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The disposition effect in securities trading: an experimental analysis

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Abstract

The 'disposition effect' is the tendency to sell assets that have gained value ('winners') and keep assets that have lost value ('losers'). Disposition effects can be explained by the two features of prospect theory: the idea that people value gains and losses relative to a reference point (the initial purchase price of shares), and the tendency to seek risk when faced with possible losses, and avoid risk when a certain gain is possible. Our experiments were designed to see if subjects would exhibit disposition effects. Subjects bought and sold shares in six risky assets. Asset prices fluctuated in each period. Contrary to Bayesian optimization, subjects did tend to sell winners and keep losers. When the shares were automatically sold after each period, the disposition effect was greatly reduced. Published by Elsevier Science B.V.

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1. Introduction

Prospect theory (Kahneman and Tversky (1979)) predicts that outcomes are coded as gains or losses relative to a reference point, and decision makers are risk-averse in the gain domain and risk-seeking in the loss domain. The use of a reference point to determine gains and losses will henceforth be called a 'reference point effect'. The difference in risk attitudes for gains and losses is called a 'reflection effect'.

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Reference point effects have been studied in a variety of economic settings (e.g., Thaler (1985) on marketing; Bowman et al. (1997), in consumption-savings models). In a financial setting the reference point effect explains the disposition to sell winning stocks too early and ride losing stocks too long, which Shefrin and Statman (1985) call the 'disposition effect'.

Empirical studies show that this disposition effect is present in market data (O'Dean, in press). However, a conclusive test of the disposition effect using real market data is usually difficult because the investors' expectations, as well as individual decisions, can not be controlled or easily observed in markets like the New York Stock Exchange (NYSE). If an effect is found at the aggregate level there are often competing plausible hypotheses to explain it. In this paper we therefore present an *experimental* investigation of the disposition effect[1].

The experiments enable us to match individuals' trading decisions with the prices at which they bought assets, allowing a direct test for disposition effects.

We proceed as follows. Section 2 describes the previous work on the disposition effect and gives a theoretical analysis of how the effect should influence selling behavior. Hypotheses and experimental design are presented in Section 3. Results appear in Section 4.

2. Related work and theory

2.1. Related work

The reflection and reference point effects can be demonstrated with an example. Suppose a decision maker has to choose between a sure 5 DM and a lottery yielding either 0 DM or 10 DM (with 0.5 probabilities). According to the prospect theory, if the reference point is a gain of 0 then most decision makers will be risk averse, i.e. prefer the sure 5 DM. If a decision maker has to choose between a sure loss of 5 DM and a lottery paying either 0 DM or a loss of 10 DM (with 0.5 probabilities), she will in general pick the risky lottery. There is an impressive amount of experimental evidence that risk attitudes do depend on the reference point, as in our example[2]. (Of course, other variables affect risk attitudes too.)

In most decision situations there are several possible reference points. In a financial setting, the purchase price of a stock is a natural reference point for evaluating the stock. Shefrin and Statman (1985) found evidence that "investors tend to sell winners too early and ride losers too long" (p. 778). This disposition effect can be explained by investors

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[1] Experiments have been used to test several hypotheses in financial settings. Copeland and Friedman, 1987, 1991, O'Brien and Srivastava, 1991, Camerer and Weigelt, 1992 tested different market efficiency assumptions. Smith et al., 1988, Camerer and Weigelt, 1993 studied price 'bubbles'. Sarin and Weber, 1993 investigated the effects of uncertainty about state probabilities ('ambiguity') on prices in auction markets. Weber et al., 1997 showed that framing effects have a strong influence on prices in experimental markets.

[2] See Kahneman and Tversky (1979), Hershey and Schoemaker (1980), Hogarth and Einhorn (1990), Thaler and Johnson (1990), Tversky and Kahneman (1992), van der Pligt and van Schie (1990).

judging gains and losses relative to their initial purchase price, and being risk-averse toward gains and risk-seeking toward losses. (We demonstrate this more formally below.)

Lakonishok and Smidt (1986) looked at abnormal volume for NYSE and Amex stocks that had risen or fallen in price over the previous 5, 11, 23, and 35 months. They found more volume for winners. Ferris et al. (1988) used price and volume data for thirty U.S. stocks. They compared current trading volume with historic trading volume. As predicted by the disposition effect, current volume was negatively (positively) correlated with the volume on those previous days in which the stock price was higher (lower) than the current price. However, their results could be due to statistical artifacts and might be explained by other hypotheses besides disposition effects (see the discussion of their paper, p. 698). Furthermore, their aggregate data offer no direct insight into the decision making processes of individual investors.

The most convincing study using field data from stock markets was done by O'Dean (in press). He obtained records of 10 000 accounts from a large discount broker. (These data rule out the possibility that disposition effects are created by broker pressure on clients, since discount brokers execute trades for clients but do not provide advice.) Several different tests all show disposition effects, and all the effects are hugely significant because of the large samples and independence across investors. Investors hold losers longer (a median of 124 days) than they hold winners (104 days). Across the entire year, investors realize about 24% of the gains they could realize by selling, but they realize only 15% of their losses. In December, however, these two figures are both close to 20% and are statistically indistinguishable, which shows that the only time investors *do not* exhibit a disposition effect is at the year-end, when there is a nearby tax advantage to selling. Finally, O'Dean is able to test the hypothesis that investors are rational to keep losers and sell winners, because they guess correctly that the losers will rebound and the winners will slip back in price. This proves to be false: unsold losers return only 5% over the subsequent year, while winners that are sold would have returned 11.6%.

Shiller and Case (1988) interviewed home buyers in areas where homes had risen in price or stayed flat. Their interviews suggested substantial disposition effects: homeowners were more eager to sell at a profit than at a loss. (It is widely thought by real estate economists and agents that volume slows, sometimes dramatically, when prices sag.)

Our experiments put people in a portfolio decision situation. Others have studied portfolio selection experimentally (without focusing on reference point effects, as we do). In Kroll et al. (1988a), (1988b) subjects could invest in risk-free assets, or borrow at the risk-free rate, and invest in two or three risky investments. In each period the prices of the risky assets (and hence, their returns from period to period) were determined by a probability distribution known to subjects, and price changes were independent. (Subjects were paid according to their performance.) Their setting predicts 'portfolio separation'– i.e., each subject should hold the same portfolio of risky assets, and adjust their mixture of risk-free assets with the risky portfolio according to their risk tastes.

Their main finding was that the subjects' behavior is quite different from the behavior predicted by the portfolio theory or by the capital asset pricing model. Subjects did not diversify properly and did not obey portfolio separation (subjects held different mixtures of risky assets). Furthermore, subjects wanted to know past price movements, even though they were told that price changes were independent. In further experiments Kroll and Levy (1992) found evidence more consistent with portfolio separation. Related empirical studies include Maital et al. (1986), Rapoport et al. (1988a), (1988b), Oehler (1994), Gerke and Bienert (1993).

2.2. Theory

We now show how reflection effects and reference point effects can combine to cause disposition effects. Suppose an investor buys a share of stock for price P. Subsequently, the stock falls in value by the amount L, to a price of $P-L$. (We call this a 'loser' stock). The investor can sell the stock or hold it. If she holds the stock, it is equally likely to return to its purchase price P or to fall by L again, to a price of $P-L-L=P-2L$. In the corresponding 'winner' stock situation, the stock rises by the amount G, to a price of $P+G$. If the investor holds the stock it is equally likely to fall back to P or to rise by G again, to a price of $P+2G$.

Fig. 1(a) shows what happens when the investor's reference point is the original purchase price P. We assume, as in prospect theory, that people value gains and losses from the reference point. Then a loser stock is worth $P-L$ if it is sold, and either P or $P-2L$ if it is held. If the reference point is P, the investor 'frames' the investment decision as a choice between a certain loss, with negative value $v(-L)$, or keeping the stock, accepting a gamble with value $v(0)$ ('breaking even') or $v(-2L)$. If she is risk-seeking in the domain of losses (and the chances of breaking even or losing another L are equal), she will keep the stock. Investors will keep losers because the pain of a further loss L is less than the pleasure of recovering the purchase price.

A winner stock is worth $P+G$ if it is sold, and either P or $P+2G$ if it is held. If investors are risk-averse toward gains gambles, they will sell the stock to 'lock in' the certain gain G (creating a gain with value $v(G)$) rather than gambling on earning $v(2G)$ or $v(0)$. Investors will sell winners.

The argument so far only considers two periods. For a larger number of periods each former price of the stock (or some weighted average of them) could serve as a reference point. It is straightforward to extend the disposition effect to any of these reference points. Note that any test for disposition effects tests the joint hypothesis that the prospect theory model is correct and a particular specification of how investors choose reference points.

Now suppose investors adjust their reference points as stock prices change. Fig. 1(b) shows what happens. Suppose the *current* price is the reference point from which gains and losses are valued, rather than the purchase price. Then the loser stock with a current price of $P-L$ will either gain $+L$ (if it returns to the purchase price P) or lose an additional $-L$ (if it falls to $P-2L$). Investors will keep these stocks if a gamble over $v(L)$ and $v(-L)$ is better than $v(0)$, and sell them otherwise. The winner stock (which is not shown in Fig. 1(b)) will either gain G or lose $-G$; investors will keep them if the gamble over $v(G)$ and $v(-G)$ is better than $v(0)$. A value function which exhibits 'loss aversion' ($v(x)<-v(-x)$ for $x>0$) predicts that for equal chance gambles the investor will always sell the lottery, regardless of whether it won or lost in the past– i.e., there should be no disposition effect if the reference point is the current price.

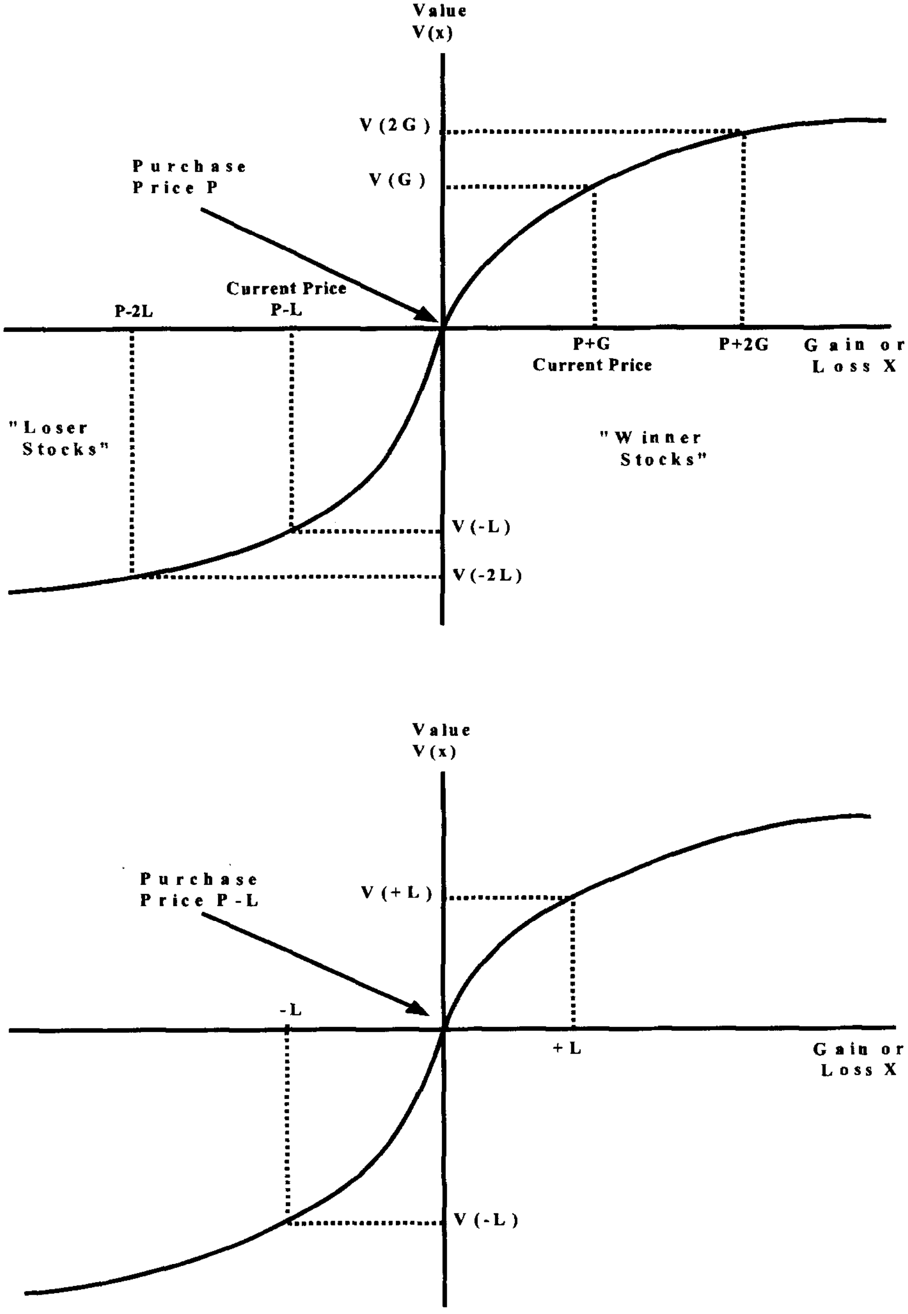

Fig. 1. How reference points create disposition effects.

In our experiments, G and L are equal because winner and loser stocks go up or down in increments of equal size. When the reference point is the current price, winner and loser stocks are treated identically. Thus, disposition effects only arise when the original purchase price or another price of a previous period is the reference point (as in Fig. 1(a)), and when reflection effects cause investors to seek risk by holding losers and avoid risk by selling winners.

2.3. Hypotheses

We can formalize our arguments in a series of hypotheses. We derive hypotheses for markets in which prices are independent of investor trading behavior (i.e., perfect competition). The main hypothesis is that the number of shares sold will be smaller for losing assets than for winning assets. Of course, it only makes sense to talk about winning and losing stocks relative to a specific reference point. We consider two possible reference points. H1 takes the purchase price as the reference point; H2 takes the previous period's price as the reference point.

H1 *(Purchase price reference point) Subjects sell more shares when the sale price is above the purchase price than when the sale price is below the purchase price.*

H2 *(Last period reference point) Subjects sell more shares when the sale price is above the last period price than when the sale price is below the last period price.*

In most markets, selling a stock requires a deliberate action. This condition can be contrasted with an 'automatic selling' condition in which all stocks are automatically sold at the end of a period and subjects have to rebuy the stocks (at the same price they were automatically sold for). With no transaction costs, a rational decision maker should behave identically in both types of experiments. If disposition effects are caused by a reluctance to deliberately incur losses, and an eagerness to guarantee gains, subjects who must sell assets deliberately will exhibit greater disposition effects than subjects who sell them automatically[3].

H3 *Disposition effects are smaller when assets are automatically sold than when selling is deliberate.*

We also investigate if the size of price changes is related to the volume (as it is in naturally-occurring markets, see Karpoff (1987). One theory of Andreassen (1988) is that a larger price change will increase the salience of a stock and thus increase the trading volume.

H4 *Trading volume is positively correlated with the size of price changes.*

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[3] The difference between deliberate and automatic selling could arise because of 'endowment effects' studied by Kahneman et al. (1990) and others.

3. Experimental design

In our experiment subjects made portfolio decisions before each of the 14 periods. Before each period they could buy and sell six risky assets at announced prices. Prices of the risky assets were generated by a random process described below in more detail. Prices were *not* determined by the trading actions of subjects, as in many market experiments, because we were interested in isolating disposition effects – the tendency to buy and sell at different prices – from the process of price formation.

Each subject was endowed with 10 000 DM at the beginning of the experimental session. At the end each subject got a percentage of the sum of their cash at hand and the final value of their portfolio. (The percentages were 0.1% and 0.2% in sessions I and II.) Subjects could not borrow money or sell assets short.

To test H3 (deliberate selling vs. automatic selling) we ran two types of sessions. In session I (deliberate selling) the holdings of shares at the beginning of each period were equal to the holdings at the end of the previous period. In session II (automatic selling) all shares which were held at the end of a period were automatically sold in the beginning of the next period, after the new share prices were announced, but subjects could buy the shares back.

In the experiment we used six different shares, labelled A–F. We described the shares using the neutral German word 'Anteile' ('parts', or 'shares') rather than calling them 'stocks'. Money not invested in shares was held in cash which paid no interest.

The process by which prices of risky shares were determined was explained in detail. In each period, it was first determined whether the price of each asset would rise or fall. The six assets had different chances of rising and falling in price (which were fixed, for each asset, during the entire 14 periods of the experiment) and rises and falls were independent across assets. The chances of a price increase were 65% for one asset (labelled ++), 55% for one asset (labelled +), 50% for each of the two assets (labelled 0), 45% for one asset (labelled −) and 35% for one asset (labelled −−). Since prices never stayed the same, the chance that a price would fall was always one minus the chance that it would rise. Subjects knew the chances of all six assets rising and falling, but they did not know which share (labelled A–F) had which probability of rising. (We used this complicated design in order to test theories of portfolio selection, reported in Weber and Camerer (1992)).

After the rise or fall was determined for each asset, it was determined randomly whether the price would rise or fall by 1, 3 or 5 DM. All three possibilities were equally likely, and were independent, for all the six stocks. (Note that the probability of a stock rising in price was uncorrelated with the *size* of price rises.) Notice that the expected value of price change for a randomly-chosen stock was zero. Price sequences were determined by the experimenter before the experiment, using a random number table. (The table was shown to subjects at the beginning of each experiment, and they were allowed to inspect it.) Predetermination of prices allowed us to have identical sequences of share prices in all experiments, so we could pool data from different subjects[4].

[4] It is unlikely that students knew the trend of shares from previous experiments because one experiment took place in Aachen (Germany) and two experiments took place in remote Kiel (Germany).

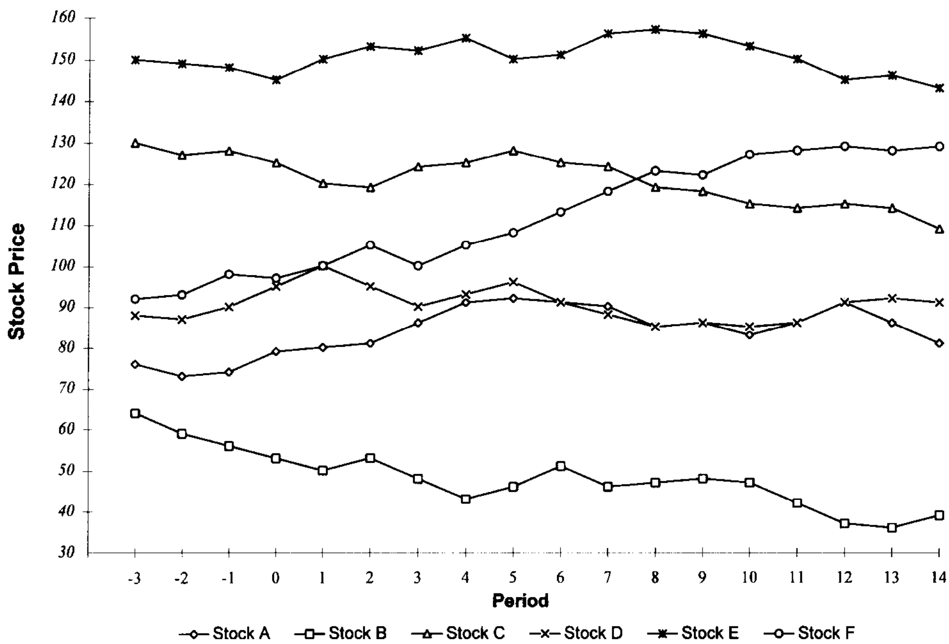

Fig. 2. Time series of stock prices used in the experiment.

In our design students had to infer the distribution underlying each share's price movements from the past data. A Bayesian subject would continually update her probabilities that each of the six shares had each of the six increase probabilities, based on observed price movements. The optimal Bayesian method corresponds to a simple heuristic way to judge which of the six stocks has which trend: count the number of times a share rose in price. The share with the most price increases is the most likely to have the trend ++; the share with the second highest number of price increases is most likely to have the trend +, etc. An investor using this Bayesian rule would have inferred the trends +, −−, −, 0, 0, ++ for shares A–F before period 8 and +, −, −−, 0, 0,−− in periods 9–14. (The actual trends for the six shares were 0, −,−−, −, +, ++.)

Fig. 2 shows the price of shares for periods −3 to 14. The prices of periods −3 to 1 were given, so the subjects had some idea of the trend of a share at the beginning of the experiment. We also started with different absolute share prices in period 1 (except for D and F).

Our design has an important advantage. Since the share that has risen most frequently is most likely to be the ++ share, the share investors should be *least* eager to sell; similarly, the most frequent loser is most likely to be −− and investors should be eager to sell it. Thus, a disposition effect is clearly a mistake in this setting.

The experiment was run using a questionnaire (rather than computerized software). In the beginning subjects were told that they could buy and sell 'Anteile' (shares) and were told how prices were determined. The questionnaire contained a record sheet where subjects recorded prices of shares and their trades. After periods 1, 7 and 14 in type II experiments (but only after period 14 in one type I experiment) subjects were asked to guess which of the six shares A–F exhibited which of the six possible trends (++, +, 0, 0, −, −−).

Experiment I was conducted in two groups, Ia and Ib. Group Ia consisted of 29 engineering students from the Aachen University, who earned from 7.65 DM to 12.93 DM with an average of 10.08 DM (with 1.50 DM=$1 US at the time). In experiments Ib and II subjects were 35 and 39 business and economic graduate students from the University of Kiel. They earned between 8.85 DM and 12.58 DM (average 10.04 DM) in experiment Ib and between 17.75 DM and 23.66 DM (average 14 20.03 DM) in experiment II. The experiments took about 1.5 h (2.5 h for experiment II). All parts of the written instructions were collected after the experiments.

4. Results

4.1. Hypothesis testing for disposition effects

H1 stated that subjects sell more shares when the price is above the purchase price than when the price is below the purchase price. As subjects were forced to sell at the beginning of each period in experiment II we only used data from sessions Ia and Ib to test this hypothesis.

The first problem in testing H1 is that when a share is sold, we do not always know its purchase price. We therefore computed results using two different accounting principles. The 'first-in, first-out' (FIFO) principle assumes that the shares which are sold are those which were bought first. The 'last-in, first-out' (LIFO) principle assumes that shares which are sold are those which were bought last. There were no substantial differences in results using the two methods.

Table 1 shows the number of shares sold after making a gain (winners), breaking even, or making a loss (losers). Aggregating across all six shares, nearly 60% of the shares sold were winners; less than 40% were losers. This is clear evidence of a disposition effect. The effect is present for four of the six shares (share D is the only dramatic exception)[5].

A second test of H1 is shown in Table 2. This table compares the average profit on shares that were sold with average profit on shares that were kept to the end of the experimental session. According to H1, subjects will sell shares which gain and keep shares which lose. Therefore, shares kept until the end should yield less profit (or a loss) than shares that were sold during the experiment. Table 2 clearly supports this hypothesis, using either accounting principle. Subjects realized an average profit of 1.0 DM (LIFO and FIFO) per share sold, while shares kept at the end gained less money on average (0.4 DM under LIFO and 0.7 DM under FIFO). The results are surprising because, as we

[5] The exceptional behavior for the D shares may be instructive. The price of D rose in the periods before the expreiment began (see Fig. 2) and subjects bought a lot of D shares in the first period (19.1 shares per subject, out of 67.2 averages total shares bought in the first period). Then the price gradually slipped, rising again in period 10. Most sales in the later periods are recorded as 'losses' because the period 14 price was below the period 1 price (the price at which most people bought). But subjects may think of those sales as gains *relative to the reference point of low prices in later periods* e.g., Period 10). This example shows the ambiguity in discovering subjects' reference points, and the need for more research.

Table 1
Total number of shares sold depending on purchase price

LIFO	A		B		C		D		E		F		Overall	
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	Total
Gain	1392	51	3103	70	420	46	542	33	678	78	1658	86	7793	59
Even	276	10	31	1	5	1	75	3	25	3	200	11	612	5
Loss	1068	39	1271	29	492	53	1739	74	161	19	64	3	4795	36
FIFO														
Gain	1455	55	3211	70	425	47	411	17	583	75	1568	83	7653	58
Even	289	11	10	0	0	0	90	4	35	5	250	13	674	5
Loss	883	34	1376	30	472	53	2385	79	156	20	64	4	4826	37

Table 2
Average profit for shares sold and kept until the end (experiment I)

LIFO	A	B	C	D	E	F	All
Sold	1.4	0.9	−0.1	4.1	1.0	7.7	1.0
Kept	−0.2	−6.4	−12.9	−8.1	−1.8	12.4	0.4
FIFO							
Sold	1.8	1	0	−4.3	1	8	1
Kept	−0.1	−6	−10.6	−6.7	−2	13	0.7

show in more detail below, subjects had a good idea of which stocks had upward and downward trends.

Next we test H2, which hypothesizes that the price of the last period is adopted as a reference point. If H2 is true (and risk attitudes reflect around the reference point), more shares should be sold if the price of a share has gone up in the last period than if the price has gone down.

Table 3 shows the number of times subjects sold shares, together with the total number of shares sold and the percentages of units sold (relative to all units sold) after prices gained twice in two consecutive periods (*GG*), lost then gained (*LG*), gained then lost (*GL*), or lost twice (*LL*). Remember that in experiment II subjects were forced to sell at the beginning of each period. Therefore, the data for Experiment II show the number of *net* sales, i.e. the number of shares which were sold that were not re-bought immediately.

Table 3 shows that in experiment I, more than twice as many units were sold when the price rose in the last period (*GG* and *LG*) as were sold when the price fell (*GL* and *LL*). The effect almost disappears in experiment II. The data are consistent with the joint hypothesis that there is a disposition effect and the previous period's price serves as a reference point. The weaker effect in experiment II, with automatic selling, suggests that most of the disposition effect can be traced to a reluctance to sell deliberately, rather

Table 3
Number of sales in period t depending on whether prices gained (G) or lost (L) in periods $t-1$ and $t-2$.

Price trend period $t-2$	$t-1$	Experiment I			Experiment II		
		Sales	Units sold %		Net sales	Units sold %	
G	G	184	3815	29	236	5480	24
L	G	155	5265	40	199	6570	29
–	G	339	9080	69	435	12 050	54
G	L	93	2067	16	182	6470	29
L	L	83	2002	15	143	3850	17
–	L	176	4069	31	325	10 320	46

Number of periods is 22 (GG), 15 (LG),19 (GL), and 20 (LL).

than an eagerness to hold losing shares. (If subjects simply preferred to hold losing shares, they would buy them back after they were automatically sold.) Thus, it appears that while subjects are reluctant to have their hopes of getting their money back extinguished, they are especially reluctant to blow out the flame of hope with their own breath.

The analyses in Tables 1, 2 and 3 pool data from all the subjects. To study individual-level effects we created an index describing the size of the disposition effect for each subject. Let S_+ (S_-) be the number of sales if the price has gone up (down) in the last period. For each subject, define a disposition coefficient $\alpha=(S_+-S_-)/(S_++S_-)$, the difference in sales of winner and loser stocks by one subject normalized by the total number of sales by that subject. The disposition coefficient α is zero if there is no disposition effect and is positive if there is a disposition effect. The coefficient is $+1$ (-1) if a subject only sells after a gain (loss).

The cumulative distribution of α's across subjects is shown in Fig. 3. About two-thirds of the subjects have positive values. On an average we have $\alpha_{\mathrm{I}}=0.300$ and $\alpha_{\mathrm{II}}=0.155$. A t-test shows that both means are significantly greater than zero (t=4.1 and 3.0, p<0.01), i.e., the proportion of subjects exhibiting a disposition effect is greater than one would expect by chance in both experiments. The disposition effect is weaker in experiment II, with automatic selling (the cumulative distribution function of α_{II} values spikes more sharply upward around zero). A t-test rejects the hypothesis that the mean α_{II} is equal to the mean α_{I} (t=1.62, p<.05), and a Kolmogorov–Smirnov test indicates that the two cumulative distributions are generally different (KS=0.31, p<0.025).

The difference between experiments I and II is important for methodological reasons also. The *only* difference between the two groups (besides an inconsequential difference in the composition of the subject pools) is that shares were automatically sold in experiment II. Even if the apparent disposition effect in experiment I is due to the idiosyncracies of subjects, inadequate motivation, uncontrolled expectations about price changes, etc., – we think it is not, of course – those features were the same in the two sessions, so they cannot explain why automatic selling virtually wipes out the disposition effect.

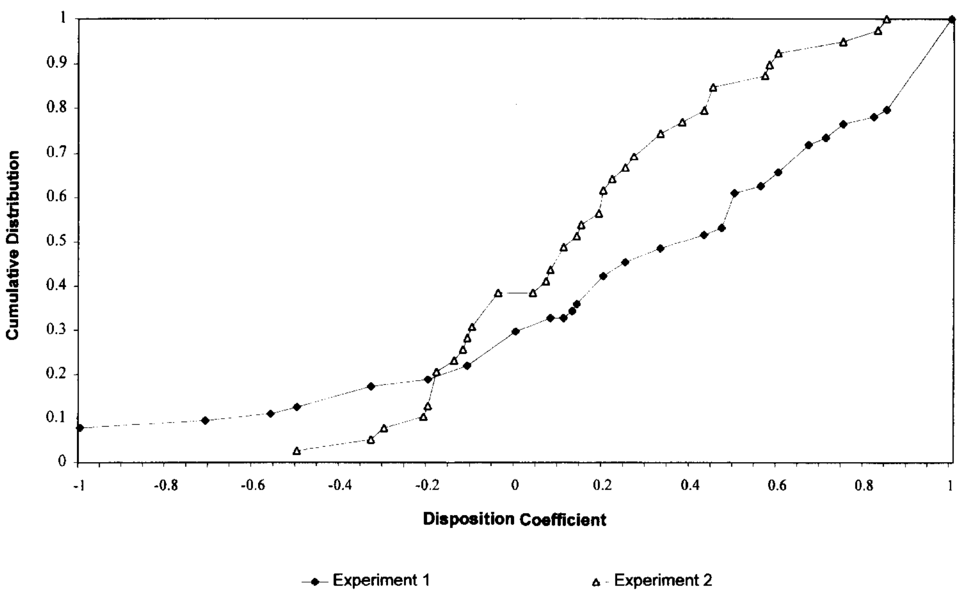

Fig. 3. Cumulative distributions of disposition coefficients.

4.2. *Price changes and trading volume*

H4 states that the amount of price change is positively correlated with the volume traded.

We define trading volume to equal the total number of shares bought and sold. The following data are from experiment I, periods 2–14:

Volume for change of 1:	9596	(per change: 299.9)
Volume for change of 3:	7386	(per change: 369.3)
Volume for change of 5:	14 105	(per change: 440.8)

The data indicate that H4 cannot be rejected. A t-test comparing the volume for a change of +5 and +1 shows that the average volume when prices change by +5 is significantly larger than the average volume with a previous change of +1 (t=2.02, p<.05) (the other comparisons are not significant). These data partially replicate the price change–volume relation observed in naturally-occurring markets.

4.3. *Portfolio selection*

It is natural to wonder whether the patterns of buying and selling we observed could be generated by rational investors following portfolio theory – i.e., forming Bayesian expectations by observing previous stock price movements, then choosing a portfolio of stocks with high expected return and low variance of returns (Markowitz (1959)). In Weber and Camerer (1992) we report detailed tests which reject this hypothesis.

Briefly summarized, risk-averse Bayesian utility maximizing subjects should hold at least 68% of their portfolio in A shares through period 6, then switch to at least 75% holdings in F after that. They should never hold B or C shares. In fact, subjects held only 24% of their shares in A in periods 2–6 and only 28% in F in periods 7–14. They also held substantial shares in B (22%) and C (8%). In short, they held a more diversified portfolio, and traded more often, than was optimal. Profits suffered, as a result: a risk-neutral Bayesian investor would have earned 12 580 DM in paper profit, or about 2.5 (5) DM more in actual earnings in experiments I (II) than subjects earned, a 25% increase in profit from behaving optimally.

4.4. Predictions of share trends

Perhaps misperception of trends of the shares by subjects can explain some of our results. The best estimate of which of the six shares has each of the six trends comes from counting the number of times a share went up in price. The share with the most price increase is the one most likely to have the trend ++; the share with the second highest number of price increases is most likely to have the trend +, etc. As mentioned above, a rational investor would infer the trends for A–F to be (+, − −, −, 00, ++) before period 8 and (+, −, − −, 00, ++) at the end.

After periods 7 and 14 of the experiment, we asked 22 subjects to guess which share had which trend. To calculate a measure of fit between the best estimate and a subject's actual guess we code ++=2, +=1, 0=0, −=−1, − −=−2 and sum over the absolute differences between the rational estimate and the student's estimates. This number 'δ' is the sum of all absolute differences and ranges from 0 (perfect estimates) to 12 (maximally wrong estimates). Table 4 gives the means and standard deviations of δ for sessions Ia, b and II, at periods 7 and 14.

Table 4 shows that trend estimates were fairly accurate to begin with after period 7–subjects only erred a total of two places, on average. Trend estimates got slightly worse (though not significantly so) between periods 7 and 14.

Table 5 shows mean trend estimates (including signs) for each of the six shares. (The top line shows the actual trends for each share too.) Subjects only systematically misperceived the trend of shares A, B and F.

Table 4
Accuracy of trend estimation (low numbers=more accurate)

	Session Ia	Session Ib	Session II
Period 7			
Mean δ	n.a.	2.11	4.18
Std. dev.	n.a.	2.40	2.80
Period 14			
Mean δ	3.93	2.43	4.82
Std. dev.	2.34	1.44	2.73

Table 5
Accuracy of trend estimation across shares

Stock	A	B	C	D	E	F
Actual trend	0	–	–	0	+	++
Ia Period 14	0.41	−1.52	−0.76	0.11	−0.17	1.79
Ib Period 7	0.97	−1.51	−0.46	−0.23	14	1.86
Ib Period 14	0.69	−1.6	−1.17	−0.11	−0.06	1.94
II Period 7	0.90	−1.13	−0.26	−0.10	0.43	1.51
II Period 14	0.08	−0.85	−0.95	0.10	−.51	1.21

There is no difference in earning across subjects depending on the quality of trend estimation (Weber and Camerer (1992)).

4.5. Purchases of shares and mean-reversion

The disposition effect only predicts variation in the numbers of shares *sold*. Our data also allow us to investigate the effect of stock price movement on buying behavior. Buying behavior is especially important because our prospect–theoretic account is not the only possible explanation for the observed fact that subjects sold more often after shares rose in value than after they fell. A competing explanation is that subjects expected mean-reversion: a disposition effect could occur if subjects thought winner stocks would fall and losers would rise. In our design, belief in mean-reversion is wrong because stocks that rise are more likely to be positive-trend stocks and are more likely to rise again; similarly, losers are likely to continue losing. (That is, price changes across all stocks were actually *positively* autocorrelated, 24 not *negatively* autocorrelated as mean-

Table 6
Fraction of all purchases in period t depending on prices in period $t-1$

	Exp. I	Exp. II
A and F		
G	57	58
L	43	42
B and C		
G	25	41
L	75	59
D and E		
G	26	40
L	74	60
All shares		
G	38	46
L	62	54

reversion predicts). Nonetheless, subjects might have mistakenly believed in mean-reversion. If they do, they should buy stocks that gained in price more than they buy stocks which lost.

Table 6 gives the percentage of purchased shares of stocks which gained in price (G) or lost (L) in the previous period. (For example, in experiment I, 57% of the purchases of A and F stocks occurred after those stocks rose).

On an average, subjects bought after losses more than they bought after gains, suggesting a belief in mean-reversion. The effect is weaker in experiment II, with automatic selling, than in experiment I.

5. Discussion

Our data show a disposition effect: subjects tend to sell fewer shares when the price falls than when it rises. They also sell less when the price is below the purchase price than when it is above. (The presence of both effects suggests that multiple reference points – both purchase prices and previous prices – affect framing and guide choices.) Disposition effects are especially harmful in our design because falling prices imply, in a statistical sense, that a stock is likely to have a downward trend and shares *should* be sold. Rising prices imply a stock has an upward trend and should *not* be sold. But subjects do exactly the opposite of what they should do: they sell 'winners' and keep 'losers'. Our findings clearly support the results in Shefrin and Statman (1985), Ferris et al. (1988) and O'Dean (in press). The results are also inconsistent with portfolio theory.

The tendency to sell winners too early and ride losers too long can be explained in two ways. First, in prospect theory disposition effects occur because subjects use their purchase price as a reference point and are reluctant to recognize losses; they gamble in the domain of losses (by keeping stocks that have lost value) and avoid risk in the domain of gains (by selling stocks that have gained value). A second explanation is that subjects misperceive probabilities of future price change: for example, they might think losing stocks will bounce back and winning stocks will fall.

Since the probabilities of price changes were given, subjects were well-trained statistically, and subjects perceived the trends of each share rather accurately, we lean toward the prospect theory explanation. Most importantly, automatically selling shares (as we did in our experiment II) did reduce the disposition effect substantially, which cannot be explained by mean-reversion.

Some features of the data are consistent with the mean-reversion explanation, however. For example, after the share B has fallen considerably a rational subject knows that B has a negative trend.

Asked about the trend, subjects seem to know that B was not a winning stock. Nevertheless, subjects bought a large number of B shares in the last periods of the experiment. Similar behavior was also found in Kroll et al. (1988b) where subjects wanted to see the past behavior of a known normal distribution, which was used to generate *independent* price changes. The idea that subjects try to outguess a random device could also explain why they trade more than they should according to the theory.

In future research it will be interesting to separate the disposition effect and mean-reversion explanations more carefully. It is possible that *both* phenomena existed in our experiments. As an explanation of why people do not adjust their reference points a more careful study of the sunk cost fallacy (Thaler (1980)) seems worthwhile. Since we found disposition effects for two different assumptions about reference points, the initial purchase price and the previous stock price, we need to know more about how reference points adapt over time and how multiple reference points are balanced. The relation of our results to phenomena in natural settings, like the overreaction research in behavioral finance (De Bondt and Thaler (1989)) should also be investigated.

Another natural direction for further research is to study whether the disposition effects are present in experiments in which the subjects set prices endogenously. For example, in the bubble experiments conducted by Smith et al. (1988) prices rise and fall substantially so there is an opportunity to observe both winners and losers. Volume is usually high during the runup, and thin on the crashes (which take place swiftly). Disposition effects may help explain these facts. For example, high runup volume occurs because subjects eagerly sell winners during the period of rising prices. As prices fall, a small 'shelf' of offers often appears, far above the bottom-fishing bids, as sellers post hopeful offers to sell at breakeven prices (see e.g., Smith et al. Fig. 3). The offer shelf is like a fragile cornice of snow on a mountaintop, which defies gravity but hence, is fragile and collapses at the slightest pressure. Similarly, the shelf of break-even offers defies reality, and hence is easily shattered when a single trade takes place at a much lower price. Then offers drop quickly and the price crash occurs, sharply, on thin volume. Searching for disposition effects in the detailed dynamics of these markets – especially 'sealed offer-bid' markets in which each trader posts a bid or offer, so every trader's 'reservation price' can be measured each period – should prove very interesting[6].

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References

Andreassen, P.A., 1988. Explaining the price-volume relationship: the difference between price changes and changing prices, Organizational Behavior and Human Decision Process 41, 371–389.

Bowman, D., Minehart, D., Rabin. M., 1997. Loss-aversion in a consumption-savings model, University of California, Berkeley working paper, 1997.

Camerer, C., Weigelt, K., 1992. Information mirages in experimental asset markets, Journal of Business 64, 463–493.

Camerer, C., Weigelt, K., 1993. Convergence in experimental double auctions for stochastically lived assets, in Friedman, D., Rust, J. (Eds.), The double auction market: theories, institutions, and experimental evaluations, Addison-Wesley, pp. 355–396.

[6] Mark van Boening supplied us with such sealed offer-bid data from experiments run by Smith et al, but we have not carefully analysed them.

Copeland, T.E., Friedman, D., 1987. The effect of sequential information arrival on asset prices: an experimental study, Journal of Finance 42, 763–797.

Copeland, T.E., Friedman, D., 1991. Partial revelation of information in experimental asset markets, Journal of Finance 42, 265–295.

De Bondt, W., Thaler, R.H., 1989. Anomalies: a mean-reverting walk down Wall Street, Journal of Economic Perspectives 3, 189–202.

Ferris, S.P., Haugen, R.A., Makhija, A.K., 1988. Predicting contemporary volume with historic volume at differential price levels: evidence supporting the disposition effect, Journal of Finance 43, 677–697.

Gerke, W., Bienert, H., 1993. Uberprufung des Dispositionseffektes und seiner Auswirkungen in computerisierten Borsenexperimenten, Zietschrift fur betriebswirtschaftliche Forschung, Sonderheft 31, 169–194.

Hershey, J.C., Schoemaker, P.J.H., 1980. Prospect theory's reflection hypothesis: a critical examination, Organizational Behavior and Human Performance 25, 395–418.

Hogarth, R.M., Einhorn, H.J., 1990. Venture theory: a model of decision weights, Management Science 36, 780–803.

Kahneman, D., Knetsch, J., Thaler, R.H., 1990. Experimental tests of the endowment effect and the coase theorem, Journal of Political Economy 98, 1325–1348.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk, Econometrica 47, 263–291.

Karpoff, J.M., 1987. The relation between price changes and trading volume: a survey, Journal of Financial and Quantitative Analysis 22, 109–126.

Kroll, Y., Levy, H., 1992. Further tests of the separation theorem and the capital asset pricing model, American Economic Review 82, 664–670.

Kroll, Y., Levy, H., Rapoport, A., 1988a. Experimental tests of mean-variance model for portfolio selection, Organizational Behavior and Human Decision Processes 42, 388–410.

Kroll, Y., Levy, H., Rapoport, A., 1988b. Experimental tests of the separation theorem and the capital asset pricing model, American Economic Review 78, 500–519.

Maital, S., Filer, R., Simon, J., 1986. What do people bring to the stock market (besides money)?, Handbook of Behavioral Economics, 273–307.

Markowitz, H., 1959. Portfolio selection, Wiley, New York.

O'Brien, J., Srivastava, S., 1991. Dynamic stock markets with multiple assets: an experimental analysis, Journal of Finance 46, 34–39.

O' Dean, T., (in press) Are investors reluctant to realize their losses? Journal of Finance.

Oehler, A., 1994. Verhaltensmuster individueller Anleger-eine experientelle Studie, Zietschrift fur betriebswirtschaftliche Forschung 46, 939–958.

Rapoport, A., Zwick, F., Funk, S.G., 1988a. Selection of portfolios with risky and riskless assets: experimental tests of two expected utility models, Journal of Economic Psychology 9, 169–194.

Rapoport, A., Zwick, F., Funk, S.G., 1988b. Investment portfolios in multistage gambling with different saving rates, Working Paper, University of North Carolina, Chapel Hill, NC.

Sarin, R.K., Weber, M., 1993. The effect of ambiguity in market experiments, Management Science. 39, 602–615.

Shefrin, H.M., Statman, M., 1985. The disposition to sell winners too early and ride losers too long, Journal of Finance 40, 777–790.

Shiller, R.J., Case, K.E., 1988. The behavior of home buyers in boom and post-boom markets, New England Economic Review, 29–46.

Smith, V.L., Suchanek, G.L., Williams, A.W., 1988. Bubbles, crashes and endogeneous expectations in experimental spot asset markets, Econometrica 56, 1119–1151.

Thaler, R.H., 1980. Toward a positive theory of consumer choice, Journal of Economic Behavior and Organization 1, 39–60.

Thaler, R.H., 1985. Mental accounting and consumer choice, Marketing Science 4, 199–214.

Thaler, R.H., Johnson, E.J., 1990. Gambling with the house money and trying to break even: effects of prior outcomes on risky choice, Management Science 36, 643–660.

Tversky, A, Kahneman, D., 1992. Advances in prospect theory: cumulative representation of uncertainty, Journal of Risk and Uncertainty 5, 297–323.

van der Pligt, J., van Schie, E.C.M., 1990. Frames of reference, judgment and preference, European Review of Social Psychology, In: Stroebe, W., Hewstone, M. (Eds.), Wiley, New York, 61–80.

Weber, M., Camerer, C., 1992. Ein Experiment zum Anlegerverhalten, Zeitschrift fur Betriebswirtschaftsliche Forschunq 44, 131–148.

Weber, M., Loomes, G., Keppe H.-J., Meyer-Delius, G., 1997. Framing effects in experimental markets, working paper 94-09, Lehrstuhle fur Finanzwirtschaft, Universitat Mannheim, Mannheim, Germany.