposite of the disposition effect. Barberis, Huang, and Santos (2001) examine the impact of past investment performance on asset demand in a model of the so-called house-money effect, "gamblers' increased willingness to bet when ahead." They assume that investors become less risk averse after gains and more risk averse after losses. Klein (2001) studies the capital gain lock-in effect. He argues that capital gains taxes induce a tendency not sell stocks with capital gains (winners) and to sell stocks with capital losses. Since both Klein (2001) and Barberis, Huang, and Santos (2001) assume behavior that is opposite to what we study, they get opposite results: They find reversals in equilibrium returns. It is of course worrisome to have different behavioral theories that rely on biases that produce opposite conclusions about investor behavior. We note, however, that the three empirical papers that study explicitly the question whether investors behave according to the theories of Klein (2001) and Barberis, Huang, and Santos (2001) or according to the disposition effect have found evidence in favor of the latter (Coval and Shumway (2000), Ferris, Haugen and Makhija (1988), Lakonishok and Smidt (1986)).

The chapter proceeds as follows. In Section 2.2 we present our assumptions on how the disposition effect links current asset demand to a past reference price and how this link generates a tendency for winners to outperform losers. In Sections 2.3 and 2.4 we calculate examples of the momentum result in linear models with finite and infinite time horizon. In Section 2.5 we discuss how our momentum result holds up when we make the empirically expedient assumption that price changes are not entirely driven by news about fundamentals. We conclude the paper by pointing out possible extensions (Section 2.6), empirical predictions (Section 2.7) and by a final discussion (Section 2.8).

## 2.2 The Disposition Effect, Asset Demand, and Momentum

Let $X_t$ denote demand for the risky asset in period $t$. The disposition effect is defined relative to "normative theory", a term which needs to be made precise. It is clear that there are many patterns of behavior that are consistent with normative theory, even if one restricts the term to expected utility maximization. So for concreteness (and simplicity) we need to narrow down "normative theory" to one special case. The special case we consider is demand that is an increasing function of risk adjusted expected excess return, $X_t = X_t\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}\right)$, where $E_t$ and $Var_t$ denote the expected value and variance conditional on information in period $t$. $Q_{t+1}$ denotes the excess return in period $t+1$, $Q_{t+1} = P_{t+1} + D_{t+1} - RP_t$, where $P_t$ and $D_t$ are price and dividend payment in period $t$ and $R = 1 + r$ is one plus the risk-free rate. Under the assumption of expected-utility maximization, such behavior can be derived from the joint assumption of CARA utility and prices and dividends that are normally distributed or from the assumption of a quadratic utility function. In this case, demand is a linear function of risk-adjusted expected return. At this simple level, economic theory postulates that asset demand depends on the expected return from, the risk associated with holding the asset, and the trade-off between risk and return. Clearly this is a caricature of "rational" behavior, but at least it is one that is very frequently used.

The disposition effect states that there is an additional argument of current demand: Prior gains or losses relative to a reference point $C$. The reference point refers to a past price. To which past price is the matter of different hypotheses. The original hypothesis by Shefrin and Statman (1985) is that the initial purchase price is the reference point. Shefrin and Statman argue that whenever a stock is purchased, a mental account is opened and a running score is kept on this account indicating gains and losses relative to the purchase price. This hypothesis is still dominant and is used in most empirical studies of the disposition effect. There are, however, other hypotheses on reference points. Weber and Camerer (1998) find experimental evidence that investors use the price of the previous period as reference point. Barberis, Huang, and Santos (2001) argue that investors use the price of the previous period scaled up by a constant factor (e.g. one plus the risk-free rate).

Gneezy (1998) finds evidence that the maximum price over the holding period is used. What is important for our results is that the reference point is a past price, and not something possibly unrelated to past information such as an exogenous aspiration level for the stock price.

The disposition effect implies that demand is lower in the case of prior gains than in the case of prior losses. To see this note that selling means a reduction of the position in the asset, i.e. demand in the current period is lower than in the previous period. Conversely, buying means an increase of the position in the asset, i.e. increased demand. Consequently, for a given prior position in the asset (i.e. demand for the asset in the previous period) a lower current demand means that for any risk-adjusted expected return $\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ there is a greater tendency to sell.

The disposition effect has been attributed to risk attitudes that depend on prior gains or losses or biases in return expectations (Odean (1998), Weber and Camerer (1998)).[2] For the most part, we focus on the former explanation, i.e. we assume that prior gains or losses shift risk attitudes. An interpretation of this assumption is that investors tend to sell winners because the fact that they have made a gain makes them less willing to bear risk. Conversely they prefer to hold on to losers because the fact that they have incurred a loss makes them less risk-averse. This is in fact the major "behavioral" explanation for the disposition effect, an explanation that is typically loosely based on Kahneman and Tversky's (1979) prospect theory (Odean (1998), Weber and Camerer (1998), Shefrin and Statman (1985)). Under prospect theory investors evaluate gambles according to their payoffs relative to a specific reference point. Hence portfolio choice depends on the reference point. More precisely, because of the decreasing sensitivity feature of the value function of prospect theory, it is assumed that risk aversion is higher following gains than

[2] The two explanations are not mutually exclusive. See Zuchel (2001b) for a survey of these and other explanations of the disposition effect.

following losses: Prior gains mean high risk aversion because the investor is relatively insensitive to further gains and very sensitive to losing the prior gains. Conversely, prior losses mean low risk aversion because the investor is not very sensitive to further losses but very eager to eliminate the prior losses so as to break even.[3]

Alternatively, we could derive the disposition effect from shifting misperceptions of future stock payoffs. The disposition effect could reflect the belief that prior gains or losses are likely to be reversed in the future. This is the second major behavioral explanation for the disposition effect that we briefly discuss in Subsection 2.6.1. While we find it more natural to think of the disposition effect as reflecting changes in risk attitude so that changing demand relates to changing taste, the basic intuition of our model carries through regardless of how prior gains or losses are introduced as an argument of the demand function to reflect the disposition effect.

In summary, we assume that demand is a function of expected return, risk, and—due to the disposition effect—prior gains or losses relative to a reference point, and that it takes the following form.

$$X_t\left(\frac{E_t\left[Q_{t+1}\right]}{Var_t\left[Q_{t+1}\right]},(P_t-C)\right) \tag{2.1}$$

Compared with the benchmark case without the disposition effect there are two new features of demand. First, there is an additional channel through which the current price $P_t$ affects demand. It not only changes expected excess return $E_t\left[Q_{t+1}\right]$, but also prior gains $(P_t - C)$. Second, and crucially, because of the reference point $C$, demand is influenced directly by a past price. Under expected utility maximization past prices affect current demand only indirectly: past prices influence past portfolio composition which influences current wealth, which in turn determines current risk aversion and hence demand. Capital gains taxes and transaction costs are potential

[3] Gomes (2000) shows, however, that maximization of the expectation of a prospect theory value function leads to complex behavior which may or may not be consistent with the disposition effect.

reasons for a direct link between prior gains and current demand (Klein (2001), Harris (1988)) under the assumption of expected utility maximization.

*Trend Continuation in Equilibrium Returns*

Suppose there is a fixed stock, $\bar{X}$, of the asset in supply. Assuming the disposition effect as in (2.1) and equating demand and supply yields a simple equilibrium link between prior gains or losses and future returns.

$$\bar{X} \stackrel{!}{=} X_t \left( \frac{E_t \left[ Q_{t+1} \right]}{Var_t \left[ Q_{t+1} \right]}, (P_t - C) \right) \tag{2.2}$$

The disposition effect means that demand is lower in the case of prior gains than in the case of prior losses. From the market clearing condition (2.2), it is immediate that this requires the risk-adjusted expected return $\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ to be higher in the case of prior gains than in the case of prior losses. The disposition effect thus generates trend continuation: Prior gains (relative to some reference point) are in risk-adjusted expected terms followed by a high return, prior losses are followed by a low return. If volatility is non-stochastic, the link is directly from prior gains to expected return (without adjustment for risk).

Moreover, if we make the additional assumption of a *monotonic* relation between prior gains or losses and current demand, we get a monotonic link between prior gains and future return. In this case higher prior gains mean higher expected returns and worse prior losses mean lower expected return. The assumption of monotonicity in the link between the magnitude of prior gains and current demand may appear natural: It simply means that a bigger stimulus generates a bigger response. Consequently, the assumption of monotonicity is typical in translating psychological evidence of behavioral biases into modeling assumptions (e.g. Barberis, Huang and Santos (2001)). In our context the assumption of monotonicity means that an investor is more eager to realize large gains than small gains and he is more reluctant to realize large losses rather than small losses. We emphasize though that the empirical literature on the disposition effect has so far largely neglected the impact of the magnitude of prior gains on behavior. Grinblatt and Keloharju (2001) do find evidence of a monotonic relation, Odean (1998) finds evidence of a monotonic relation for losers, but not for winners.

Finally, note that if equation (2.2) is linear, or can reasonably be approximated linearly, we can express the positive relation that follows from monotonicity as a positive correlation:

$$Cov\left[E_t\left[Q_{t+1}\right],(P_t - C)\right] > 0$$

The positive correlation between prior gains $(P_t - C)$ and future return $Q_{t+1}$ translates into a positive autocorrelation of excess returns, provided that prior gains and *current* excess return $Q_t$ are positively autocorrelated.[4]

$$Cov\left[Q_t, Q_{t+1}\right] > 0 \Longleftrightarrow Cov\left[Q_t, (P_t - C)\right] > 0 \tag{2.3}$$

This condition for positive autocorrelation of excess returns (i.e. momentum) can be interpreted as a condition on the setting of the reference point. Momentum obtains if the reference point is set such that an above average current return indicates an above average prior gain. A simple example where this condition is met is the case where the price of last period is used as a reference point, where the riskless rate is zero, and where there are no dividend payments. In this case, prior gains are equal to the current excess return, $P_t - C = P_t - P_{t-1} = Q_t$, so that $Cov\left[Q_t, (P_t - C)\right] = Var\left[Q_t\right] > 0$ so that according to equation (2.3) there is momentum.

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[4]**Proof.** $Cov[Q_t, Q_{t+1}] = Cov\left[Q_t, E_t\left[Q_{t+1}\right] + \theta_{t+1}\right]$ where $\theta_{t+1}$ is a residual with $E_t\left[\theta_{t+1}\right] = 0$. Therefore $E\left[\theta_{t+1}\right] = E\left[E_t\left[\theta_{t+1}\right]\right] = 0$ and thus $Cov\left[Q_t, \theta_{t+1}\right] = E\left[Q_t\theta_{t+1}\right] = E\left[E_t\left[Q_t\theta_{t+1}\right]\right] = E\left[Q_t E_t\left[\theta_{t+1}\right]\right] = 0$. Hence $Cov[Q_t, Q_{t+1}] = Cov\left[Q_t, E_t\left[Q_{t+1}\right]\right]$ which has the same sign as $Cov\left[Q_t, (P_t - C)\right]$ under the assumption that $E_t\left[Q_{t+1}\right]$ is an affine-linear function of $(P_t - C)$. ■

To summarize: (i) the disposition effect leads to trend continuation: Prior gains are on average followed by high returns, prior losses are on average followed by low returns. This general conclusion stems from the negative feedback nature of the disposition effect. If investors like to hold losers and do not like to hold winners, then—in equilibrium—there has to be a reward for holding winners and selling losers. Furthermore, (ii) if the link between prior gains and current demand implied by the disposition effect is monotonic, then there is a monotonic relation between prior gains and future return. Expected future return is then an increasing function of prior gains. Finally, (iii) a sufficient condition for the positive relation between prior gains and future returns to translate into a positive autocorrelation is for the market clearing condition to be linear. A positive autocorrelation of excess returns (momentum) then obtains if investors set the reference point such that there is a positive correlation between current return and prior gains.

The following sections explore these results through a sequence of examples. We begin by discussing the simple case with only two trading periods and then go on to discuss the case with any finite number of trading periods (section 2.3). Next we discuss the case of an infinitely lived risky asset without or with rational speculative bubbles (sections 2.4 and 2.5). We pick our assumptions on the setting of reference points, the stochastic process of dividends (fundamental value), and the bubble so that the resulting price function is linear and the autocorrelation function of excess returns can be expressed explicitly.

## 2.3 The Model with a Finite Number of Trading Periods

Consider a model asset prices with a finite number of trading periods. A riskless and a risky asset are traded over $T \in \mathbb{N}$ trading periods, $t = 1, 2, ..., T$. The risky asset pays a single stochastic dividend $F$ in period $t = T + 1$. In each period there is a signal $\varepsilon_t$ about final value.

$$F = \mu_0 + \varepsilon_1 + \varepsilon_2 ... + \varepsilon_{T+1} \tag{2.4}$$

where $\mu_0 > 0$ is a constant and the innovation terms $\varepsilon_t$ are white noise with variance $Var[\varepsilon_t] = \sigma^2$. There is a fixed supply $\bar{X}$ of the risky asset. The riskless asset is in elastic supply and pays interest $R = 1 + r$.

For the demand side, we assume that demand depends *linearly* on risk-adjusted expected excess return:

$$X_t = \frac{E_t[Q_{t+1}]}{\gamma Var_t[Q_{t+1}]}$$

where $\gamma > 0$ is a risk preference parameter. We model the disposition effect by assuming that prior gains or losses shift the parameter of risk preference, so that $\gamma$ becomes a function of prior gains, $\gamma(P_t - C)$. Moreover, we assume that the link between prior gains and risk attitude is affine-linear, $\gamma(P_t - C) = a + b(P_t - C)$ where $a, b$ are two positive constants. Finally, we assume that the initial purchase price $P_1$ is used as a reference point. Demand is hence

$$X_t = \frac{E_t[Q_{t+1}]}{[a + b(P_t - P_1)] Var_t[Q_{t+1}]}$$

Note that demand is not linear in the current price, since the current price affects both expected return and prior gains or losses. It is however still monotonic as long as the parameter of risk aversion $\gamma$ and expected returns are positive, which we impose as a restriction: The model parameters and the distribution of $(\varepsilon_t)$ are such that the parameter $\gamma$ is positive for all realizations of $(\varepsilon_t)_{t=1}^{T+1}$. Demand for winners, $(P_t - P_1) > 0$, is lower than for current losers, $(P_t - P_1)$, as long as there is a positive expected return, which is the case in equilibrium due to the assumption that $\gamma$ and $\bar{X}$ are always positive. The benchmark compared to which "winners are sold too early and losers are held too long" is then characterized by a demand function with constant slope, $b = 0$.

We begin by discussing the simplest case that allows the discussion of return autocorrelation, the case of two trading periods, $T = 2$.

### 2.3.1 Two Periods

In period $t = 3$, fundamental value $F$ is realized. In period $t = 2$ the equilibrium condition $X_2 = \bar{X}$ implies

$$P_2 = \frac{E_2\left[F\right] - \bar{X}\left(a - bP_1\right)\sigma^2}{R + \bar{X}b\sigma^2} \tag{2.5}$$

$P_2$ is an increasing function of the past price $P_1$ (the initial purchase price) because of the disposition effect. A higher initial price $P_1$ implies a worse prior gain, thus lowering the expected return $E_2\left[Q_3\right]$. Note that compared with the case of a constant parameter of risk preference, $b = 0$, the price $P_1$ reacts less to the arrival in period $t = 2$ of information about fundamental value $F$. Formally, $\frac{\partial P_2}{\partial \varepsilon_2} = \frac{1}{R + \bar{X}b\sigma^2} < \frac{1}{R}$. So, in this model, the disposition effect leads to underreaction to news about fundamentals and dampened volatility. In Subsection 2.5.1 we will discuss a model with excess volatility.

For the initial period $t = 1$ the equilibrium condition yields

$$P_1 = \frac{1}{R}\left(E_1\left[P_2\right] - \bar{X}aVar_1\left[P_2\right]\right) \tag{2.6}$$

Equations (2.5) and (2.6) can be solved using the assumptions about the process of news about fundamentals (2.4). Due to the disposition effect, excess returns are positively autocorrelated, so we have momentum.

$$Cov\left[Q_3, Q_2\right] = \sigma^2\left(\frac{\bar{X}b\sigma^2}{R + \bar{X}b\sigma^2}\right)^2 > 0$$

In the absence of the disposition effect, $b = 0$, we would have the standard case of constant expected returns and excess returns would be uncorrelated. Here, a capital gain in the second period, $P_2 - P_1 > 0$, means that the asset is a winner. Through the disposition effect this lowers demand for the asset in period $t = 1$ which translates into higher expected returns. Similarly, a negative return means that the asset is a loser which increases demand and lowers future expected returns. Since capital gains and excess returns are positively correlated we have positive autocorrelation of excess returns.

### 2.3.2 More Than Two Periods

The simple case of two periods is special because the period over which the investor evaluates prior investment performance that matters for the disposition effect coincides with the previous return of the asset. If there are more periods, and if the investor uses the initial purchase price as reference point, the return earned over the previous period will be only part of the total prior performance. In particular there are cases where prior performance overall is positive while the return over the previous period was negative (or vice versa). In this section we show that momentum obtains with any finite time horizon. The proof of this result is in two steps. First, we show that there is a positive relationship between prior performance, $(P_t - C)$ and expected return. Second, there is a positive relationship between current return and prior performance. Taken together this implies a positive relationship between current return and expected return, i.e. momentum.

Using the equilibrium condition, we get the following representation of expected returns

$$E_t\left[Q_{t+1}\right] = \bar{X}\left(a + b\left(P_t - C\right)\right) Var_t\left[Q_{t+1}\right] \tag{2.7}$$

Increases in prior performance $(P_t - C)$ thus translate into increases in expected return or decreases in the volatility of returns or both.

We can express equilibrium prices as a linear function of current expectations of the final dividend.

**Result 2.1** *Prices are*

$$P_t = \frac{E_t[F]}{\prod_{i=0}^{T-t}\left(R + \bar{X}bVar_{t+i}[Q_{t+1+i}]\right)} + c(t)$$

*where* $c(\cdot)$ *and* $Var_{t+i}[Q_{t+1+i}]$ *are deterministic functions of time.*

All proofs are in the appendix. This representation finally allows us to show that returns are positively autocorrelated. Since the conditional variance of prices does not depend on prior performance, condition (2.7) implies that prior performance and expected return are positively autocorrelated

$$Cov[P_t - C, E_t[Q_{t+1}]] = bVar_t[Q_{t+1}]\,Var[P_t - C] > 0$$

**Result 2.2** *Excess returns are positively autocorrelated at lag* 1 *for all* $T \geq 2$.

So momentum obtains with any finite number of trading periods.

## 2.4 The Infinite Time Horizon Case

With infinite time horizon, two issues concerning the use of reference points arise: How are reference points affected by dividend payments, and how does the reference point adjust over time. For an infinitely-lived asset we can no longer ignore interim dividend payments as we did in the finite horizon model. Since the disposition effect relates current demand to prior gains or losses, dividends raise the question how investors measure prior gains. In particular, do prior gains refer to prior total returns, i.e. to capital gains plus dividends, or to prior capital gains only? Empirical results on this question are ambiguous. The early empirical literature (Lakonishok and Smidt (1986) and Ferris, Haugen and Makhija (1988)) focused on capital gains/losses. Odean (1998) finds that there is a disposition effect irrespective of whether investors are affected by total returns or capital gains only. We discuss both cases.

### 2.4.1 Capital Gains as Measure of Prior Gains

So far, we have assumed that the reference point is fixed at the initial price level. In a setup with infinite time horizon such an assumption appears implausible. While investors may "irrationally" be influenced by historical information, we would expect the impact of any individual piece of historical information on current behavior to vanish over time. Also, technically a fixed reference-point would imply non-stationary returns. We consequently give up the assumption of a fixed reference point and assume that the reference point $C_t$ is equal to the price of the last period, $C_t = P_{t-1}$. There is some empirical support for this assumption: Weber and Camerer (1998) report that subjects in their experiment use the price of the previous period as reference point.

Let $Z_t$ denote the measure of prior gains defined as the difference between the current price to current reference price, $Z_t = P_t - C_t$. We continue to assume that demand takes the form

$$X_t = \frac{E_t\left[Q_{t+1}\right]}{\left(a + bZ_t\right) Var_t\left[Q_{t+1}\right]}, \quad a, b > 0$$

where $a$ and $b$ are again two constants. We assume that $R = 1 + r > 1$.

Aggregate supply of the asset is again fixed at $\bar{X}$. In equilibrium expected returns are driven by the single variable $Z_t$ that measures prior gains and losses.

$$E_t\left[Q_{t+1}\right] = \bar{X} Var_t\left[Q_{t+1}\right]\left(a + bZ_t\right) =: c\left(a + bZ_t\right)$$

Since we will be able to represent excess returns as a stationary ARMA process, the conditional variance $Var_t\left[Q_{t+1}\right]$ is constant and does not influence expected returns. So the first autocorrelation of the return process is

$$Cov\left[Q_t, Q_{t+1}\right] = Cov\left[Q_t, E_t\left[Q_{t+1}\right]\right] = bc\, Cov\left[Q_t, Z_t\right]$$

Intuitively, returns are positively autocorrelated (i.e. there is momentum) whenever current returns are positively correlated with the measure of gains/losses $Z_t$, i.e. whenever $Cov\left[Q_t, P_t - C_t\right] > 0$.

To derive an explicit solution for the return autocovariance, we need to close the model with assumptions about the dividend process. As an example, assume that dividends follow a random walk, $D_{t+1} = D_t + \varepsilon_t$ where $(\varepsilon_t)$ is white noise. Note that this means that dividends and prices can become negative.

These assumptions allow us to calculate a simple solution that is a linear function of the reference price $P_{t-1}$ and the dividend.

$$P_t = \frac{1}{1+\alpha_1}\left[\alpha_1 P_{t-1} + \frac{D_t}{r} - \alpha_0\right]$$

where $\alpha_0$ and $\alpha_1$ are two positive constants. See the appendix for a proof. Equivalently, we can express the asset price as a linear combination of current dividends and the measure of prior gains $Z_t = P_t - P_{t-1}$:

$$P_t = \frac{D_t}{r} - (\alpha_0 + \alpha_1 Z_t) \tag{2.8}$$

The first term on the right-hand side of (2.8) is the present value of expected future dividends. The second term, $(\alpha_0 + \alpha_1 Z_t)$, is the present value of expected future excess returns. Both present values are calculated using the riskless rate $r$ as discount rate. The asset price is increasing in expected dividends and decreasing in expected returns.

It follows from the price function (2.8) that the measure of prior gains $Z_t = \Delta P_t$ that determines expected returns follows a stationary first-order autoregressive process

$$Z_t = \frac{\alpha_1}{1+\alpha_1} Z_t + \frac{1}{(1+\alpha_1)\, r} \varepsilon_t$$

This implies that expected returns are positively autocorrelated, since $Z_t$ is positively autocorrelated at all lags. Realized excess returns are given by

$$\begin{aligned} Q_{t+1} &= Z_{t+1} + D_{t+1} - rP_t \\ &= r\alpha_0 + \left( r\alpha_1 + \frac{\alpha_1}{1+\alpha_1} \right) Z_t + \left( 1 + \frac{1}{r\left(1+\alpha_1\right)} \right) \varepsilon_{t+1} \end{aligned}$$

where all the coefficients are positive which implies positive autocorrelation of returns at all lags.

### 2.4.2 Total Return as Measure of Prior Gains

An alternative measure of prior gains would be to simply use past total return rather than capital gains only. Suppose that the reference point is the price of the past period $P_{t-1}$ scaled up by the risk-free rate, $C_t = RP_{t-1}$, so that the measure of prior gains is just the prior excess return, $Z_t = P_t + D_t - RP_{t-1} = Q_t$. That investors use a past price scaled up by a constant factor as reference point, and that their demand is connected to past total returns has been suggested by Barberis, Huang, and Santos (2001). We need the scaling of the reference point for a technical reason. Without scaling excess returns would not be stationary.[5]

The analysis in this case is very similar to the case of the previous section where only capital gains matter. Prices are again a linear function of the reference price and dividends. Excess returns follow a stationary AR(1) process with positive coefficient so that excess returns are positively autocorrelated at all lags.

[5] Without scaling of the reference point we would have $Q_{t+1} = P_{t+1} + D_{t+1} - RP_t = Z_t - rP_t$. Since $(P_t)$ is non-stationary, we cannot have both $(Q_t)$ and $(Z_t)$ stationary.

## 2.5 Momentum with Bubbles and Noise: Overreaction and Excess Volatility

There is strong evidence, that asset price changes are to a significant extent driven by something other than news about fundamentals (e.g. Shiller (1989), Roll (1984)). In contrast to this observation, we have so far attributed price changes entirely to the arrival of news about dividends. In this section we address the question how the momentum result holds up if factors other than dividend news drive price changes. The factors we consider are rational price bubbles and noise or liquidity trading.

### 2.5.1 Rational Speculative Bubbles

Reconsider the infinite time horizon case of section 2.4.[6] Through recursive substitution in the definition of expected excess returns, one can represent the asset price as a linear combination of discounted expected dividends, returns and the limit of future prices.

$$P_t = \underbrace{\sum_{i=1}^{\infty} \left(\frac{1}{R}\right)^i E_t\left[D_{t+i}\right] - \sum_{i=1}^{\infty} \left(\frac{1}{R}\right)^i E_t\left[Q_{t+i}\right]}_{P_t^*} + \underbrace{\lim_{i\to\infty} \left(\frac{1}{R}\right)^i E_t\left[P_{t+i}\right]}_{B_t} \qquad (2.9)$$

We will use the standard terminology and call $P_t^*$ the fundamental solution and $B_t$ the bubble.[7] The solution discussed in section 2.4 was derived by implicitly imposing the condition that expected future prices do not grow too fast, i.e. $B_t = 0$. Once we relax this arbitrary condition, there are possibly many other solutions to equation

[6] In our model with finite time horizon, there cannot be a rational speculative bubble since the asset price is forced back to fundamental value at maturity.

[7] This terminology is standard but in our context slightly inappropriate since the fundamental solution $P_t^*$ is not indendent of the bubble. A stochastic bubble introduces variance into returns which, given our assumption that investors are risk-averse, is reflected in the "fundamental solution" part of the asset price.

(2.9). Using the definition of expected returns we can show that the only restriction that has to be imposed on the term $B_t$ in order to satisfy (2.9) is that in expected terms it has to grow at rate $R$.

$$E_t\left[B_{t+1}\right] = RB_t \tag{2.10}$$

There are three remarkable results concerning momentum based on the disposition effect in the presence of bubbles. First, there is momentum in the presence of a bubble. This is because the disposition effect stems from the use of past prices as reference points and not from biased expectations of fundamentals: Investors care about expected return, risk, and prior gains or losses relative to a reference point regardless of what is driving stock returns. Second, if the bubble is stochastic, it introduces variance into stock prices that is unrelated to news about fundamentals (dividends). Hence it can reconcile momentum based on the disposition effect with excess volatility. Finally, since unexpected changes in the bubble, $B_{t+1} - RB_t$, can be correlated with dividend innovations (or more generally unexpected movements in any variable), momentum based on the disposition effect is consistent with overreaction as well as with underreaction to news about fundamentals.[8]

Consider the following simple example of a bubble

$$B_{t+1} = RB_{t+1} + \eta_{t+1} \tag{2.11}$$

where $\left(\eta_{t+1}\right)$ is a white-noise process of "bubble innovations." This bubble grows on average at rate $R$ so that condition (2.10) is satisfied.[9] Bubble innovations can

[8] We expect these results to be true for any explanation of momentum based on feedback trading rather than on biases in expected future fundamentals.

[9] We choose this simple bubble because it is consistent with a stationary return process. The point is often made that such a simple bubble cannot exist in equilibrium because it implies that asset prices can become "too big" or that asset prices can become negative (which is something, that was possible in our model even without a bubble). As pointed out by Blanchard and Fischer

be correlated with dividend innovations. Let $\sigma_{\varepsilon\eta} = Cov[\varepsilon_t, \eta_t]$ denote the time independent covariance of the two innovations.

Suppose the investor uses the price of the previous period scaled up by the risk-free rate as reference point, $C_t = RP_{t-1}$, and is affected by total gains relative to the reference point. Her measure of prior gains is consequently $Z_t = P_t + D_t - RP_{t-1} = Q_t$. Then we can find the asset price as a linear function of the reference price, the current dividend and a bubble.

**Result 2.3** *Under the stability condition $\bar{X}bVar_t[Q_{t+1}] < 1$, there is an equilibrium asset price of the following form*

$$P_t = \frac{1}{1+\beta_1}\left[\left(\frac{1}{r} - \beta_1\right)D_t - (\beta_0 + \beta_1 RP_{t-1}) + B_t\right]$$

*where $\beta_0$, $\beta_1$, and $Var_t[Q_{t+1}]$ are constants.*

Equivalently, the price can be expressed as a function of the measure of prior gains $Z_t$

$$P_t = \frac{D_t}{r} - (\beta_0 + \beta_1 Z_t) + B_t$$

Excess returns follow an AR(1) process with positive coefficient. Consequently, excess returns are positively autocorrelated so there is momentum. Momentum based on the disposition effect is hence consistent with any bubble of the form (2.11), at least as long as the stability condition is not violated.

Stochastic bubbles introduce additional variance into prices. If this additional variance is sufficiently large relative to the variance due to dividend innovations,

(1989), such arguments are not altogether convincing because they rely on an extreme form of rationality: "Often bubbles are ruled out because they imply, with a very small probability and very far in the future, some violation of rationality, such as nonnegativity of prices or the bubble becoming larger than the economy. It is conceivable that the probability may be so small, or the future so distant, that it is simply ignored by market participants." (p. 238) Also, Weil (1987) shows that more complex stochastic bubbles can exist in general equilibrium of an OLG economy.

there is excess volatility of prices, i.e. volatility is higher than in the case of constant risk aversion and no bubble. Let $\hat{P}_t$ denote the benchmark price that obtains in the absence of the disposition effect ($b = 0$) and without bubble. $\hat{P}_t$ is a linear combination of discounted expected dividends and a constant risk premium, $\hat{P}_t = \frac{D_t}{r} - const$, so that the benchmark volatility is $Var_t\left[\hat{P}_{t+1}\right] = \frac{1}{r^2}\sigma_\varepsilon^2$. With the disposition effect (i.e. with time-varying expected return) and a bubble, price volatility is $Var_t\left[P_{t+1}\right] = \frac{1}{(1+\beta_1)^2}\left[\left(\frac{1}{r} - \beta_1\right)^2\sigma_\varepsilon^2 + \sigma_\eta^2 + 2\left(\frac{1}{r} - \beta_1\right)\sigma_{\varepsilon\eta}\right]$. For a given variance of bubble innovations $\sigma_\eta^2 > 0$ and a given correlation of bubble and dividend innovations, we know that there is excess volatility, $Var_t\left[P_{t+1}\right] > Var_t\left[\hat{P}_{t+1}\right]$, since $\lim_{\sigma_\varepsilon \to 0} Var_t\left[\hat{P}_{t+1}\right] = 0$ and $\lim_{\sigma_\varepsilon \to 0} Var_t\left[P_{t+1}\right] = \frac{\sigma_\eta^2}{\left(\frac{1}{2}+\sqrt{\frac{1}{4}+\frac{\bar{X}b\sigma_\eta^2}{R}}\right)^2} > 0$. Consequently, there can be excess volatility of prices. Moreover, the momentum result is independent of whether there is excess volatility or dampened volatility.

Similarly, depending on the specification of the bubble there can be either under- or overreaction. The terms under- and overreaction are used relative to the benchmark case of constant expected returns and no stochastic bubble, $\hat{P}_t = \frac{D_t}{r} - const$. In the benchmark case, the price reaction to dividend innovations is $\frac{\partial \hat{P}_t}{\partial \varepsilon_t} = \frac{1}{r}$. For simplicity, consider the special case $\eta_t = c\varepsilon_t + \zeta_t$ for some constant $c > 0$ where $(\zeta_t)$ is white noise uncorrelated with $(\varepsilon_t)$. Price reaction to dividend innovations in this case is

$$\frac{\partial P_t}{\partial \varepsilon_t} = \frac{1}{1+\beta_1}\left[\left(\frac{1}{r} - \beta_1\right) + c\right]$$

where $\beta_1 = -\frac{1}{2} + \sqrt{\frac{1}{4} + \frac{\bar{X}b\left[\sigma_\varepsilon^2\left(\frac{R}{r}+c\right)^2+\sigma_\zeta^2\right]}{R}} > 0$. Since $\lim_{\beta_1 \to 0} \frac{\partial P_t}{\partial \varepsilon_t} = \frac{1}{r} + c$ we can find examples of overreaction, i.e. $\frac{\partial P_t}{\partial \varepsilon_t} > \frac{\partial \hat{P}_t}{\partial \varepsilon_t}$ by choosing $\bar{X}$ or $b$ sufficiently small. Hence, in this example, there can be overreaction if bubble innovations and dividend innovations are positively correlated. Momentum obtains regardless of whether there is under- or overreaction.

### 2.5.2 Noise

Once again, the basic logic behind our momentum result is unaffected, since the disposition effect links current demand to prior gains and losses irrespective of whether these gains or losses reflect noise or news. This reasoning is very similar to that of the previous section. The effects of noise or bubbles on prices can be very similar. As was pointed out by Shiller (1984), fads, i.e. noise that is stable and leads to long undervaluations or overvaluations, look very much like bubbles.

However, unlike the stochastic bubbles considered in the previous section, noise itself can give rise to serial correlation of returns. So while the disposition effect generates positive autocorrelation, noise possibly gives rise to negative autocorrelation. In particular if demand by noise traders is largely transitory, this will induce negative autocorrelation of returns. It is hence possible that the effect of noise on autocorrelations dominates the disposition effect leading to negative autocorrelation overall. In such a case the price impact of disposition effect would be swamped by noise, i.e. by other factors that are not explicitly modeled. While this is a theoretical possibility there is strong evidence that noise is highly persistent at time horizons relevant for the momentum effect (e.g. Poterba and Summers (1988)).

The fact that the link between the disposition effect and momentum is consistent with prices being driven by noise reconciles the momentum result with the observation of excess volatility of stock prices and, if noise is correlated with fundamentals, with overreaction. Campbell and Kyle (1993) find that the "type of noise that appears to be empirically important is highly correlated with fundamental value" (p. 27).

## 2.6 Extensions

There are a number of ways to extend the basic model of the previous two sections. We argue that the momentum result goes through under an alternative explanation for the disposition effect and agent heterogeneity.

### 2.6.1 Irrational Belief in Mean Reversion

Based on experimental evidence Odean (1998) argues that "investors might choose to hold their losers and sell their winners [...] because they believe that today's losers will soon outperform today's winners." (p. 1777). To capture the disposition effect such a belief has to be unjustified (or irrational).[10]

Consider the following simple formalization. The representative investor does not have rational expectations of future prices. Rather, his price expectations can be represented in the form $E_t\left[P_{t+1}\right] - \delta\left(P_t - C\right)$, where $\delta$ is a positive constant. Given the distribution of $P_{t+1}$ this implies that the investor will overestimate the expected return for a stock that has been losing and underestimate the expected return for a stock that has gone up. The investor irrationally believes that "today's losers will soon outperform today's winners."

Suppose the representative investor chooses his demand so as to maximize a CARA utility function with risk aversion coefficient $\gamma$. Let prices be normally distributed. Then demand is

$$X_t = \frac{E_t\left[Q_{t+1}\right] - \delta\left(P_t - C\right)}{\gamma Var_t\left[Q_{t+1}\right]} \tag{2.12}$$

Demand is decreasing in the current price $P_t$ and prior performance $(P_t - C)$. An increase in the current price reduces expected returns in two ways: First, it of course raises current price but secondly, it also reduces the expectation of tomorrows

[10] See Chapter 1 for a discussion of this explanation for the disposition effect.

price. This makes demand more price-sensitive compared to the case of unbiased expectations, $\delta = 0$.

It is straightforward to show that demand of the form (2.12) yields momentum.

### 2.6.2 Heterogeneous Agents

We have presented our results in a model with a representative agent. While such an approach is common there may be some concern that it is particularly inappropriate in the context of the disposition effect. The disposition effect is closely connected with the idea of trade, after all it describes investors cashing in on gains and not selling after losses. More to the point, not all investors are directly affected by the disposition effect - only those who hold the asset. These facts can conveniently be ignored in the representative-agent formulation where the single investor holds the asset at all times (and hence never trades).

Our momentum result does not require the assumption of a representative investor. The basic logic how the disposition effect leads to momentum is hardly changed with heterogeneous investors.[11] The additional assumption needed is that the behavior of those investors who do not hold the asset is not biased in such a way so as to offset the behavior of the investors who display the disposition effect. Suppose in period $t$ there is a shock (e.g. dividend news or bubble innovation) so that prices increase. Risk preferences of those investors who do not hold the asset are unaffected by this price increase. Due to the disposition effect, however, the investors that do hold the asset are now less willing to hold the asset. With unchanged risk-adjusted expected return, they would want to sell (parts of) their holdings. At unchanged risk-adjusted expected return, there are no buyers since investors who preferred not to hold in the last period have unchanged preferences and

[11] See Zuchel (2001a) for a model of trading with heterogeneous investors who display the disposition effect.

other investors who do hold the asset want to sell themselves.[12] Hence for the market to clear, risk-adjusted expected return has to increase, leading to momentum. Conversely in the case of a price decrease.

Allowing for heterogeneity also allows us to address the question what happens if not all investors exhibit the disposition effect. First, even if a sizeable group of investors exhibits the disposition effect, arbitrage might eliminate any price impact. In this case there would be no momentum. There are many arguments and counterarguments as to why arbitrage may fail to eliminate price biases (e.g. Hirshleifer (2001)). Our analysis is based on the assumption that the price impact of the disposition effect is not completely eliminated by arbitrage. Second, if the subset of investors that exhibits the disposition effect is small, we would expect the price impact of the disposition effect to be negligible even if other market participants fail to eliminate it through arbitrage. For example, as we discussed in Subsection 2.5.2, the price impact of the disposition effect can be swamped by transitory noise trading. Or, the disposition effect could be rendered irrelevant for prices if there are many investors using stop-loss orders (or other forms of positive feedback strategies).

## 2.7 Empirical Predictions

In the sense of comparative statics, our model suggests that momentum is strongest when the disposition effect displayed by investors trading that stock is most pronounced. This observation suggests the following predictions as to when and for which stocks momentum should be strongest.

First, if the disposition effect is relatively more prevalent among individual in-

[12] This ignores the case where there are many investors not holding the asset who are indifferent between purchasing and not purchasing the asset at the given risk-adjusted expected return. If there are enough of such investors, risk-adjusted expected return will not change in equlibrium. Clearly this is a special case.

vestors as opposed to institutional investors, stocks held primarily by individuals—in particular small stocks—exhibit stronger momentum. That smaller stocks have indeed stronger momentum has been documented subject to some qualifications by Hong, Lim, and Stein (2000).

Second, as documented by Odean (1998) and Lakonishok and Smidt (1986) there is a strong seasonality in the disposition effect: Investors exhibit the disposition in every month except December. This seasonality is typically attributed to tax considerations. If the disposition effect drives momentum, we would expect this seasonality to translate into a seasonality in momentum profits. If there is no disposition effect at year-end we would expect no momentum over the beginning of the following year. Such a seasonality in momentum profits has indeed been documented by Jegadeesh and Titman (1993, 1999) for the U.S.: they find that winners outperform losers in all months except January. August, Schiereck and Weber (2000) report similar results for Germany.

Finally, note that if initial purchase prices are used as reference points, the disposition effect leads naturally to a link between momentum profits and past trading volume. Such a link has been documented by Lee and Swaminathan (2000). Trade determines who holds the asset and at what initial purchase price, i.e. at what reference price. According to the disposition effect it is precisely the distribution of reference prices and asset holdings that determines expected returns and hence momentum profits. Zuchel (2001a) discusses these issues in detail and shows that momentum based on the disposition effect reproduces the two most salient stylized facts from Lee and Swaminathan (2000): (i) Momentum profits are typically higher for high volume stocks. (ii) The positive relation between momentum profits and volume is primarily driven by the return differential in the loser portfolio: Low volume losers go on to perform significantly better than high volume losers.

## 2.8 Discussion

If a sufficiently large number of investors display the disposition effect so that they affect prices, the disposition effect leads to positive autocorrelation of returns, i.e. momentum. This if-then proposition raises the question how important the disposition effect really is? Most empirical studies demonstrate the disposition effect for individual investors only. The two exceptions are Locke and Mann (1999) and Coval and Shumway (2000) who demonstrate that professional futures traders display the disposition effect. If for instance institutional investors do not exhibit the disposition effect, the disposition effect may not matter much since institutional investors dominate trading volume for many stocks. So what do we know about the investment behavior of institutions? Badrinath and Wahal (1999) who study investment decisions by U.S. institutions conclude that "the data suggest that the landscape of institutional trading is one in which institutions follow a broad array of trading strategies across a large cross-section of stocks, which, at an aggregate level, offset each other" (p. 0). Lakonishok, Shleifer, and Vishny (1992) reach a similar conclusion.

In our model there is positive autocorrelation at all lags. The actual autocorrelation function of stock returns is of course more complex than that. In particular, at long lags, returns are negatively autocorrelated. Our model is too simple to generate both positive and negative autocorrelations. We do not feel that this is a problem given that there are already many convincing models available of why there should be negative autocorrelation of returns. One way to enhance our model to generate negative autocorrelations would be to allow for the house-money effect over longer time horizons. The house-money effect as modeled by Barberis, Huang, and Santos (2001) implies that—contrary to the disposition effect—prior gains increase the willingness to take risk and prior losses decrease it which leads to negative autocorrelation of returns. Neilson (1989) suggests how the disposition effect and the house-money effect can be combined in a model of sequential decision making. The intuition for the combination of the two effects would be that investors are initially unwilling to accept losses and therefore hold on to or escalate their commitment to losers (the disposition effect), but after some time accept their losses and consequently reduce their risk exposure to be protected from further losses. Conversely, in the case of gains, investors would initially be eager to realize their gains (the disposition effect) thus reducing their risk exposure, but, after some time or investing in a different risky asset, they would be willing to take on greater risk due to the house-money effect. Another possibility to introduce negative autocorrelations would be to introduce "momentum traders" as in Hong and Stein (1999) or transitory demand from noise traders.

The disposition effect is only an incomplete description of investor behavior. First it only describes how investors are biased in their decisions to sell or to hold an asset. It is silent on how investors make buy decisions. Second, the disposition effect distinguishes only winners and losers. While it indicates that the sign of prior performance matters for investor behavior it does not indicate the impact of the magnitude of prior gains or losses. So to get a complete description of investor behavior we were forced to make additional assumptions about how buy decisions are made, and how the magnitude of prior gains/losses affects investors. Concerning buy decisions we made the assumption that the disposition effect works through affecting risk attitudes or return expectations. Concerning the impact of the magnitude of gains and losses we assumed monotonicity. If the influence of prior performance on demand is non-monotonic, e.g. if large gains make realization less desirable than small gains, there is no longer an increasing relation between prior gains and future returns as in our model. Given the little evidence that we have on the precise relationship between the magnitude of prior gains and losses and investor behavior, the monotonicity assumption emerges as the weakest part of the link between the disposition effect and momentum.

## 2.9 Appendix: Proofs

### Proofs for Subsection 2.3.2

Prices are

$$P_t = \frac{E_t[F]}{\prod_{i=0}^{T-t}\left(R + \bar{X}bVar_{t+i}[Q_{t+1+i}]\right)} + c(t)$$

where $c(\cdot)$ and $Var_{t+i}[Q_{t+1+i}]$ are deterministic functions of time. (Result 2.1 in the text)

**Proof.** First we conjecture that $Var_t[Q_{t+1}] = f(t)$ for some deterministic function $f$. Then the price function can be proved by induction. The inductive hypothesis is true for $t = T$, since

$$P_T = \frac{E_T[F] - \bar{X}Var_T[F](a - bC)}{R + \bar{X}Var_T[F]b} = \frac{E_T[F]}{R + \bar{X}b\sigma^2} - \frac{\sigma^2(a - bC)}{R + \bar{X}b\sigma^2}$$

by assumption. Inductive step: The inductive hypothesis holds for some $t$. Then it also holds for $t - 1$, since

$$\begin{aligned}
P_{t-1} &= \frac{E_{t-1}[Q_t] - \bar{X}Var_{t-1}[Q_t](a - bC)}{R + \bar{X}bVar_{t-1}[Q_t]} \\
&= \frac{E_{t-1}\left[\frac{E_t[F]}{\prod_{i=0}^{T-t}\left(R+\bar{X}bVar_{t-1+j}[Q_{t+j}]\right)} + c(t)\right]}{R + b\bar{X}Var_{t-1}[Q_t]} + c'(t-1) \\
&= \frac{E_{t-1}[F]}{\prod_{i=0}^{T-(t-1)}\left(R + \bar{X}bVar_{t-1}[Q_{t+j}]\right)} + \frac{c(t)}{R + \bar{X}bVar_{t-1}[Q_t]} + c'(t-1) \\
&= \frac{E_{t-1}[F]}{\prod_{i=0}^{T-(t-1)}\left(R + \bar{X}bVar_{t-1}[Q_{t+j}]\right)} + c(t-1)
\end{aligned}$$

Given this price function, we can verify that the conjectured relation $Var_t[Q_{t+1}] = f(t)$ holds indeed for all $t$. Define $f(t)$ inductively, beginning with $t = T$:

$$Var_T[Q_{T+1}] = Var_T[F] = \sigma^2 =: f(T)$$

Then, for $1 \leq t < T$ and given $f(t+1), ..., f(T)$, $f(t)$ obtains as

$$\begin{aligned}
Var_t[Q_{t+1}] &= Var_t[P_{t+1}] \\
&= Var_t\left[\frac{E_{t+1}[F]}{\prod_{j=0}^{T-(t+1)}\left(R+\bar{X}bf(t+1+j)\right)} + c(t+1)\right] \\
&= \frac{1}{\left(\prod_{j=0}^{T-(t+1)}\left(R+\bar{X}bf(t+1+j)\right)\right)^2} Var_t[E_{t+1}[F]] \\
&= \left(\frac{\sigma}{\prod_{j=0}^{T-(t+1)}\left(R+\bar{X}bf(t+1+j)\right)}\right)^2 \\
&= : f(t)
\end{aligned}$$

■

Excess returns are positively autocorrelated at lag 1 for all $T \geq 2$. (Result 2.2 in the text)

**Proof.** Using the symbol $m(t) = \begin{cases} \prod_{i=0}^{T-t}\left(R+\bar{X}bf(t+i)\right) & \text{, for } t = 1, ..., T \\ 1 & \text{, for } t = T+1 \end{cases}$ where $f(t) = Var_t[Q_{t+1}]$ as in the preceding proof, and the price function $P_t = \frac{E_t[F]}{m(t)} + c(t)$ we can express excess returns for as

$$\begin{aligned}
Q_{t+1} &= P_{t+1} - RP_t = \frac{E_{t+1}[F]}{m(t+1)} + c(t+1) - R\left(\frac{E_t[F]}{m(t+1)} + c(t)\right) \\
&= \frac{\varepsilon_{t+1}}{m(t+1)} + E_t[F]\underbrace{\left(\frac{1}{m(t+1)} - \frac{R}{m(t)}\right)}_{>0} + c(t+1) - Rc(t)
\end{aligned}$$

The term $\left(\frac{1}{m(t+1)} - \frac{R}{m(t)}\right)$ is positive since $\frac{m(t)}{m(t+1)} = R + \bar{X}bf(t) > R$ given our assumption of a positive net supply of the risky asset, $\bar{X} > 0$. This implies

$$\begin{aligned}
Cov\left[Q_{t+1}, Q_t\right] &= Cov\left[\begin{array}{c} \frac{\varepsilon_{t+1}}{m(t+1)} + E_t\left[F\right]\left(\frac{1}{m(t+1)} - \frac{R}{m(t)}\right) + c\left(t+1\right) - Rc\left(t\right), \\ \frac{\varepsilon_t}{m(t)} + E_{t-1}\left[F\right]\left(\frac{1}{m(t)} - \frac{R}{m(t-1)}\right) + c\left(t\right) - Rc\left(t-1\right) \end{array}\right] \\
&= Cov\left[\begin{array}{c} \left(\varepsilon_t + E_{t-1}\left[F\right]\right)\left(\frac{1}{m(t+1)} - \frac{R}{m(t)}\right), \\ \frac{\varepsilon_t}{m(t)} + E_{t-1}\left[F\right]\left(\frac{1}{m(t)} - \frac{R}{m(t-1)}\right) \end{array}\right] \\
&= \frac{m\left(t\right) - Rm\left(t+1\right)}{m\left(t+1\right)m\left(t\right)}\frac{m\left(t-1\right) - Rm\left(t\right)}{m\left(t\right)m\left(t-1\right)}Var\left[E_{t-1}\left[F\right]\right] + \frac{\sigma^2}{m\left(t\right)} \\
&> 0
\end{aligned}$$

■

## Proofs for Subsection 2.4.1

Recall the assumptions made in section 2.4.1: $X_t = \frac{E_t Q_{t+1}}{(a+bZ_t)Var_t Q_{t+1}}$, where $a, b$ are two positive constants, $Z_t = P_t - C_t$, $C_t = P_{t-1}$, and dividends follow a random walk, $D_{t+1} = D_t + \varepsilon_{t+1}$.

The claims made in the text are based on the following two results.

**Result 2.4** *There exists an equilibrium price of the stock that has the following form*

$$P_t = \frac{D_t}{r} - \left(\alpha_0 + \alpha_1 \Delta P_t\right)$$

*where* $\alpha_1 = \frac{1}{2r}\left(b\bar{X}\sigma_\varepsilon^2 - r + \sqrt{\left(b\bar{X}\sigma_\varepsilon^2 - r\right)^2 + 4b\bar{X}\sigma_\varepsilon^2\left(1+r\right)}\right) > 0$ *and* $\alpha_0 = \frac{1}{r}a\bar{X}\left(1 + \frac{1}{r(1+\alpha_1)}\right)^2\sigma_\varepsilon^2 - \alpha_1$.

**Proof.** The proof follows the standard pattern. First we conjecture that the equilibrium price function has the given form. Then we use the assumptions about behavior, i.e. the demand functions, and the market clearing condition to verify the conjecture. Suppose the solution is of the form

$$P_t = \frac{D_t}{r} - (\alpha_0 + \alpha_1 Z_t) \tag{2.13}$$

where $\alpha_0$ and $\alpha_1$ are constants. Plugging the supposed solution (2.13) into the definition of the measure of prior gains, we get an AR(1)-representation for $Z_t$:

$$\begin{aligned} Z_t &= P_t - P_{t-1} = \frac{D_t}{r} - (\alpha_0 + \alpha_1 Z_t) - \frac{D_{t-1}}{r} + (\alpha_0 + \alpha_1 Z_{t-1}) \\ &= -\alpha_1 (Z_t - Z_{t-1}) + \frac{1}{r}\varepsilon_t \end{aligned}$$

Note that the process of the measure of prior gains $(Z_t)$ is stationary and positively autocorrelated at all lags if and only if $\alpha_1 > 0$.

Using again the supposed solution we can express excess returns as a function of $Z_t$ and dividend innovations

$$\begin{aligned} Q_{t+1} &= Z_{t+1} + D_{t+1} - rP_t \\ &= Z_{t+1} + D_{t+1} - D_t + r\alpha_0 + r\alpha_1 Z_t \\ &= r\alpha_0 + \left(r\alpha_1 + \frac{\alpha_1}{1+\alpha_1}\right) Z_t + \left(1 + \frac{1}{r(1+\alpha_1)}\right)\varepsilon_{t+1} \end{aligned}$$

which, together with the AR-representation for $Z_t$ allows us to compute expected return and variance:

$$E_t Q_{t+1} = r\alpha_0 + \left(r\alpha_1 + \frac{\alpha_1}{1+\alpha_1}\right) Z_t$$

and

$$Var_t Q_{t+1} = \left(1 + \frac{1}{r(1+\alpha_1)}\right)^2 \sigma_\varepsilon^2$$

Market clearing requires

$$\frac{E_t Q_{t+1}}{(a + bZ_t)\, Var_t Q_{t+1}} = \bar{X}$$

Hence

$$r\alpha_0 + \left(r\alpha_1 + \frac{\alpha_1}{1+\alpha_1}\right) Z_t = \bar{X}\left(a + bZ_t\right)\left(1 + \frac{1}{r\left(1+\alpha_1\right)}\right)^2 \sigma_\varepsilon^2 \tag{2.14}$$

Comparing coefficients of $Z_t$ we get a quadratic equation for $\alpha_1$

$$r\alpha_1 = b\bar{X}\sigma_\varepsilon^2\left(1 + \frac{1}{r\left(1+\alpha_1\right)}\right)$$

We choose the positive root $\alpha_1 = \frac{1}{2r}\left(b\bar{X}\sigma_\varepsilon^2 - r + \sqrt{\left(b\bar{X}\sigma_\varepsilon^2 - r\right)^2 + 4b\bar{X}\sigma_\varepsilon^2\left(1+r\right)}\right)$.
Comparing constants in (2.14) we get $\alpha_0 = \frac{1}{r}a\bar{X}\left(1 + \frac{1}{r(1+\alpha_1)}\right)^2 \sigma_\varepsilon^2 - \alpha_1$. ■

**Result 2.5** *Excess returns are positively autocorrelated at all lags.*

**Proof.** The measure of prior gains $Z_t$ follows an AR(1) process with positive coefficients, $Z_t = \frac{\alpha_1}{1+\alpha_1}Z_{t-1} + \frac{1}{r(1+\alpha_1)}\varepsilon_t$, and is hence positively autocorrelated at all lags

$$\forall j \in \mathbb{N}: \; Cov\left(Z_t, Z_{t-j}\right) = \left(\frac{\alpha_1}{1+\alpha_1}\right)^j \sigma_Z^2$$

where $\sigma_Z^2 = Var\left[Z_t\right] = \frac{\sigma_\varepsilon^2}{r^2(1+2\alpha_1)}$ is the unconditional variance of the state variable.

Excess returns are a function of the measure of prior gains and dividend innovations

$$Q_t = r\alpha_0 + c_Z Z_{t-1} + c_\varepsilon \varepsilon_t$$

where $c_Z = r\alpha_1 + \frac{\alpha_1}{1+\alpha_1} > 0$ and $c_\varepsilon = 1 + \frac{1}{r(1+\alpha_1)} > 0$.

Hence,

$$\forall j \in \mathbb{N}: \; Cov\left[Q_t, Q_{t+j}\right] = c_Z^2\left(\frac{\alpha_1}{1+\alpha_1}\right)^j \sigma_Z^2 + c_Z c_\varepsilon \frac{1}{r\left(1+\alpha_1\right)}\left(\frac{\alpha_1}{1+\alpha_1}\right)^{j-1} \sigma_\varepsilon^2 > 0$$

■

## Proofs for Subsection 2.4.2

Recall the assumptions made in section 2.4.2: $X_t = \frac{E_t Q_{t+1}}{(a+bZ_t)Var_t Q_{t+1}}$, where $a, b$ are two positive constants, $Z_t = Q_t$, and dividends follow a random walk, $D_{t+1} = D_t + \varepsilon_{t+1}$.

**Result 2.6** *Under the stability condition $\bar{X}b\left(\frac{R}{r}\sigma_\varepsilon\right)^2 < 1$, there is an equilibrium asset price of the following form*

$$P_t = \frac{1}{1+\beta_1}\left[\left(\frac{1}{r} - \beta_1\right)D_t - (\beta_0 + \beta_1 R P_{t-1})\right]$$

*where $\beta_0$, $\beta_1$, are constants.*

**Proof.** This is a special case of the result with bubble ($B_t \equiv 0$) proved in the next subsection. ■

The equilibrium price function implies $Q_{t+1} = \frac{r\beta_0}{1+\beta_1} + \frac{R\beta_1}{1+\beta_1}Q_t + \frac{R}{r}\varepsilon_t$ which means that excess returns are positively autocorrelated at all lags.

## Proofs for Subsection 2.5.1

Recall the assumptions made in section 2.5.1: $X_t = \frac{E_t Q_{t+1}}{(a+bZ_t)Var_t Q_{t+1}}$, where $a, b$ are two positive constants, $Z_t = P_t + D_t - RP_{t-1} = Q_t$, dividends follow a random walk, $D_{t+1} = D_t + \varepsilon_{t+1}$, and the bubble has the form $B_{t+1} = RB_t + \eta_{t+1}$.

Under the stability condition $\bar{X}bVar_t\left[Q_{t+1}\right] < 1$, there is an equilibrium asset price of the following form

$$P_t = \frac{1}{1+\beta_1}\left[\left(\frac{1}{r} - \beta_1\right)D_t - (\beta_0 + \beta_1 R P_{t-1}) + B_t\right]$$

where $\beta_0$, $\beta_1$, and $Var_t\left[Q_{t+1}\right]$ are constants. (Result 2.3 in the text.)

**Proof.** We conjecture that the price function is of the form $P_t = \frac{D_t}{r} - (\beta_0 + \beta_1 Z_t) + B_t$. Using this conjecture and the definition of excess returns we have

$$Q_{t+1} = \frac{1}{1+\beta_1}\left[r\beta_0 + R\beta_1 Q_t + \frac{R}{r}\varepsilon_{t+1} + \eta_{t+1}\right] \tag{2.15}$$

So,

$$\begin{aligned} E_t\left[Q_{t+1}\right] &= \frac{r\beta_0}{1+\beta_1}+\frac{R\beta_1}{1+\beta_1}Q_t \\ Var_t\left[Q_{t+1}\right] &= \frac{1}{\left(1+\beta_1\right)^2}\left[\left(\frac{R}{r}\right)^2\sigma_\varepsilon^2+\sigma_\eta^2+2\frac{R}{r}\sigma_{\varepsilon\eta}\right]=:\frac{k}{\left(1+\beta_1\right)^2} \end{aligned}$$

and the equilibrium condition $X_t = \bar{X}$ becomes

$$\bar{X}\frac{k}{\left(1+\beta_1\right)^2}\left(a+bQ_t\right)=\frac{r\beta_0}{1+\beta_1}+\frac{R\beta_1}{1+\beta_1}Q_t \tag{2.16}$$

Comparing coefficients we get

$$\beta_1\left(1+\beta_1\right)=\frac{\bar{X}bk}{R}$$

We choose the positive root $\beta_1 = -\frac{1}{2}+\sqrt{\frac{1}{4}+\frac{\bar{X}bk}{R}}$. From (2.15) we know that the process $(Q_t)$ is stationary if $\left|\frac{R\beta_1}{(1+\beta_1)}\right| = \bar{X}bVar_t\left[Q_{t+1}\right] < 1$ or $r\beta_1 < 1$. Again from comparing coefficients in (2.16), $\beta_0 = \frac{\bar{X}ka}{r(1+\beta_1)}$ obtains.

Hence the conjectured price function is—under the stability condition—an equilibrium price function. ■

# Chapter 3

# The Disposition Effect and Trading Volume

## 3.1 Introduction

There is a growing recent literature in finance that examines theoretically how deviations from standard assumptions about behavior can affect financial market outcomes.[1] This literature is based on the notion that the behavior of a subset of investors may not simply be rendered irrelevant by smart arbitrageurs who jump in to eliminate any profit opportunity. The present paper is in the spirit of this literature. I study how the disposition effect—a documented pattern in investor behavior—affects equilibrium returns and trading volume.

The term disposition effect was coined by Shefrin and Statman (1985) to describe the tendency of investors to be too eager to sell winners (assets with paper gains)

[1] In two recent examples, Gervais and Odean (2001) examine the role of overconfident traders and Barberis, Huang and Santos (2001) study how the equity premium can be rationalized by assuming that investors care about fluctuations in their financial wealth in a way that reflects experimental evidence on risk-taking behavior.

and to reluctant to sell losers (assets with paper losses) relative to a normative theory of investor behavior. That the disposition effect describes the behavior of some investors has since been directly demonstrated by Odean (1998) for a sample of discount brokerage accounts, by Weber and Camerer (1998) in an experimental asset market, by Grinblatt and Keloharju (2001) for individual investors, by Coval and Shumway (2000) and Locke and Mann (1999) for professional futures traders, and by Heisler (1994) for a small sample of non-professional futures traders.

There is also some evidence that the disposition effect influences aggregate trading volume. Lakonishok and Smidt (1986) find that current trading volume is positively correlated with past price changes in line with the disposition effect. Ferris, Haugen and Makhija (1988) demonstrate for small stocks that contemporary volume can be predicted with historic volume at differential price levels: If there was high volume at higher than current prices in the past, i.e. there are many investors sitting on a loss, current volume is low. The opposite is true if there was high volume at lower prices in the past. They attribute this finding to the disposition effect. Lee and Swaminathan (2000) appeal to the disposition effect to help explain the observation that volume declines as "stocks fall out of favor."

Finally, the disposition effect is indirectly supported by a large body of psychological evidence. In the literature on entrapment, psychologists have studied extensively the tendency to "irrationally stick to or even intensify losing courses of action" (Schulz-Hardt and Frey (1998, p. 487)).[2] An entrapment situation is characterized by repeated (rather than one-shot) decision making under uncertainty, in the face of negative feedback about prior decisions, and choice about whether to continue (Brockner (1992)). This is a neat description of the decision situation faced by an investor who has made a loss on an investment.[3] In the context of investments,

[2] Entrapment is sometimes also referred to as escalation of commitment or the sunk-cost effect.

[3] In his survey of the entrapment literature, Staw (1997) explicitly refers to investment decisions as an example of an entrapment situtation: "When people have lost money in common stocks or

entrapment means that investors tend to be reluctant to realize losses or maybe even escalate their commitment by increasing their investment.

In the present paper I take the empirical evidence on the disposition effect seriously and address the question how the disposition effect influences asset returns and trading volume. I show that, by linking current asset demand to prior returns, the disposition effect motivates trade: Prior gains lead to a tendency to sell to lock in these gains (profit-taking motive). Prior losses possibly lead to a tendency to buy so as to intensify the exposure to the asset (escalating-commitment motive). Finally, in the case of many assets, profit taking on one asset leads to a tendency to re-invest the realized gains in a different asset (re-investment motive). Moreover, trade typically indicates changes in equilibrium expected return. Profit taking implies an increase in expected return whereas escalating commitment after losses implies a decrease in expected return. The disposition effect can thus give rise to return continuation, i.e. to momentum.

Momentum is a well-documented and much discussed feature of actual stock returns (Jegadeesh and Titman (1993)), and the disposition effect is but one possible explanation. Recently, three other explanations based on biases in investor behavior have been proposed (Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer and Subrahmanyam (1998), and Hong and Stein (1999)). To compare different explanations for the momentum effect, data on stock returns alone is insufficient, because different explanations have very similar implications for the time-series of returns. A possible remedy to this identification problem is to use data on trading volume. The link between momentum and trading volume (or more precisely turnover, i.e.

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mutual funds, they often face a dilemma. Should they stick with their losing investments, increase their stake (perhaps through dollar cost averaging), or move to an entirely different investment vehicle?" (p. 191) See Zuchel (2001) for a discussion of the disposition effect as an example of entrapment.

number of shares traded divided by number of shares outstanding) has been analyzed by Lee and Swaminathan (2000) for a sample of U.S. stocks. In contrast to existing models of momentum, the disposition effect leads naturally to a link between momentum profits and past trading volume. I show that momentum based on the disposition effect reproduces the two most salient stylized facts from Lee and Swaminathan (2000): (i) High volume indicates strong return continuation. (ii) The positive relation between return continuation and volume is more pronounced for losers than for winners.

The next Section discusses the model. In Section 3.3 I relate the theoretical results to their empirical evidence on the link between trading volume and momentum and show that they are qualitatively consistent. Sections 3.4 and 3.5 point out possible extensions and discuss the results.

## 3.2 Equilibrium Returns and Trading Volume

### 3.2.1 Demand

The disposition effect is defined as a preference for selling winners rather than losers compared with some normative theory of investor behavior. The term "winner" refers to a stock that currently trades at a price that is higher than the purchase price (=the reference price). Conversely, an asset is a "loser" if its current price is lower than the initial purchase price. The disposition effect describes a bias in the decision to sell or hold an asset and consequently applies only for investors who already hold the asset. Note that there are many good reasons why prior gains and losses should influence current investment decision such as portfolio rebalancing, transaction costs, capital gains taxes, etc. This is not what the disposition effect is about. The disposition effect describes a tendency to sell winners and hold losers over and above what is implied by normative theory.

There are various non-exclusive theories as to why investors might display the disposition effect: The disposition effect has been attributed to biases in return expectations, time-varying risk-aversion based on the value function of prospect theory, and the desire for self-justification.[4] For the purpose of the present study it suffices to note that all these theories have one common element: For investors who are holding the asset, demand is affected by how the current asset price compares with a reference price. It is this common element that I model in this paper.

Let $X^d_{j,t}$ denote investor $j$'s demand for the risky asset at time $t$. The disposition effect is defined relative to the benchmark "normative theory." It is clear that there are many behavioral patterns that are consistent with normative theory, even if one restricts normative theory to expected-utility maximization (Arrow (1986)). I consider only the special case of mean-variance behavior, or more precisely the case of demand that is an increasing function of risk-adjusted expected excess return, $\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$, where $E_t$ and $Var_t$ denote the expected value and variance conditional on information at time $t$, and $Q_{t+1}$ denotes the excess return in period $t+1$. Such behavior can and often is motivated by the joint assumption of CARA utility and prices and dividends that are normally distributed.

The disposition effect can then be thought of as an additional argument of the demand function. Relative to normative theory (as defined narrowly above), demand depends also on how the current asset price compares to a reference price $C_{j,t}$,

$$X^d_{j,t} = X^d_{j,t}\left(\frac{E_t\left[Q_{t+1}\right]}{Var_t\left[Q_{t+1}\right]}, P_t - C_{j,t}\right) \tag{3.1}$$

The reference price is equal to the initial purchase price for those investors who are holding the asset, and equal to the current price $P_t$ for those investors who do not hold the asset. To capture the disposition effect I assume that, ceteris paribus,

[4] See Zuchel (2001) for a discussion of the different explanations for the disposition effect.

demand is lower for winners than for losers. More precisely,

$$\forall s \in \mathbb{R},\ g > 0,\ l < 0 : X_{j,t}^{d}(s,g) \leq X_{j,t}^{d}(s,0) \leq X_{j,t}^{d}(s,l)$$

i.e. for any given risk-adjusted expected return, demand is lower in the presence of capital gains than in the absence of prior gains or losses which in turn is lower than demand in the presence of prior losses. A special case are demand functions that are weakly decreasing in prior performance, $X_{j,t}^{d}\left(\cdot, \underset{(-)}{P_t - C_{j,t}}\right)$.

How does this specification imply the disposition effect? For an investor $j$ who is not holding the asset, demand is simply $X_{j,t}^{d} = X_{j,t}^{d}\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}, 0\right)$, irrespective of the prior performance of the asset. Her demand is hence unaffected by prior performance of the asset so that it is a function of risk-adjusted expected return only. In contrast, for an investor who is already holding the asset with an initial purchase price $\bar{P}$, demand is affected by prior gains or losses $P_t - \bar{P}$. Her demand is $X_{j,t}^{d}\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}, P_t - \bar{P}\right)$. For a disposition investor (henceforth used as a shorthand for "investor exhibiting the disposition effect") who is holding the asset, demand is a function of two arguments: risk adjusted expected return, and prior gains or losses. A higher current price at the same time lowers the expected return and increases prior gains (or reduces prior losses). Both factors contribute to a lower demand for the risky asset. By linking current demand to prior performance, the disposition effect thus constitutes an additional channel through which the current price affects demand. This means that compared with the case without the disposition effect, the demand curve is no steeper, i.e. demand is always more sensitive to price changes.

Note that this specification implies a tendency to sell winners and to hold losers, but not at all cost. If risk-adjusted return changes over time then this demand function can well imply not to sell winners or to sell losers. Two simple examples may clarify the specification:

**Example 1:** Consider the case of an investor who thinks about investing as a binary decision: Either he is invested in the risky asset or not. This either/or structure of asset demand allows to express demand in terms of a reservation price, the highest price the investor would be willing to pay to buy the stock: An investor $j$ buys or holds one unit of the asset when its price at time $t$, $P_t$, is at or below his reservation price $P^*_{j,t}$, he sells or does not buy one unit of the asset, whenever the price $P_t$ exceeds the reservation price $P^*_{j,t}$. Formally, investor $j$'s asset demand at time $t$ is

$$X^d_{j,t} = \begin{cases} 1 & \text{, if } P_t \leq P^*_{j,t} \\ 0 & \text{, else} \end{cases}$$

If the reservation price is a function of risk-adjusted expected return and prior performance, $P^*_{j,t} = P^*_{j,t}\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}, P_t - C_{j,t}\right)$ this is a special case of the general specification (3.1).

Note that, given a constant risk-adjusted expected return, such a demand function is consistent with profit-taking but inconsistent with escalation of commitment, i.e. additional purchases, since by assumption the investor will never increase his or her exposure to the risky asset above one unit. A demand function of this type corresponds to the notion of "eagerness to realize gains and reluctance to realize losses" described by Shefrin and Statman (1985).

**Example 2:** A second special case is linear demand

$$X^d_{j,t} = a\frac{E_t\left[Q_{t+1}\right]}{Var_t\left[Q_{t+1}\right]} - b\left(P_t - C_{j,t}\right)$$

where $a$ and $b$ are two positive constants. If risk-adjusted expected return is constant such a demand function corresponds to simple negative feedback trading. This means that capital gains lead to profit taking and capital losses lead to the purchase of additional units, i.e. to escalation of commitment.

Let $G^d$ denote the distribution function of disposition investors. Aggregate demand by disposition investors, $X^d_t$, is then given by aggregating the individual demand functions

$$X_t^d = \int X_{j,t}^d dG^d(j)$$

**Demand by Smart Investors**

I assume there is a second subset of investors whose asset demand is not affected by prior performance or, in fact, any past information. Demand for any investor $k$ of this group is assumed to be a continuous, *strictly* increasing function of risk-adjusted expected return:

$$X_{k,t}^s = X_{k,t}^s \left( \frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]} \right) \tag{3.2}$$

In line with the literature (e.g. Shiller (1984)) I call these investors smart investors. Whether the behavior of these investors can be considered smart is debatable, since they behave myopically. A special case would be the familiar linear demand function of the form $X_{k,t}^s = \tau \frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ where the coefficient of risk tolerance, $\tau$, is a positive constant.

There are two reasons for me to introduce smart investors. First, while the disposition effect has been shown to be relevant for some investors, it certainly does not describe the behavior of all investors. The second reason is technical: the introduction of smart money investors ensures that aggregate demand is strictly monotonic ensuring that there is at most one price that clears the market.

Let $G^s$ denote the distribution function of smart investors. Aggregate demand by smart money investors, $X_t^s$, is then given by integrating the individual demand functions

$$X_t^s = \int X_{j,t}^s dG^s(j)$$

### Aggregate Demand

Aggregate demand at time $t$, $X_t$, is simply the sum of the demands by disposition investors and smart money investors.

$$X_t = X_t^d + X_t^s$$

How is aggregate demand affected by the disposition effect? Demand by smart investors is simply a function of risk-adjusted expected return. For disposition investors the situation is more complex. Their demand depends on who holds the asset (and is consequently affected by the disposition effect) and their reference points, i.e. at which prices those that hold the asset purchased their holdings. It is easy to see that characterizing demand for disposition investors is in general quite complex since it cannot easily be summarized by a few state variables. In special cases, however, the answer is simple: For example, in the extreme cases when either every disposition investor who holds the asset is sitting on a loss or when every disposition investor who holds the asset is sitting on a gain. In the former case demand is no lower while in the latter case demand is no higher than without the disposition effect. Aggregate demand is monotonic as are the individual demand functions.

## 3.2.2 The Assets

Consider trading of a riskless and a risky asset over 2 periods. In period 3 the risky asset is liquidated and the value $F$ collected. In periods $t = 1, 2, 3$ each agent receives a common signal $\varepsilon_t$ about final value so that information is symmetric.

$$F = \mu_0 + \varepsilon_1 + \varepsilon_2 + \varepsilon_3$$

where $\mu_0$ is a constant. The signals are independent across time. There is a fixed stock $\bar{X}$ of the risky asset in supply in all periods.

The risk-free asset, which is in elastic supply, guarantees a rate of return $R = 1+r$ with $r \geq 0$.

### 3.2.3 Equilibrium

The variables of interest are the process of equilibrium risk-adjusted expected return $(S_1, S_2)$ and the process of trading volume $(V_1, V_2)$. Risk-adjusted expected return is defined as $S_t = \frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$. Volume is defined as the measure of units of the risky asset changing hands.[5]

Prices in the model are completely driven by news about fundamental value $F$. Even though the individual pieces of news, $\varepsilon_t$, are independent, current prices are nevertheless influenced by past news over and above what they imply for the expected value of the final dividend because of the disposition effect. But, as a benchmark, consider equilibrium in the absence of the disposition effect, i.e. when demand is unaffected by prior performance for all disposition investors $j$, $X^d_{j,t} = X^d_{j,t}\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}, 0\right)$. In this case all trade will occur in the first period and risk-adjusted expected return will be the same in both periods. This is just a simple application of the No-Trade Theorem (e.g. Varian (1989)). Since there are no asymmetries in information or beliefs, and no liquidity trading, risk sharing is the sole motive for trade. And since preferences for risk-taking are assumed to be constant (in particular, there are by assumption no wealth effects on risk preference), after a single round of trading motivated by risk sharing (or more fundamentally by differences in endowments and risk aversion) there is no further reason to trade.

**Result 3.1 (No-Trade-Theorem)** *In an equilibrium without the disposition ef-*

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[5] Formally

$$V_t = \int \max\left\{X^d_{j,t} - X^d_{j,t-1}, 0\right\} dG^d(j) + \int \max\left\{X^s_{k,t} - X^s_{k,t-1}, 0\right\} dG^s(k)$$

where $X^d_{j,0}$, $X^s_{k,0}$ refers to the initial endowments. Trade that does not lead to a change of holdings is not counted in this definition. Since trade is costless in our model any amount of such inconsequential trading is consistent with equilibrium. Under the assumption that there is no inconsequential trading the definition used here is the standard definition of volume.

*fect,* $X^d_{j,t} = X^d_{j,t}\left(\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}\right)$ $\forall j$*, there is no trade after the first period,* $V_2 = 0$*, and risk-adjusted expected return* $S_t = \frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ *is the same in both periods,* 1 *and* 2*.*

**Proof.** In equilibrium, $S_1$ clears the market in period 1. Since aggregate demand is a function of $S_t$ alone (in the absence of the disposition effect), and since aggregate demand is strictly monotonic, any change in $S$ over time is inconsistent with equilibrium. Hence $S_1 = S_2$.

Unchanged risk-adjusted expected return, $S_t = S_{t-1}$, implies that demand by any individual smart money investor is unchanged, $X^s_2 = X^s_1$, and also that the demand from any individual disposition investor (who, in the absence of the disposition effect, behave just like smart money investors) is unchanged. Hence there is no volume in period $t = 2$.

This is the only equilibrium due to the strict monotonicity of aggregate demand.

■

From the No-Trade Theorem we know that unchanged preferences for holding the asset in the second period imply no trade. Put differently, if there is trade, the preferences for holding the asset of some investors need to have changed. Changing the preference for holding the asset is of course precisely what the disposition effect does. Recall that demand depends on the current distribution of asset holdings as well as the distribution of reference points, all of which are a function of past $\varepsilon$'s. This intertemporal connection can generate trade, and thereby lead to a change in risk-adjusted expected return.

**Result 3.2** *In equilibrium, expected risk-adjusted return* $\frac{E_t[Q_{t+1}]}{Var_t[Q_{t+1}]}$ *changes if and only if there is trade at time* $t$*. Formally,*

$$\frac{E_2\left[Q_3\right]}{Var_2\left[Q_3\right]} \neq \frac{E_1\left[Q_2\right]}{Var_1\left[Q_2\right]} \iff V_2 > 0$$

**Proof.** " $\Longrightarrow$ ": From the strict monotonicity of smart money demand, a change in risk-adjusted expected return implies a change in the holdings of smart money investors and hence volume: $S_2 \neq S_1 \Longrightarrow X_1^s \neq X_2^s \Longrightarrow V_2 > 0$.

" $\Longleftarrow$ ": Suppose $S_2 = S_1$. This means unchanged smart money demand, $X_2^s = X_1^s$, and unchanged demand from disposition investors who are not holding the asset at the beginning of the period. Since disposition investors who are holding the asset all want to trade in the same direction, market clearing requires that they do not want to trade at all. ■

The sign of the prior price change determines the sign of the change of risk-adjusted expected return.

**Result 3.3** *For winners, $P_2 - P_1 > 0$, volume indicates an increase in risk-adjusted expected return. The increase in risk-adjusted expected return is an increasing function of volume. No volume means unchanged expected return.*

**Proof.** We know from Result 3.2 that no volume means unchanged risk-adjusted expected return and that positive volume means a change in risk-adjusted expected return. Suppose there is trade in period 2 and risk-adjusted expected return is lower than in period 1. This would mean that $X_2^d \leq X_1^d$ and $X_2^s < X_1^s$ which cannot be in equilibrium. Volume on a price increase thus indicates $\frac{E_2[Q_3]}{Var_2[Q_3]} \geq \frac{E_1[Q_2]}{Var_1[Q_2]}$.

Suppose there are two different realizations $\varepsilon_2^*$ and $\tilde{\varepsilon}_2$ both associated with an equilibrium price increase, $P_2 > P_1$, and such that the equilibrium values for volume and risk-adjusted expected return are as follows: $V_2(\varepsilon_2^*) > V_2(\tilde{\varepsilon}_2)$ and $S_2(\varepsilon_2^*) < S_2(\tilde{\varepsilon}_2)$. This means that in the case of $\varepsilon_2^*$ there is less buying from smart money investors in the second period. For $V_2(\varepsilon_2^*) > V_2(\tilde{\varepsilon}_2)$ to hold, it has therefore to be the case that there is more buying by disposition investors which requires $S_2(\varepsilon_2^*) > S_2(\tilde{\varepsilon}_2)$ - a contradiction. The increase in expected return $S_2 - S_1$ is hence an increasing function of volume. ■

A winner, i.e. an asset with a capital gain, has an increased risk-adjusted expected return in the second period. In other words there is a tendency for return continuation or momentum for winners. The reason is simple equilibrium logic. For winners trading indicates profit taking which necessitates an increase in expected return. Profit taking means selling by disposition investors to realize capital gains. In equilibrium, someone (either a smart investor or another disposition investors) has to buy the assets that are sold by profit takers. To induce them to purchase the additional units and to consequently bear the additional risk, risk-adjusted expected return has to increase. Moreover the result shows that it is volume that indicates the degree of return continuation: For winners, equilibrium risk-adjusted expected return is an increasing function of trading volume. Higher capital gains $(P_2 - P_1)$ do not necessarily mean stronger momentum, since large capital gains may lead to less profit taking than small capital gains.

For losers, $P_2 - P_1 < 0$, we have the converse effect. Here, any volume indicates buying by disposition investors who want to escalate their commitment to the asset. Volume consequently indicates a decreased expected return.

**Result 3.4** *For losers, $P_2 - P_1 < 0$, a higher volume indicates a greater decrease in the risk-adjusted expected return. No volume means unchanged expected return.*

**Proof.** We know once again from Result 3.2 that no volume means unchanged risk-adjusted expected return and that positive volume means a change in risk-adjusted expected return. Suppose there is trade in period 2 and risk-adjusted expected return is higher than in period 1. This would mean that $X_2^d \geq X_1^d$ and $X_2^s > X_1^s$ which cannot be in equilibrium. Volume on a price decline thus indicates $\frac{E_2[Q_3]}{Var_2[Q_3]} \leq \frac{E_1[Q_2]}{Var_1[Q_2]}$.

Suppose you have two different realizations $\varepsilon_2^*$ and $\tilde{\varepsilon}_2$ both associated with a price decline, $P_2 < P_1$, and such that the equilibrium values for volume and risk-adjusted expected return are as follows: $V_2(\varepsilon_2^*) > V_2(\tilde{\varepsilon}_2)$ and $S_2(\varepsilon_2^*) > S_2(\tilde{\varepsilon}_2)$. This means that in the case of $\varepsilon_2^*$ there is less selling by smart money investors in the second period. For $V_2(\varepsilon_2^*) > V_2(\tilde{\varepsilon}_2)$ to hold, it has therefore to be the case that there is more selling by disposition investors which requires $S_2(\varepsilon_2^*) < S_2(\tilde{\varepsilon}_2)$ - a contradiction. The decrease in expected return $S_2 - S_1$ is hence an increasing function of volume. ■

So also for losers, volume indicates momentum. Note that the result implies that there will be momentum for losers only if there are some disposition investors who escalate their commitment to the "losing asset" by purchasing additional units.

**Corollary 3.1** *In the absence of escalation of commitment, there is no volume for losers and hence no momentum.*

If investors are simply reluctant to sell losers but refrain from purchasing additional units then there is no momentum for losers. An example of such behavior is given in Example 1 where investors think about investing as a binary decision. Even though after losses disposition investors holding the asset become particularly attached to the units they already have, this attachment does not translate into trade. The loss simply means the disposition investors who hold the asset are now even more eager to hold on to their positions without wanting to purchase additional shares. This, however, makes them inframarginal so that they do not affect prices. This result is worth emphasizing, since it means that (in this simple example) the disposition effect cannot lead at the same time to momentum for losers and to the observation, often attributed to the disposition effect, that volume declines on price declines. If there is momentum for losers, there is also escalation of commitment by some disposition investors and hence trading. This result is changed when we allow for the re-investment of realized gains in Subsection 3.2.4.

To summarize, in the context of a single risky asset, the disposition effect provides two motives for trade: profit taking following gains and escalation of commitment following losses. Trade indicates changes in expected return: profit taking leads to an increase in risk-adjusted expected return whereas escalation of commitment decreases expected return. There is hence return continuation, or momentum, in the sense that gains are followed by higher expected returns and losses are followed by lower expected returns (and an unchanged price means no trade and unchanged risk-adjusted expected return). Trading volume serves as an indicator for the strength of return momentum. Under the additional assumption that disposition demand depends monotonically on prior gains/losses there is also a positive relation between absolute price change in period $t$ and volume in period $t$.

### 3.2.4 Re-Investment in the Case of Many Assets

So far I have presented the model as one with one riskless and one risky asset. In such a model, profit takers are constrained to use the funds freed up by the realization of a paper profit either to purchase the riskless asset—it is the only other asset around—or to use these funds outside the asset markets, e.g. to purchase consumption goods, and hence outside the model.

In practice, investors have of course a third option: They can use the proceeds from profit-taking to purchase another risky asset. And this is of course in fact what is done by most investors most of the time (Cf. Odean (2000)).[6] So in addition to the two motives for trade discussed so far, profit-taking and escalation of commitment, the disposition effect gives rise to a third motive for trade—re-investment of realized profits.[7]

A thorough analysis of this third trading motive would require a model with many different assets, and additional assumptions about preferences, in particular

[6] In a mean-variance setup (partial) re-investment in a different asset will occur if returns on both assets are positively correlated.

[7] With many assets, there is also a fourth trading motive: To sell one asset to have funds available to escalate commitment to another asset. This motive is absent if there is no escalation of commitment as in Example 1.

how the disposition effect interacts with the preference for diversification. This is beyond the scope of this paper. It is however, easily possible, to extend the model to account for re-investment trading *from a partial equilibrium perspective*. In this case, all that differs from the model considered so far is that there is some additional demand for the asset, $X_2^r$, in period 2, that stems from disposition investors who would like to re-invest the proceeds from realizing paper profits on other risky assets. How would this affect the results?

For losers any buying driven by the desire to re-invest realized gains would bid up prices and hence reduce expected return. The result that higher volume indicates lower expected return hence goes through and is even strengthened. For winners, however, re-investment dampens momentum. In particular re-investment breaks down the link between volume and expected return. A high volume could either indicate strong profit-taking, implying high expected return, or it could indicate a strong inflow from gains that were realized elsewhere implying a low expected return.

## 3.3 The Empirical Link between Turnover and Momentum

The profitability of momentum strategies, i.e. strategies that buy past winners and sell past losers, is well documented (e.g., Jegadeesh and Titman (1993) for U.S. stocks and Schiereck, De Bondt and Weber (2000) for German stocks). There is little evidence that the profitability of momentum strategies can be traced to differences in exposure to economically meaningful risk factors or industry effects (Grundy and Martin (2001)). Fama and French (1996) remark that the momentum findings of Jegadeesh and Titman (1993) constitute the "main embarrassment" (p. 81) for their three-factor model.

Recently, Lee and Swaminathan (2000) have examined the link between volume, defined as turnover, i.e. number of shares traded divided by number of shares outstanding, and momentum for U.S. stocks. Examining momentum strategies using a variety of time horizons, they report three major stylized facts: First, they find that momentum profits are typically higher for high volume stocks: A momentum strategy using high volume winners and losers is more profitable than one using low volume winners and losers. Second, they find that the positive relation between momentum profits and volume is primarily driven by the return differential in the loser portfolio: Low volume losers go on to perform significantly better than high volume losers, whereas the return differential for winners is not nearly as large and in most cases statistically insignificant. As an example, Table 1 reports their results for a momentum strategy with three-month formation period and three-month holding period (see their paper for details). The third stylized fact is that volume typically declines in a sequence of low returns ("as stocks fall out of favor").

The first stylized fact can easily be linked to the disposition effect. As was shown in the previous section, the disposition effect leads to a positive link between trading volume and return continuation. Moreover, if there is no escalation of commitment,

| | Low volume | High volume |
|---|---|---|
| Return of the loser portfolio | 1.24 | 0.19 |
| Return of the winner portfolio | 1.25 | 1.45 |
| Momentum profit | 0.01 | 1.26 |

Table 3.1: Monthly returns based on price momentum and trading volume. From Lee and Swaminathan (2000). The momentum strategy used is with three-month formation and three-month holding period.

i.e. if disposition investors are reluctant to realize losses but do not actively purchase additional shares of losing stocks as in example 1, the stylized facts 2 and 3 obtain. If investors are reluctant to realize losses the absence of volume indicates no trend continuation (see Result 3.4). If there is volume at all for losers, this indicates buying pressure (e.g., from disposition investors who want to re-invest funds freed-up by the realization of profit on other stocks). These buyers need to bid up prices a lot to induce disposition investors who are holding the asset at a loss to sell. Volume thus indicates a strong return continuation for losers. In contrast, for winners volume indicates either profit taking (implying high expected return) or re-investment (implying low expected return). There is consequently no strong relation between volume and return continuation for winners. Finally, as was suggested by Lee and Swaminathan (2000), that volume dries up for losers (the third stylized fact) can be seen as a consequence of investors' reluctance to realize losses.

To summarize, the implications of the disposition effect for prices and volume are roughly consistent with the stylized facts from Lee and Swaminathan (2000). This distinguishes the disposition effect from the other three recent explanations for the momentum effect (Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer and Subrahmanyam (1998), and Hong and Stein (1999)) which according to Lee and Swaminathan do not capture their stylized facts.

## 3.4 Extensions

One natural way to extend the model would be to allow for more than two trading periods. This would allow for more complex dynamics of asset holdings, reference points and, since demand depends on the distribution of holdings and reference points, returns and trading volume. It would also require a much better understanding of investor behavior than we currently have. Suppose an investor sold his asset holdings at one point. Does he, when making investment decisions later, continue to use his original reference point? Or does he "forget" his reference point completely and behave like an otherwise identical investor who never held the asset? Similarly, for an investor who holds the asset and makes a purchase of additional units at a different price later. Which reference price does he use, the initial purchase price, the later purchase price, a weighted average of the two? Or does he treat his two purchases of the same asset as two separate mental accounts (Thaler (1985))? We simply do not know. So the analysis of the dynamics of returns and trading volume for the case of more than two trading periods would require a number of additional assumptions. One such assumption would be that the demand by disposition investors is a (weakly) monotonic function of prior gains or losses. Then the basic logic underlying the momentum result remains intact in the case of more than two trading periods. A higher current capital gain ($P_t - P_{t-1}$) implies that there are (weakly) more disposition investors with larger gains to realize, implying more profit taking and stronger return continuation.

One counterfactual implication of the model is that, compared with the case without the disposition effect, prices underreact to news about fundamentals and there is dampened volatility rather than excess volatility. This is however a simple consequence of the fact that in the model, due to the finite-time horizon of the asset, price changes are necessarily driven entirely by news about fundamentals. In practice, asset price changes are not driven solely by news about fundamentals even when the asset has a finite maturity (e.g. Roll (1984)). Note that the logic of the momentum result does not rely at all on whether price changes are driven by news about fundamentals or something else. So, if for example in the model price changes were instead (partly) driven by a stochastic asset bubble, the trade and momentum results would go through, while there can be excess volatility (Zuchel and Weber (2001)).

## 3.5 Discussion

The disposition effect links current asset demand to prior investment performance. In the present paper, I analyze this link and the resulting patterns in returns and trading volume in a model with heterogeneous investors. I find that the disposition effect leads to trading and that this trading leads to a positive relation between current return and expected future returns. Furthermore, I find that the disposition effect implies a positive relation between momentum profits and volume. Such patterns have been documented in empirical studies of stock returns and trading volume. The disposition effect can thus be helpful in understanding qualitatively some of the stylized facts about momentum and trading volume.

There are, however, at least two reasons for being careful not to overinterpret the model's implications. First, the patterns reported by Lee and Swaminathan (2000) hold at the portfolio level. To what extent they extend to individual asset returns is unclear. Second, there are many motives for trade (e.g. differences of opinion, or information) that are absent from our model. Compared with these other motives the disposition effect is likely to play only a small role in determining volume. Still, the empirical studies by Lakonishok and Smidt (1986) and Ferris, Haugen and Makhija (1988) do suggest that the influence of the disposition effect on volume is not completely swamped by other factors.

An obvious objection to the conclusions drawn in this paper is that they are based on too much irrationality. In particular, there are no investors who actively arbitrage away the fluctuations in risk-adjusted expected return implied by the disposition effect. Clearly, in the presence of such investors there would be no momentum. There would, however, still be a positive relation between current returns and current trading volume as in this model as long as there are some disposition investors holding the asset. It is worth noting though that—outside the market microstructure literature, which presumably is concerned with phenomena that occur at shorter horizons than three to twelve months—there is as yet no model of the momentum effect using orthodox assumptions about behavior.

Part of the disposition effect is the reluctance to sell losing stocks. One reason unrelated to psychology why investors might refrain from selling are short-selling constraints. It is natural to ask whether it is not institutional features like short-selling constraints that lead to the patterns in volume and returns reported by Lee and Swaminathan (2000). Here I simply rely on the results of Diamond and Verrechia (1987) who show that short-selling constraints alone do not bias prices.[8]

Even though the model discussed here is one of a single risky asset, it is meant to apply to individual assets. It consequently suffers from a lack of consideration of general equilibrium issues. In particular, the "misvaluations" implied by the disposition effect are—in the context of many assets—diversifiable and so can easily be arbitraged away by smart investors. As emphasized by Campbell (2000), this is a general limitation of models of this kind. It is thus all the more remarkable that the implication that momentum profits are due to the idiosyncratic (stock-specific) component of returns is borne out by the data (Grundy and Martin (2001)).

This paper is concerned with the impact of the disposition effect on trade and returns. A natural extension would be to study the impact of the disposition effect on volatility. For example, the well-known fact that volatility increases after losses (Campbell and Kyle (1993)) may well be due to the fact that the reluctance to realize losses leads to reduced liquidity which in turn increases volatility.

I take the results of this paper as an indication that a better understanding of investor behavior can in fact be helpful in understanding the behavior of market outcomes. Standard economic modeling allows to elucidate the consequences of

[8] Jarrow (1980) shows that, without rational expectations, prices can be biased upward, downward, or not biased at all. Note that a necessary condition for short-sale constraints to be binding is that different market participants have different expectations for the market (e.g. due to information asymmetries).

behavioral patterns in the aggregate. The usefulness of this approach hinges on the accuracy with which the observed behavioral patterns can be modeled, which suggests a need for further research on how investors actually behave. While so far (understandably) empirical research has paid a lot of attention to the question whether there is a disposition effect at all, the question of what actually drives the disposition effect has largely been ignored. This is regrettable because a better understanding of the causes of the disposition effect would allow more accurate modeling and also might give us some clues on who is subject to the disposition effect. It is remarkable how little we still know about investor behavior.

# Chapter 4

# How Do Prior Outcomes Affect Risky Choice?

## 4.1 Introduction

There is a growing theoretical literature in finance that studies how observed features of asset prices can be linked to departures from conventional assumptions about investor behavior, i.e. departures from expected-utility theory.[1] In this literature, it has become common to use pre-existing evidence from the psychological literature on individual decision making to substantiate the particular departure from expected-utility theory used (see, for example, Odean (1998b), Barberis, Shleifer and Vishny (1998), or Daniel, Hirshleifer and Subrahmanyam (1998)).[2] In fact, some authors go so far as to demand that "the basic building blocks of new theory must derive

[1] Hirshleifer (2001) surveys this literature.

[2] There are other ways to justify deviations from the assumption of expected-utility maximization. Some authors simply appeal to plausibility (e.g. Hong and Stein (1999)), while others use well-defined preference theories such as disappointment aversion (Ang, Bekaert and Liu (2000)) or prospect theory (Gomes (2000)). Yet others appeal to observed investor behavior (De Long, Shleifer, Summers and Waldmann (1990), Zuchel and Weber (2001)).

empirical and experimental support from our sister social sciences" (De Bondt and Thaler (1995, p. 388)).

One problem with the use of pre-existing psychological evidence is that this evidence typically comes from studies that were not designed to specifically investigate behavior in investment settings. Hirshleifer (2001) stresses this problem and points out a possible remedy: "It is often not obvious how to translate pre-existing evidence from psychological experiments into assumptions about investors in real financial settings. Routine experimental testing of the assumptions [...] of asset pricing theories is needed to guide modeling" (p. 43).

In this paper, we consider the problem of sequential decisions under risk. A question that has been addressed by psychologists in this context is whether behavior in later stages of the sequence is influenced by the outcomes resulting from earlier decisions: Do prior gains induce different behavior than prior losses? Such research is potentially very relevant for researchers in asset pricing since investors are, of course, making sequential decisions under uncertainty, and any influence of prior gains or losses on current behavior—if present in aggregate—would lead to patterns in equilibrium returns. Suppose, for example, that prior gains increase risk tolerance and, conversely, prior losses decrease risk tolerance. Barberis, Huang and Santos (2001) show that such a link can help explain the high premium, excess volatility, and predictability of observed stock returns.[3]

The purpose of the present paper is to shed further light on the influence of prior outcomes on risky choice. We study how prior outcomes affect risk taking, and which factors influence the link between prior outcome and risk taking. Our aim is to make sense of the at times conflicting empirical results concerning sequential decision making under risk,[4] and to evaluate recent theories of investor behavior that,

[3] Marcus (1989) and Sharpe (1990) make similar points.
[4] We briefly discuss the literature in Section 4.3.

based on some experimental results, make strong assumptions on how investors are affected by prior gains and losses (e.g., Barberis, Huang and Santos (2001)).

In our experiment we confront subjects with two versions of a sequential decision-making problem under risk which are identical from an economic perspective in the sense that the set of attainable probability distributions over outcomes is identical. The two versions differ, however, in the presentation format. In the first version, the portfolio treatment, the decision situation faced by subjects shares many characteristics of a dynamic portfolio choice problem. Subjects are endowed with an initial amount of money that they can invest in two successive periods. Money can either be kept in cash or invested in a risky asset whose price fluctuates randomly. In the second version, the lottery treatment, the decision situation resembles a sequence of two rounds of a lottery (betting game). In each round, subjects receive an amount of money that they can use to purchase lottery tickets that generate a random payoff. For both versions we investigate if the fact that subjects were (or were not) responsible for the initial decision influences subsequent behavior. We do so by either assigning a choice for the first period or by allowing free choice.

We find that there is a strong link between prior outcome and risky choice in the portfolio treatment and a less pronounced link working in the opposite direction in the lottery treatment. In the portfolio treatment, subjects take significantly greater risk following a loss than following a gain. This difference reflects escalation of commitment (Staw (1976)), i.e. increased risk-taking following a loss. Conversely, in the lottery treatment there is greater risk taking after a gain than after a loss. This difference reflects the house-money effect (Thaler and Johnson (1990)), i.e. increased risk taking following a gain. Assigning the initial choice does not make much of a difference for the link between prior outcome and risky choice. If anything, this link is strengthened when the prior outcome results from an assigned choice.

The next section explains the design and procedure of the experiment. We go on to spell out competing hypotheses, based on existing theory and evidence, in Section 4.3. In Section 4.4 we present our results that we discuss in 4.5 and relate to existing evidence on the link between prior outcomes and investor behavior in 4.6. Section 4.7 concludes. In the Appendix we provide the instructions and other material used in the experiment.

## 4.2 Design and Procedure

We study the simplest case of sequential decision making: a sequence of decisions in two successive periods. We are interested in whether and how risky choice in the second period is affected by the prior outcome, i.e. the outcome in the first period. To address this question we simply compare risk taking after a gain with risk taking after a loss. To find out which factors influence the link between prior outcome and risky choice, we introduce two additional treatment variables: We vary across subjects the presentation format between a portfolio format and a lottery format. Also, we vary whether the decision for period 1 is assigned or whether subjects can choose freely.

### 4.2.1 Portfolio versus Lottery Presentation Format

In the portfolio format the decision situation is presented as a simple dynamic portfolio choice problem: Subjects are endowed with an initial amount of money that they can invest in two successive periods. Money can either be kept in cash or invested in a risky asset whose price fluctuates randomly. Subjects are paid, as real earnings from the experiment, the final value of their portfolio, i.e. their cash position plus the value of their holdings of the risky asset.

In the first period, subjects were endowed with DM6.[5] They had to decide how

[5] At the time of the experiment, DM1 exchanged for about US$0.50.

many "units" to buy. We used neutral terms, e.g. we referred to units rather than "shares" or "assets."[6] The initial price of a unit was DM0.60. We constrained subjects' choice of the number of units between zero and ten. Subjects kept any money not used for the purchase of units. Over the course of the first period, the price of a unit would either rise by DM0.40 with probability 1/2 or drop by DM0.30 with probability 1/2. Subjects were fully informed about the objective probabilities of winning and losing, and about the corresponding size of price changes. The actual price change would be determined by the throw of a die.

In the second period, subjects could purchase additional units or sell units at the new price, or leave their number of units constant. The only constraint for their decision was that their total number of units had to remain between zero and ten. This implies that the number of units that could be held (i.e. the opportunities for risk taking) is the same in both periods and independent of whether there was a gain or a loss in the first period. Over the course of the second period the price of a unit would change once more. The price change in the second period was independent of the price change in the first period and identically distributed. Subjects were again fully informed about the probabilities and magnitudes of price changes. The actual price change would again be determined by the throw of a die.

Subjects were paid the final value of their units plus their cash holdings. As an illustration, consider the case of a subject who goes for maximum risk and always hold ten units. Her probability distribution of payoffs from the experiment would be $(DM14, .25; DM7, .5; DM0, .25)$.

In the lottery format we confront subjects with the same opportunities for risk taking, but in a different presentation format. Rather than a dynamic portfolio choice problem, the decision situation in the lottery format resembles a sequence of two opportunities to participate in a lottery (betting game). The lottery treatment

[6] See the appendix for the full instructions to the experiment.

is close to the basic setup used in Gneezy and Potters (1997). Again, we used only neutral terms to describe the decision situation and simply referred to units. In both periods, subjects were endowed with DM3. They had to decide how many units to buy at a price of DM0.30. Units would either pay out DM0.70 with probability 1/2 or nothing with probability 1/2. Subjects were again fully informed about the probability distribution. Subjects could not bet money accumulated in the first period. They could purchase between zero and ten units. The money earned in the experiment is equal to the sum of the endowments in both periods minus the cost of purchases of units plus the payoffs from units.

It can easily be verified that the lottery treatment is equivalent to the portfolio treatment in the sense that the set of attainable payoff distributions is the same under both treatments. In both treatments, one unit implies the possibility of a gain of DM0.40 with probability 1/2 and the possibility of a loss of DM0.30 with probability 1/2. In the portfolio treatment the gain comes in the form of a price increase and the loss in the form of a price decrease. In the lottery treatment, the gain comes in the form of a positive payoff from one unit minus the cost of purchase of the unit. The loss is simply the cost of purchase in the case of a zero payoff from the unit. When formulating the two treatments we made sure that the formulation of the instructions and decision sheets for both treatments were similar (see Appendix).

A crucial feature of the design for both formats is that the actual outcome in the first period was determined only at the end of the experiment, i.e. after subjects had made all their decisions. This means that when making their (binding) decisions for the second period, subjects did not know the actual outcome in the first period. So they had to make two contingent decisions for the second period: One for the case of a gain in the first period and one for the case of a loss. This way, we vary the treatment variable "prior outcome" within subject: For any subject who purchased units in the first period we observe behavior in the case of a prior gain and in the case of a prior loss.[7] Within-subject comparisons have also been used by Thaler and Johnson (1990) to investigate the effect of prior outcomes on risky choice. The within-subject design can be seen as an application of Selten's (1967) strategy method.

The simple setup allows us to test for a link between prior outcomes on risky choice. Do subjects behave differently in the second period in the case of a gain in the first period and in the case of a loss in the first period? Our variable of interest is the number of units held. More units mean greater risk taking. If prior outcomes affect risky choice we would expect the number of units held to differ between the case of a gain in the first period and the case of a loss.

### 4.2.2 Free versus Assigned Initial Choice

With respect to the number of units held in period 1 we investigate two conditions. In the free-choice treatments, subjects choose their number of units in period 1 as described above. In the assigned-choice treatments we eliminate the choice in period 1. Rather than having the subjects decide, the number of units in the first period was given; subjects decided only about the number of units to be held in the second period after a gain and after a loss. The assigned choices were 6 units in the portfolio treatment and 7 units in the lottery treatment. These numbers correspond roughly to the average first-period holdings in the free-choice treatments. Note that, unlike the change in the presentation format from portfolio to lottery format, eliminating free choice in the first period changes an economic aspect of the decision situation: Without free choice in the first period, subjects have less freedom.[8]

[7] We alternated across subjects the order in which we asked for behavior after a gain and after a loss.

[8] In the portfolio/assigned-choice treatment we also reduced the (implicit) initial endowment by DM0.10 relative to the free-choice case: Subjects began the experiment with 6 units at a price of

We introduced the assigned-choice treatments for two reasons. First, as we will explain in more detail later on, cognitive-dissonance theory suggests that decision makers have a tendency to stick to their initial (first-period) choice when making subsequent decisions. This tendency is eliminated when there is no free initial choice. Second, a given initial choice eliminates variation in the magnitude of the gain or loss in the first period. Hence, unlike in the free-choice treatments, the magnitude of the prior outcome (from the perspective of the second period) is the same for all subjects.

### 4.2.3 Subjective Reaction to Losses

We included a second part in the experiment, which was common to all treatments. Here we asked subjects about their "subjective reactions to losses." These question are essentially a translation from Thaler and Johnson (1990).

(a) You lose DM20

(b) You lose DM20 after having gained DM60

The loss of DM 20 hurts more in: (a), (b), or (no preference)

(a) You lose DM20

(b) You lose DM20 after having lost DM60

The loss of DM20 hurts more in: (a), (b), or (no preference)

We use the Thaler-Johnson questions to see if we can replicate their results and to see if statements about subjective reaction to losses are related to actual risk-taking behavior in the experiment.

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DM0.60 and DM2.30 in cash. We did so to avoid any confusion between the amount of the initial cash holding and the potential gain of DM2.40 (6 units times a price increase of DM0.40) in the first period.

In addition, we asked subjects for some personal information such as age, gender, etc. The last question was an open question on what subjects thought when making their decisions under risk.

### 4.2.4 Procedure

The experiment was conducted at Mannheim University. The subjects were 133 male and female undergraduate students mostly with a major in economics or business administration with an average age of 23. The experiment is a pen and paper experiment, conducted in the classroom. We recruited subjects by announcing at the end of various economics or business administration classes the opportunity to participate voluntarily in a paid experiment on decisions under risk. One session of the experiment took about 20 to 30 minutes. The average number of subjects per session was 17. There was a large variation between sessions with 3 subjects in the smallest session and 47 in the biggest.

## 4.3 Competing Hypotheses

The effect of prior outcomes on subsequent choice has been the subject of several empirical studies. Even the most cursory glance at these studies reveals that results are often conflicting. For example, prior losses have at times been found to increase risk-taking and at times to decrease risk-taking. Based on their research on the influence of prior outcomes, Thaler and Johnson (1990) state that "[p]erhaps the most important conclusion to be reached from this research is that making generalizations about risk-taking preferences is difficult" (p. 660). We discuss some of the empirical studies in the following subsections. This discussion is organized around the theoretical predictions based on expected-utility theory, prospect theory, and the self-justification hypothesis derived from cognitive dissonance theory. Just like the empirical evidence, theory provides no clear-cut predictions. As we discuss briefly, expected-utility maximization or prospect theory are consistent with very different kinds of behavior. It is important to stress that we do not attempt to test these different theories. Rather we ascertain which factors induce which of the different kinds of behavior that have been found in the empirical literature.

### 4.3.1 Expected-Utility Theory

Under expected-utility maximization prior gains and losses can affect risky choice because any prior outcome changes current wealth which in turn determines risk aversion. Increased risk taking following a gain is consistent with expected-utility maximization if the utility function exhibits decreasing absolute risk aversion. Increased risk taking following a loss is consistent with expected-utility maximization if risk aversion is an increasing function of wealth. If risk aversion is constant there is no effect of prior outcomes on risky choice.

So without restrictions on the shape of the utility function, expected-utility maximization is consistent with different kinds of behavior within a single treatment. Additional restrictions yield sharper predictions. Suppose that we impose the restriction that the utility functions of subjects be "reasonable" in the sense that they represent reasonable preferences over large-scale gambles. Suppose also that the utility function is differentiable. These restrictions imply that subjects should go for maximum risk in every single decision, a point that is made forcefully in Rabin (2000). This result is just an application of the local-risk-neutrality property of expected-utility maximization with a differentiable utility function (Arrow (1971)). Local risk-neutrality implies that subjects always take maximum risk in "small" gambles, such as the ones in our experiment.

**Hypothesis 4.1** *Local risk-neutrality*
*Subjects go for maximum risk, i.e. they choose 10 units, in every decision.*

Even without restrictions on the shape of the utility function, there is a sharp prediction concerning behavior across different treatments. Expected utility depends only on the probability distribution of outcomes and is consequently independent of the presentation format of the decision problem. In our experiment, we vary across subjects the presentation format of the decision problem (lottery/free-choice and the portfolio/free-choice treatments) while keeping the probabilities and magnitudes of possible outcomes fixed. Expected-utility maximization implies that behavior should not differ between different presentation formats.

**Hypothesis 4.2** *Invariance of behavior across presentation formats*
*Behavior is the same in the lottery/free-choice and portfolio/free-choice treatments.*

### 4.3.2 Maximization of a Prospect-Theory Value Function

Prospect theory was introduced by Kahneman and Tversky (1979) as a descriptive theory of decision under risk. Under prospect theory individuals behave as if maximizing the expectation of a value function.[9] The value function has three important characteristics: (i) It is defined over gains and losses relative to a specific reference point. (ii) It is S-shaped, i.e. it is convex for losses and concave for gains. (iii) The value function is steeper for losses than for gains, $v(x) < -v(-x)$ for $x \neq 0$ , a feature called loss aversion, and it has a kink at the origin. See Figure 1.1 on page 8 for an example of a value function.

The reference point turns out to be crucial for risk taking. Different assumptions about what reference point subjects use to evaluate outcomes can lead to very different predictions about risk taking and about the effect of prior outcomes on risky choice. To be fair, it should be noted that prospect theory was designed

[9] To derive our hypotheses we do not need to consider the probability weighting function nor do we need to take into account the cumulative form of prospect theory (Tversky and Kahneman (1992)).

to understand single period decision making. What we need in this context is an extension of prospect theory to a dynamic setting.

It is easy to see that if, for example, the reference point always equals the status quo (current wealth) prior outcomes have no effect on risky choice. However, if the reference point does not fully reflect prior gains or losses there is scope for an influence of prior outcome on subsequent risky choice. The important point is that different reference points induce different behavior, and that the reference point may be influenced by the presentation format of the decision problem. Unlike in the case of expected-utility maximization, we cannot rule out prospect theory as an explanation for behavior on the basis of different behavior in treatments that differ only in presentation format. It is precisely the point of framing effects based on prospect theory that reframing equivalent options can induce different setting of reference points and, consequently, different behavior. Framing effects refer to the case that different phrasing of the same outcomes results in different choices.[10] In prospect theory, framing effects result from the S-shape of the value function together with the fact that the reference point, relative to which gains and losses are measured, can be manipulated by the phrasing of outcomes.

### The Evidence in Thaler and Johnson (1990)

Thaler and Johnson (1990) study in an experiment how subjects frame decision situations under risk in the presence of a prior outcome. Their quasi-hedonic editing hypothesis suggests, that individuals do not integrate subsequent losses with an initial loss, but that they do integrate subsequent losses with an initial gain. Using a sample of undergraduate and MBA students, Thaler and Johnson demonstrate that prior gains and losses affect the willingness to take risk, see the following example;

[10] The classic example of a framing effect is the Asian disease problem developed by Kahneman and Tversky (1981).

the percentage of students that chose each option is in parentheses.

1. You have just won $30. Choose between:
(a) A 50% chance to gain $9 and a 50% chance to lose $9 (82 percent)
(b) No further gain or loss (18 percent)
2. You have just lost $30. Choose between:
(a) A 50% chance to gain $9 and a 50% chance to lose $9 (36 percent)
(b) No further gain or loss (64 percent)

There is a clear influence of prior outcomes on risky choice. Following a gain, a large percentage of subjects is risk-seeking. Conversely, after a loss the majority of subjects is risk averse. Thaler and Johnson interpret their findings as indicating that "a prior gain can increase subjects willingness to accept gambles. [...] In contrast, prior losses can decrease the willingness to take risks." (p. 643-644).

Thaler and Johnson (1990) termed the phenomenon that risk taking increases in the presence of a prior gains the house-money effect. Translated to our experiment this hypothesis implies that subjects increase (or leave constant) the number of units held after a gain.

**Hypothesis 4.3** *House-money effect*
*A gain in the first period leads to an increase (or no change) in the number of units held in the second period.*

Similarly, the Thaler-Johnson result that prior losses decrease the willingness to take risk translates into the following hypothesis.

**Hypothesis 4.4** *Increased sensitivity following a loss*
*A loss in the first period leads to a decrease (or no change) in the number of units held.*

Hedonic editing can explain such behavior. Hedonic editing calls for the integration (cancellation) of smaller losses with larger gains. If subjects in our experiment use the wealth they bring to the experiment as reference point, any outcome of the experiment will be perceived as a gain. The initial endowment in the experiment is a first gain, that, over the course of the experiment, can be increased through further gains or reduced through "losses." In this way, all possible outcomes in the experiment lie in the "gain part," i.e. the concave part of the value function. This part is typically assumed to be a power function $v(x) = x^{\alpha}$ (e.g. Tversky and Kahneman (1992)), where $0 < \alpha < 1$, which implies decreasing absolute risk aversion. Under this extra assumption then, subjects would take greater risk following a gain in the experiment and reduce risk taking following a "loss." Without the additional assumption of decreasing absolute risk aversion over gains, we cannot make any prediction about behavior, just as in the case of expected-utility maximization.

From all the treatments in our experiment, the "lottery/assigned choice" treatment is the one that is closest to the experimental situation studied by Thaler and Johnson (1990). Recall the type of questions they asked: "You have just won $30. Choose between: (a) A 50% chance to gain $9 and a 50% chance to lose $9, or (b) No further gain or loss." Clearly in such situation there is no free choice that leads to the prior outcome. Nor is there a portfolio (with some risk) carried over from a previous period as in our portfolio treatment. This is similar in our lottery/assigned-choice treatment. By contrast, in our portfolio/free-choice treatment the prior outcome results from a free choice that initiates a course of action. Based on this observation we would expect behavior in the lottery/assigned-choice treatment to conform best to the results in Thaler and Johnson (1990).

In our experiment we also replicate a question from Thaler and Johnson (1990) on subjective reaction to losses. When do losses hurt most, in isolation, or after a gain, or after a loss? The majority of subjects in Thaler and Johnson (1990) state that a given loss hurts more when it occurs after a loss than when it occurs alone. Conversely, a given loss hurts less when it occurs after a gain than when it occurs in isolation. Thaler and Johnson (1990) interpret this as an indication that prior losses "sensitize people to subsequent losses of a similar magnitude" (p. 656), while prior gains are perceived as—in gambling parlance—"house money" and that "losing some of «their money» doesn't hurt as much as losing one's own cash." (p. 657). Barberis, Huang and Santos (2001) stress this interpretation and use it to motivate their theory of investor behavior: "[...] how loss averse the investor is, depends on his prior investment performance. After prior gains, he becomes less loss averse: the prior gains will cushion any subsequent loss, making it more bearable. Conversely, after a prior loss he becomes more loss averse: after being burned by the initial loss, he is much more sensitive to additional setbacks" (p. 2). Given the suggestiveness of the question, we expect to confirm the Thaler-Johnson results – irrespective of actual risk-taking behavior in the experiment.

**Hypothesis 4.5** *Subjective reaction to losses*
*Subjects indicate that losses hurt more after a prior loss and less after a prior gain relative to the case of no prior outcome.*

### Evidence on Escalation of Commitment

Thaler and Johnson (1990) document that a prior loss decreases risk taking. There is, however, some evidence, experimental and otherwise, that indicates the opposite behavior.[11] The psychological literature on escalation of commitment (e.g. Staw (1997)) studies repeated (rather than one-shot) decision making under uncertainty

[11] Thaler and Johnson (1990) themselves do find special situations where a prior loss leads to increased risk-taking. These situations are characterized by the opportunity to exactly break even, i.e. the gamble involves a gain that would exactly offset the prior loss. Thaler and Johnson term this observation the break-even effect.

in the face of negative feedback about prior decisions.[12] It documents the tendency to stick to or even intensify risky courses of action (e.g. investment projects) following losses. Contrary to the evidence in Thaler and Johnson (1990), escalation of commitment indicates greater risk taking after a loss than after a gain.

A typical "escalation situation" is faced by investors who have lost money in stocks or mutual funds. Odean (1998a) documents the "disposition effect" (Shefrin and Statman (1985)) in the trading behavior of individual investors, Weber and Camerer (1998) document the disposition effect in an experiment. Both studies find, that investors sell stocks that trade above the purchase price (winners) relatively more often than stocks that trade below purchase price (losers). Also, investors purchase additional shares of winners relatively less often than they purchase additional shares of losers. Odean (1998a) and Weber and Camerer (1998) interpret this behavior as evidence of decreased risk aversion after a loss and increased risk aversion after a gain.

One major explanation for escalation of commitment is based on the value function from prospect theory (e.g. Brockner (1992)). Consider the case when subjects use the wealth they bring to the experiment plus any initial endowment in the experiment as reference point. In this case, any loss during the experiment will be perceived as a loss, not as a reduced gain as in the hedonic-editing case, which, in our experiment, that subjects take greater risk following a loss. The intuition is that, due to the convex shape of the value function over losses, following a loss any subsequent loss hurts relatively less and any subsequent gain is particularly sweet, because it (partly) offsets the prior loss.

**Result 4.1** *If initial wealth serves as a reference point in any decision of the sequence, maximization of the expectation of an S-shaped value function, that is strictly*

[12] Related strands of the psychological literature study entrapment (e.g. Brockner and Rubin 1985) or the sunk-cost fallacy (e.g. Arkes and Blumer 1985).

*convex for losses and strictly concave for gains, implies that risk-taking after a loss is at least as great as initial risk-taking.*

**Proof.** Let $x_0^*$ denote the optimal number of units with no prior gain or loss and $x_l^*$ the optimal number following a prior loss $-l < 0$. Suppose that, contrary to the result, $x_0^* > x_l^*$. This implies that $l + .4x_l^* > 0$, otherwise strict convexity of the value function over losses would imply maximal risk-taking, i.e. $x_l^* = 10$. Maximization of the expectation of the value function in the case without prior gain or loss implies that $v(.4x_0^*) + v(-.3x_0^*) \geq v(.4x_l^*) + v(-.3x_l^*)$ or equivalently $v(.4x_0^*) - v(.4x_l^*) \geq v(-.3x_l^*) - v(-.3x_0^*)$. From the strict convexity over losses and strict concavity over gains, it follows that $v(l + .4x_0^*) - v(l + .4x_l^*) \geq v(l - .3x_l^*) - v(l - .3x_0^*)$, which contradicts optimality of $x_l^*$. ■

This leads to the following hypothesis.

**Hypothesis 4.6** *Escalation of commitment*
*A loss in the first period leads to an increase (or no change) in the number of units held in the second period.*

For the case of a prior gain, there is no such unambiguous result. Intuitively, a prior gain has two effects: It moves the outcomes of subsequent gambles into or closer to the gain region, this effect may increase risk aversion due to the concave shape of the value function over gains. But a prior gain, also moves the status quo away from the kink of the value function at the origin, where risk aversion is locally infinite. This reduces risk aversion.

The literature on escalation of commitment suggests that it matters for behavior whether subjects perceive the initial decision as "initiating a course of action." This is the case in our portfolio treatment. Here subjects are likely to think about their decision in period 2 as a decision to change their initial decision (in period 1). By contrast, in the lottery treatment we would expect subjects to be less likely to perceive the initial decision as initiating a course of action, since there is no "portfolio" of units carried over from one period to the next. Consequently, we would expect less escalation of commitment in the lottery treatment.

**Hypothesis 4.7** *Presentation format matters*
*The portfolio treatment induces a stronger tendency toward escalation of commitment.*

### 4.3.3 The Self-Justification Hypothesis

The second major explanation for escalation of commitment—based on cognitive dissonance theory—is the self-justification hypothesis (Staw (1976)). The self-justification hypothesis states that individuals stick to a course of action because they feel the need to justify or rationalize their initial decision in the face of losses. "Put simply, people do not like to admit that their past decisions were incorrect, what better way to (re)affirm the correctness of those earlier decisions than by becoming even more committed to them." (Brockner (1992, p. 41))

So under the self-justification hypothesis, we would expect escalation of commitment, i.e. increased risk taking following a loss, and we would again expect escalation of commitment to be more pronounced in the portfolio treatments.

In contrast to the prospect-theory based explanation for escalation of commitment, the self-justification hypothesis predicts different behavior in the free and assigned-choice treatments. In the case of free choice the decision in the first period is undertaken freely and with the understanding that adverse outcomes are possible. Such a condition is favorable to the creation of cognitive dissonance (Gilad, Kaish and Loeb (1987)), which, according to the self-justification hypothesis, creates a preference for sticking with the initial decision later on. In the case of assigned choice, there is no commitment in the first period. Put differently, in the assigned-choice treatments there is no initial decision "to be justified" in later decisions. So, in these treatments, the motive of self-justification should be absent. If self-justification were the driving force behind escalation of commitment in our experiment, then we would expect any tendency toward escalation of commitment to be more pronounced in our free-choice treatments.

**Hypothesis 4.8** *Self-justification*
*There is less escalation of commitment in the assigned-choice treatments.*

## 4.4 Results

Analyzing the results of our experiment is straightforward. We simply compare the average number of units held, i.e. the risk taken, in the different experimental treatments. These averages together with the standard deviations (across subjects) are presented in Table 4.1. We also report median values.

There are clear treatment effects. The average number of units held is influenced by the prior outcome. For example, in the portfolio/free-choice treatment, the average number of units following a gain is 5.2 and the average number of units following a loss is 8.0. Moreover, the link between prior outcome and risk taking reverses its sign across different treatments. While the portfolio format induces less risk taking after a gain than after a loss, there is the opposite effect in the lottery treatment.

Consider first the portfolio/free-choice treatment. The influence of prior outcomes on risk taking in this treatment is summarized in Figure 4.1 which depicts the (sorted) difference in the number of units held after a gain and after a loss across subjects.

The majority of subjects (23 out of 34) held more units following a loss than following a gain. Such behavior runs counter to the hypotheses derived from Thaler and Johnson (1990) which imply greater risk-taking following a gain than following

| | Period 1 | Following gain | Following loss |
|---|---|---|---|
| **Portfolio/free choice (N=34)** | | | |
| Average | 6.1 | 5.2 | 8.0 |
| Standard deviation | 2.6 | 3.5 | 3.1 |
| Median | 6 | 5.5 | 10 |
| **Lottery/free choice (N=35)** | | | |
| Average | 7.6 | 7.6 | 6.7 |
| Standard deviation | 2.3 | 2.6 | 3.4 |
| Median | 8 | 8 | 7 |
| **Portfolio/assigned choice (N=31)** | | | |
| Average | 6 | 5.1 | 8.5 |
| Standard deviation | 0 | 3.0 | 2.3 |
| Median | 6 | 4 | 10 |
| **Lottery/assigned choice (N=33)** | | | |
| Average | 7 | 7.8 | 6.7 |
| Standard deviation | 0 | 3.1 | 3.0 |
| Median | 7 | 9 | 7 |

Table 4.1: Summary statistics on the number of units held

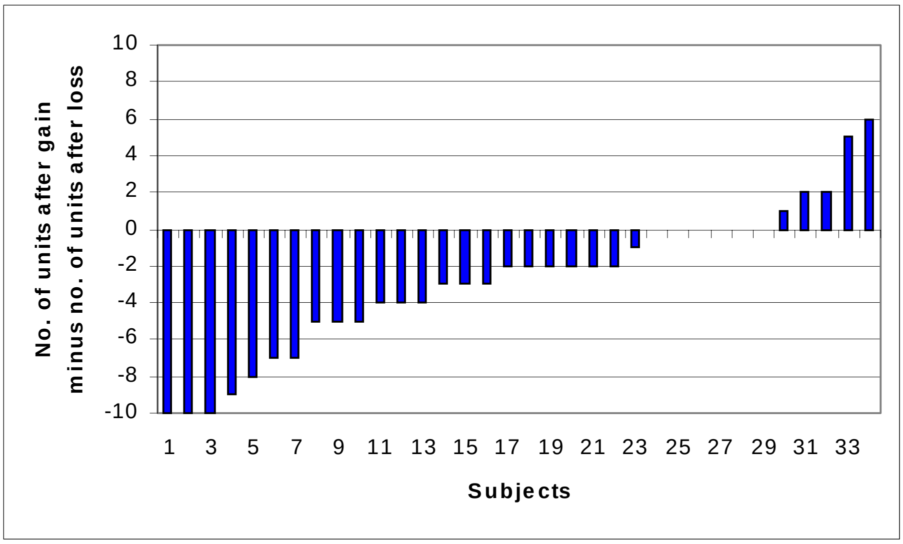



Figure 4.1: Behavior in the portfolio/free-choice treatment. Difference in the number of units held after a gain and after a loss.

a loss. Table 4.2 provides the relevant statistics. A (non-parametric) Wilcoxon test indicates that the difference in average holdings after gains and losses is highly significant ($p = 0.001$).[13] To understand where this difference comes from, we look at how risk taking after gain or loss compares with risk taking in the first period. A prior gain leads to reduced risk-taking, but this effect is insignificant ($p = 0.196$). A prior loss leads to increased risk-taking and this effect is highly significant ($p = 0.001$). So it appears that the difference in behavior after gain and loss is mainly driven by increased risk taking following a loss, i.e. we observe strong escalation of commitment. Our observations are inconsistent with either the

[13] We do not use the parametric t-test since our observations do not come from a normal distribution (the number of units is constrained between 0 and 10) and the sample size is small. We also report $p$-values from a binomial test. The $p$-values quoted in the text refer to the Wilcoxon test. All reported $p$-values are from two-sided tests.

| | Difference in holdings | $p$ (Wilcoxon) | $p$ (Binomial) |
|---|---|---|---|
| After gain / after loss | −2.8 (4.0) | 0.001 | 0.001 |
| After gain / in period 1 | −0.9 (3.6) | 0.196 | 0.345 |
| After loss / in period 1 | 1.9 (2.5) | 0.001 | 0.000 |

Table 4.2: Comparison of the number of units held in the portfolio/free-choice treatment. Standard deviations in parentheses. $p$-values are based on two-sided Wilcoxon and Binomial tests and, in the case of the Wilcoxon test, on the asymptotic distribution of the test statistic.

house-money effect or the hypothesis that a prior loss decreases risk taking.[14]

Next, consider the lottery/free-choice treatment. Compared with the portfolio-free-choice treatment only the presentation format differs. Figure 4.2 summarizes behavior in this treatment analogous to Figure 4.1.

The difference to the portfolio/free-choice treatment is evident. Here the majority of subjects (21 out of 35) holds the same number of units after a gain and after a loss. Their behavior is completely unaffected by whether there is a prior gain or loss. 9 subjects take greater risk after a gain, 5 take greater risk after a loss. The average number of units held is slightly increased after a gain and slightly reduced

[14] We also examined differences in second-period behavior based on risk taking in the first period. A Mann-Whitney test indicates no significant difference in the difference of the number of units held after a gain and after a loss for those subjects that took greater than average risk in the first period versus those subjects who took below average risk. Subjects with below average risk in the first period increase their risk significantly more than subjects with above average risk in the first period ($p = 0.041$), however, but this effect is probably best explained by the fact that the upper bound on risk taking (10 units) binds relatively more often for subjects who already hold more units: Of those subjects who took above average risk in the first period (i.e. held six or more units) 15 out of 18 hold ten units following a loss, while of those who took below average risk in the first period, only 6 out of 16 held ten units after a loss.

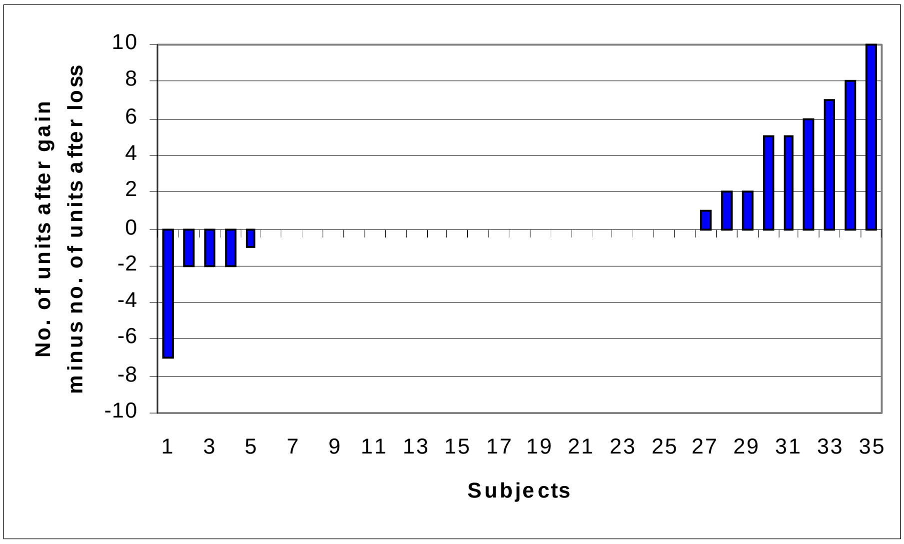



Figure 4.2: Behavior in the lottery/free-choice treatment. Difference in the number of units held after a gain and after a loss.

after a loss.

As Table 4.3 reveals, however, none of theses differences are significant. So in the lottery/free-choice treatment there is no effect of prior outcomes on risky choice.[15]

The remaining two treatments use an assigned choice in the first period. Subjects could only decide on the number of units in the second period. Behavior in the portfolio/assigned choice treatment was very similar to the free-choice case, as is clear from Figure 4.3 (compare Figure 4.1 for the portfolio/free-choice treatment).

If anything the assigned choice induces a greater preference for escalation of commitment, i.e. for increased risk taking after a loss. The majority, 26 out of 31 chose to hold more units following a loss than following a gain. Once again this

[15] We again compared behavior in the second period for subjects who took above average risk in the first period and those who took below average risk. There are no significant differences (based on a Mann-Whitney test).

| | Difference in holdings | $p$ (Wilcoxon) | $p$ (Binomial) |
|---|---|---|---|
| After gain / after loss | 0.9 (3.2) | 0.122 | 0.424 |
| After gain / in period 1 | 0.1 (2.2) | 0.378 | 0.581 |
| After loss / in period 1 | −0.9 (3.0) | 0.116 | 0.791 |

Table 4.3: Comparison of the number of units held in the lottery/free-choice treatment. Standard deviations in parentheses. $p$-values are based on two-sided Wilcoxon and Binomial tests and, in the case of the Wilcoxon test, on the asymptotic distribution of the test statistic.

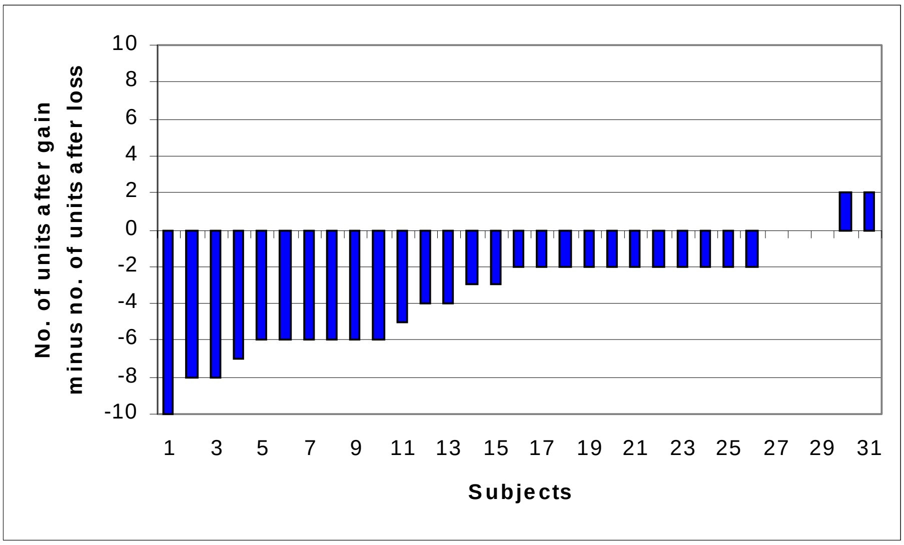



Figure 4.3: Behavior in the portfolio/assigned-choice treatment. Difference in the number of units held after a gain and after a loss.

| Comparison of | Difference in holdings | $p$ (Wilcoxon) | $p$ (Binomial) |
|---|---|---|---|
| After gain / after loss | $-3.4$ (2.9) | 0.000 | 0.000 |
| After gain / in period 1 | $-0.9$ (3.0) | 0.057 | 0.720 |
| After loss / in period 1 | 2.5 (2.3) | 0.000 | 0.000 |

Table 4.4: Comparison of the number of units held in the portfolio/assigned-choice treatment. Standard deviations in parentheses. $p$-values are based on two-sided Wilcoxon and Binomial tests and, in the case of the Wilcoxon test, on the asymptotic distribution of the test statistic.

difference stems largely from an increase in the number of units held after a loss (8.5 units) relative to the first period (6 units) (see Table 4.4). Units held decline slightly following a gain, but this effect is only marginally significant under a Wilcoxon test ($p = 0.057$) and insignificant under a binomial test ($p = 0.720$).[16]

Figure 4.4 summarizes behavior in the lottery/assigned-choice treatment. The relative majority of subjects (16 out of 33) chose greater risk following a gain than following a loss. Behavior conforms to the hypotheses of Thaler and Johnson (1990): There is greater risk-taking following a gain than following a loss. Table 4.5 reports statistics for this treatment. The difference in risk taking following gains and losses is statistically significant ($p = 0.041$). We also report differences in second period choices to the assigned choice from the first period. Relative to the assigned choice in the first period, risk taking is significantly increased after a gain and insignificantly decreased after a loss.

[16] The large difference in $p$-values from the Wilcoxon and the binomial test reflect the fact that the absolute frequency of increases and decreases in risk taking was about the same (14 increases versus 17 decreases), which leads to a high $p$-value for the binomial test, and the fact that the average magnitude of increases was lower than that of decreases (2.1 is the average increase, -3.4 is the average decrease) which explains the much lower $p$-value from the Wilcoxon test.

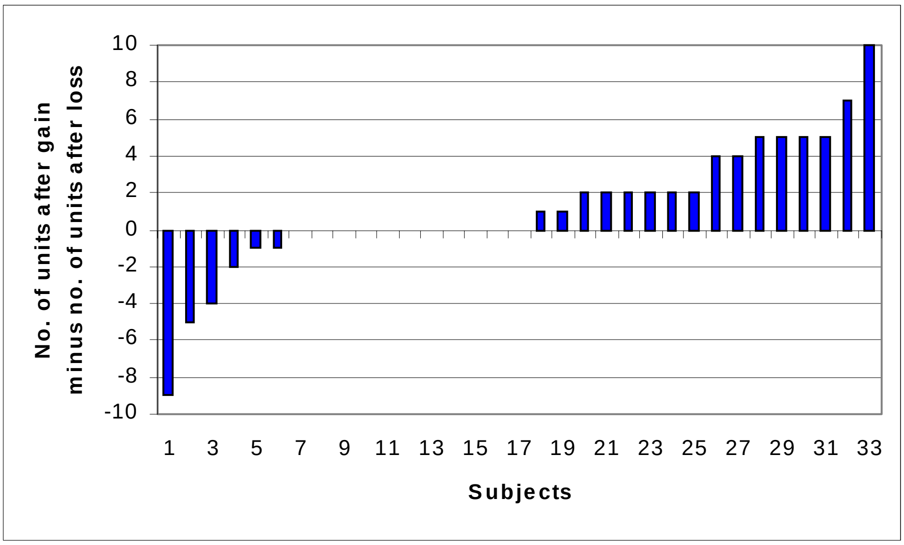



Figure 4.4: Behavior in the lottery/assigned-choice treatment. Difference in the number of units held after a gain and after a loss.

| Comparison of | Difference in holdings | $p$ (Wilcoxon) | $p$ (Binomial) |
|---|---|---|---|
| After gain / after loss | 1.1(3.5) | 0.041 | 0.052 |
| After gain / in period 1 | 0.8(3.1) | 0.028 | 0.029 |
| After loss / in period 1 | −0.3(3.0) | 0.801 | 1 |

Table 4.5: Comparison of the number of units held in the lottery/assigned-choice treatment. Standard deviations in parentheses. $p$-values are based on two-sided Wilcoxon and Binomial tests and, in the case of the Wilcoxon test, on the asymptotic distribution of the test statistic.

Finally we have the results from the questionnaire. Here we asked questions taken from Thaler and Johnson (1990). These questions were designed to ascertain "subjective reaction to losses" as a function of prior gains or losses. Thaler and Johnson (1990) present evidence that losses are less painful after a prior gain and more painful after a prior loss. Our results are in Table 4.6. We essentially get the same results as Thaler and Johnson (1990). Subjects on average indicate that prior gains decrease the discomfort caused by a given loss and that prior losses increase the discomfort of a given loss.

We find these results remarkable for two reasons. First, they replicate very well the results obtained by Thaler and Johnson (1990) whose results are also given in Table 4.6. Second, the answer to these questions appear not to be related to actual decision making under risk in the experiment. Behavior is very different between the lottery and portfolio treatments. Still the answers to the question on subjective reaction to losses is very similar in all treatments. A different way to see this is to compare the risk-taking behavior of those subjects that gave answers consistent with the Thaler-Johnson results, i.e. those who indicated that a loss in isolation hurts less than following a loss and more than following a gain, with the behavior of those who answered differently. Comparing these two groups, a Mann-Whitney test shows that for all treatments, the difference between the number of units held after a gain and after a loss is not significantly different ($p$-values $> 0.2$).

## 4.5 Interpretation

We designed our experiment to address two questions: What is the effect of prior outcomes on risky choice, and which factors influence this effect? We find that there is an effect of prior outcomes on risky choice and that this effect depends strongly on the presentation format of the decision problem and that it does not depend on

| | | | |
|---|---|---|---|
| (a) You lose DM 20 | | | |
| (b) You lose DM 20 after having lost DM 60 | | | |
| The loss hurts more in: | | | |
| Portfolio/free choice | (a) 18% | (b) 62% | (no preference) 21% |
| Lottery/free choice | (a) 29% | (b) 57% | (no preference) 14% |
| Portfolio/assigned choice | (a) 23% | (b) 61% | (no preference) 16% |
| Lottery/assigned choice | (a) 36% | (b) 52% | (no preference) 12% |
| Results of Thaler-Johnson | (a) 13% | (b) 55% | (no preference) 31% |
| (c) You lose DM 20 | | | |
| (d) You lose DM 20 after having gained DM 60 | | | |
| The loss hurts more in: | | | |
| Portfolio/free choice | (a) 76% | (b) 6% | (no preference) 18% |
| Lottery/free choice | (a) 80% | (b) 6% | (no preference) 14% |
| Portfolio/assigned choice | (a) 61% | (b) 26% | (no preference) 13% |
| Lottery/assigned choice | (a) 82% | (b) 15% | (no preference) 3% |
| Results of Thaler-Johnson | (a) 70% | (b) 9% | (no preference) 21% |

Table 4.6: Subjective reaction to losses. Some percentages do not add up to 100 percent due to rounding. The Thaler-Johnson results refer to the answers from Cornell MBAs. The amounts used in the original Thaler-Johnson questions were \$9 and \$30 instead of DM20 and DM60.

whether the prior outcome results from a free choice or not.

There is a strong framing effect. Behavior differs significantly between the portfolio and lottery treatments (both for free-choice and assigned-choice), even though there is only a difference in presentation format. This effect can result from the S-shape of the value function together with the fact that the reference point, relative to which gains and losses are measured, is manipulated by the phrasing of outcomes.

We find that our results make sense in the light of what we know from the literature on escalation of commitment. In the portfolio treatment, where the first-period decision can be seen as initiating a course of action, there is strong escalation of commitment. In the lottery treatment, however, where there is no "portfolio" of units carried over from one period to the next, there is no escalation of commitment. This suggest that the initial decision is not perceived as "initiating a course of action," which eliminates escalation of commitment.

There are different explanations for escalation of commitment. Most prominent are the self-justification hypothesis and framing effects based on prospect theory. Escalation of commitment in our experiment does not seem to be driven by the desire for self-justification. Assigning the first-period choice in the portfolio treatment does not weaken or eliminate escalation of commitment.

### 4.5.1 Alternative Explanations

Our results are open to alternative explanations. Maybe the behavior in our portfolio treatments reflects a belief that a loss in the first period is more likely to be followed by a gain in the second period than by another loss. Such a belief could be a consequence of the processes that give rise to the gambler's fallacy (Tversky and Kahneman (1971)). Such an argument fails to explain, however, why the behavior is different in the portfolio and lottery treatments.

Maybe profit-taking in the portfolio treatments reflects the misunderstanding that gains need to be realized to count for the earnings from the experiment. We stressed in the instruction that this is not the case. In any case, the majority of subjects escalate their commitment to losers that is they purchase additional units following losses. Clearly such behavior cannot be driven by the idea that the value of units does not count for final pay.

Another explanation is based on the fact that a loss in the portfolio treatment involves a price decrease. The price decrease could induce a tendency toward buying based on the (naive) logic that a low price means a good buying opportunity. We cannot rule out such an explanation based on our experiment. We know, however, from a different experiment, that this logic alone does not explain behavior after losses in a portfolio setup. Weber and Camerer (1998) study trading of assets at exogenous prices. They do find evidence of a disposition effect, i.e. escalation of commitment, in their "portfolio/free-choice treatment." In a second treatment, however, in which the portfolio is automatically sold at the end of each trading period the disposition effect is greatly reduced. Note that in this automatic-selling treatment losses are still associated with a lower price.

Yet another explanation for behavior in the portfolio treatments is naive portfolio rebalancing. Subjects might sell after a gain and buy after a loss so as to keep the portfolio weight of the risky asset constant. Such behavior would be optimal under expected-utility maximization with constant relative risk aversion if log-returns of the asset were i.i.d. normally distributed. In our design, where price changes rather than rates of returns are i.i.d., portfolio rebalancing is consistent with expected-utility maximization only if the utility function exhibits increasing absolute risk aversion. This does not, of course, preclude the possibility that subjects were naively using the heuristic to have constant portfolio weights.

### 4.5.2 Challenges

Our results can be challenged on the following grounds: There was no scope for learning, the within-subjects design is "unrealistic," the experiment did not involve any real losses, and the amounts at stake were very small. We discuss these challenges in turn.

Subjects participated in only one sequence of two periods. They were not given the opportunity to become acquainted to the experimental setup through trial rounds and there was no learning from "prior plays." Note that all experimental treatments are the same in this respect, but there may still be a concern to what extent behavior in the experiment reflects deliberate choice or just confusion. That subjects were not simply confused (with the confusion working in different directions in different treatments) can be seen from the responses to the open question at the end of the experiment where subjects displayed a reasonable understanding of what was going on in the experiment. Also, in the experiment we had subjects make all the relevant calculations, such as the calculation of gains, losses, cost of purchase of units, on their own. By checking these calculations we can make sure that subjects understood the basic procedure. The large majority of subjects did not make a mistake in their calculations (113 out of 133). Our results are essentially unchanged if we leave out subjects that made mistakes in their calculations from our analysis.

We avoided repetitions in our design so as to avoid tiring the subjects by asking the same (or very similar questions) over and over again. This means, however, that our data do not allow us to address the question of learning. Here we simply rely on other experimental work that has used similar setups with many repetitions and concluded that there was not much change in behavior from "early plays" to "late plays." We discuss the relation of our results to this work in the next section.

A second challenge to our interpretation of the results is that within-subject design to get at the impact of prior outcomes is unnatural and unrealistic. We find it important to stress that there is of course a difference in asking for the behavior in the face of gains or losses after the gain/loss has actually occurred or before (as we do). Shafir und Tversky (1992) have found that subjects sometimes find it hard to think through conclusions they would draw if hypothetical events were to occur. We chose the within-subjects design because it makes our results more easily comparable to those of Thaler and Johnson (1990) who also use a within-subjects design. And, as we will discuss in the next section, our results are similar to those obtained in studies that use a between-subjects design.

Finally, our experiment does not involve real losses in the sense that it was not possible that subjects would leave the experiment with less money than they brought to the experiment. It is plausible that risk-taking behavior is influenced by whether real losses in this sense are possible.

## 4.6 Relation to Pre-Existing Evidence

Our experiment demonstrates that risk taking can be influenced by prior outcomes and that this influence depends on the presentation format of the choice problem. As the statistics show, our results are significant so we can have some confidence in the validity of our results in the context of our experiment. Moreover, as we argue in this section, our results replicate well those from other, similar but different experimental studies. This suggests that subjects in our experiment were well calibrated relative to theses other studies. Finally, non-experimental evidence from actual investment choices suggests that some investors display a similar pattern of behavior as subjects in our portfolio treatment.

### 4.6.1 Other Experimental Evidence

#### Portfolio-Treatment

In our portfolio treatment we essentially look at a very simple dynamic problem of portfolio choice. Dynamic portfolio choice is also studied by Weber and Camerer (1998). They find strong evidence of the disposition effect. Similarly, we find strong evidence of escalation of commitment, i.e. of increased risk-taking following losses.

While their setup is similar in that they have subjects make a sequence of portfolio decisions, it is important to stress some of the differences. In their setup subjects face assets with uncertain return distributions, and returns are determined in each period.[17] In our setup, the exact return distribution is known and actual gains or losses are determined only at the end of the experiment.

Our results in the portfolio treatment are also related to the large psychological literature on escalation of commitment (e.g. Staw (1997)), that demonstrates in a number of experiments the tendency to stick to or even intensify losing courses of action.

#### Lottery-Treatment

In the lottery treatment, subjects are confronted with a sequence of two identical rounds of a betting game. This is essentially the situation studied by Gneezy and Potters (1997). We find that there is no significant effect of prior outcomes on risky choice in this treatment (in the free-choice case). So do Gneezy and Potters (1997). They compare the risk taken by subjects who have just experienced a loss with the risk taken by subjects who have just experienced a gain and find that the risk taken is (insignificantly) larger after a loss. The main differences between our experiments are that Gneezy and Potters (1997) use more rounds of the betting game

[17] Weber and Camerer (1998) also use six assets instead of just one and 14 trading periods instead of just two.

and determine payoffs each period. Langer and Weber (2000) replicate and extend the Gneezy-Potters study. They also find no significant effect of prior outcomes.

#### Questionnaire

We used questions translated from Thaler and Johnson (1990) to explore subjective reaction to losses. In line with their results we find that the incremental effect of a loss is smaller after a gain and greater after a loss than in isolation.

### 4.6.2 Observed Investor Behavior

There is by now a large and growing literature that documents that some investors are influenced by prior gains and losses (e.g. Grinblatt and Keloharju (2001), Odean (1998a)). Investors appear to have a preference for holding losers (stocks with paper losses) rather than winners (stocks with paper gains), a finding that was termed the disposition effect by Shefrin and Statman (1985). This preference manifests itself not only in a reluctance to realize losses, but also in a tendency to purchase additional shares of losers rather than winners (Odean (1998a)). This is of course precisely the kind of behavior that we observe in our portfolio treatments.

In a study of the trading behavior of professional futures traders, Coval and Shumway (2000) contrast the hypotheses whether gains increase or decrease risk-taking (conversely for losses), just like we do in our experiment. They find precisely the same result as we do in our portfolio treatments: Gains lead to decreased and losses lead to increased risk-taking.

We stress that all the observation of investor behavior mentioned so far concern the influence of prior gains or losses on an individual asset for the trading of this particular asset. At the portfolio level, there is some evidence of positive feedback trading that can be interpreted as increased risk taking after gains (Bange (2000)). The design of our experiment does not allow us to distinguish between the behavior at the level of the portfolio and at the level of the individual asset. Since there is only one asset, gains or losses on this asset are synonymous with overall gains and losses.

## 4.7 Conclusion

Prior outcomes affect risky choice. We find that there is a strong link between prior outcome and risky choice in the portfolio treatment, a treatment in which subjects were confronted with a dynamic portfolio choice problem under risk. When confronted with the same decision problem (in the sense of probability distributions over outcomes) but in a different presentation format, there is a less pronounced link working in the opposite direction. The alternative presentation format, our lottery treatment, presents the decision problem, using the same neutral wording, as a sequence of rounds of a lottery (betting game).

In the portfolio treatment, subjects take significantly greater risk following a loss than following a gain. This difference reflects escalation of commitment (Staw (1976)), i.e. increased risk-taking following a loss. In the lottery treatment there is greater risk taking after a gain than after a loss. This difference reflects the house-money effect (Thaler and Johnson (1990)), i.e. increased risk taking following a gain. Our results can be explained as framing effects based on the value function of prospect theory. We do not find evidence in favor of the self-justification hypothesis as an explanation for escalation of commitment.

Just like Thaler and Johnson (1990), we find that making generalizations about risk-taking preferences is difficult. Given that a simple reframing of options can lead to very different behavior, predictions of behavior have to be based on predictions of how individuals frame their options. However, researchers in finance are typically not interested in risk-taking preferences in general, but rather risk-taking preferences in the specific context of investment decisions. Our experiment suggests that the perception of investments as ongoing courses of action is likely to induce a tendency toward escalation of commitment. We find it interesting to note that behavior in the portfolio treatment, the treatment that resembles most closely the context of actual investment decisions, conforms to the predictions of the disposition effect, a pattern of behavior that has been observed in actual investment decision making.

## 4.8 Appendix: Experimental Procedures

### Portfolio/Free-Choice Treatment: Instructions

Thank you for participating in our experiment on decision under risk. The experiment will last about 20 minutes. The instructions for the experiment are simple and if you read them carefully, you can earn money, that will be paid to you in cash immediately after the experiment.

In the experiment you can use fictitious money, to buy or sell units of a fictitious commodity. Over the course of the experiment the price of a unit changes. Thereby you can gain money (if the price rises) or lose money (if the price drops). The following section explains the course of the experiment in detail. Please ask, if anything is not clear to you. Raise your hand, I will come to you.

**Instructions for the Experiment**

Together with this instruction you have received an "Information and Decision Sheet" and a "Questionnaire" (stapled together). Please note your decisions and answers on these sheets. Please work on the "Information and Decision Sheet" first and then on the "Questionnaire".

The experiment proceeds in two successive periods. In both periods you can first make a decision on the purchase or sale of units. Subsequently the price of a unit changes.

*Period 1:*

You have money at your disposal. At the beginning of period 1 you decide how many units to buy. You can buy 0 to 10 units. You keep the money that you do not use to purchase units. Please find precise information on your Information and Decision Sheet. After you have made your decision, the price of a unit changes.

*Period 2:*

At the beginning of period 2 you can sell units at the new and changed price or purchase additional units at the new price. The total number of units must remain between 0 and 10. Please find precise information on your Information and Decision Sheet. Please note: The actual price change in period 1 will be determined at the end of the experiment by throwing a die. You must therefore make two decisions in period 2: One for the case that the price dropped in period 1, one for the case that the price rose in period 1. Only one of the decisions will — depending on the actual price change in period 1 — be used in the end. You do not know in advance which decision will be used.

- **Please note that the price changes in period 1 and period 2 are independent.**
- **The only restriction for all your decisions is that your total number of units has to be between 0 and 10.**

When you have finished the Information and Decision Sheet, please fill in the brief Questionnaire. After you have filled in the Information and Decision Sheet and the Questionnaire, please come to us. You can then no longer change your decisions and answers. We will then determine the actual price changes and you will receive your pay for the experiment.

**How is your pay for the participation in the experiment determined?**
Your pay is equal to your total amount. Your total amount is the sum of the value of your units and your money at the end of period 2.

**Total amount = Value of units + Money**

The value of your units at the end of period 2 is equal to your number of units multiplied by the price of a unit at the end of period 2. Your money is equal to your initial 6 DM minus the cost of purchases of units plus the proceeds from the sale of units. Your stock of money can be negative. However, the parameters of the experiment are chosen such that it is not possible to reach a negative total amount regardless of which decisions you make.

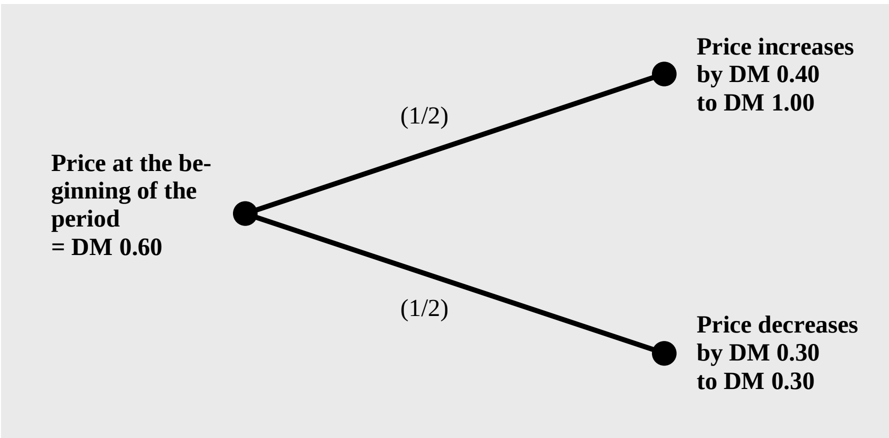
First we determine the price change in period 1 by throwing a die. This determines at the same time which of your decisions for period 2 is used. If the price rises in period 1, your decision for his case is used. If the price drops in period 1, your decision for this case is used. By throwing a die once more we determine the price change in period 2. With this information we calculate your total amount that will be paid to you in cash.

## Portfolio/Free-Choice Treatment: Information and Decision Sheet

# Period 1

You begin this period with **DM 6**.

The initial price of a unit is DM 0.60. In period 1 the price will either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).




How many units do you purchase at a price of DM 0.60? Please pick a number of units between 0 and 10.

**Your decision:**

How many units do you purchase at a price of DM 0.60? _______________

You keep the money that you do not use to purchase units.

Your money after the purchase of units DM______________

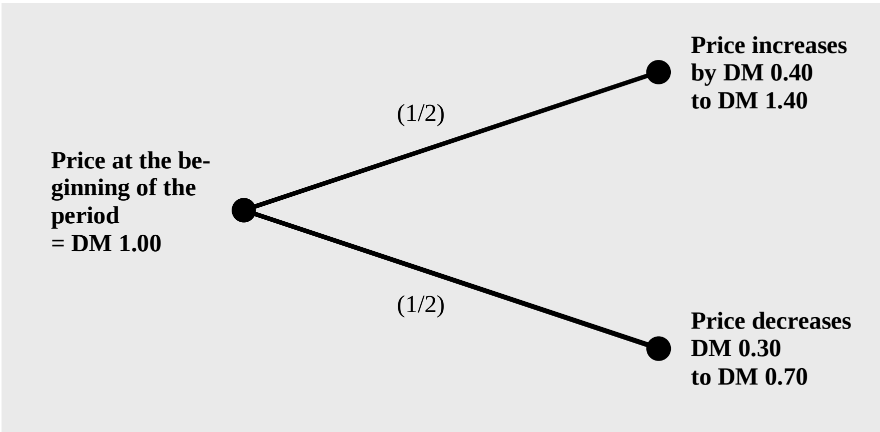
# Period 2 in the <u>case of a price increase</u>

You begin this period with ________ units *(=number of units that you purchased in period 1).*

The price of a unit has increased in period 1 and is now DM 1.00.

| | |
|---|---|
| Your total gain from units in period 1 is therefore<br>*(=number of units times the price increase of DM 0.40)* | DM___________ |

In period 2, the price will again either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).




At the beginning of the period you can purchase additional units at the price of DM 1.00, or you can sell units, **under the sole restriction that your total number of units remains between 0 and 10,** or you can leave your number of units unchanged.

**The situation at the end of period 1:**

Your number of units at the end of period 1 _______________

Your money at the end of period 1 DM___________

**Your decision:**

How many units do you *purchase* at the price DM 1.00? _______________

Total cost of the additional units DM___________

How many units do you *sell* at the price of DM 1.00? _______________

Total proceeds from the selling of units DM___________

**The new situation:**

Total number of units after purchase or sale: _______________

*(Make sure that the total number of units is between 0 and 10)*

Your money after purchase or sale DM___________

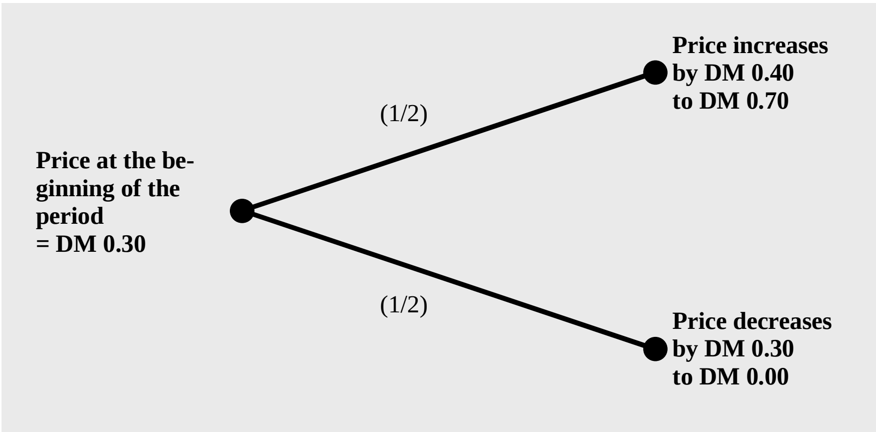
# Period 2 in the case of a price decrease

You begin this period with ________ units *(=number of units that you purchased in period 1).*

The price of a unit has decreased in period 1 and is now DM 0.30.

| | |
|---|---|
| Your total loss from units in period 1 is therefore<br>*(=number of units times the price decrease of DM 0.30)* | DM___________ |

In period 2, the price will again either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).




At the beginning of the period you can purchase additional units at the price of DM 0.30, or you can sell units, **under the sole restriction that your total number of units remains between 0 and 10,** or you can leave your number of units unchanged.

**The situation at the end of period 1:**

Your number of units at the end of period 1 ______________

Your money at the end of period 1 DM___________

**Your decision:**

How many units do you *purchase* at the price of DM 0.30? ______________

Total cost of the additional units DM___________

How many units do you *sell* at the price of DM 0.30? ______________

Total proceeds from the selling of units DM___________

**The new situation:**

Total number of units after purchase or sale: ______________

*(Make sure that the total number of units is between 0 and 10)*

Your money after purchase or sale DM___________

## Lottery/Free-Choice Treatment: Instructions

Thank you for participating in our experiment on decision under risk. The experiment will last about 20 minutes. The instructions for the experiment are simple and if you read them carefully, you can earn money, that will be paid to you in cash immediately after the experiment.

In the experiment you can use fictitious money, to buy units of a fictitious commodity. Units generate a single random payoff and then disappear. Thereby you can gain money (if units pay out something) or lose money (if units do not pay out anything). The following section explains the course of the experiment in detail. Please ask, if anything is not clear to you. Raise your hand, I will come to you.

### Instructions for the Experiment

Together with this instruction you have received an "Information and Decision Sheet" and a "Questionnaire" (stapled together). Please note your decisions and answers on these sheets. Please work on the "Information and Decision Sheet" first and then on the "Questionnaire".

The experiment proceeds in two successive periods. In both periods you can first purchase units. These units generate a random payoff at the end of the period and then disappear.

*Period 1:*

You receive money that you can use to purchase 0 to 10 units. At the beginning of period 1 you decide how many units to buy. You keep the money that you do not use to purchase units. Please find precise information on your Information and Decision Sheet. After you have made your decision, units either pay out a positive amount or nothing. All units in period 1 pay out the same amount.

*Period 2:*

You again receive money that you can use to purchase 0 to 10 units. Your units from period 1 have disappeared. At the beginning of period 2 you decide again how many units to buy. Please find precise information on your Information and Decision Sheet. Please note: The actual payoff in period 1 will be determined at the end of the experiment by throwing a die. You must therefore make two decisions in period 2: One for the case that units generated a positive payoff in period 1, one for the case that units did not pay out anything in period 1. Only one of the decisions will — depending on the actual payoff in period 1 — be used in the end. You do not know in advance which decision will be used.

- **Please note that the payoffs of units in period 1 and period 2 are independent.**
- **The only restriction for all your decisions is that your total number of units has to be between 0 and 10.**

When you have finished the Information and Decision Sheet, please fill in the brief Questionnaire.

After you have filled in the Information and Decision Sheet and the Questionnaire, please come to us. You can then no longer change your decisions and answers. We will then determine the actual payoffs and you will receive your pay for the experiment.

**How is your pay for the participation in the experiment determined?**
Your pay is equal to your total amount. Your total amount is equal to the money you received at the beginning of periods 1 and 2, minus the cost of purchases of units, plus the payoffs of units in both periods.

**Total amount = Money at beginning - Cost + Payoffs of units**

The parameters of the experiment are chosen such that it is not possible to reach a negative total amount regardless of which decisions you make.

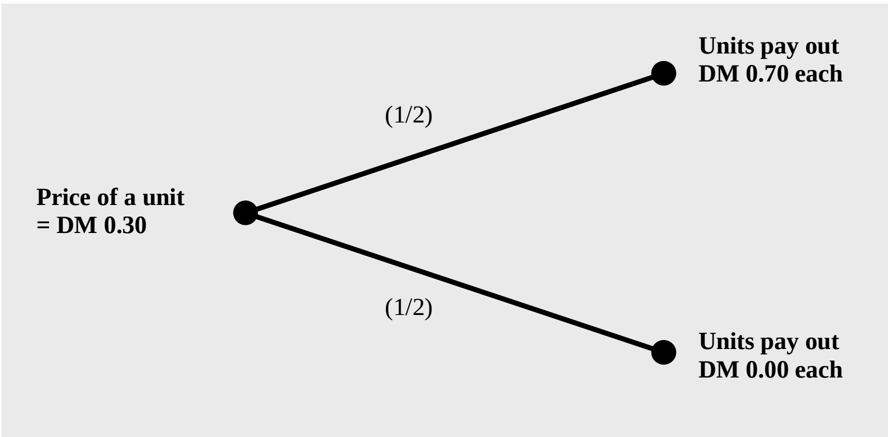
First we determine the payoff of units in period 1 by throwing a die. This determines at the same time which of your decisions for period 2 is used. If there is a positive payoff in period 1, your decision for his case is used. If the payoff is zero, your decision for this case is used. By throwing a die once more we determine the payoff of units in period 2. With this information we calculate your total amount that will be paid to you in cash.

## Lottery/Free-Choice Treatment: Information and Decision Sheet

# Period 1

You begin this period with **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




How many units do you purchase at the price of DM 0.30? Please pick a number of units between 0 and 10. You keep the money that you do not use to purchase units.

| | |
|---|---|
| **Your decision:** | |
| How many units do you purchase at a price of DM 0.30? | _______________ |
| Total cost of the purchase of units *(=number of units purchased times price)* | DM___________ |

# Period 2 in the case that units paid out something

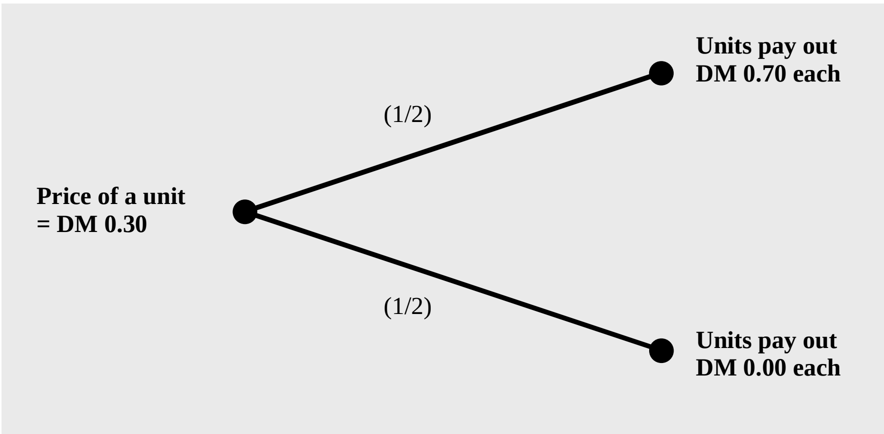
In period 1, units paid out DM 0.70 each.

| | |
|---|---|
| Your gain from units in period 1 is therefore | DM___________ |
| *(=Your number of units in period 1 times the payoff of DM 0.70 per unit minus the total cost of units* | |

You begin this period with 0 units.

You receive again **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will again either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




You can purchase units under the sole restriction that the number of units is between 0 and 10.

You keep the money that you do not use to purchase units.

| | | |
|---|---|---|
| **Your decision:** | | |
| How many units do you purchase at a price of DM 0.30? | ______________ | |
| Total cost of the purchase of units | | DM___________ |

# Period 2 in the case that units paid out nothing

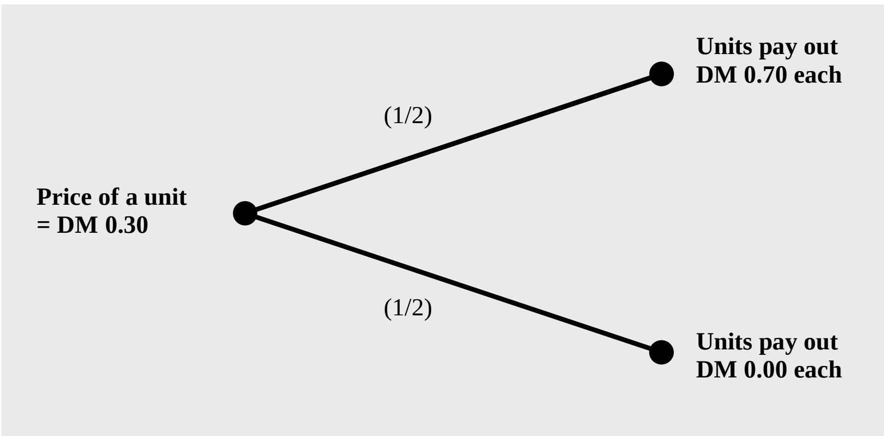
In period 1, units paid out DM 0.00 each.

| | |
|---|---|
| Your loss from units in period 1 is therefore<br>*(=Total cost of units purchased in period 1)* | DM___________ |

You begin this period with 0 units.

You receive again **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will again either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




You can purchase units under the sole restriction that the number of units is between 0 and 10.

You keep the money that you do not use to purchase units.

| | |
|---|---|
| **Your decision:** | |
| How many units do you purchase at a price of DM 0.30? | _____________ |
| Total cost of the purchase of units | DM___________ |

## Portolio/Assigned-Choice Treatment: Instructions

Thank you for participating in our experiment on decision under risk. The experiment will last about 20 minutes. The instructions for the experiment are simple and if you read them carefully, you can earn money, that will be paid to you in cash immediately after the experiment.

In the experiment you can use fictitious money, to buy or sell units of a fictitious commodity. Over the course of the experiment the price of a unit changes. Thereby you can gain money (if the price rises) or lose money (if the price drops). The following section explains the course of the experiment in detail. Please ask, if anything is not clear to you. Raise your hand, I will come to you.

### Instructions for the Experiment

Together with this instruction you have received an "Information and Decision Sheet" and a "Questionnaire" (stapled together). Please note your decisions and answers on these sheets. Please work on the "Information and Decision Sheet" first and then on the "Questionnaire".

The experiment proceeds in two successive periods. In period 1 you have a given number of units. The price of a unit changes duringperiod 1. In period 2 you can first make a decision on the purchase or sale of units. Subsequently the price of a unit changes again.

*Period 1:*

**In period 1 you do not make any decision.** You begin period 1 with a given number of units and a given amount of money. Please find precise information on your Information and Decision Sheet. The price of a unit changes in period 1.

*Period 2:*

At the beginning of period 2 you can sell units at the new and changed price or purchase additional units at the new price. The total number of units must remain between 0 and 10. Please find precise information on your Information and Decision Sheet. Please note: The actual price change in period 1 will be determined at the end of the experiment by throwing a die. You must therefore make two decisions in period 2: One for the case that the price dropped in period 1, one for the case that the price rose in period 1. Only one of the decisions will — depending on the actual price change in period 1 — be used in the end. You do not know in advance which decision will be used.

- **Please note that the price changes in period 1 and period 2 are independent.**
- **The only restriction for all your decisions is that your total number of units has to be between 0 and 10.**

When you have finished the Information and Decision Sheet, please fill in the brief Questionnaire. After you have filled in the Information and Decision Sheet and the Questionnaire, please come to us. You can then no longer change your decisions and answers. We will then determine the actual price changes and you will receive your pay for the experiment.

**How is your pay for the participation in the experiment determined?**
Your pay is equal to your total amount. Your total amount is the sum of the value of your units and your money at the end of period 2.

**Total amount = Value of units + Money**

The value of your units at the end of period 2 is equal to your number of units multiplied by the price of a unit at the end of period 2. Your money is equal to your initial 6 DM minus the cost of purchases of units plus the proceeds from the sale of units. Your stock of money can be negative. However, the parameters of the experiment are chosen such that it is not possible to reach a negative total amount regardless of which decisions you make.

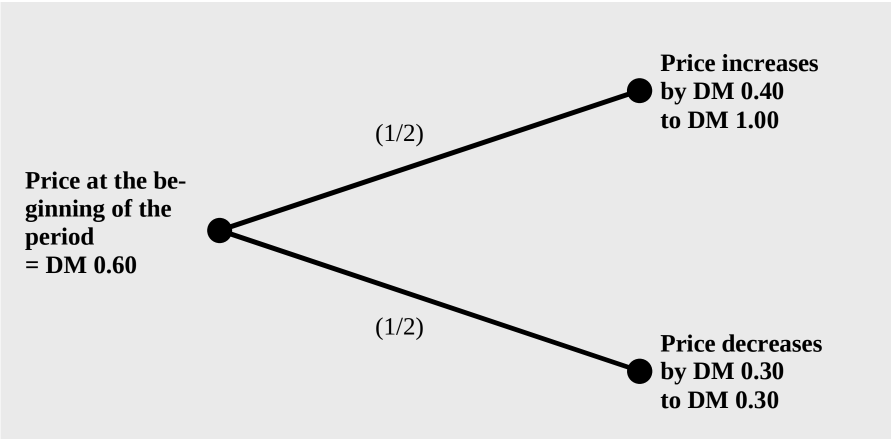
First we determine the price change in period 1 by throwing a die. This determines at the same time which of your decisions for period 2 is used. If the price rises in period 1, your decision for his case is used. If the price drops in period 1, your decision for this case is used. By throwing a die once more we determine the price change in period 2. With this information we calculate your total amount that will be paid to you in cash.

## Portolio/Assigned-Choice Treatment: Information and Decision Sheet

# Period 1

You begin this period with **6 units and DM 2.30**.

The initial price of a unit is DM 0.60. In period 1 the price will either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).



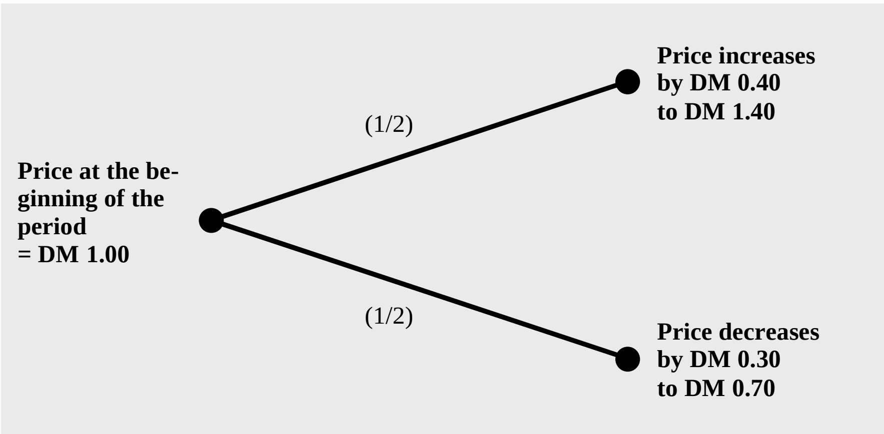
# Period 2 in the <u>case of a price increase</u>

You begin this period with 6 units *(=number of units that you purchased in period 1).*

The price of a unit has increased in period 1 and is now DM 1.00.

| | |
|---|---|
| **Your total *gain* from units in period 1 is therefore**<br>*(=number of units times the price increase of DM 0.40)* | **DM 2.40** |

In period 2, the price will again either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).




At the beginning of the period you can purchase additional units at the price of DM 1.00, or you can sell units, **under the sole restriction that your total number of units remains between 0 and 10**, or you can leave your number of units unchanged.

**The situation at the end of period 1:**

| | | |
|---|---|---|
| Your number of units at the end of period 1 | 6 units | |
| Your money at the end of period 1 | | DM 2.30 |

**Your decision:**

| | | |
|---|---|---|
| How many units do you *purchase* at the price of DM 1.00? | ______________ | |
| Total cost of the additional units | | DM___________ |
| How many units do you *sell* at the price of DM 1.00? | ______________ | |
| Total proceeds from the selling of units | | DM___________ |

**The new situation:**

| | | |
|---|---|---|
| Total number of units after purchase or sale:<br>*(Make sure that the total number of units is between 0 and 10)* | ______________ | |
| Your money after purchase or sale | | DM___________ |

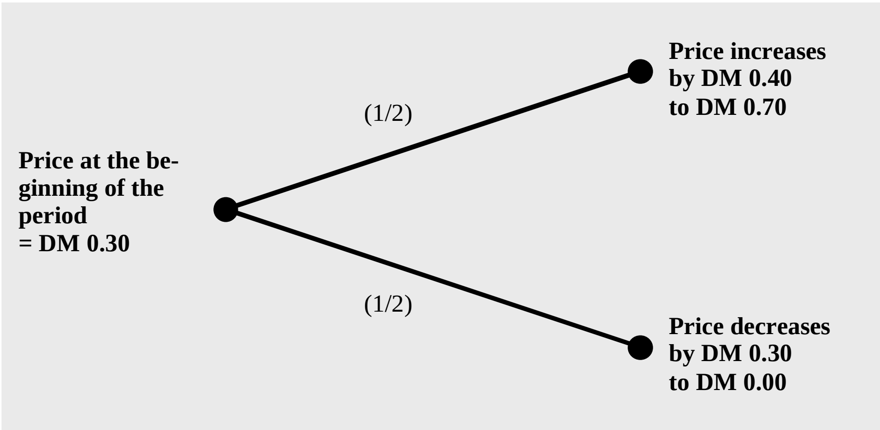
# Period 2 in the case of a price decrease

You begin this period with 6 units *(=number of units that you purchased in period 1).*

The price of a unit has decreased in period 1 and is now DM 0.30.

| | |
|---|---|
| **Your total *loss* from units in period 1 is therefore**<br>*(=number of units times the price decrease of DM 0.30)* | **DM 1.80** |

In period 2, the price will again either increase by DM 0.40 (with probability 1/2) or decrease by DM 0.30 (with probability 1/2).




At the beginning of the period you can purchase additional units at the price of DM 0.30, or you can sell units, **under the sole restriction that your total number of units remains between 0 and 10,** or you can leave your number of units unchanged.

**The situation at the end of period 1:**

| | | |
|---|---|---|
| Your number of units at the end of period 1 | 6 units | |
| Your money at the end of period 1 | | DM 2.30 |

| | | |
|---|---|---|
| **Your decision:** | | |
| How many units do you *purchase* at the price of DM 0.30? | ______________ | |
| Total cost of the additional units | | DM__________ |
| How many units do you *sell* at the price of DM 0.30? | ______________ | |
| Total proceeds from the selling of units | | DM__________ |

**The new situation:**

| | | |
|---|---|---|
| Total number of units after purchase or sale:<br>*(Make sure that the total number of units is between 0 and 10)* | ______________ | |
| Your money after purchase or sale | | DM__________ |

## Lottery/Assigned-Choice Treatment: Instructions

Thank you for participating in our experiment on decision under risk. The experiment will last about 20 minutes. The instructions for the experiment are simple and if you read them carefully, you can earn money, that will be paid to you in cash immediately after the experiment.

In the experiment you can use fictitious money, to buy units of a fictitious commodity. Units generate a single random payoff and then disappear. Thereby you can gain money (if units pay out something) or lose money (if units do not pay out anything). The following section explains the course of the experiment in detail. Please ask, if anything is not clear to you. Raise your hand, I will come to you.

**Instructions for the Experiment**

Together with this instruction you have received an "Information and Decision Sheet" and a "Questionnaire" (stapled together). Please note your decisions and answers on these sheets. Please work on the "Information and Decision Sheet" first and then on the "Questionnaire".

The experiment proceeds in two successive periods. In period 1 you have a given number of units. These units generate a random payoff at the end of the period and then disappear. In period you can make a decision to purchase units. These units again generate a random payoff at the end of the period and then disappear.

*Period 1:*

**In period 1 you do not make any decision.** You receive money that you use to purchase a given number of units. At the beginning of period 1 you decide how many units to buy. Please find precise information on your Information and Decision Sheet. After you have made your decision, units either pay out a positive amount or nothing. All units in period 1 pay out the same amount.

*Period 2:*

You receive money that you can use to purchase 0 to 10 units. Your units from period 1 have disappeared. At the beginning of period 2 you decide how many units to buy. Please find precise information on your Information and Decision Sheet. Please note: The actual payoff in period 1 will be determined at the end of the experiment by throwing a die. You must therefore make two decisions in period 2: One for the case that units generated a positive payoff in period 1, one for the case that units did not pay out anything in period 1. Only one of the decisions will — depending on the actual payoff in period 1 — be used in the end. You do not know in advance which decision will be used.

- **Please note that the payoffs of units in period 1 and period 2 are independent.**
- **The only restriction for all your decisions is that your total number of units has to be between 0 and 10.**

When you have finished the Information and Decision Sheet, please fill in the brief Questionnaire.

After you have filled in the Information and Decision Sheet and the Questionnaire, please come to us. You can then no longer change your decisions and answers. We will then determine the actual payoffs and you will receive your pay for the experiment.

**How is your pay for the participation in the experiment determined?**
Your pay is equal to your total amount. Your total amount is equal to the money you received at the beginning of periods 1 and 2, minus the cost of purchases of units, plus the payoffs of units in both periods.

**Total amount = Money at beginning - Cost + Payoffs of units**

The parameters of the experiment are chosen such that it is not possible to reach a negative total amount regardless of which decisions you make.

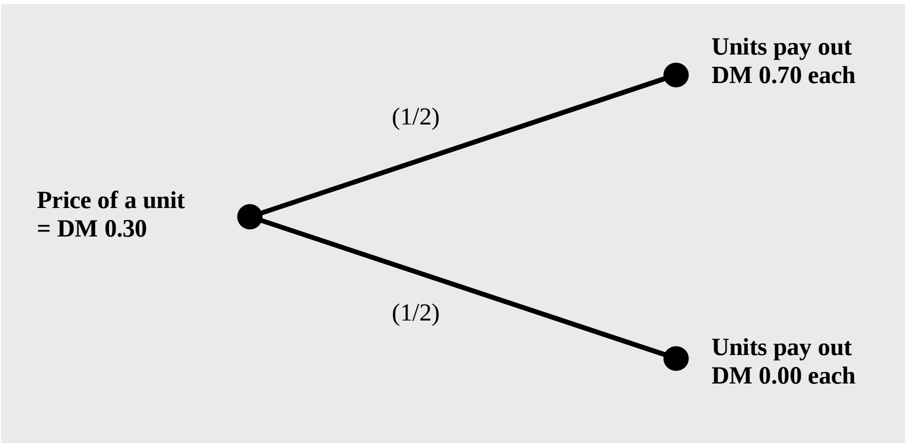
First we determine the payoff of units in period 1 by throwing a die. This determines at the same time which of your decisions for period 2 is used. If there is a positive payoff in period 1, your decision for his case is used. If the payoff is zero, your decision for this case is used. By throwing a die once more we determine the payoff of units in period 2. With this information we calculate your total amount that will be paid to you in cash.

## Lottery/Assigned-Choice Treatment: Information and Decision Sheet

# Period 1

You begin this period with **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




You purchase 7 units at a price of DM 0.70.
You keep the money that you do not use to purchase units.
So you have **7 units** and **DM 0.90**.

# Period 2 in the case that units paid out something

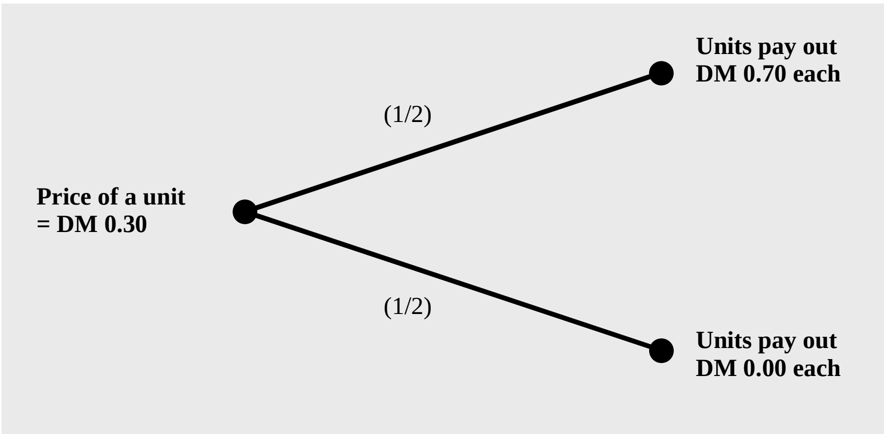
In period 1, units paid out DM 0.70 each.

| | |
|---|---|
| **Your *gain* from units in period 1 is therefore**<br>*(=Your number of units in period 1 times the payoff of DM 0.70 per unit minus the total cost of units)* | **DM 2.80** |

You begin this period with 0 units.

You receive again **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will again either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




You can purchase units under the sole restriction that the number of units is between 0 and 10.

You keep the money that you do not use to purchase units.

**Your decision:**

How many units do you purchase at a price of DM 0.30? _______________

Total cost of the purchase of units DM___________

# Period 2 in the <u>case that units paid out nothing</u>

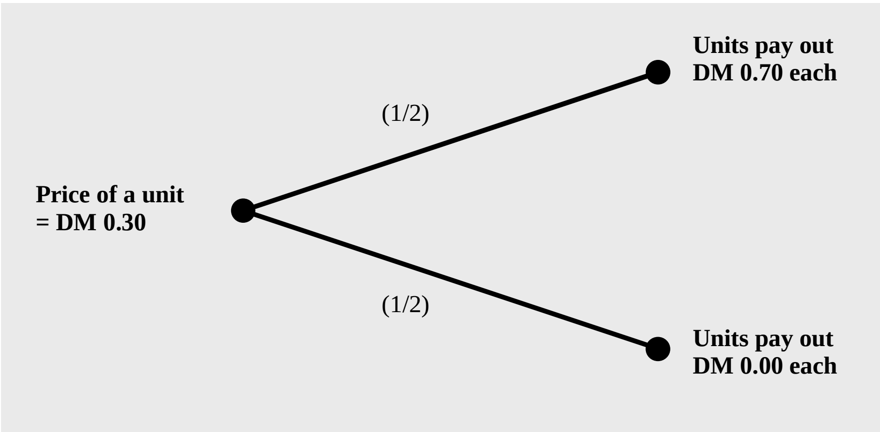
In period 1, units paid out DM 0.00 each.

| | |
|---|---|
| **Your *loss* from units in period 1 is therefore**<br>*(=Total cost of units purchased in period 1)* | **DM 2.10** |

You begin this period with 0 units.

You receive again **DM 3**.

The price of a unit is DM 0.30. At the end of the period, units will again either pay out DM 0.70 (with probability 1/2) or nothing (with probability 1/2). All units have the same payoff.




You can purchase units under the sole restriction that the number of units is between 0 and 10.

You keep the money that you do not use to purchase units.

| | |
|---|---|
| **Your decision:** | |
| How many units do you purchase at a price of DM 0.30? | ______________ |
| Total cost of the purchase of units | DM___________ |

## Questionnaire

Consider the following two events: (a) you lose DM x. (b) you lose DM x after gaining DM y. We are interested in the emotional impact of the loss of DM x in both cases. Are you more upset about the loss of money when it occurs alone (a), or when it occurs directly after a gain (b)? Of course you are happier in total in (b), but we are interested only in the incremental impact of the loss. Below you will find several questions of this type. In each case please compare the incremental effect of the event described. If you feel there is no difference you may check that, but please express a preference if you have one.

1.

(a) You lose DM 20

(b) You lose DM 20 after having gained DM 60

The loss of DM 20 hurts more in:

☐ (a) ☐ (b) ☐ (no difference)

2.

(a) You lose DM 20

(b) You lose DM 20 after having lost DM 60

The loss of DM 20 hurts more in:

☐ (a) ☐ (b) ☐ (no difference)

Your age ______________________________

Gender ______________________________

Major ______________________________

Semester in school ______________________________

In which country were you raised? ______________________________

Your own income from all sources before taxes in 2000: Do not include income from other household members.

☐ 10,000 DM or less ☐ 10,001 DM to 30,000 DM
☐ 30,001 DM to 60,000 DM ☐ 60,001 DM or more
☐ no information

What did you think when making the decisions on your "Information and Decision Sheet?

______________________________

______________________________

______________________________

______________________________

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# Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die Dissertation selbständig angefertigt und mich anderer als der in ihr angegebenen Hilfsmittel nicht bedient habe, insbesondere, dass aus anderen Schriften Entlehnungen, soweit sie in der Dissertation nicht ausdrücklich als solche gekennzeichnet und mit Quellenangaben versehen sind, nicht stattgefunden haben.

Mannheim, 16. Oktober 2001