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Disposed to Be Overconfident

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ABSTRACT

In this paper we show that the disposition effect, a well documented pattern in investor behavior, can be a source of investor overconfidence. We identify a biased learning process through which the disposition effect leads to investor overconfidence. Our experimental results show that investors update beliefs about their own investment ability based on realized gains and losses rather than the overall performance of their portfolio. We formalize this learning process in a theoretical model in which the disposition effect leads to overconfidence, excessive trading, and lower investment performance.

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I. Introduction

Most investors tend to sell winners and hold onto losers (Shefrin and Statman, 1985; Odean, 1998a; Frazzini, 2006). This tendency is called the disposition effect and has been documented for investors across different countries and for a variety of asset classes.[1] Many investors are overconfident. They systematically believe that their own investment abilities are better than they actually are. In theoretical settings, experimental markets, and actual markets, overconfident investors trade more than is in their own best interest and contribute to price volatility (Odean, 1998b; Deaves, Lüders, and Luo, 2009; Barber and Odean, 2001). Although both the disposition effect and overconfidence are well-documented facts about investor behavior, the interaction between the two remains largely unexplored.

In this paper, we propose that the disposition effect can create, or increase, investor overconfidence. The intuition is as follows. Investors vary in ability and often assess their abilities by observing their investment outcomes. While an econometrician might assess an investor's ability by regressing the investor's portfolio returns on a set of factors, we hypothesize that many real-world investors learn about their own abilities simply by counting how many of their investments were successes and how many were failures. We further hypothesize that investors focus more on realized gains and losses rather than paper (i.e., unrealized) gains and losses when counting successes and failures. Investors exhibiting the disposition effect will realize many of their gains and hold onto losing positions. This will upwardly bias the proportion of positions sold for a gain and thus lead investors to overestimate their abilities. We support our proposal with a laboratory experiment and a theoretical model.

The main contribution of our paper is to show that a the disposition effect, a well documented investor behavior, can be a source of investor overconfidence. We identify a biased learning process through which the disposition effect influences investor confidence. We provide experimental evidence that investors update beliefs about their own investment ability based on realized gains and losses rather than the overall performance of their portfolio. We formalize this process in a theoretical model in which the disposition effect leads to overconfidence, excessive trading, and lower investment performance.

We conduct a laboratory experiment in which subjects participate in an investment task. At the beginning of the first investment period, subjects choose an initial portfolio of five stocks from a group of twenty. Before making their choices, subjects observe the three previous price changes for the twenty stocks. There are two types of stocks, a high type and a low type which differ in the probability of a price increase or decrease each period. Subjects do not directly observe stock types; they only see previous price changes. At the beginning

[1] The disposition effect has been found in the United States, Israel, Finland, China, and Sweden by Odean (1998a), Shapira and Venezia (2001), Grinblatt and Keloharju (2001), Feng and Seasholes (2005), and Calvet, Campbell, and Sodini (2009). It is also documented for the real estate market and the option market by Genesove and Mayer (2001) and Heath, Huddart, and Lang (1999).

of each subsequent investment period, subjects sell one stock from their portfolio and purchase one stock from a new group of four stocks for which they observe the three previous price changes. The experiment ends at the end of five investment periods.

We test for the effect of gain or loss realizations on subjects' beliefs about their ability to choose stocks. To do so, we exogenously manipulate whether subjects sell for a gain or loss. Specifically, we impose two conditions. In the *Selling Gains* condition, a winning stock—a stock whose current price is above its purchase price—is randomly selected and sold. In the *Selling Losses* condition, a losing stock is randomly selected and sold.[2] We randomly assign subjects to one of these two conditions. For stocks in their portfolio, subjects observe both realized gains and losses as well as paper gains and losses. At the end of the final period, we measure subjects' self-reported confidence in their ability to select the high-type stocks.

The experiment has four main findings. First, at the end of the investment task, subjects in the *Selling Gains* condition are more confident in their ability to select high-type stocks compared to those in the *Selling Losses* condition, although stock picking success and portfolio performance do not vary across the two conditions. Second, our treatments affect subjects' beliefs about the number of high-type stocks they have selected during the investment task: subjects in the *Selling Gains* condition believe they have selected a significantly greater number of high-type stocks than do subjects in the *Selling Losses* condition. Third, subjects follow a biased learning process: their beliefs about their investment ability depend up their realized gains and losses but not upon their portfolio performance. Fourth, gain realizations lead to overconfidence. Controlling for actual performance on the investment task (and for gender), subjects in the *Selling Gains* condition are significantly more confident than those in the *Selling Losses* condition that they will perform well on a future investment task. Furthermore, subjects in the *Selling Gains* condition believe that they have selected significantly more high-type stocks than they actually did.

To formalize the implications of investors' biased learning process, we develop a theoretical model. In line with our experimental results, the model makes the critical assumption that investors form their beliefs about their investment ability by counting the number of gains and losses they have realized. The model considers two types of investors: a high ability investor whose actual ability to choose stocks is high, and a low ability. Investors vary in their disposition effect. The model produces three implications. First, investor overconfidence increases with their disposition effect: investors who are more likely to realize gains than losses overestimate their abilities to choose stocks. This result is consistent with the findings from our experiment. Second, the dynamics of investor overconfidence depend strongly on the investor's type. Low-ability investors who exhibit a disposition effect tend to become more overconfident, that is their subjective

[2] If the portfolio has no winning stocks in the *Selling Gains* condition or has no losing stocks in the *Selling Losses* condition, then an arbitrary stock is randomly selected and sold.

expectation about their ability increases over time, though the rational expectation about their ability decreases. Third, investor overconfidence, generated by the disposition effect, gives rises to both excessive trading and low trading profits.

Most studies in financial economics treat investor overconfidence as a *static* personal trait; they do not examine the processes through which investors become more—or less—overconfident.[3] One exception is the theory of Gervais and Odean (2001), who argue that overconfidence can arise from self-attribution bias, the notion that people tend to ascribe their success in some activity to their own ability while attributing failure to bad luck.[4] Our paper differs from Gervais and Odean (2001) in three important ways. First, Gervais and Odean (2001) assume that investors form biased beliefs about their investment ability by over-weighting their past successes in predicting stock specific news (dividend changes). In contrast, our paper proposes a distinct learning process in which investors assess their ability by counting the number of realized gains and losses. Second, Gervais and Odean (2001) analyze the interaction between self-attribution bias and overconfidence, whereas our paper focuses on how the disposition effect—which does not directly relate to self-attribution bias—gives rise to investor overconfidence. Third, while both papers develop theoretical models, our paper also provides strong experimental evidence supporting biased learning process we propose.

We study the link between two common investor biases: the disposition effect and overconfidence. Although many behavioral finance work focuses on a single bias, biases can interact in ways that magnify or offset their influence on behavior (Barberis and Thaler, 2003; Benjamin, 2019; Liao, Peng, and Zhu, 2021). We document a clear causal effect of one bias (the disposition effect) on another (overconfidence). Thus we indirectly link the disposition effect with excessive trading, a behavior that detracts from investor welfare.

We also contribute to a recent literature on how prior choices affect investor beliefs. Kuhnen, Rudorf, and Weber (2017) provide experimental evidence that people's expectations about asset values are biased by whether their prior choices seem right ex-post: disconfirming information tends to be neglected. Hartzmark, Hirshman, and Imas (2021) show that ownership of a good affects learning and beliefs about the good's quality; in particular, ownership causes people to form more optimistic beliefs after receiving a positive signal about the good and more pessimistic beliefs after receiving a negative signal. Our paper complements this line of research by showing that investors' prior gain and loss realizations directly affect their beliefs about their investment ability.

More broadly, our paper adds to a literature that examines how past experienced outcomes affect sub-

[3] In a broader economic literature on motivated beliefs, several papers argue that people derive utility from overconfidence and other self-serving beliefs (Bénabou and Tirole, 2002; Köszegi, 2006; Brunnermeier and Parker, 2005). Consistent with these studies, recent experimental work provides evidence that people form optimistic beliefs from ego-relevant information on intelligence (Zimmermann, 2020), beauty (Eil and Rao, 2011), and generosity (Saucet and Villeval, 2019; Di Tella, Perez-Truglia, Babino, and Sigman (2015); Carlson, Maréchal, Oud, Fehr, and Crockett, 2020).

[4] Barberis and Thaler (2003) conjecture that overconfidence may also arise from hindsight bias, but they do not provide tests of this conjecture.

sequent investment decisions and risk taking behavior (Thaler and Johnson, 1990; Weber and Camerer, 1998; Kaustia and Knüpfer, 2008; Choi, Laibson, Madrian, and Metrick, 2009; Strahilevitz, Odean, and Barber, 2011; Malmendier and Nagel, 2011; Campbell, Ramadorai, and Ranish, 2014; Imas, 2016). One limitation of this literature is that it often does not clearly identify whether past experiences affect future behavior through a beliefs or preferences channel. In contrast, our experimental results provide direct evidence that past outcomes lead to biased beliefs about future investments.

The paper proceeds as follows. Section II describes the experimental design and discusses our main findings. Section III presents a theory and analyzes its implications. Section IV concludes. Additional details of the experimental instructions are in the Appendix.

II. The Experiment

A. *Experimental Design*

To investigate how gain and loss realizations affect an investor's beliefs about her ability to select stocks, we adopt an experimental set-up with (i) a decision that generates investment outcomes, (ii) exogenous variation in realized investment outcomes (gains and losses), (iii) an environment that facilitates learning about own ability, and (iv) a direct elicitation of beliefs about own ability. In this section, we outline these features in more detail. The experiment instructions are provided in Appendix A.

In our experiment, subjects make investment decisions. They invest in risky stocks for five periods. In each period t, subjects select the stock(s) to invest in from a set of risky stocks. Subjects know the return generating process of the stocks. The purchase price of each stock is the same ($30). Each period, the stock price increases or decreases.

There are two types of stocks, an ordinary type and a high type. These two stock types differ in the probability that their price increases or decreases. An ordinary-type stock has a 40% probability of a price increase and a 60% probability of a price decrease. A high-type stock has a 60% probability of a price increase and a 40% probability of a price decrease. The price change is drawn from {–3, –1, 2, 6}. In particular, if the price increases, the price change is $2 or $6, with equal probability. If the price decreases, the price change is –$1 or –$3, with equal probability. Subjects are not told which stock is of which type. However, before each choice, subjects view three recent outcomes of each of the stocks they can select from.

Subjects begin with an endowment of $180 and must buy a portfolio of 5 stocks from a list of 20 available stocks. The list contains exactly 15 ordinary-type stocks and 5 high-type stocks. After the initial portfolio selection, the investment periods (1-5) begin. In each period, subjects (i) observe the period price change for each of the stocks in their portfolio. After the new prices are displayed, (ii) one of the stocks is automatically sold by the computer program at the stock's current price. Subjects accumulate earnings from sales from period to period. After the sale of one stock, (iii) subjects must buy an additional stock from a new list of four stocks. Each time, the new list contains exactly 3 ordinary-type stocks and 1 high-type stock.

We follow convention in randomly generating the price paths at the beginning of the experiment for both treatments (Fischbacher, Hoffmann, and Schudy, 2017). This facilitates between-subject analyses since it reduces noise in response data that stems from different price paths across treatments. We draw seven sets of price paths.[5]

We endogenously manipulate whether the computer sells winning stocks or losing stocks from subjects' portfolios. We have two between-subjects conditions. Subjects are randomly assigned to one of the two conditions. In *Selling Gains*, each period, a winning stock is liquidated if the portfolio contains at least one winning stock and otherwise a random stock is liquidated. In *Selling Losses*, each period, a losing stock is liquidated if the portfolio contains at least one losing and otherwise a random stock is liquidated. Note that a winning stock is a stock with its current price higher than the initial purchase price of $30, and a losing stock is a stock with its current price lower than the initial purchase price of $30.

Our main outcome variable is subjects' confidence. We adapt the confidence measure used by Zimmermann (2020) and elicit subjects' beliefs about their ability to invest in a forward-looking manner. We tell each subject to imagine that they are going to participate in another trial of the investment task and we will compare their performance to the performance of 9 other randomly selected people who were invited to participate in this study. We then measure subjects' beliefs about their anticipated rank in this group. Specifically, we asked subjects to indicate the likelihood that they would be ranked in the upper half of that group.

In addition, we elicit subjects' beliefs about how many high-type stocks they selected during the investment task. This measure helps us to shed light on whether our treatments lead people to believe that they selected more or less high-type stocks than they actually did and whether this is a possible mechanism leading to overconfidence about their own investment ability.

In this setting, a price decrease is a negative signal about the selected stock's quality while a price increase is a positive signal for a Bayesian agent. Importantly, across both treatments a Bayesian agent learns from all price increases and decreases – paper gains and losses as well – irrespective of whether a stock sale realized a gain or a loss at a specific point in time.

[5] That is, we draw seven price sets of 72 stocks each (each of the two task trials includes 36 available stocks).

B. *Procedure, Incentives, and Sample*

The experiment was conducted online with US residents of the Prolific subject pool in May 2021.[6] It was organized into two parts. The first part consisted of the investment task. In both treatments, subjects had to participate in two trials of the investment task. Their payoff depended on their choices and on the randomly generated price changes for stocks in their portfolio in one of the two task trials. In particular, each period subjects accumulated the proceeds from stock sales in their cash holdings and paid the cost of stocks purchased. Their potential payoff for each trial was 1/100 of their final holdings at the end of the task trial; that is, the sum of final cash holdings and the value (i.e., the current prices) of the stocks in the final portfolio after period 5. Thus, payment to subjects was based on both realized and unrealized gains and losses. Part 2 of the experiment consisted of the belief elicitation, which was not incentivized. At the end of the experiment, one of the two task trials was randomly selected for payment. In addition, subjects received a fixed participation fee of $1.

We designed comprehension questions to test subjects' understanding of the experimental instructions. Subjects had to answer five comprehension questions after reading the instructions and before participating in the first part of the experiment. We excluded subjects from the experiment who gave an incorrect answer to more than one comprehension question.

A total of 301 subjects participated in the experiment, 139 subjects in treatment *Selling Gains* and 162 in treatment *Selling Losses*. Participating in the experiment took on average 12 minutes and 42 seconds. The experiment was programmed and conducted with oTree (Chen, Schonger, and Wickens, 2016). This study was pre-registered at AsPredicted under ID 66925. Table I reports descriptive statistics. Our sample consists of 167 female (55% of the sample) and 134 male (45% of the sample) subjects. On average, subjects were 33 years old (min. 18 years and max. 70 years). As intended, subjects' number of realized gains differed significantly between our two conditions (T-test, $p = 0.000$). In the *Selling Gains* treatment, subjects realized on average 7.74 gains, whereas subjects in the *Selling Losses* treatment realized on average 0.98 gains. Subjects' profit from the investment task was similar across treatments (T-test, $p = 0.957$) and subjects selected on average a similar number of high-type stocks across treatments, namely 5.80 in the *Selling Gains* and 5.76 in the *Selling Losses* treatment (T-test, $p = 0.873$). The average payment was $2.98, which translates to $14 per hour.

[6] The experiment and its procedure were approved under ethical approval code ERCIC_212_28_09_2020 by the Ethical Review Committee Inner City Faculties (ERCIC) of Maastricht University. We obtained subjects' informed consent before they participated in the experiment.

Table I. Descriptive statistics.

	Full sample (N = 301)			*Selling Gains* (N = 139)			*Selling Losses* (N = 162)		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Female	0.55	1.00	0.50	0.53	1.00	0.50	0.58	1.00	0.50
Age (in years)	33.10	31.00	11.55	32.83	30.00	11.56	33.34	31.00	11.57
Total number of realized gains	4.10	3.00	3.48	7.74	8.00	0.50	0.98	1.00	1.03
Average portfolio performance (profit in $)	17.97	18.00	11.34	17.92	17.00	10.82	18.01	18.50	11.81
Total number of high-type stocks selected	5.78	6.00	2.12	5.80	6.00	2.11	5.76	6.00	2.13
Subject payment (in $)	2.98	2.97	0.18	2.98	2.97	0.19	2.98	2.98	0.17

C. Results

The results from our experiment provide evidence for a biased learning process in which subjects become overconfident about their ability to invest.

Result 1. *Subjects report significantly higher confidence in their own ability to invest if more gains were realized than if more losses were realized.*

The key outcome measure for our subsequent analysis is subjects' forward-looking belief about their group rank based on investment performance. Subjects' reported the likelihood that they would be ranked in the upper half of a group of 10 subjects if they were to participate in another investment trial. Subjects had to provide their answer as a percentage, and every integer between 0 and 100 was admissible.

Figure 1 shows subjects' average beliefs for the two treatments. The figure confirms the basic pattern we hypothesized. On average, subjects in the *Selling Gains* treatment report significantly higher confidence in their investment ability than subjects in the *Selling Losses* treatment (T-test, $p = 0.000$). Subjects for whom mainly gains were realized, indicate a mean belief of 59.27%, whereas subjects for whom mainly losses were realized, indicate a mean belief of 47.40%.

This finding is confirmed in a regression analysis. Table II provides coefficients from linear estimates of subjects' beliefs. Column 1 documents the treatment effect. The coefficient of the treatment dummy is significantly positive. Subjects' average beliefs are 11.87% higher in the *Selling Gains* treatment compared

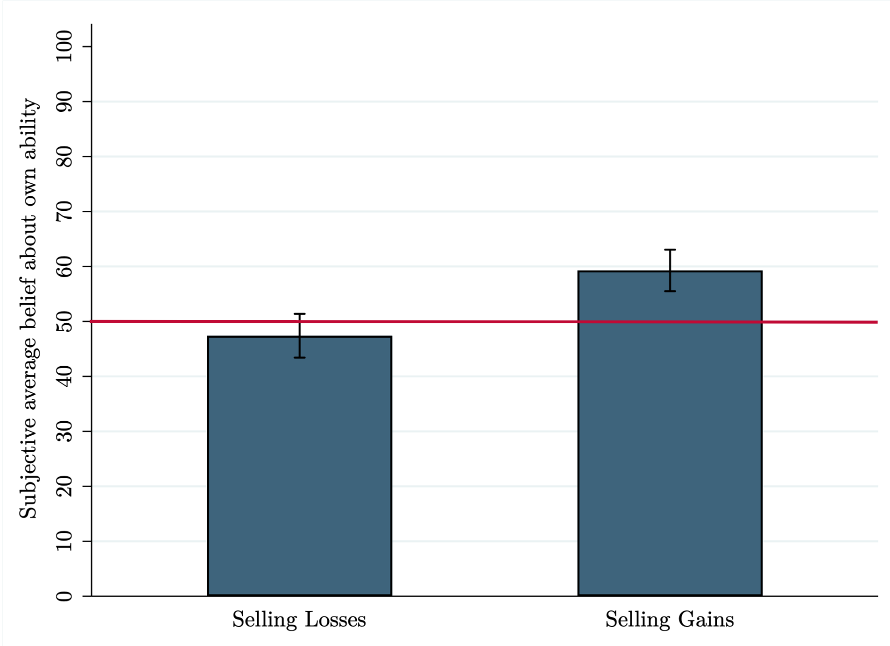

Figure 1. Average subjective beliefs about own ability. This figure displays mean values of subjects' belief about own ability measured by subjects' elicited likelihood in percent of being ranked in the upper half of a group of 10 participants based on performance in the task (from 0% to 100%). The bars represent the mean values by treatment. Error bars indicate 95% confidence intervals. The red reference line represents the average belief if all subjects report an accurate belief about their own ability relative to others in the group (50%).

to the *Selling Losses* treatment. Note that in the *Selling Gains* treatment, subjects sold on average 7.74 stocks for a gain, whereas subjects in the *Selling Losses* treatment sold on average 0.96 stocks for a gain. However, the number of gains a subject actually realized varies within treatment. Column 2 reports the result of a regression analysis with the actual number of gains a subject has realized as explanatory variable. The coefficient is significantly positive, confirming the finding from column 1.

Result 2. *The observed confidence patterns are related to subjects' beliefs about how many high-type stocks they have selected.*

In total, subjects selected 18 stocks during the two trials of the investment task. We let them report their belief about how many high-type stocks they selected during the investment task. The measure ranges from 0 to 18.

To begin, subjects' confidence in own ability is positively correlated with their reports of how many high-type stocks they believe they have selected. Column 4 of Table II shows a significantly positive association between the two variables. Subjects' confidence increases by 2.7 percentage points for each additional high-type stock that they believe they have selected.

Further, we investigate whether our treatment leads people to believe that they have selected more or

Table II. Subjective beliefs about own ability. This table contains the coefficient and robust standard error (in parentheses) of OLS regression. The dependent variable is the subjective likelihood in percent of being ranked in the upper half of a group of 10 participants based on performance in the task (from 0% to 100%). *Treatment* is a dummy variable representing our treatment with 1 = Selling Gains and 0 = Selling Losses. *Realized Gains* is the number of gains a subject has realized during the task. *Portfolio Performance* is subjects' average portfolio performance of both investment trials, including paper gains and losses and the cash position and excluding initial endowment. *Belief High Types Selected* is subjects' reported number of high-type stocks selected (from 0 to 18). *, **, and *** denote significance at the 10%, the 5%, and the 1% level, respectively.

	(1) Belief Ability	(2) Belief Ability	(3) Belief Ability	(4) Belief Ability
Treatment	11.872***		11.889***	
	(2.79)		(2.79)	
Realized Gains		1.671***		
		(0.40)		
Portfolio Performance			0.194	
			(0.13)	
Belief High Types Selected				2.710***
				(0.33)
Constant	47.401***	46.035***	43.904***	33.084***
	(2.02)	(2.31)	(3.12)	(2.81)
N	301	301	301	301
R^2	0.06	0.05	0.06	0.18

less high-type stocks. Table III provides coefficients from linear estimates of subjects' report of how many high-type stocks they believe they have selected during the investment task. We find that subjects believe that they have selected significantly more high-type stocks if more gains were realized than if more losses were realized. The coefficient of the treatment dummy in column 1 is significantly positive. Subjects for whom mainly gains were realized believe they have selected on average 7.82 high-type stocks, whereas subjects for whom mainly losses were realized believe they have selected on average 6.86 high-type stocks.

Moreover, column 2 of Table III provides coefficients from linear estimates of subjects' beliefs with the treatment dummy as well as their past average portfolio performance as explanatory variables. Similar to subjects' confidence, we find that subjects form beliefs about how many high-type stocks they have selected based on realized gains and losses rather than overall portfolio performance. The coefficient of the treatment dummy is significantly positive, however, subjects' portfolio performance has no significant association with subjects' beliefs about selected high-type stocks selected.

Result 3. *Subjects form beliefs about their own ability to invest based on realized gains and losses rather than overall portfolio performance.*

We further analyze whether subjects' actual past performance in the two investment trials is related to subsequent belief reports and how it compares to our treatment effect. Subjects' past portfolio performance

Table III. Subjective beliefs about about selected high-type stocks. This table contains the coefficient and robust standard error (in parentheses) of OLS regression. The dependent variable is subjects' reported number of high-type stocks selected (from 0 to 18). *Treatment* is a dummy variable representing our treatment with 1 = Selling Gains and 0 = Selling Losses. *Portfolio Performance* is subjects' average portfolio performance of both investment trials, including paper gains and losses and the cash position and excluding initial endowment. *, **, and *** denote significance at the 10%, the 5%, and the 1% level, respectively.

	(1) Belief High Types Selected	(2) Belief High Types Selected
Treatment	0.956^{**}	0.958^{**}
	(0.45)	(0.45)
Portfolio Performance		0.029
		(0.02)
Constant	6.864^{***}	6.348^{***}
	(0.31)	(0.48)
N	301	301
R^2	0.01	0.02

includes paper gains and losses and the cash position at the end of the investment trials from realized gains and losses. We take the average portfolio performance across both investment trials.

Column 3 of Table II provides coefficients from linear estimates of subjects' beliefs with the treatment dummy as well as their past average portfolio performance as explanatory variables. The results show that subjects in our experiment form their beliefs about own investment ability based on realized gains and losses and not based on overall portfolio performance, including paper gains and losses. The coefficient of the treatment dummy is significantly positive, however, subjects' portfolio performance with the added position of paper gains and losses has no significant association with subjects' beliefs about own ability.

Result 4. *Realizing more gains leads to overconfidence.*

Besides providing evidence for a treatment effect on subjects' confidence, the experimental results document significant overconfidence in the *Selling Gains* treatment. In Figure 1, the red reference line represents the average belief if all subjects reported an accurate belief about their own ability relative to others in the group (50%). Yet, subjects' average belief is larger than 50% in the *Selling Gains* treatment. The figure illustrates that subjects for whom mainly gains were realized significantly overestimate their ability relative to the others. T-test statistics confirm that subjects' mean belief is significantly different from and larger than 50% (T-test, $p = 0.000$).

In addition, we compare subjects' individual belief about how many high-type stocks they selected during the investment task to the number of high-type stocks they actually selected. We find that subjects believe they have selected significantly more high-type stocks than they actually did if more gains were realized.

Specifically, the number of high-type stocks subjects in the *Selling Gains* believe they have selected is on average 2.02 higher than the actual number of high-type stocks they have selected (T-test, $p = 0.000$).

D. Robustness of Results

It has been documented that while both men and women tend to exhibit overconfidence in many domains, men are generally more overconfident than women (Taylor and Brown, 1988; Lundeberg, Fox, and Punćcohaŕ, 1994). Especially in areas that are perceived as masculine, such as finance, men claim more ability than women (Beyer and Bowden, 1997; Prince, 1993). Our experimental data is in line with this established pattern. In our sample, men's reported confidence in their ability to invest is on average 8.79 percentage points higher than women's confidence (T-test, $p = 0.002$). Yet, our treatment effect is robust to differences in gender. Figure 2 illustrates subjects' average beliefs for the two treatments by gender. For both genders, subjects' average belief is significantly higher in the *Selling Gains* treatment than in the *Selling Losses* treatment.

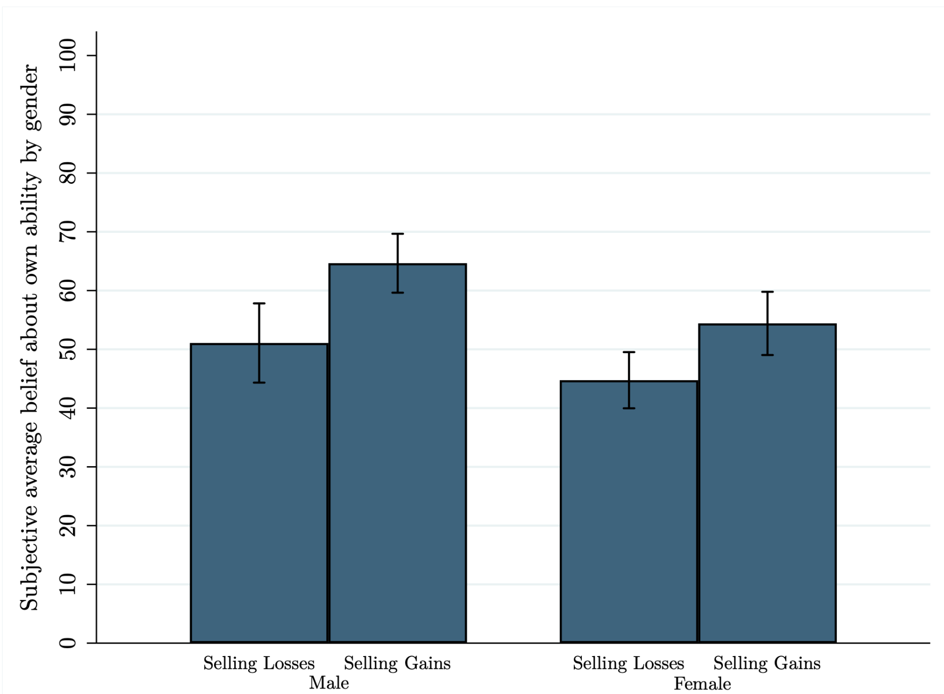

Figure 2. Average subjective beliefs about own ability by gender. This figure displays mean values of subjects' belief about own ability measured by subjects' elicited likelihood in percent of being ranked in the upper half of a group of 10 participants based on performance in the task (from 0% to 100%). The bars represent the mean values by treatment and gender. Error bars indicate 95% confidence intervals.

Table IV presents results from linear regressions. The table provides coefficients from estimates of subjects' beliefs about their ability across gender. The first two columns present our documented treatment

Table IV. Subjective beliefs about about own ability by gender. This table contains the coefficient and robust standard error (in parentheses) of OLS regression. The dependent variable is the subjective likelihood in percent of being ranked in the upper half of a group of 10 participants based on performance in the task (from 0% to 100%). *Treatment* is a dummy variable representing our treatment with 1 = Selling Gains and 0 = Selling Losses. *Portfolio Performance* is subjects' average portfolio performance of both investment trials, including paper gains and losses and the cash position and excluding initial endowment. *Female* is a dummy variable representing subject's gender with 1 = Female and 0 = Male. *, **, and *** denote significance at the 10%, the 5%, and the 1% level, respectively.

	(1) Belief Ability	(2) Belief Ability	(3) Belief Ability (male subjects)	(4) Belief Ability (female subjects)
Treatment	11.889***	11.455***	13.937***	8.965**
	(2.79)	(2.78)	(4.35)	(3.68)
Portfolio Performance	0.194	0.165	0.101	0.274
	(0.13)	(0.13)	(0.18)	(0.18)
Female		-7.836***		
		(2.86)		
Constant	43.904***	48.981***	48.977***	40.364***
	(3.12)	(3.83)	(5.44)	(3.71)
N	301	301	134	167
R^2	0.06	0.09	0.07	0.05

effect from Table II while controlling for actual portfolio performance (column 1) as well as both portfolio performance and gender (column 2). Column 3 documents the treatment effect restricting the sample to male subjects and column 4 provides evidence for the treatment effect restricting the sample to female subjects. Both coefficients of the treatment dummy are significantly positive. Male subjects' average beliefs are 13.94% higher in the *Selling Gains* treatment compared to the *Selling Losses* treatment. Female subjects report on average beliefs that are 8.97% higher in the *Selling Gains* treatment compared to the *Selling Losses* treatment.

III. The Model

In this section, we present a simple model with two assumptions. First, investors assess their trading ability (which will be defined precisely later) by counting past realized gains and losses. Second, investors are subject to the disposition effect. We study the implications of such a model.

A. Model Setup

Asset space.—We consider a finite-horizon economy with N risky assets which we also refer to as stocks. Each asset has a liquidating dividend paid at the end of period T; denote the liquidating dividend for asset i as $D_{i,T}$. News about $D_{i,T}$ is sequentially released over time. The incremental news released at the end of period t about $D_{i,T}$ is denoted as $v_{i,t}$ and the cumulative news released by the end of period t about $D_{i,T}$ is denoted as $D_{i,t}$. We have

$$D_{i,t} = D_{i,0} + v_{i,1} + v_{i,2} + \cdots + v_{i,t}, \quad 1 \leq i \leq N \text{ and } 1 \leq t \leq T. \tag{1}$$

We further assume

$$\begin{gathered} v_{i,t} \sim \mathcal{N}(0, \sigma_i^2), \quad t \geq 1, \ \forall i, \\ \text{i.i.d. over time and independent across stocks.} \end{gathered} \tag{2}$$

Signal structure.—At the beginning of period t, a risky asset—asset i, say—is randomly selected from N risky assets. One type of market participant, an investor, is endowed with the following signal about asset i

$$\theta_{i,t} = \delta_{i,t} v_{i,t} + (1 - \delta_{i,t}) \varepsilon_{i,t}, \tag{3}$$

where $\varepsilon_{i,t}$ has an identical distribution as $v_{i,t}$ but is independent from it. The variable $\delta_{i,t}$ takes the values of one or zero, and the investor's ability for correctly anticipating the payoff of asset i is measured by the *probability* that $\delta_{i,t}$ takes the value of one. Denote this probability as a_i and refer to it as the investor's ability. We assume that there are two possible ability levels: $a_i = H$ and $a_i = L$, where $0 < L < H < 1$.

We assume that no market participant, including the investor, knows the investor's ability. Instead, market participants are endowed with the correct prior belief that $a_i = H$ with probability ϕ_0 and $a_i = L$ with probability $1 - \phi_0$, where $0 < \phi_0 < 1$. Moreover, we assume that the investor's ability for correctly anticipating the payoff of asset i also represents his ability for correctly anticipating the payoff of another asset; that is, ability is at the investor level, not at the asset level. As such, we abbreviate a_i as a. Finally, we assume $N \gg T$, so the probability that the investor obtains a signal for the same asset twice (over different time periods) is negligible.

Market participants.—There are three market participants: the investor mentioned above, a liquidity trader, and a market maker. We discuss them in order.

Although the investor has rational prior beliefs about his ability, he develops biased beliefs over time. We first describe the rational beliefs about the investor's ability. We then discuss how the investor's beliefs differ from the rational beliefs. As in Gervais and Odean (2001), let s_t denote the number of times that the investor's information about risky assets was real by the end of the first t periods: we write $s_t = \sum_{u=1}^{t} \delta_{i(u),u}$, where $i(u)$ denotes the asset with which the investor has a signal in period u; $\delta_{i(u),u}$ equals one if $\theta_{i(u),u} = v_{i(u),u}$;

and $\delta_{i(u),u}$ equals zero if $\theta_{i(u),u} \neq v_{i(u),u}$. Under rational beliefs, the probability that $a = H$, computed at the beginning of period t, is

$$\phi_{t-1}(s) \equiv \Pr(a = H | s_{t-1} = s) = \frac{H^s (1-H)^{t-1-s} \phi_0}{H^s (1-H)^{t-1-s} \phi_0 + L^s (1-L)^{t-1-s} (1-\phi_0)}. \tag{4}$$

Therefore, the rational expectation about the investor's ability, computed at the beginning of period t, is

$$\xi_{t-1}(s) \equiv \mathbb{E}(a | s_{t-1} = s) = \phi_{t-1}(s) \cdot H + (1 - \phi_{t-1}(s)) \cdot L. \tag{5}$$

The investor deviates from rational beliefs as follows. Rather than using s_t to assess his ability, the investor uses the number of times that stocks are sold at a gain, denoted by k_t, to assess his ability; later we will provide a precise definition of a stock-level gain or loss. Under these biased beliefs, the probability that $a = H$, computed at the beginning of period t, is

$$\psi_{t-1}(k) \equiv \Pr_b(a = H | k_{t-1} = k) = \frac{H^k (1-H)^{t-1-k} \phi_0}{H^k (1-H)^{t-1-k} \phi_0 + L^k (1-L)^{t-1-k} (1-\phi_0)}, \tag{6}$$

where the subscript "b" denotes biased beliefs. The investor's expectation about his ability is

$$\Xi_{t-1}(k) \equiv \mathbb{E}_b(a | k_{t-1} = k) = \psi_{t-1}(k) \cdot H + (1 - \psi_{t-1}(k)) \cdot L. \tag{7}$$

We now turn to the investor's buying and selling decisions. Selling decisions are exogenously specified. At any time $t < T$, the investor holds $M \ll N$ risky assets in his portfolio. Suppose that M_1 out of M stocks are held at a gain, and that the remaining $M - M_1$ stocks are held at a loss. With probability χ, the investor will randomly sell one of the M_1 stocks resulting in a gain realization; with the remaining probability $1 - \chi$, the investor will randomly sell one of the $M - M_1$ stocks resulting in a loss realization.[7] Intuitively, this probability χ measures the degree of the disposition effect that the investor is subject to. At time T, the investor sells all his stocks.

At the beginning of period $t < T$, once the investor sells a stock, he receives a signal $\theta_{i,t}$ about a new asset i; the signal structure is described above. Given this signal and the investor's belief about his ability (as characterized by k_{t-1}), the investor maximizes the expected profit of holding asset i over $x_{i,t}$, his share demand for asset i. We further describe this maximization problem in the next section. Each asset in the investor's portfolio may be held for multiple periods, however, the investor only receives a signal about an asset when he makes the initial buying decision. At the end of each period, the price of the asset is set to

[7] If M_1 equals zero or M, then the investor randomly sells one out of all M stocks.

its fair value, $D_{i,t}$.

The liquidity trader has a random demand for the asset that the investor buys; denote this demand at the beginning of period t as $z_{i,t}$. We suppose that $z_{i,t}$ is a Normal random variable: $z_{i,t} \sim \mathcal{N}(0, \sigma_{i,z}^2)$.

The market maker is risk-neutral and has rational beliefs. At the beginning of period t, he observes s_{t-1}, k_{t-1}, and $\omega_{i,t} = x_{i,t} + z_{i,t}$, which is the total demand from the investor and the liquidity trader for asset i. The market maker then sets a competitive price $p_{i,t}$ for asset i. Notice that, at the beginning of period t, the market maker does not observe the signal $\theta_{i,t}$.

B. *Model Solution*

We now describe the procedure for solving the model. First, at the beginning of period t, we conjecture the following linear equilibrium for asset i that is being traded:

$$\begin{aligned} p_{i,t}(\omega_{i,t}, s_{t-1}, k_{t-1}) &= D_{i,t-1} + \lambda_{i,t}(s_{t-1}, k_{t-1}) \cdot \omega_{i,t}, \\ x_{i,t}(\theta_{i,t}, s_{t-1}, k_{t-1}) &= \beta_{i,t}(s_{t-1}, k_{t-1}) \cdot \theta_{i,t}, \end{aligned} \tag{8}$$

where $p_{i,t}$ is the price for asset i, $x_{i,t}$ is the investor's demand for asset i, and $\omega_{i,t} = x_{i,t} + z_{i,t}$ is the total demand from the investor and the liquidity trader.

The investor maximizes, over $x_{i,t}$, his biased expectation of the end-of-period-t profit for holding asset i

$$\begin{aligned} \mathbb{E}_b[\pi_{i,t}|\theta_{i,t}, k_{t-1}, x_{i,t}] &= \mathbb{E}_b\left[x_{i,t} \cdot (D_{i,t} - p_{i,t}(\omega_{i,t}, s_{t-1}, k_{t-1}))|\theta_{i,t}, k_{t-1}, x_{i,t}\right] \\ &= x_{i,t} \cdot [D_{i,t-1} + \mathbb{E}_b[v_{i,t}|\theta_{i,t}, k_{t-1}] - \lambda_{i,t}(s_{t-1}, k_{t-1}) \cdot x_{i,t} - D_{i,t-1}]. \end{aligned} \tag{9}$$

As a result,

$$x_{i,t}(\theta_{i,t}, s_{t-1}, k_{t-1}) = \frac{\mathbb{E}_b[v_{i,t}|\theta_{i,t}, k_{t-1}]}{2\lambda_{i,t}(s_{t-1}, k_{t-1})} = \frac{\Xi_{t-1}(k_{t-1})}{2\lambda_{i,t}(s_{t-1}, k_{t-1})} \cdot \theta_{i,t} \equiv \beta_{i,t}(s_{t-1}, k_{t-1}) \cdot \theta_{i,t}. \tag{10}$$

Next, we turn to the market maker. At the beginning of period t, he sets the price for asset i as follows

$$\begin{aligned} p_{i,t} &= D_{i,t-1} + \mathbb{E}[v_{i,t}|\omega_{i,t}, s_{t-1}, k_{t-1}] = \mathbb{E}\left[\mathbb{E}[v_{i,t}|\omega_{i,t}, s_{t-1}, k_{t-1}, \delta_{i,t}]|\omega_{i,t}, s_{t-1}, k_{t-1}\right] \\ &= D_{i,t-1} + \mathbb{E}\left[\delta_{i,t} \cdot \mathbb{E}[v_{i,t}|\omega_{i,t} = \beta_{i,t}(s_{t-1}, k_{t-1}) \cdot v_{i,t} + z_{i,t}, s_{t-1}, k_{t-1}]|\omega_{i,t}, s_{t-1}, k_{t-1}\right]. \end{aligned} \tag{11}$$

Note that $v_{i,t}$ and $\omega_{i,t}$ are jointly Normal. As such, we obtain

$$\mathbb{E}[v_{i,t}|\omega_{i,t} = \beta_{i,t}(s_{t-1}, k_{t-1}) \cdot v_{i,t} + z_{i,t}, s_{t-1}, k_{t-1}] = \frac{\beta_{i,t}(s_{t-1}, k_{t-1})\sigma_i^2}{\beta_{i,t}^2(s_{t-1}, k_{t-1})\sigma_i^2 + \sigma_{i,z}^2}\omega_{i,t}. \tag{12}$$

Substituting (12) into (11) gives

$$p_{i,t} = D_{i,t-1} + \frac{\xi_{t-1}(s_{t-1}) \cdot \beta_{i,t}(s_{t-1}, k_{t-1})\sigma_i^2}{\beta_{i,t}^2(s_{t-1}, k_{t-1})\sigma_i^2 + \sigma_{i,z}^2}\omega_{i,t} \equiv D_{i,t-1} + \lambda_{i,t}(s_{t-1}, k_{t-1}) \cdot \omega_{i,t}. \tag{13}$$

Equations (10) and (13) together imply

$$\begin{aligned} \beta_{i,t}(s_{t-1}, k_{t-1}) &\equiv \sqrt{\frac{\sigma_{i,z}^2}{\sigma_i^2} \cdot \frac{\Xi_{t-1}(k_{t-1})}{2\xi_{t-1}(s_{t-1}) - \Xi_{t-1}(k_{t-1})}}, \\ \lambda_{i,t}(s_{t-1}, k_{t-1}) &\equiv \frac{1}{2}\sqrt{\frac{\sigma_i^2}{\sigma_{i,z}^2} \cdot \Xi_{t-1}(k_{t-1}) \cdot [2\xi_{t-1}(s_{t-1}) - \Xi_{t-1}(k_{t-1})]}\,. \end{aligned} \tag{14}$$

Equation (14) makes it clear that the existence of equilibrium requires

$$2\xi_{t-1}(s_{t-1}) > \Xi_{t-1}(k_{t-1}). \tag{15}$$

And it is easy to show that

$$2L \geq H \tag{16}$$

is *sufficient* to guarantee (15) and hence the existence of equilibrium.

Finally, we formally define the gain or loss of asset i. When the asset is first purchased, its price is set according to (13). For subsequent periods, the market maker sets the beginning-of-period-t price for asset i as

$$p_{i,t} = D_{i,t-1}. \tag{17}$$

Denote t_0 as the period when the investor purchases asset i. At the beginning of a subsequent period t, $t > t_0$, asset i's gain or loss is defined as follows. If $x_{i,t_0} \geq 0$,

$$\begin{aligned} g_{i,t} &\equiv D_{i,t-1} - p_{i,t_0} = \textstyle\sum_{j=t_0}^{t-1} v_{i,j} - \lambda_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot \omega_{i,t_0} \\ &= \textstyle\sum_{j=t_0}^{t-1} v_{i,j} - \lambda_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot (\beta_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot \theta_{i,t_0} + z_{i,t_0}). \end{aligned} \tag{18}$$

If $x_{i,t_0} < 0$,

$$\begin{aligned} g_{i,t} &\equiv p_{i,t_0} - D_{i,t-1} = \lambda_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot \omega_{i,t_0} - \textstyle\sum_{j=t_0}^{t-1} v_{i,j} \\ &= \lambda_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot (\beta_{i,t_0}(s_{t_0-1}, k_{t_0-1}) \cdot \theta_{i,t_0} + z_{i,t_0}) - \textstyle\sum_{j=t_0}^{t-1} v_{i,j}. \end{aligned} \tag{19}$$

C. Model Implications

With the model's solution in hand, we now examine the model's implications through numerical simulations. We organize the model's implications by three parts: the implications for investor confidence; the implications for trading behavior; and the implications for the investor's expected profit.

Specifically, we set $M = 10$, $T = 10$, $L = 0.4$, $H = 0.6$, $\sigma_i = 1$, $\sigma_{i,z} = 1$, and $\phi_0 = 0.5$. With $T = 0$, the economy has eleven dates (date t goes from zero to ten) and ten periods. At date 0, the investor's ability level is drawn: with probability ϕ_0, $a = H$; and with probability $1 - \phi_0$, $a = L$. The investor is then endowed with ten stocks. At each date $1 \leq t \leq 9$, the investor sells one of the ten stocks according to the probability χ described in the previous section; he is endowed with a signal about a new stock; and he decides his share demand for the stock. At date $t = 10$, the investor sells all his stocks.

Investor overconfidence.—We record the investor's overconfidence level at date $t = 9$ (the beginning of the final period, period 10), measured by $\Xi(k) - \xi(s)$. We simulate the above economy for 10,000 times. We compute the level of overconfidence averaged across the 10,000 investors and then plot it against probability χ, our measure of the disposition effect. Figure 3 below presents this result.

[Place Figure 3 about here]

Figure 3 shows that investor overconfidence increases with χ. Moreover, when χ is low, $\xi(s)$ tends to be greater than $\Xi(k)$ and hence investors exhibit underconfidence. When χ is high, $\xi(s)$ tends to be lower than $\Xi(k)$ and hence investors exhibit overconfidence.

We further look at investor overconfidence separately for the low-type investors and the high-type investors. We find that, for all values of χ, the low-type investors tend to be more overconfident than the high-type investors. In particular, when χ is high, the rational expectation about the low-type investors' ability, computed at date $t = 9$, is close to $L = 0.4$. However, the low-type investors' subjective expectation about their ability, after these investors have experienced many gain realizations by date $t = 9$, is significantly higher than 0.4.

[Place Figure 4 about here]

Next, we examine how investor overconfidence varies over time. For this exercise, we set $T = 21$ so the economy has 22 dates (date t goes from zero to 21) and 21 periods. We set $\chi = 1$, so investors always sell stocks at a gain (so long as there is at least one stock in the portfolio that is held at a gain). Figure 4 plots, for $1 \leq t \leq 20$, the level of overconfidence averaged across all investors, across the high-type investors, and across the low-type investors. Overall, the level of investor overconfidence increases over time: the increase is particularly significant for the first few periods and then becomes smaller and eventually negligible.

Interestingly, the dynamics of investor overconfidence depend strongly on the investor's type. Low-type investors tend to become more overconfident over time: their subjective expectation about their ability increases as they experience a higher number of gain realizations, while the rational expectation about their ability decreases over time towards their true ability $a = L$. High-type investors, however, tend to become more overconfident only for the first few periods; subsequently, their level of overconfidence decreases towards zero. For these investors, their subjective expectation about their trading ability initially increases at a faster pace compared to the rational expectation, leading to a higher level of overconfidence. As time goes, both the subjective expectation and the rational expectation converges to the investors' true ability $a = H$, and therefore the level of overconfidence drops.

Trading behavior.—We set $T = 10$ and simulate the economy for 10,000 times. For each simulation, we compute the magnitude of the investor's share demand for the new risky asset at the beginning of the final period (period 10), measured by $|x|$, where x is the share demand from equation (10). Note that x is computed under the investor's subjective expectation. If, instead, the investor holds the objective expectation, then the share demand in equation (10) should be replaced by

$$x_{i,t}^R(\theta_{i,t}, s_{t-1}, k_{t-1}) = \frac{\mathbb{E}[v_{i,t}|\theta_{i,t}, s_{t-1}]}{2\lambda_{i,t}(s_{t-1}, k_{t-1})} = \frac{\xi_{t-1}(s_{t-1})}{2\lambda_{i,t}(s_{t-1}, k_{t-1})} \cdot \theta_{i,t}. \tag{20}$$

We then compute the absolute share demands, $|x|$ and $|x^R|$, averaged across the 10,000 investors and plot these share demands against probability χ. Figure 5 below presents this result.

[Place Figure 5 about here]

Figure 5 shows that the magnitude of the investor's share demand for risky assets increases with χ, our measure of the disposition effect. Moreover, for high values of χ, the disposition effect gives rise to investor overconfidence, which in turn generates excessive trading ($|x| > |x^R|$).

Expected profit.—At the beginning of the final period, the investor's subjective expectation of his profit from the final investment is given by

$$\begin{aligned}\mathbb{E}_b[\pi_{i,t}|\theta_{i,t},k_{t-1},x_{i,t}] &= x_{i,t}\cdot[\mathbb{E}_b[v_{i,t}|\theta_{i,t},k_{t-1}]-\lambda_{i,t}(s_{t-1},k_{t-1})\cdot x_{i,t}] \\ &= \frac{\Xi_{t-1}(k_{t-1})\beta_{i,t}(s_{t-1},k_{t-1})}{2}\cdot\theta_{i,t}^2.\end{aligned} \tag{21}$$

On the other hand, the *objective* expectation of the investor's profit from the final investment is

$$\begin{aligned}\mathbb{E}[\pi_{i,t}|\theta_{i,t},s_{t-1},k_{t-1},x_{i,t}] &= x_{i,t}\cdot[\mathbb{E}[v_{i,t}|\theta_{i,t},s_{t-1}]-\lambda_{i,t}(s_{t-1},k_{t-1})\cdot x_{i,t}] \\ &= x_{i,t}\cdot[\xi_{t-1}(s_{t-1})\cdot\theta_{i,t}-\lambda_{i,t}(s_{t-1},k_{t-1})\cdot x_{i,t}].\end{aligned} \tag{22}$$

Figure 6 below plots both the subjective expectation and the objective expectation of the investor's profit against probability χ.

[Place Figure 6 about here]

Figure 6 shows that the investor's subjective expectation of his investment profit increases with χ, our measure of the disposition effect. By contrast, the *rational* expectation of the investor's gross profit is insensitive to changes in χ. This result, in conjunction with the findings from Figure 5, implies that the investor's net profit tends to decrease with the disposition effect. In our model, the disposition effect, captured by high values of χ, leads to investor overconfidence, which in turn gives rise to excessive trading. Excessive trading is detrimental to the investor's gross profit because such trading reveals too much information to the market maker. In actual markets, retail investors who trade excessively also pay higher transaction costs, causing their net profit to be significantly lower than the gross profit (Barber and Odean, 2000).

IV. Conclusion

We have conducted an experimental study to shed new light on the source of investor overconfidence. The results show that the disposition effect, a commonly observed pattern in investor behavior, creates or increases investor overconfidence. Further, we identify a a biased learning process as the channel through which the disposition effect influences investor confidence. When assessing their ability to invest, realized gains and losses have a much stronger influence on individuals' beliefs about own ability than overall portfolio performance. Controlling for actual performance on the investment task (and for gender) subjects in our *Selling Gains* condition, who realized mainly gains during the task, are more confident in their ability to select high-type stocks than subjects in the *Selling Losses* condition, who realized mainly losses. Further, subjects in the *Selling Gains* believe that they selected significantly more high-type stocks than they actually did.

Building on our experimental results, we develop a theoretical model that formalizes this intuition. In our model, investors assess their trading ability by counting past realized gains and losses and are subject to the disposition effect. We outline the implications of such a model. First, investor overconfidence increases with the degree of the disposition effect the investor exhibits. That is, when the investor tends to realize rather gains than losses, the biased learning process leads them to overestimate their abilities and become overconfident. Second, the dynamics of investor overconfidence depend on the investor's type. Especially low-type investors tend to become more overconfident over time as their subjective expectation about their ability increases with the number of gain realizations, while the rational expectation about their ability decreases over time towards the actual low level. Lastly, investor overconfidence, generated by the disposition effect, gives rises to both excessive trading and low trading profits.

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Appendices

A. Experimental Instructions

Instructions of Investment Task

In the investment task, you select **stocks**. Each period a stock can either increase or decrease in price.

There are two types of stock: an ordinary type and a high type. **These two stock types differ in the probability that their price increases or decreases**. An ordinary-type stock has a 40% probability of a price increase and a 60% probability of a price decrease. A high-type stock has a 60% probability of a price increase and a 40% probability of a price decrease.

If the price increases, the price change is **+ $2 or + $6, with equal probability**.
If the price decreases, the price change is **- $1 or - $3, with equal probability**.

The purchase price of a stock is always $30.

NEXT SCREEN

The investment task consists of 5 periods. Each period, a stock's price either increases or decreases.

First investment choice
You begin the investment task with $180 and must buy a portfolio of 5 stocks from a list of 20 available stocks. Each stock is priced at $30.

The list contains exactly 15 ordinary-type stocks and exactly 5 high-type stocks. You are not told which stock is of which type. However, for each of the 20 stocks, you are shown price changes from the three previous periods.

The picture below shows you how your choice screen will look like. You will be asked to choose 5 stocks of such a list.

Stock	3 periods ago	2 periods ago	1 period ago	Current price	Your choice
Stock 1	$ 23	$ 22	$ 28	$ 30	☐
Stock 2	$ 32	$ 31	$ 28	$ 30	☐
Stock 3	$ 28	$ 34	$ 31	$ 30	☐
Stock 4	$ 26	$ 25	$ 31	$ 30	☐
Stock 5	$ 28	$ 27	$ 24	$ 30	☐
Stock 6	$ 37	$ 36	$ 33	$ 30	☐
Stock 7	$ 34	$ 31	$ 33	$ 30	☐
Stock 8	$ 16	$ 22	$ 24	$ 30	☐
Stock 9	$ 37	$ 36	$ 33	$ 30	☐
Stock 10	$ 33	$ 32	$ 31	$ 30	☐
Stock 11	$ 34	$ 36	$ 33	$ 30	☐
Stock 12	$ 34	$ 31	$ 33	$ 30	☐
Stock 13	$ 32	$ 29	$ 28	$ 30	☐
Stock 14	$ 37	$ 34	$ 33	$ 30	☐
Stock 15	$ 33	$ 32	$ 31	$ 30	☐
Stock 16	$ 33	$ 32	$ 31	$ 30	☐
Stock 17	$ 26	$ 25	$ 31	$ 30	☐
Stock 18	$ 34	$ 36	$ 33	$ 30	☐
Stock 19	$ 34	$ 31	$ 28	$ 30	☐
Stock 20	$ 33	$ 32	$ 31	$ 30	☐

Example Screen.

NEXT SCREEN

First period

After the initial portfolio selection, you observe the first period price changes for each of the stocks in your portfolio. After the new prices are displayed, **one of the stocks is automatically sold** by the computer program at the stock's current price. After the sale of one stock, you **must buy an additional stock from a new list of four stocks**. Once again, you observe the previous three price changes for each of the four stocks. The purchase price of each stock is always $30.

The list contains exactly 3 ordinary-type stocks and exactly 1 high-type stock. You are not told which stock is of which type. However, for each of the 4 stocks, you are shown price changes from the three previous periods.

Periods 2-4

You observe the next period's new prices for each of the stocks in your portfolio. After the new prices are displayed, **one of the stocks is automatically sold** by the computer program at the stock's current price. After the sale of one stock, you **must buy an additional stock from a new list of four stocks**. Once again, you observe the previous three price changes for each of the four stocks. The purchase price of each stock is always $30.

As in period 1, the list contains exactly 3 ordinary-type stocks and exactly 1 high-type stock. You are not told which stock is of which type. However, for each of the 4 stocks, you are shown price changes from the three previous periods.

Period 5

You observe the new prices for each of the stocks in your portfolio. The investment task is now over.

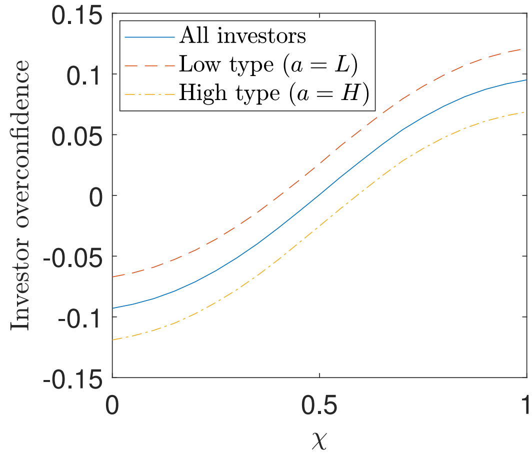

Figure 3. Investor overconfidence as a function of χ. The graph plots the average level of investor overconfidence as a function of probability χ, our measure of the disposition effect. We simulate the economy for 10,000 times. Each time, we simulate the economy for T periods, and at date 0, we draw the investor's ability level: with probability ϕ_0, $a = H$; and with probability $1 - \phi_0$, $a = L$. We record the investor's overconfidence level at the beginning of the final period (period T), measured by $\Xi(k) - \xi(s)$. We then compute the average level of investor overconfidence in three ways: 1) overconfidence averaged across all 10,000 investors; 2) overconfidence averaged across investors of the low type ($a = L$); and 3) overconfidence averaged across investors of the high type ($a = H$). Besides χ, the other parameter values are: $M = 10$, $T = 10$, $L = 0.4$, $H = 0.6$, $\sigma_i = 1$, $\sigma_{i,z} = 1$, and $\phi_0 = 0.5$.

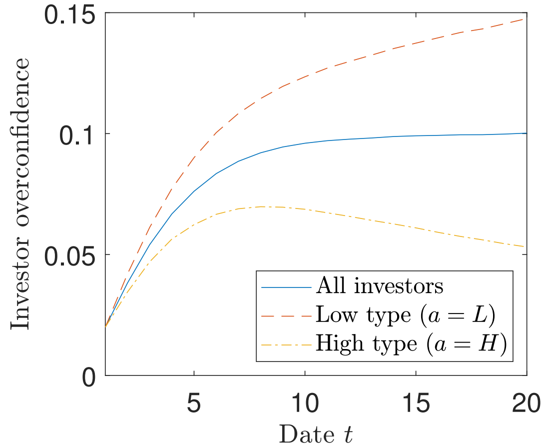

Figure 4. Time evolution of investor overconfidence. The graph plots investor overconfidence as a function of time. We simulate the economy for 10,000 times. Each time, we simulate the economy for T periods, and at date 0, we draw the investor's ability level: with probability ϕ_0, $a = H$; and with probability $1 - \phi_0$, $a = L$. We record the investor's overconfidence level, measured by $\Xi(k) - \xi(s)$, on date $1 \leq t \leq T - 1$. We then compute, for each of these dates, the average level of investor overconfidence in three ways: 1) overconfidence averaged across all 10,000 investors; 2) overconfidence averaged across investors of the low type ($a = L$); and 3) overconfidence averaged across investors of the high type ($a = H$). The parameter values are: $M = 10$, $T = 21$, $L = 0.4$, $H = 0.6$, $\sigma_i = 1$, $\sigma_{i,z} = 1$, $\phi_0 = 0.5$, and $\chi = 1$.

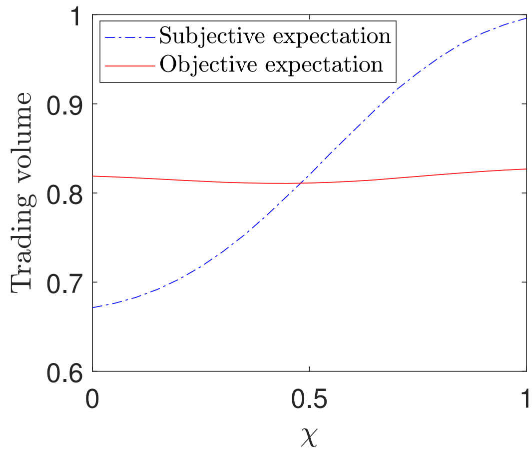

Figure 5. Trading volume as a function of χ. The graph plots the average trading volume, computed under either the subjective expectation or the objective expectation, as a function of probability χ, our measure of the disposition effect. We simulate the economy for 10,000 times. Each time, we simulate the economy for T periods, and at date 0, we draw the investor's ability level: with probability ϕ_0, $a = H$; and with probability $1 - \phi_0$, $a = L$. We record the investor's absolute share demand for a risky asset at the beginning of the final period (period T), measured by either $|x|$ (if investors hold subjective expectations) or by $|x^R|$ (if investors hold objective expectations). We then take the average of these absolute share demands across the 10,000 investors. Besides χ, the other parameter values are: $M = 10$, $T = 10$, $L = 0.4$, $H = 0.6$, $\sigma_i = 1$, $\sigma_{i,z} = 1$, and $\phi_0 = 0.5$.

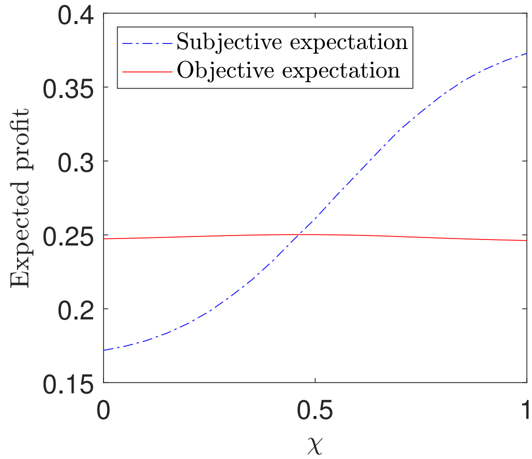

Figure 6. Expected profit as a function of χ. The graph plots the subjective expectation and the objective expectation of the investor's profit from the final investment, each against probability χ, our measure of the disposition effect. We simulate the economy for 10,000 times. Each time, we simulate the economy for T periods, and at date 0, we draw the investor's ability level: with probability ϕ_0, $a = H$; and with probability $1 - \phi_0$, $a = L$. We record the subjective expectation and the objective expectation of the investor's profit from the final investment made at the beginning of the final period (period T). We then take the average of these expected profits across the 10,000 investors. Besides χ, the other parameter values are: $M = 10$, $T = 10$, $L = 0.4$, $H = 0.6$, $\sigma_i = 1$, $\sigma_{i,z} = 1$, and $\phi_0 = 0.5$.