



WP-AD 2017-07

# Optimistic and stubborn: An experimental analysis of the disposition effect

*Carlos Cueva, Iñigo Iturbe-Ormaetxe, Giovanni Ponti and Josefa Tomás*

**Ivie**

Working papers  
Working papers  
Working papers

Los documentos de trabajo del Ivie ofrecen un avance de los resultados de las investigaciones económicas en curso, con objeto de generar un proceso de discusión previo a su remisión a las revistas científicas. Al publicar este documento de trabajo, el Ivie no asume responsabilidad sobre su contenido.

Ivie working papers offer in advance the results of economic research under way in order to encourage a discussion process before sending them to scientific journals for their final publication. Ivie's decision to publish this working paper does not imply any responsibility for its content.

La Serie AD es continuadora de la labor iniciada por el Departamento de Fundamentos de Análisis Económico de la Universidad de Alicante en su colección "A DISCUSIÓN" y difunde trabajos de marcado contenido teórico. Esta serie es coordinada por Carmen Herrero.

The AD series, coordinated by Carmen Herrero, is a continuation of the work initiated by the Department of Economic Analysis of the Universidad de Alicante in its collection "A DISCUSIÓN", providing and distributing papers marked by their theoretical content.

Todos los documentos de trabajo están disponibles de forma gratuita en la web del Ivie <http://www.ivie.es>, así como las instrucciones para los autores que desean publicar en nuestras series.

Working papers can be downloaded free of charge from the Ivie website <http://www.ivie.es>, as well as the instructions for authors who are interested in publishing in our series.

Versión: octubre 2017 / Version: October 2017

Edita / Published by:  
Instituto Valenciano de Investigaciones Económicas, S.A.  
C/ Guardia Civil, 22 esc. 2 1º - 46020 Valencia (Spain)

DOI: <http://dx.medra.org/10.12842/WPAD-2017-07>

# Optimistic and Stubborn: An experimental analysis of the disposition effect\*

Carlos Cueva, Iñigo Iturbe-Ormaetxe,  
Giovanni Ponti and Josefa Tomás\*\*

## Abstract

The disposition effect (DE) is a common bias by which investors tend to sell profitable assets too soon and hold losing assets too long. We investigate psychological correlates of the DE in a standard experimental environment and find that subjects scoring high in *optimism* and *stubbornness* (difficulty recognizing one's errors) tend to sell fewer losers and consequently exhibit a larger DE. We then test a beliefs-based explanation for these findings by conducting two additional treatments, called *allocate* (A) and *choose* (CH), in which we elicit price expectations after subjects are either randomly allocated assets, or forced to choose some, respectively. We find that subjects' beliefs are more optimistic about assets that they own than about other assets, regardless of the treatment. However, while beliefs about owned assets in A adjust in line with Bayesian inference, beliefs remain stubbornly optimistic in CH even when an asset is more likely to be a loser.

**Keywords:** Behavioral Finance, Trading, Biases, Psychological Measures, Beliefs, Cognitive Dissonance.

**JEL classification numbers:** C91, D70, D81, D91.

---

\* We thank Pedro Albarrán and Holger Rau for useful comments and Esther Mata-Pérez, Haihan Yu and Vita Zhukova for their valuable research assistance. Financial support from the Spanish Ministries of Education and Science and Economics and Competitiveness (ECO2015-65820-P), Generalitat Valenciana (Research Projects Grupo3/086 and PROMETEO/2013/037) and Instituto Valenciano de Investigaciones Económicas (Ivie) is gratefully acknowledged.

\*\* C. Cueva, I. Iturbe-Ormaetxe and J. Tomás: Universidad de Alicante. G. Ponti: Universidad de Alicante, The University of Chicago and LUISS Guido Carli Roma. **Corresponding author:** Carlos Cueva, Departamento de Fundamentos del Análisis Económico, Universidad de Alicante. 03071 Alicante (SPAIN), E-mail: ccuevah@gmail.com.

## 1 Introduction

Originally coined by Shefrin and Statman (1985), the disposition effect (DE) is the tendency of investors to sell winning assets too early and hold losing assets too long. Such a tendency has been persistently documented in empirical studies of investor behavior and is among the most established findings in Behavioral Finance.<sup>1</sup>

Experimental studies, starting with the work of Weber and Camerer (1998), have confirmed the prevalence of the DE in controlled environments, where such a tendency is unambiguously suboptimal. However, few studies have empirically investigated the role of psychological factors, or that of beliefs, as determinants of the DE. This paper reports the empirical findings of two complementary studies that contribute to the literature on the DE in two main directions.

In Study 1, we examine the impact of specific psychological factors that have been proposed as potential determinants of the DE, such as optimism, difficulty recognizing errors (or stubbornness, for short), enjoyment of winning, competitiveness, self-control and financial literacy. Our results show that optimism and stubbornness are the only psychological factors strongly correlated with the DE and that this effect operates via a reduction in the propensity to sell losing assets. These results are established using the widely used experimental framework of Weber and Camerer (1998), in combination with questionnaire data.

In Study 2, we build upon the benchmark experimental design to investigate a beliefs-based explanation of our evidence regarding optimism and stubbornness. In two new treatments, subjects are either randomly allocated some assets or have to choose a given number of assets which they have to hold on to. We find that subjects are indeed optimistic in their beliefs: in both treatments, subjects are significantly more likely to guess that an asset will appreciate when they own it, and this effect is much stronger when the asset has been chosen by the subject. Finally, whereas beliefs over randomly allocated assets tend to update in line with Bayesian inference, subjects are stubbornly optimistic about assets that they have chosen themselves: they tend to expect that the asset will appreciate with a high probability and do not update their beliefs downwards when the asset is more likely to be a loser. Together, our results suggest that distorted beliefs aimed at reducing cognitive dissonance are important determinants of the DE.

The remainder of the paper is arranged as follows. Section 2 reviews the literature on the DE, individual heterogeneity and beliefs. Sections 3 and 4 describe the results of experiments 1 and 2, respectively. Section 5 concludes. Additional results and a translation of the experimental instructions can be found in the Appendix.

---

<sup>1</sup> See, for example, Shefrin and Statman (1985), Ferris *et al.* (1988), Odean (1998), Grinblatt and Keloharju (2001), Shapira and Venezia (2001), Dhar and Zhu (2006), Brown *et al.* (2006), Barber *et al.* (2007), Kaustia (2010a, 2010b), Duxbury (2015).

## 2 Related literature: theory and evidence

Several large empirical studies have documented the existence of the DE. Odean (1998) finds that individual investors have a strong preference for selling winners and holding losers, except in December when tax motivated selling prevails. Using a comprehensive data set of stock market investors in Finland, Grinblatt and Keloharju (2000, 2001) find that investors are about twice as likely to sell a stock at a moderate gain as at a moderate loss. Shapira and Venezia (2001) confirm the prevalence of the DE among independent investors and professional brokers in Israel. Dhar and Zhu (2006), Brown *et al.* (2006) and Barber *et al.* (2007) document similar findings among investors in the United States, Australia and Taiwan, respectively.

A few empirical studies have also investigated investor heterogeneity in the DE. Shapira and Venezia (2001) compare independent investors with those whose accounts were managed by brokerage professionals and find that professionally managed accounts exhibit a smaller, though still positive, DE. Feng and Seasholes (2005) use proxies for investor sophistication in China based on age, gender, trading rights and initial diversification and find a lower DE in sophisticated and more experienced traders. Similarly, Dhar and Zhu (2006) find that wealthier and more experienced investors, as well as those with professional occupations exhibit a lower DE.

There are several experimental studies of the DE. Weber and Camerer (1998) find that individuals exhibit a significant DE in an experiment in which subjects have the opportunity to buy and sell units of six risky assets with constant, but unknown, probabilities of changing prices.<sup>2</sup> Da Costa *et al.* (2008, 2013) and Rau (2014, 2015) replicate these results employing similar designs. Weber and Welfens (2007) combine field and lab data employing a similar experimental design and also replicate these findings. Additionally, they find evidence that wealthier investors exhibit a smaller DE and that experience attenuates this bias both in the field and in the lab. Magnani (2015) confirms the existence of the DE in an experiment involving the exercise of a put option. Here subjects take too long to exercise their option when the share price is falling and cash the value of the asset too early when its price is raising.

Various theories have tried to explain why the DE happens. These theories may be classified as either *preference-based*, *beliefs-based* or *mixed*. The most long-standing preference-based theory of the DE draws on a combination of mental accounting and Prospect Theory (PT, Kahneman and Tversky, 1979). According to this theory, investors keep separate mental accounts for each of their investments, tracking how they each perform with respect to the initial purchase price, which constitutes the reference point. PT in turn implies that investors are risk averse in the gain domain and risk loving in the loss domain, leading them to sell winners earlier than losers (Shefrin and Statman, 1985; Barberis and Xiong, 2009; Kaustia, 2010a). Another prominent

---

<sup>2</sup> Note that the fact that probabilities are unknown but constant implies that the DE is clearly a costly decision-making bias, since subjects should instead hold onto winners and sell losers in this environment.

preference-based explanation is that of realization utility, which posits that individuals experience positive (negative) utility by the act of selling assets at a gain (loss) as opposed to holding on to these assets (Shefrin and Statman, 1985; Barberis and Xiong, 2012; Ingersoll and Jin, 2013; Frydman *et al.*, 2014). Finally, the DE has also been hypothesized to appear as a failure to exercise self-control (Thaler and Shefrin, 1981; Shefrin and Statman, 1985).

A pure beliefs-based explanation of the DE is that of irrational beliefs in mean-reversion (Odean, 1998; Weber and Camerer, 1998; Kaustia, 2010a). This theory posits that investors hold on to losers and sell winners because they irrationally believe that stock prices tend to revert back to the mean in the short term. This theory, however, has received little empirical support (Weber and Camerer, 1998). Ben-David and Hirshleifer (2012) also argue for a beliefs-based explanation of the DE. They find a V-shaped relationship between the probability of a sale and a stock's price change from purchase, with a minimum at zero. The DE arises due to the asymmetry of the V-shape, which is steeper in the gain region. However, contrary to preference-based interpretations of the DE, the selling probability does not jump up to the right of zero. Furthermore, the buying probability also exhibits a V-shape pattern which in this case is steeper in the loss region. Ben-David and Hirshleifer (2012) argue that belief revisions by speculative traders can explain these patterns of behavior.

An important theory of the DE which combines both beliefs and preferences is that of *cognitive dissonance*. According to cognitive dissonance theory (Festinger, 1957), individuals tend to hold consistent beliefs, attitudes and actions. Events that upset this consistency are psychologically costly and are therefore often avoided. Applied to financial decisions, selling a losing asset carries an additional psychological cost to investors, since it involves the acceptance that their prior beliefs and actions were wrong (Gross, 1982; Shefrin and Statman, 1985). Investors may therefore postpone or avoid the sale of losing assets in order to reduce cognitive dissonance (Kaustia, 2010b, Chang et al, 2016). Finally, other related mechanisms suggested in the literature with elements in common with cognitive dissonance theory are regret aversion (Shefrin and Statman, 1985; Strahilevitz *et al.*, 2011; Frydman and Camerer, 2016) and self-deception (Hirshleifer, 2001).

As it can be seen, multiple competing theories of the DE coexist, which highlights the need for further empirical work which can help to assess the relative merits of each. In this paper, we contribute to this debate by providing empirical results on two underexplored aspects of the DE: psychological correlates and price beliefs. Surprisingly little work has been done in terms of psychological correlates of the DE, particularly since the DE has often been linked to easily measurable psychological traits such, as for example, overconfidence (Odean, 1999) or poor self-control (Shefrin and Statman, 1985).<sup>3</sup> In terms of beliefs, even though they are a central ingredient

---

<sup>3</sup> The only exception to this is Chui (2001), who finds that subjects with an internal locus of control (a

in various prominent theories of the DE, there is no data on how they relate to the DE. Natural difficulties involved in reliably measuring beliefs in the field make an experimental approach particularly suited here. Along these lines, psychologists have examined beliefs in the context of the sunk-cost effect (the tendency to continue an endeavor once an investment has been made). In particular, Arkes and Hutzel (2000) find that individuals believe that the probability of success of a hypothetical investment is higher when an initial investment of money, effort or time has been made. Much in line with cognitive dissonance theory, the authors interpret the inflated probability estimates as a “post-hoc” rationalization of the prior decision to invest.

As we will argue, our results regarding *(i)* psychological correlates and *(ii)* price beliefs provide consistent evidence in favor of a cognitive dissonance explanation of the DE.

### 3 Study 1

As explained earlier, the main purpose of Study 1 is to examine individual correlates of the DE, with particular focus on psychological variables theoretically predicted to play a role.

#### 3.1 Design

We recruited 192 subjects, 97 female and 95 male, to participate in this study. Experiments were conducted in 8 sessions of 24 subjects each. All subjects were recruited from the undergraduate population of the University of Alicante. The experiment was programmed in z-Tree (Fischbacher, 2007). Subjects were recruited using ORSEE (Greiner, 2004) and earned around 19€ on average for an experiment that lasted approximately two hours.

We borrow the baseline design from Weber and Camerer (1998) and Weber and Welfens (2007), with some modifications. In our baseline treatment, subjects can buy and sell six risky assets (A, B, C, D, E, and F) over 9 periods using experimental currency. Each asset follows a different stochastic price path, independent of subjects’ actions. We introduce two variations of the baseline treatment: *i)* transaction costs and *ii)* a competitive payment scheme. The purpose of introducing these variations was to examine gender differences in trading volume, which is not the focus of the present paper. Indeed, as our subsequent analysis shows, the DE was not affected by either of these treatments.

Subjects are assigned randomly into groups of two males and two females. They know that they are in a group of four but are not told the identity, or gender, of their group mates.<sup>4</sup> All

---

tendency to feel that events are under their own control) have a higher DE than those with an external locus of control. It is not clear, however, how these results fit in with the various theories of the DE.

<sup>4</sup> To ensure that subjects perceive a similar gender-balanced environment in every session, their positions in the laboratory are always male, female, male, female... This is done by asking male and female subjects to randomly draw a number from different boxes: one box contains odd numbers and the other contains even numbers. Subjects are then seated on the cubicle corresponding to their drawn number. In some sessions the gender balance was not perfect, in which case the extra subjects from the more numerous gender group were asked to draw a number from the box corresponding to the less numerous gender group.

subjects go through the baseline treatment (B), the transaction costs treatment (T), the competitive treatment (C), and the competitive & transaction costs treatment (CT). The treatment order is counterbalanced.<sup>5</sup> Individuals are endowed with 5,000 pesetas in each treatment to trade in the market.<sup>6</sup> In B, subjects earn the value of the portfolio upon liquidation (period 10) plus their remaining cash. In C, only the “winner” (i.e. the investor whose liquidated portfolio plus remaining cash is the largest in each group of four) earns the value of her portfolio plus the remaining cash, multiplied by two. The remaining three members of the group do not receive the value of their portfolios, nor their remaining cash. In T, subjects have to pay a fee for each transaction. The fee is a fixed rate, chosen from the set {1%, 4%, 7%} so that a third of the groups in each session face each fee. All individuals in a given group face the same fee throughout the treatment. The fee is the same for purchases and sales. Finally, in CT, we combine the features of treatments C and T.

To elicit subjects’ self-confidence, we ask them to guess, at the beginning and at the end of each treatment, their own ranking in terms of earnings within their group. They receive 100 pesetas every time they guess their position right.

### 3.1.1 Prices

Subjects are told that each group of four faces the same price path of the six assets. The history of each market begins in period -3, with the same initial price of 100 pesetas for all assets. From period -2 onwards, prices can go up by 6% or down by 5%. Subjects are told that each asset has a different probability of a price increase, but are not told the actual probabilities. However, they are informed that, for each asset, the probability of a price increase is constant over the whole treatment and that price changes are independent of previous prices and subjects’ actions. In particular, we assign randomly to each asset a probability of a price increase that is chosen without replacement from the set {0.6, 0.55, 0.5, 0.5, 0.45, 0.4}. This implements a market in which there are always two “good” assets (those with a probability of 0.6 and 0.55 that the price will increase), two “neutral” assets (0.5), and two “bad” assets (0.45 and 0.4). Individuals observe prices from period -3 to 10, but can only trade from period 1 to 9. Prices at period 10 are only used to liquidate portfolios.

Since the probability of a price increase for each asset is unknown and constant, a rational subject should infer that appreciating assets are more likely to continue appreciating than depreciating assets. This implies that rational subjects should be more likely to sell losing assets than winning assets. Therefore, a positive DE clearly constitutes a costly decision-making bias in this environment.

---

<sup>5</sup> Sessions 1 and 2: B, C, T, CT; sessions 3 and 4: T, CT, B, C; sessions 5 and 6: C, B, CT, T; sessions 7 and 8: CT, T, C, B. Subjects played a short trial period before each treatment.

<sup>6</sup> We call the experimental currency “pesetas.” Exchange rate: 1,000 pesetas = 1€.

### 3.1.2 Individual measures

At the end of the experiment subjects complete a survey including the Financial Literacy Test (FLT, Lusardi and Mitchell, 2011) and other socio-demographic questions. We also use some self-assessed psychological measures gathered using a Likert-type scale including a reduced version of the Big Five Test,<sup>7</sup> questions regarding indecisiveness (Germeijs and De Boeck, 2002), self-control (Tangney *et al.*, 2004), difficulty recognizing errors, optimism, willingness to take risks, confidence, competitiveness and enjoyment of winning (see Appendix C for the exact wording of these questions). All these questions aim to capture different traits that have been associated to the DE or to closely related phenomena. For instance:

1. Indecisiveness is related to regret aversion (Germeijs and De Boeck, 2002), which has been proposed as a possible source of the DE (Shefrin and Statman, 1985; Frydman and Camerer, 2016).
2. Self-control has also been related to the DE (Shefrin and Statman, 1985).
3. Enjoyment of winning and competitiveness are two measures intended to capture “realization utility”, which has been proposed as a possible cause of the DE (Shefrin and Statman, 1985; Barberis and Xiong, 2012; Ingersoll and Jin, 2013).
4. Optimism and confidence feature prominently as explanations of overtrading, momentum, and the January effect (Odean, 1999; Ciccone, 2011; Antoniou *et al.*, 2013) and could therefore influence the DE by lowering the propensity to sell losers.
5. Difficulty recognizing one’s errors has been proposed as a contributing factor for the reluctance to sell losers (Gross, 1982; Shefrin and Statman, 1985). By the same token, cognitive dissonance theory suggests that individuals who are optimistic and who have difficulty recognizing their errors might hold on to losers and therefore be vulnerable to the DE.

Before the beginning of the trading period, we elicit risk preferences using a Multiple Price List task (Holt and Laury, 2002) in which subjects go through a sequence of 21 binary decisions between a lottery and a safe option. The lottery is always the same: 5,000 or 0 pesetas with equal probability. The safe option ranges from 0 to 5,000 pesetas, increasing by a constant step of 250 pesetas along the sequence. To minimize wealth effects, we randomly select one of the binary decisions for payment at the end of the experiment.

---

<sup>7</sup> We use a Spanish translation of the reduced form of the Big 5 test (Benet-Martinez and John, 1998; John and Srivastava, 1999).

### 3.2 Results

To calculate the DE, we follow Odean (1998) by computing the number of units sold at a price above the reference price (“Realized Gains”), the number of units sold at a price below the reference price (“Realized Losses”), the number of units not sold and whose price exceeds the reference price (“Paper Gains”), and the number of units not sold and whose price is below the reference price (“Paper Losses”). The DE is defined as  $DE = PGR - PLR$ , where:

$$\text{Proportion of Gains Realized, } PGR = \frac{\text{Realized Gains}}{\text{Realized Gains} + \text{Paper Gains}}, \text{ and}$$

$$\text{Proportion of Losses Realized, } PLR = \frac{\text{Realized Losses}}{\text{Realized Losses} + \text{Paper Losses}}.$$

PGR and PLR are between 0 and 1, so DE is between -1 and 1.

An alternative measure of the DE introduced by Weber and Camerer (1998) and often used in the experimental literature is the so-called “alpha” coefficient, defined as  $alpha = \frac{S^+ - S^-}{S^+ + S^-}$ , where  $S^+$  ( $S^-$ ) are the number of sales of stocks whose price has gone up (down) in the last period.

The first issue when calculating PGR and PLR, is defining a *reference price* from which gains and losses are computed. As Odean (1998, p. 1782) put it: “*Any test of the DE is a joint test of the hypothesis that people sell gains more readily than losses and of the specification of the reference point from which gains and losses are determined.*”

A number of different reference prices have been used in the literature, such as the *weighted average price*, the *first period price*, the *last period price*, the *first-in-first-out* rule (FIFO) or the *last-in-first-out* rule (LIFO). Most empirical studies follow Odean (1998) in employing the weighted average price.<sup>8</sup> However, experimental studies are more varied: Weber and Camerer (1998) use FIFO and LIFO; Weber and Welfens (2007) use the weighted average price; Da Costa *et al.* (2008) use LIFO and last price; Rau (2014) uses only LIFO.

In Appendix A we describe the various reference prices and compare our aggregate results according to each. We also present the results from a questionnaire which shows that the weighted average price is regarded by our subjects as the most reasonable reference price. We therefore use the weighted average reference price for most of our analysis, unless otherwise stated.<sup>9</sup> However, our results are robust to other reference prices and the alternative alpha measure.

The average DE in our baseline treatment is 0.069 and is significantly different from zero ( $p = 0.002$ , Wilcoxon signed-rank test). In this respect, our findings are comparable to those obtained in related works. For instance, Odean (1998, Table 1) also uses the average reference price and

---

<sup>8</sup> This is also how capital gains are usually computed for tax purposes.

<sup>9</sup> Suppose an individual holds 10 units of asset A in period 6. She bought 3 units in period 2 and 7 units in period 5. The weighted average reference price for asset A in period 6 is the price in period 2 multiplied by (3/10) plus the price in period 5 multiplied by (7/10).

finds that 14.8 percent of the gains available for realization are actually realized, while only 9.8 percent of the losses are realized, which yields a DE of 0.05.

As expected, treatment conditions do not have a significant effect on the DE (Skillings-Mack test,  $p = 0.363$ ). The DE is 0.069 ( $\pm 0.023$  SE) in B, 0.070 ( $\pm 0.024$  SE) in C, 0.105 ( $\pm 0.019$  SE) in T, and 0.068 ( $\pm 0.020$  SE) in CT. Although the DE is higher in T than in B, this difference is not significant (Wilcoxon test,  $p = 0.391$ ). Finally, Wilcoxon tests reject the null hypothesis that  $DE = 0$  ( $p < 0.01$ ) for each treatment. Results using alternative reference prices can be found in Appendix A.

### 3.2.1 Psychological correlates of the DE

We estimate three regression models with DE, PLR and PGR as dependent variables, using as covariates measures gathered from the questionnaire. A similar analysis with the alternative reference prices as well as summary statistics of the individual measures used can be found in Appendix B.

To ease the interpretation of the quantitative effect associated with each coefficient, we create dummy variables which take a positive value whenever the associated measure (an integer between 1 and 7) is above the median.<sup>10</sup> We do this for the eight variables that measure optimism, risk, confidence, difficulty recognizing errors, competitiveness, enjoyment of winning, decisiveness, and self-control, respectively. Following common practice in the literature, Big Five personality traits are standardized. The variables *experience2* to *experience4* are dummies capturing the order of treatments within a session.<sup>11</sup> We also include four dummy variables measuring ability and confidence: *high financial literacy*, *high grades*, *>1 switches* and *high confidence before*.<sup>12</sup> Finally, since our experimental subjects are students from all fields (Social Sciences, Art and Literature, Health, Sciences, and Engineering), we control for the field of studies with four dummy variables, with students from Social Sciences selected as baseline group.<sup>13</sup>

---

<sup>10</sup> Qualitatively similar results are obtained when using these variables in “raw” form in the regressions.

<sup>11</sup> For example, in the 1<sup>st</sup> session, the treatment order was B, C, T, CT. The variables *experience2*, 3 and 4 would then take value 0 in B, *experience2* = 1 in C, *experience3* = 1 in T, and *experience4* = 1 in CT. On the other hand, in the 8<sup>th</sup> session, the treatment order was CT, T, C, B. So here *experience2* would take value 1 in T and so on.

<sup>12</sup> *High financial literacy* = 1 if a subject answers the three questions of the Financial Literacy Test (Lusardi and Mitchell, 2011, 2014) correctly; *high grade* = 1 if a subject reports an average grade of 7 or higher (out of 10) in their studies; *>1 switches* = 1 if a subject switches more than once in the risk elicitation task, reflecting inconsistent behavior; *high confidence before* = 1 if a subject guesses that she will be the best in her group of 4 before a given treatment. To avoid reducing the sample size significantly, we do not include the measure of risk aversion gathered in the risk elicitation task, since we would have to exclude 42 subjects who switched more than once. This variable was nevertheless insignificant when included in the regressions and did not significantly affect our other results.

<sup>13</sup> These are the five official categories of fields of studies in Spanish universities. Our sample was distributed as follows: 10% Art and Literature, 30% Social Sciences, 32% Health, 10% Science, 18% Engineering.

**Table 1.** DE, PGR and PLR with average reference price. Random effects regression.

VARIABLES	Average Price		
	DE	PGR	PLR
<b>Female</b>	0.00666 (0.0391)	-0.0459 (0.0315)	-0.0557** (0.0223)
<b>C</b>	0.000574 (0.0318)	0.00172 (0.0245)	-0.00147 (0.0201)
<b>T</b>	0.0207 (0.0427)	-0.0584** (0.0296)	-0.0903*** (0.0235)
<b>CT</b>	-0.00234 (0.0352)	-0.0916*** (0.0262)	-0.0878*** (0.0208)
<b>Female×C</b>	0.0166 (0.0366)	0.0203 (0.0288)	0.00794 (0.0291)
<b>Female×T</b>	0.0267 (0.0481)	0.0598* (0.0350)	0.0462* (0.0250)
<b>Female×CT</b>	0.0152 (0.0346)	0.0809*** (0.0294)	0.0614*** (0.0197)
<b>Experience2</b>	-0.0369 (0.0239)	-0.0193 (0.0196)	0.0175 (0.0111)
<b>Experience3</b>	-0.0377 (0.0275)	-0.0198 (0.0199)	0.00804 (0.0195)
<b>Experience4</b>	-0.0680*** (0.0249)	-0.0507*** (0.0157)	0.0172 (0.0154)
<b>Optimism</b>	0.0713** (0.0341)	0.00993 (0.0350)	-0.0614** (0.0268)
<b>Risk</b>	-0.0240 (0.0325)	-0.0213 (0.0311)	0.00758 (0.0189)
<b>Confidence</b>	-0.0554 (0.0343)	-0.00764 (0.0346)	0.0440 (0.0269)
<b>Difficulty recognizing errors</b>	0.0878*** (0.0295)	0.0344 (0.0300)	-0.0569*** (0.0167)
<b>Competitiveness</b>	0.0448 (0.0392)	0.0141 (0.0290)	-0.0286 (0.0235)
<b>Enjoys Winning</b>	-0.0481 (0.0298)	-0.0396 (0.0258)	0.00958 (0.0223)
<b>Decisiveness</b>	-0.0153 (0.0355)	-0.0274 (0.0358)	-0.0144 (0.0184)
<b>Self-control</b>	0.0593 (0.0410)	0.0575* (0.0307)	-0.00518 (0.0251)
<b>High Confidence</b>	-0.00963 (0.0222)	-0.0142 (0.0193)	-0.00366 (0.0135)
<b>High Financial Literacy</b>	-0.0331 (0.0385)	-0.0193 (0.0333)	0.0120 (0.0237)
<b>High Grades</b>	-0.00124 (0.0365)	-0.00268 (0.0322)	-0.00247 (0.0212)
<b>&gt;1 Switches</b>	0.0108 (0.0384)	0.00885 (0.0291)	-0.00364 (0.0219)
<b>Neuroticism</b>	0.0145 (0.0174)	0.0189 (0.0180)	0.00313 (0.0122)

<b>Extraversion</b>	0.0163 (0.0139)	0.0149 (0.0153)	-0.00238 (0.0114)
<b>Agreeableness</b>	-0.0144 (0.0178)	-0.0193 (0.0160)	-0.000641 (0.00950)
<b>Openness</b>	0.0236* (0.0139)	0.0207 (0.0132)	-0.00445 (0.00887)
<b>Conscientiousness</b>	-0.00417 (0.0196)	-0.00800 (0.0167)	-0.00412 (0.0116)
<b>Art</b>	-0.0150 (0.0460)	-0.0538 (0.0462)	-0.0385 (0.0293)
<b>Health</b>	0.0313 (0.0448)	-0.0210 (0.0387)	-0.0534** (0.0222)
<b>Science</b>	0.0256 (0.0494)	-0.0503 (0.0386)	-0.0778** (0.0307)
<b>Engineering</b>	-0.0984** (0.0477)	-0.106*** (0.0351)	-0.00988 (0.0374)
<b>Constant</b>	0.0514 (0.0846)	0.331*** (0.0724)	0.288*** (0.0363)
<b>Observations</b>	706	720	710
<b>Number of id</b>	192	192	192

Note: We show the coefficients of three different regressions in which the dependent variables are DE, PGR, and PLR, respectively. The set of regressors is the same in the three regressions. All variables except Female, Treatment and Experience standardized to zero mean and unit standard deviation. Robust standard errors clustered by group and session in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 1 reports the estimated coefficients. The results are as follows:<sup>14</sup>

1. Among our psychological measures, the only significant ones are *optimism* and *difficulty recognizing errors*.<sup>15</sup> We investigate these two factors in more detail in the following section.
2. The variable *experience4* has a negative and significant effect on the DE. This is consistent with previous evidence that trading frequency and experience help to mitigate the DE (Feng and Seasholes, 2005; Dhar and Zhu, 2006; Weber and Welfens, 2007; Da Costa *et al.*, 2013).
3. Students from Engineering exhibit lower DE and PGR for all reference prices. Given that this field of studies is the most mathematically oriented in our sample, a natural interpretation is that Engineering students are better able to understand the price process in the experiment, and that this discourages them from selling winners. This result is consistent with field evidence that sophisticated investors tend to exhibit a lower DE (Odean, 1998, Grinblatt and Keloharju, 2001; Shapira and Venezia, 2001; Dhar and Zhu, 2006, Brown *et al.*, 2006).
4. Females exhibit a significantly lower PLR without transaction costs (treatments B and C), but

<sup>14</sup> As robustness checks, we re-estimate the model with: (i) bootstrapped standard errors and (ii) removing 10% of the subjects with the most extreme values of DE. All the results are maintained.

<sup>15</sup> We also find a moderate effect of *openness*. However, this result is not robust to all reference prices (see Appendix B).

this difference disappears with transaction costs (treatments T and CT, see also Table B6 in Appendix B). A lower PLR of females was also found in an experimental study by Rau (2014) and is also consistent with empirical evidence by Feng and Seasholes (2005) on Chinese investors.<sup>16</sup>

5. Although the PLR is significantly reduced in the presence of transaction costs (treatments T and CT), the effect on the DE is not significant. This is because the drop in PLR provoked by transaction costs is offset by an equivalent drop in PGR.

### 3.2.2 Optimism and difficulty recognizing errors

Optimism is considered a common investment bias, which has been suggested to have a significant impact on stock prices (Diether *et al.*, 2002; Ciccone, 2011; Antoniou *et al.*, 2013) and venture performance (Hmieleski and Baron, 2009). In particular, Antoniou *et al.* (2013) use the Consumer Confidence Index to partition the last 40 years of stock market data into “optimistic” and “pessimistic” periods and find that in optimistic periods small investors are slower to sell losers than in pessimistic periods. The authors argue that, due to cognitive dissonance, unsophisticated optimistic investors are slow to incorporate bad news.

The regressions in Table 1 show that *optimism* has a significant positive effect on the DE via a decrease in the PLR, while having no effect on the PGR. This result seems intuitive: optimistic subjects are more likely to believe that their investments will eventually turn out to be profitable, and therefore take longer to accept losses. This result is robust to all reference price specifications except LIFO (see Appendix B). Our results provide further support for the role of optimism on the reluctance to sell losing assets.

*Difficulty recognizing errors* also has a significant positive effect on the DE. Like *optimism*, it reduces the PLR, while having no effect on the PGR. Again, this result is robust to all reference price specifications except LIFO. This finding confirms an observation originally made by Gross (1982) and cited by Shefrin and Statman (1985) as one possible cause of the DE. Namely, that “investors are also reluctant to accept and realize losses because the very act of doing so proves that their first judgment was wrong” (Gross, 1982, p. 150). Other studies point towards this

---

<sup>16</sup> On the other hand, our result of no gender differences in the DE contradicts previous experimental studies. In particular, Da Costa *et al.* (2008) find that only men fall into the DE when using alpha as the measure of the DE. On the other hand, Rau (2014) reports values of the DE using the LIFO rule and finds significant gender differences. In particular, he finds a negative average DE for males and a positive one for females. There are a number of differences between our experimental set-up and that of Da Costa *et al.* (2008) and Rau (2014), which might explain the discrepancy of our results. First, in these studies all participants face the same market, which corresponds exactly to the price path in Weber and Camerer (1998). In our experiment, instead, each group faces a different market, with randomly generated price paths. Second, our sample is substantially larger. We have 192 subjects, roughly half for each gender. Rau’s sample is composed of 55 subjects, of which 28 are female; Da Costa *et al.* (2008) have 96 subjects, of which 52 are female. Finally, our experiment is incentivized, whereas Da Costa *et al.* (2008) use hypothetical payoffs.

interpretation of the DE, for instance, by showing that the DE disappears when losing stocks are “inherited” rather than purchased directly by the investor (Jin and Scherbina, 2010; Lehenkari, 2012; Summers and Duxbury, 2012; Chang *et al.*, 2015).

Although *optimism* and *difficulty recognizing errors* have very similar effects, they constitute two distinct mechanisms. For instance, the raw variables are uncorrelated ( $\rho = -0.086$ ,  $p = 0.236$ ). Our interpretation is that the main channel through which optimism and difficulty recognizing errors reduce the willingness to realize losses is via their impact on beliefs. In this respect, optimism can be understood as an upward bias on the beliefs about future price changes of an individual’s assets *regardless* of the involvement of the individual in the original investment decision. On the other hand, difficulty recognizing errors would entail an upward bias on the beliefs only for those assets that were personally purchased by the investor. In Study 2 we report the findings of two treatments that have been specifically designed around these working hypotheses.

## 4 Study 2

### 4.1 Design

For Experiment 2 we recruited 96 subjects, 52 males and 44 females. Subjects were again undergraduates of the University of Alicante, although participants in Experiment 1 were excluded from the subject pool of Experiment 2. We conducted a total of 4 sessions with 24 subjects in each session. As before, the experiment was programmed in z-Tree (Fischbacher, 2007) and recruitment was carried out using ORSEE (Greiner, 2004). Average payment was 19€ for an experiment lasting, on average, two hours.<sup>17</sup>

As before, there were 4 treatments and all subjects participated in all of them. Subjects were matched randomly into groups of 4 as in Experiment 1. The baseline treatment (B) was identical to that of Experiment 1. The rebates treatment (R) was also identical to the transaction costs treatment in Experiment 1 with the exception that subjects received a 50% rebate on realized losses at the end of the treatment.<sup>18</sup> Our aim here was to assess whether this policy might mitigate the DE.<sup>19</sup> The remaining two treatments, which we call allocate treatment (A) and choose treatment (CH), were primarily designed to study subjects’ price beliefs. The order was counterbalanced from session to session.<sup>20</sup>

As always, subjects in A and CH could see the price paths of 6 risky assets, which behaved in the same way as in Experiment 1. In these two treatments, however, subjects could not buy or sell

---

<sup>17</sup> We adjusted the exchange rate downwards to 1,500 pesetas = 1€ to keep average payoffs similar to Experiment 1.

<sup>18</sup> These were calculated according the weighted average rule. A simple explanation relying on examples was given in the Instructions (see Appendix C).

<sup>19</sup> We thank an anonymous reviewer for suggesting this treatment.

<sup>20</sup> Session 1: B, R, A, CH. Session 2: R, B, CH, A. Session 3: A, CH, B, R. Session 4: CH, A, R, B.

any assets until period 5, and were instead asked to forecast the direction of price movement of each asset from period to period. Each correct guess was rewarded with 100 pesetas. In period 5, 10 units of each of 3 randomly selected assets were given to each subject in A.<sup>21</sup> In CH, subjects were asked to choose 3 assets and to purchase 10 units of each also in period 5. In both treatments, the cost of these assets was deducted from their initial cash endowment of 5,000 pesetas. From period 6 to 9, subjects continued making forecasts as before and were not allowed to buy or sell any assets. Finally, after making price guesses in period 9, subjects could freely sell as many units of each owned asset as they wished. Profits were then calculated as the sum of their cash endowment plus the value of their remaining assets at period 10 prices.

## **4.2 Results**

### **4.2.1 Baseline and Rebates treatments**

Mean values for DE, PGR and PLR for B and R are displayed in Appendix B (Table B7). We do not find support for the effectiveness of rebates at reducing the DE (B vs R, Wilcoxon test,  $p = 0.767$ ). As expected, we find no significant differences in the DE in B between Study 1 and 2 (Mann-Whitney test,  $p = 0.329$ ). DE in T (Study 1) and in R were also not significantly different from each other (Mann-Whitney test,  $p = 0.514$ ), again suggesting that rebates were not able to mitigate the DE.

### **4.2.2 Choose and Allocate treatments**

A natural interpretation of the evidence from Study 1 regarding *optimism* and *stubbornness* is that investors are reluctant to realize losses because they tend to have overly optimistic beliefs about the assets they own, particularly when believing otherwise would contradict their original investment decision. Such is the prediction of cognitive dissonance theory. The purpose of these last two treatments is to study price expectations in order to further test this hypothesis.

The first part of this hypothesis is that subjects have an optimistic element which may bias their beliefs about stocks they own, regardless of whether they were personally chosen by them or randomly allocated to them by the experimenter. The second part of the hypothesis is more specifically related to cognitive dissonance theory. In our experiment, cognitive dissonance would arise in a situation in which subjects must form beliefs about a purchased asset which is performing poorly. If this asset was personally chosen by the subject, cognitive dissonance would result in an upwards bias in the subject's beliefs about the asset. This bias should be present in CH but not in A, since it is only in CH that subjects make active investment decisions and thus experience cognitive dissonance.

---

<sup>21</sup> Subjects in the same group saw identical prices and received the same assets.

We derive three testable predictions from this hypothesis:

- *Optimism*: In both A and CH, and controlling for price levels, subjects believe that stocks that they own are more likely to appreciate than stocks that they do not own.
- *Stubbornness 1*: The above effect is larger in CH than in A.
- *Stubbornness 2*: Beliefs are less sensitive to prices in CH than in A for assets owned by the subjects.

To test these predictions, we estimate logit regressions in which the dependent variable (*GuessUp*) takes value 1 (0) if a subject guessed that a specific asset at a given period would go up (down) in price.

Recall that asset prices are all equal to 100 at period -3 and then move up or down with constant probabilities. This implies that an asset's current price is a sufficient statistic to estimate the probability that it will go up or down at any given period. A rational agent should therefore only use the current price to form price expectations. In particular, if the price of an asset is above 100, then it means that the asset has jumped up in price at least as many times as it has jumped down, so a rational agent should forecast the probability of an upward jump to be higher or equal to 0.5.<sup>22</sup> Such forecast should be closer to 1 the higher the price. We therefore include current price and the dummy variable *price100*, which equals 1 if the current price is above 100.

Estimation results are presented in Table 2 and the relevant marginal effects are shown in Table 3.<sup>23</sup> The first two predictions are clearly supported by the data: owning an asset significantly increases the likelihood that subjects guess its price will go up (*Optimism*), and this effect is much stronger in CH (*Stubbornness 1*). The left panel of Table 2 displays the effect of owning an asset for each treatment. The estimated effects are 0.038 ( $p=0.037$ ) in A and 0.137 ( $p<0.001$ ) in CH, which correspond to increases in the probability of an upward guess of approximately 4 and 14 percentage points, respectively. The difference between these two effects is highly significant (Chi-squared test,  $p<0.001$ ).

---

<sup>22</sup> If the size of upward and downward jumps were equal, then a price of 100 would indicate that an asset has had the same number of upward jumps than downward jumps. Therefore, subjects should guess "down" if the asset price is below 100 and "up" if it is above 100. In our experiment, upward jumps are slightly bigger than downward jumps (6% vs 5%), so, for example, an asset that has jumped up and down the same number of times would have a price of 101.4 in period 1, 102.1 in period 3, 102.8 in period 5 and so on. However, since price jumps are of discrete size, using 100 as the cut-off turns out to separate assets into those with equal or higher upward jumps than downward jumps equally well.

<sup>23</sup> We also estimated OLS regressions as a robustness check with similar results.

**Table 2.** Logit regressions. Dependent variable is  $GuessUp=1$  ( $=0$ ) if a subject guesses that the price of a stock will go up (down).

VARIABLES	(1)	(2)
CH	-0.306** (0.141)	-0.703 (0.477)
Owned	0.168** (0.0810)	-0.0301 (0.515)
CH×Owned	0.448*** (0.116)	2.157*** (0.740)
Price	0.0113*** (0.00276)	0.0182*** (0.00307)
CH×Price		0.00379 (0.00460)
Owned×Price		0.00169 (0.00493)
CH×Owned×Price)		-0.0160** (0.00701)
Price100	0.308*** (0.0846)	
Observations	10,260	10,260

Models 1 and 2 include subject and group fixed effects. Each group of four individuals face the same asset prices. Standard errors (in parentheses) are clustered by the interaction of subject and asset. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

In order to estimate the different impact of an asset's current price in each treatment, Model (2) in Table 2 drops *price100* and interacts current price with treatment and ownership conditions. The right panel of Table 3 reports the estimated marginal effects from this regression. The current price has a highly significant effect on subjects' guesses in all conditions ( $p < 0.001$ ) except in the case of owned assets in CH ( $p = 0.055$ ). The magnitude of the effect is 3 to 4 times larger when subjects are either in A or do not own the asset. We reject the null that these four marginal effects are equal (Chi-squared test,  $p = 0.005$ ), and cannot reject that the first three effects are equal (Chi-squared test,  $p = 0.659$ ). We also run three pairwise Chi-squared tests comparing the case of owned assets in CH with the other three cases. In all of them we reject the null that the effect is the same.<sup>25</sup> In sum, the third prediction (*Stubbornness 2*) is also supported by the data.

<sup>25</sup> CH=1 & Owned=1 vs. CH=0 & Owned=0,  $p = 0.011$ ; CH=1 & Owned=1 vs. CH=0 & Owned=1,  $p = 0.016$ ; CH=1 & Owned=1 vs. CH=1 & Owned=0,  $p = 0.0006$ .

**Table 3.** Marginal effects (probabilities) from regressions in Table 2.

	Effect of Owned		Effect of Price
CH=0	0.0384** (0.0184)	CH=0 & Owned=0	0.00423*** (0.000682)
CH=1	0.137*** (0.0181)	CH=0 & Owned=1	0.00448*** (0.000910)
		CH=1 & Owned=0	0.00516*** (0.000761)
		CH=1 & Owned=1	0.00155* (0.000808)

Left panel: Effect of Owned on *GuessUp* disaggregated by treatment, based on estimation results from model (1) of Table 2. Right panel: Effect of Price on *GuessUp* disaggregated by Treatment and Owned, based on estimation results from model (2) of Table 2. Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Figure 1 illustrates the sensitivity of subjects' beliefs to current prices in each treatment. We group prices of owned assets from period 5 onwards into 8 bins and compute the average guess in A and CH separately. Several patterns emerge which help to illustrate the results from the previous regressions. Firstly, the proportion of upward guesses about owned assets is increasing in the current price in A, but this pattern is much less pronounced in CH. Secondly, the difference between the two treatments is most pronounced in the lower range of prices. In particular, while expectations become increasingly pessimistic in A as prices fall below 100, they remain fairly stable and high in CH.

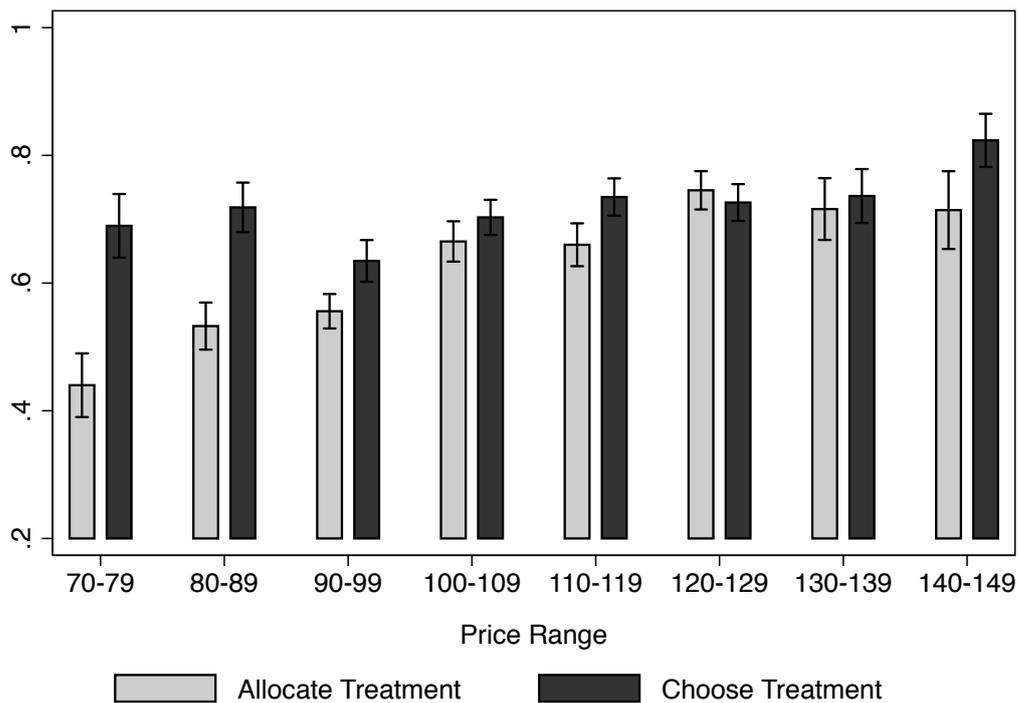
Before moving onto selling behavior, we briefly investigate whether subjects make reasonable choices in the buying stage of period 5 in CH. A rational agent should purchase the 3 stocks with the highest price. If there were no ties in prices, the average rank of her purchased assets (if rank=6 for the asset with the highest price, rank=5 for the asset with the second highest price, etc.) would be 5. With ties, the number can be somewhat lower, between 4 and 5. In contrast, random purchases would result in an average rank of 3.5. The average rank of purchased assets in period 5 is 4.09 in CH and 3.35 in A. As expected, we cannot reject the hypothesis that the average rank is 3.5 in A (Wilcoxon signed-rank test, p=0.201, N=96), but we can soundly reject this hypothesis in CH (p<0.001, N=96).

Turning to selling behavior in period 9, Table 4 presents mean DE, PGR and PLR in A and CH.<sup>26</sup> The DE is higher, and PLR lower in CH than in A. However, these differences are not statistically significant. Given that subjects only owned 3 assets and could only sell at a single period, our sample size is relatively small due to missing observations, particularly when carrying out paired tests. This is because, in order to measure the DE, a subject must own at least one

<sup>26</sup> Note that since all assets are bought in period 5, all criteria for computing the reference prices coincide in these treatments.

winning asset and one losing asset in period 9. This is the case for only 76 subjects in A, 68 in CH, and only 56 subjects have a defined DE in both treatments simultaneously (allowing us to perform paired tests). Another factor which may have reduced our ability to detect a treatment effect is the fact that the selling decision has a rather limited impact on subjects' payoffs, since all assets are liquidated in the following period anyway.

We study selling behavior in more detail by modeling the decision to sell an asset as a function of its current price (period 9), its purchase price (period 5) and whether a subject is in A or CH. A rational agent should only base her decision to sell on the current price, selling with lower probability the higher the price of the asset. In contrast, an agent who suffers from the DE would be more likely to sell if the current price was high and if the purchase price was low. Table 5 displays estimation results from two Tobit regressions and Table 6 displays the marginal effects of current price and purchase price.<sup>27</sup>



**Figure 1.** Proportion of upward guesses for owned assets for periods 5 onwards disaggregated by prices. Prices below 70 and above 149 are excluded due to insufficient observations. Vertical bars represent standard errors.

<sup>27</sup> We use Tobit regressions because selling data is bounded between 0 and 10. However, results are robust to alternative specifications such as OLS.

**Table 4.** Mean DE, PGR and PLR in the Allocate and Choose treatments.

	DE	PGR	PLR
<i>Allocate</i>	0.126*	0.528	0.436
	(0.067)	(0.039)	(0.043)
<i>N</i>	76	96	76
<i>Choose</i>	0.163**	0.552	0.369
	(0.067)	(0.040)	(0.041)
<i>N</i>	68	87	77
<i>p-value</i>	0.828 ( <i>N</i> =56)	0.808 ( <i>N</i> =87)	0.530 ( <i>N</i> =57)

*Note:* Wilcoxon signed-rank test of DE=0. Standard errors in parentheses. *p*-values from Wilcoxon signed-rank tests of treatment effects. \*\*  $p < 0.05$ , \*  $p < 0.1$

Model (1) in Table 5 includes period 9 forecasts about the asset's next price movement. As expected, subjects sell fewer assets when they expect their price to go up. Table 6 shows that, contrary to rationality and in line with the DE, the current price correlates positively and the purchase price negatively with selling. As expected, these effects appear substantially larger in CH than in A, especially if we do not control for beliefs. However, we cannot reject the hypothesis that the effects of current prices and purchase prices are equal in A and CH (Chi-squared tests,  $p=0.2755$  and  $p=0.2761$ , respectively).

**Table 5.** Tobit regression. Dependent variable: sales in period 9.

VARIABLES	(1)	(2)
Price	0.103**	0.0700
	(0.0484)	(0.0497)
CH	2.765	0.763
	(4.476)	(4.432)
CH×Price	0.0311	0.0535
	(0.0488)	(0.0491)
Purchase Price	-0.0982*	-0.0879
	(0.0552)	(0.0587)
CH×(Purchase Price)	-0.0683	-0.0716
	(0.0650)	(0.0657)
GuessUp	-3.489***	
	(0.974)	
Observations	576	576

Models 1 and 2 include subject and group fixed effects. Each group of four individuals face the same asset prices. Standard errors are clustered by subject. Robust standard errors in parentheses; \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

**Table 6.** Marginal effects from regressions in Table 5.

	Effect of Price			Effect of Price <sup>5</sup>	
	(1)	(2)		(1)	(2)
CH=0	0.103** (0.0484)	0.0700 (0.0498)	CH=0	-0.0982* (0.0552)	-0.0879 (0.0587)
CH=1	0.134*** (0.0384)	0.123*** (0.0389)	CH=1	-0.167*** (0.0506)	-0.159*** (0.0505)

Left panel: Effect of current price on selling disaggregated by treatment estimated from models (1) and (2) in Table 5. Right panel: Effect of purchase price on selling. Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## 5 Summary and Conclusions

In Study 1, we investigate the possible psychological causes of the DE by administering a questionnaire at the end of a standard trading experiment covering various psychological measures suggested in the literature to contribute to the DE. These include self-control, decisiveness, optimism, difficulty recognizing errors, financial literacy and a reduced version of the Big Five personality questionnaire. Out of all of these, *optimism* and *difficulty recognizing errors* turn out to be the only significant psychological predictors of subjects' PLR and DE. In particular, our findings suggest that both factors increase the DE by making individuals more reluctant to sell losing assets, while having no effect on the PGR.

With regards to *optimism*, our results have an intuitive interpretation: subjects postpone the sale of losing assets under the optimistic belief that their investments will eventually turn out to be profitable. With regards to *difficulty recognizing errors*, the fact that it increases the DE by reducing the PLR provides direct evidence that “*investors are also reluctant to accept and realize losses because the very act of doing so proves that their first judgment was wrong*” (Gross, 1982, p. 150; Shefrin and Statman, 1985).

In Study 2, we further test the implications of these findings by systematically measuring beliefs while tightly controlling the investment decision. Throughout treatments A and CH, subjects were not allowed to make any purchases or sales (except at period 5) and were asked to forecast whether each asset would go up or down in price in each period. At period 5 of treatment A, 3 out of the 6 available assets were randomly selected and 10 units of each of these assets were purchased on behalf of the subjects. In CH, these 3 assets had to be chosen by the subjects themselves. Finally, in period 9 subjects could sell as many units as they wished.

Supporting the intuitions of Study 1, we observe that subjects are more optimistic about assets that they own than about other assets in both A and CH. Regardless of owning an asset or not, subjects in A update their beliefs upwards (downwards) when an asset's price goes up (down), in line with Bayesian inference. In CH, however, subjects become almost unresponsive to prices once the asset has been purchased, resulting in highly optimistic predictions regardless of the current price. Consequently, beliefs in CH are particularly biased upward for owned losing assets.

These findings support the notion that investors may be reluctant to sell losing assets because they are unwilling to revise their beliefs due to cognitive dissonance.

The idea of optimistic and stubborn beliefs can help to explain several striking results in the literature. For instance, it illustrates why small investors are slower to sell losers during optimistic periods than during pessimistic periods (Antoniou *et al.*, 2013). It also explains why investors tend to find it much easier to sell losers when doing so does not reflect badly on their own initial judgment, such as when the assets are initially purchased by the experimenter (Summers and Duxbury, 2012), when they are received as gifts (Lehenkari, 2012), when they are inherited from a previous fund manager (Jin and Scherbina, 2010), or when an external manager can be blamed (Calvet *et al.* 2009; Ivković and Weisbenner, 2009; Chang *et al.* 2016). Our experiments add further support to the cognitive dissonance interpretation of the DE suggested by these studies and identify the important role played by psychological characteristics and biased beliefs.

## References

- Antoniou, C., Doukas, J. A. and Subrahmanyam, A., 2013, "Cognitive Dissonance, Sentiment, and Momentum," *Journal of Financial and Quantitative Analysis*, 48, 1, 245–275.
- Arkes, H., Hutzler, L., 2000, "The Role of Probability of Success Estimates in the Sunk Cost Effect," *J. of Behavioral Decision Making* 13, 295-306.
- Barber, B., Lee, Y., Liu, Y. and Odean, T., 2007, "Is the Aggregate Investor Reluctant to Realize Losses? Evidence from Taiwan," *European Financial Management*, 13, 3, 423–447.
- Barberis, N. and Xiong, W., 2009, "What Drives the Disposition Effect? An Analysis of a Long-Standing Explanation," *The Journal of Finance*, 64, 2, 751–784.
- Barberis, N. and Xiong, W., 2012, "Realization utility," *Journal of Financial Economics*, 104, 2, 251–271.
- Ben-David, I., and Hirshleifer, D., 2012, "Are Investors Really Reluctant to Realize Their Losses? Trading Responses to Past Returns and the Disposition Effect." *Review of Financial Studies* 25, 8, 2485–2532.
- Benet-Martinez, V. and John, O., 1998, "Los Cinco Grandes across cultures and ethnic groups: Multitrait-multimethod analyses of the Big Five in Spanish and English," *Journal of Personality and Social Psychology*, 75, 3, 729–750.
- Brown, P., Chappel, N., da Silva Rosa, R., and Walter, T., 2006, "The Reach of the Disposition Effect: Large Sample Evidence across Investor Classes," *International Review of Finance*, 6, 1-2, 43–78.
- Calvet, L., Campbell, J. and Sodini, P., 2009, "Fight or flight? Portfolio rebalancing by individual investors," *Quarterly Journal of Economics*, 124, 1, 301–348.
- Chang, T., Solomon, D. and Westerfield, M., 2016, "Looking for Someone to Blame: Delegation, Cognitive Dissonance, and the Disposition Effect," *The Journal of Finance*, 71, 1, 267–302.
- Chui, P. M., 2001, "An experimental study of the disposition effect: Evidence from Macau," *The Journal of Psychology and Financial Markets*, 2, 4, 216–222.
- Ciccone, S. J., 2011, "Investor optimism, false hopes and the January effect," *Journal of Behavioral Finance*, 12, 3, 158–168.
- Da Costa, N., Mineto, C. and Da Silva, S., 2008, "Disposition effect and gender," *Applied*

Economics Letters, 15, 6, 411–416.

Da Costa, N., Goulart, M., Cupertino, C., Macedo, J. and Da Silva, S., 2013, “The Disposition Effect and Investor Experience,” *Journal of Banking and Finance* 37, 5, 1669–1675.

Dhar, R. and Zhu, N., 2006, “Up Close and Personal: An individual Level Analysis of the Disposition Effect,” *Management Science*, 52, 5, 726–740.

Diether, K. B., Malloy, C. J. and Scherbina, A., 2002, “Differences of opinion and the cross section of stock returns,” *The Journal of Finance*, 57, 5, 2113–2141.

Duxbury, D., 2015, “Behavioral Finance: Insights from Experiments II: Biases, Moods and Emotions,” *Review of Behavioral Finance*, 7, 2, 151–175.

Feng, L. and Seasholes, M., 2005, “Do investor sophistication and trading experience eliminate behavioral biases in finance markets?” *Review of Finance* 9, 3, 305–351.

Ferris, S., Haugen, R. and Makhija, A., 1988, “Predicting Contemporary Volume with Historic Volume at Differential Price Levels: Evidence Supporting the Disposition Effect.” *The Journal of Finance* 43, 3, 677–97.

Festinger, L., 1957, “A Theory of cognitive dissonance,” Stanford University Press, Stanford, CA.

Fischbacher, U., 2007, “z-Tree: Zurich Toolbox for Ready-made Economic Experiments,” *Experimental Economics*, 10, 2, 171–178.

Frydman, C., Barberis, N., Camerer, C., Bossaerts, P. and Rangel, A., 2014, “Using neural data to test a theory of investor behavior: an application to realization utility,” *The Journal of Finance* 79, 2, 907–945.

Frydman, C., and Camerer, C., 2016, “Neural Evidence of Regret and Its Implications for Investor Behavior,” *Review of Financial Studies* 29, 11, 3108-3139.

Germeijs, V., and De Boeck, P., 2002, “A measurement scale for indecisiveness and its relationship to career indecision and other types of indecision,” *European Journal of Psychological Assessment*, 18, 2, 113–122.

Greiner, B., 2004, “The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics,” University of Cologne WP Series in Economics 10.

Grinblatt, M., and Keloharju, M., 2000, “The investment behavior and performance of various investor types: a study of Finland's unique data set,” *Journal of Financial Economics* 55, 1, 43–

67.

Grinblatt, M. and Keloharju, M., 2001, "What Makes Investors Trade?" *The Journal of Finance*, 56, 2, 549–578.

Gross, L., 1982, "The art of selling intangibles: How to make your million (\$) by investing other people's money," Prentice Hall.

Hirshleifer, D., 2001, "Investor Psychology and Asset Pricing." *The Journal of Finance* 56, 4, 1533–97.

Hmieleski, K., and Baron, R., 2009, "Entrepreneurs' optimism and new venture performance: A social cognitive perspective," *Academy of Management Journal*, 52, 3, 473-488.

Holt, C. and Laury, S., 2002, "Risk aversion and incentive effects," *American Economic Review*, 92, 5, 1644–1655.

Ingersoll, J. and Jin, L., 2013, "Realization utility with reference-dependent preferences," *Review of Financial Studies* 26, 723–767.

Ivković, Z. and Weisbenner, S., 2009, "Individual Investor Mutual Fund Flows," *Journal of Financial Economics*, 92, 2, 223–237.

Jin, L. and Scherbina, A., 2010, "Inheriting losers," *Review of Financial Studies*, hhq084.

John, O. and Srivastava, S., 1999, "The big five trait taxonomy: History, measurement, and theoretical perspectives," In L. A. Pervin and O. P. John (eds.), *Handbook of Personality: Theory and Research*, 2nd edition, Guilford Press New York, NY, 102–138.

Kahneman, D. and Tversky, A., 1979, "Prospect theory: An analysis of decision under risk," *Econometrica*, 47, 2, 263–291.

Kaustia, M., 2010a, "Prospect theory and the disposition effect." *Journal of Financial and Quantitative Analysis* 45, 3, 791-812.

Kaustia, M., 2010b, "Disposition effect." Chapter 10 in *Behavioral Finance* (Robert W. Kolb Series in Finance), H. Kent Baker and John R. Nofsinger, eds., John Wiley & Sons, Inc.

Kohsaka, Y., Mardyla, G., Takenaka, S., and Tsutsui, Y., 2013, "Disposition effect and loss aversion: an analysis based on a simulated experimental stock market," GCOE Discussion Paper No. 296, Osaka University.

- Lehenkari, M., 2012, "In Search of the Underlying Mechanism of the Disposition Effect," *Journal of Behavioral Decision Making* 25, 2, 196–209.
- Lusardi, A. and Mitchell, O., 2011, "Financial Literacy around the World: An Overview," *Journal of Pension Economics and Finance*, 10, 4, 497–508.
- Lusardi, A. and Mitchell, O., 2014, "The Economic Importance of Financial Literacy: Theory and Evidence," *Journal of Economic Literature* 52, 1, 5–44.
- Magnani, J., 2015, "Testing for the Disposition Effect on Optimal Stopping Decisions," *American Economic Review: Papers & Proceedings*, 105, 5, 371–75.
- Odean, T., 1998, "Volume, Volatility, Price, and Profit when all Traders are above average," *Journal of Finance*, 53, 1887–1934.
- Odean, T., 1999, "Do Investors Trade Too Much?" *American Economic Review*, 89, 5, 1279-1298.
- Rau, H., 2014, "The disposition effect and loss aversion: Do gender differences matter?" *Economic Letters*, 123, 33–36.
- Rau, H., 2015, "The Disposition Effect in Team Investment Decisions: Experimental Evidence," *Journal of Banking and Finance* 61, 272–82.
- Shapira, Z. and Venezia, I., 2001, "Patterns of behavior of professionally managed and independent investors," *Journal of Banking and Finance*, 25, 8, 1573–1587.
- Shefrin, H. and Statman, M., 1985, "The disposition to sell winners too early and ride losers too long," *Journal of Finance*, 40, 777–790.
- Strahilevitz, M.A., Odean, T., Barber, B.M., 2011, "Once Burned, Twice Shy: How Naive Learning, Counterfactuals, and Regret Affect the Repurchase of Stocks Previously Sold," *Journal of Marketing Research*, 48, S102–S120.
- Summers, B. and Duxbury, D., 2012, "Decision-dependent emotions and behavioral anomalies," *Organizational Behavior and Human Decision Processes*, 118, 2, 226–238.
- Tangney, J., Baumeister, R., and Boone, A., 2004, "High Self-Control Predicts Good Adjustment, Less Pathology, Better Grades, and Interpersonal Success," *Journal of Personality*, 72, 2, 271–324.
- Thaler, R., and Shefrin, H., 1981, "An economic theory of self-control." *Journal of Political*

Economy, 89, 2, 392-406.

Weber, M., and Camerer, C., 1998, "The disposition effect in securities trading: an experimental analysis," *Journal of Economic Behavior and Organization* 33, 167–184.

Weber, M., and Welfens, F., 2007, "An Individual Level Analysis of the Disposition Effect: Empirical and Experimental Evidence," Working Paper No. 07-45. Universität Mannheim.

## Appendix A. Reference prices

In this appendix we discuss alternative reference price specifications in relation to our findings. The various alternatives to the weighted average price are the initial price, the last price, FIFO and LIFO. Lastly, we also consider alpha as an alternative measure of the DE.

To see how each of these reference prices is computed, suppose that an individual has 10 units of asset A in period 7. She bought 3 units in period 2 and 7 units in period 5. The initial price is the stock's price at period 1 (always 100 in our experiment). The last price reference would take the price of the asset in the previous period, i.e. period 6. FIFO and LIFO take the price at which that asset was purchased, according to a "first-in first-out" principle or a "last-in first-out" principle, respectively. In the example above, reference prices according to FIFO and LIFO are the price in period 2 and the price in period 5, respectively.

Table A1 presents mean values of the DE, PGR and PLR for our baseline treatment, using each of the five reference prices mentioned above.

**Table A1.** DE, PGR, and PLR in the baseline treatment for different reference prices

		Reference prices				
		Average	Initial	FIFO	LIFO	Last
<b>DE</b>	<b>Mean</b>	0.0685***	0.0177*	0.1205***	0.0243**	0.0994***
	<b>St. Error</b>	(0.0228)	(0.0244)	(0.0193)	(0.0171)	(0.0176)
	<b>Obs.</b>	163	154	164	145	165
	<b>p-value</b>	0.0021	0.0685	0.0000	0.0294	0.0000
<b>PGR</b>	<b>Mean</b>	0.2452	0.2222	0.2402	0.0901	0.2124
	<b>St. Error</b>	(0.0170)	(0.0151)	(0.0163)	(0.0115)	(0.0148)
	<b>Obs.</b>	164	164	164	145	165
<b>PLR</b>	<b>Mean</b>	0.1771	0.2109	0.1183	0.0608	0.1123
	<b>St. Error</b>	(0.0147)	(0.0192)	(0.0108)	(0.0106)	(0.0101)
	<b>Obs.</b>	164	155	166	157	166

Note: Standard errors in parentheses. From a total of 192 individuals, each reference price generated some missing observations. The line Obs. refers to the number of individuals used in each calculation. The p-values correspond to a Wilcoxon signed-rank test in which the null is that the corresponding DE is zero. We do not report p-values for PGR and PLR since all of them are below 0.0001. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

The values we get for the DE range from 0.0177 (initial price) to 0.1205 (FIFO). The weighted average yields the median value of the DE among the five reference prices. With respect to the PGR, all reference prices but LIFO yield similar results. We get more variation with the PLR, where again the lowest value corresponds to LIFO. We also calculate alpha, which is equal to 0.198 ( $\pm 0.0513$  SE).

Results in Table A1 are average values. It is interesting to see how individual DE measures computed according to different reference prices are correlated with each other. As Table A2

shows, all five measures are highly and positively correlated. However, while the measures of the DE calculated using the average price, the initial price, FIFO, and the last price exhibit correlation coefficients well above 0.5 (the smallest one is 0.6411), the correlation between the DE using LIFO and the other four measures is always below 0.5.<sup>30</sup> Pairwise Kolmogorov-Smirnov tests confirm that the LIFO rule results in a significantly different distribution of the DE than any other accounting rule ( $p < 0.001$ ). The correlation table includes alpha, which again shows a lower correlation with LIFO than with all other DE measures.

**Table A2.** Correlation matrix of DE in the baseline treatment using different reference prices.

	<b>Average</b>	<b>Initial</b>	<b>FIFO</b>	<b>LIFO</b>	<b>Last</b>
<b>Initial</b>	0.7069				
<b>FIFO</b>	0.9396	0.6846			
<b>LIFO</b>	0.4579	0.3779	0.4569		
<b>Last</b>	0.8327	0.6411	0.8585	0.4295	
<b>Alpha</b>	0.657	0.5713	0.64	0.4139	0.731

Note: p-values of all pairwise correlations  $< 0.0001$

The results in Table A2 highlight that the choice of a reference price may lead to substantially different measures of the DE. In particular, because of the low correlation of the measure of DE using LIFO with the other measures, results using this last measure can differ substantially from results using alternative measures (see Tables B2 – B4 in Appendix B).

To assess the adequacy of the different reference prices, we follow an approach similar to that of Kohsaka *et al.* (2013). At the end of the experiment we present subjects with a hypothetical price path and transaction history and ask them to rate the degree to which they agree with various ways of computing gains or losses associated with the last sale in the example (subjects are presented with two scenarios, one involving gains and one involving losses, see Appendix C).

The results of this survey are presented in Table A3. Consistently with Kohsaka *et al.* (2013), the *weighted average* reference price received the highest average rating. The results are similar for the loss and gain scenarios and across genders.

<sup>30</sup> We find the same result with the other three treatments, and also if we compute correlation coefficients separately by gender.

**Table A3.** Subjective evaluation of reference prices.

	Mean score Loss domain	Mean score Gains domain
<b>Initial Price</b>	3.8021 (2.4306)	4.0729 (2.4804)
<b>FIFO</b>	3.5208 (1.9411)	3.875 (2.0378)
<b>Average Price</b>	4.1458 (1.9357)	4.2708 (1.9867)
<b>LIFO</b>	3.5938 (2.1155)	3.5521 (2.0358)
<b>Last Price</b>	3.3021 (2.1281)	3.1563 (2.1586)
<b>Observations</b>	96	96

Note: Each column corresponds to the mean score received by each reference price in the questionnaire for the loss domain and the gain domain respectively (from *completely disagree* = 1 to *completely agree* = 7). Standard errors in parentheses. The number of observations is only 96 because we ask this question only in half of the sessions.

**Table A4.** DE for all treatments with different reference prices

Treatment		Reference prices					
		Average	Initial	FIFO	LIFO	Last	Alpha
<b>B</b>	<b>Mean</b>	0.0685***	0.0177*	0.1205***	0.0243**	0.0994***	0.1984***
	<b>St. Error</b>	(0.0228)	(0.0244)	(0.0193)	(0.0171)	(0.0176)	(0.0513)
	<b>Obs.</b>	163	154	164	145	165	162
	<b>p-value</b>	0.0021	0.0685	0.0000	0.0294	0.0000	0.0002
<b>C</b>	<b>Mean</b>	0.0703***	-0.0099	0.1031***	0.0275***	0.0678***	0.1605***
	<b>St. Error</b>	(0.0228)	(0.0228)	(0.0196)	(0.0097)	(0.0180)	(0.0498)
	<b>Obs.</b>	182	172	182	166	183	181
	<b>p-value</b>	0.0017	0.4125	0.0000	0.0003	0.0001	0.0020
<b>T</b>	<b>Mean</b>	0.1045***	0.0321***	0.1422***	0.0950***	0.0865***	0.2168***
	<b>St. Error</b>	(0.0189)	(0.0196)	(0.0163)	(0.0135)	(0.0140)	(0.0577)
	<b>Obs.</b>	179	171	186	153	188	171
	<b>p-value</b>	0.0000	0.0076	0.0000	0.0000	0.0000	0.0005
<b>CT</b>	<b>Mean</b>	0.0684***	0.0127	0.0968***	0.0459***	0.0585***	0.1506**
	<b>St. Error</b>	(0.0195)	(0.0225)	(0.0167)	(0.0122)	(0.0136)	(0.0542)
	<b>Obs.</b>	182	171	187	148	187	173
	<b>p-value</b>	0.0011	0.2482	0.0000	0.001	0.0007	0.0130

Note: Standard errors in parentheses. From a total of 192 individuals, each reference price generated some missing observations. The line Obs. refers to the number of individuals used in each calculation. The p-values correspond to a Wilcoxon signed-rank test in which the null is that the corresponding DE is zero. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Appendix B. Additional tables.

**Table B1.** Summary statistics of the individual measures

VARIABLES	Mean	Std. Dev.	Min	Max	Obs	Cronbach's $\alpha$
DE	0.0797	0.2228	-0.6282	0.7134	192	
PGR	0.2279	0.1884	0	0.8472	192	
PLR	0.1470	0.1349	0	0.7843	192	
Female	0.5052	0.5013	0	1	192	
Optimism	4.8229	1.3420	1	7	192	
Risk	4.6615	1.5536	1	7	192	
Confidence	4.7604	1.5195	1	7	192	
Not Recognize Errors	3.9479	1.6681	1	7	192	
Competitiveness	4.9740	1.5933	1	7	192	
Enjoys Winning	5.9010	1.3047	2	7	192	
Decisiveness	3.2708	1.7183	1	7	192	
Self-control	42.1719	9.3443	20	67	192	0.7061
Optimism dummy	0.6302	0.4840	0	1	192	
Risk dummy	0.5729	0.4959	0	1	192	
Confidence dummy	0.6146	0.4880	0	1	192	
Not Recognize Errors dummy	0.5833	0.4943	0	1	192	
Competitiveness dummy	0.6458	0.4795	0	1	192	
Enjoys Winning dummy	0.6875	0.4647	0	1	192	
Decisiveness dummy	0.5990	0.4914	0	1	192	
Self-control dummy	0.5365	0.5000	0	1	192	
High Confidence	0.3372	0.3204	0	1	192	
High Financial Literacy	0.3802	0.4867	0	1	192	
High Grades	0.6198	0.4867	0	1	192	
>1 Switches	0.2188	0.4145	0	1	192	
Neuroticism	4.1128	1.1998	1.5	7	192	0.7758
Extraversion	4.3896	1.3874	1	7	192	0.8392
Agreeableness	4.7969	0.7378	2.4	7	192	0.3043
Openness	5.2314	0.9016	2.8571	7	192	0.6882
Conscientiousness	5.0490	0.9537	2.4	7	192	0.6633
Art	0.1042	0.3063	0	1	192	
Health	0.3177	0.4668	0	1	192	
Science	0.0990	0.2994	0	1	192	
Engineering	0.1771	0.3827	0	1	192	
Social Sciences	0.3021	0.4604	0	1	192	

Note: DE, PGR, and PLR are calculated with weighted average reference price. Cronbach's  $\alpha$ , a measure of internal consistency, is only relevant for measures involving multiple items. For the Big 5 and Self-control measures, we find  $\alpha$  levels very close to those of the original studies, with the exception of Agreeableness. This trait, however, was originally found to display the lowest internal consistency out of the five traits (Benet-Martinez and John, 1998).

**Table B2.** Disposition Effect according to each reference price

VARIABLES	Average Price	Initial Price	FIFO	LIFO	Last Price	Alpha
<b>Female</b>	0.00666 (0.0391)	0.0525 (0.0508)	0.0102 (0.0363)	-0.00477 (0.0291)	0.00773 (0.0324)	0.00257 (0.0982)
<b>C</b>	0.000574 (0.0318)	-0.0318 (0.0389)	-0.0217 (0.0274)	0.00794 (0.0264)	-0.0380 (0.0318)	-0.0724 (0.0778)
<b>T</b>	0.0207 (0.0427)	0.00587 (0.0425)	0.0264 (0.0357)	0.0535* (0.0293)	-0.0159 (0.0312)	-0.0339 (0.0846)
<b>CT</b>	-0.00234 (0.0352)	-0.00741 (0.0510)	-0.0245 (0.0314)	0.00249 (0.0339)	-0.0540* (0.0281)	-0.0841 (0.0779)
<b>Female*C</b>	0.0166 (0.0366)	0.0263 (0.0550)	0.0209 (0.0324)	-0.00394 (0.0319)	0.0244 (0.0371)	0.0880 (0.0999)
<b>Female*T</b>	0.0267 (0.0481)	0.0265 (0.0525)	-0.00181 (0.0399)	0.0302 (0.0344)	0.0218 (0.0325)	0.121 (0.106)
<b>Female*CT</b>	0.0152 (0.0346)	0.0231 (0.0554)	0.0155 (0.0329)	0.0340 (0.0411)	0.0400 (0.0288)	0.0976 (0.110)
<b>Experience2</b>	-0.0369 (0.0239)	-0.0310 (0.0235)	-0.0314 (0.0213)	-0.0373* (0.0199)	-0.0451** (0.0190)	-0.0944* (0.0515)
<b>Experience3</b>	-0.0377 (0.0275)	-0.0564* (0.0303)	-0.0338 (0.0214)	-0.0117 (0.0214)	-0.0604*** (0.0219)	-0.110 (0.0709)
<b>Experience4</b>	-0.0680*** (0.0249)	-0.0649** (0.0263)	-0.0629*** (0.0219)	-0.0523** (0.0205)	-0.0863*** (0.0210)	-0.241*** (0.0630)
<b>Optimism</b>	0.0713** (0.0341)	0.0861*** (0.0334)	0.0574** (0.0284)	0.00687 (0.0180)	0.0501** (0.0232)	0.228*** (0.0851)
<b>Risk</b>	-0.0240 (0.0325)	-0.0334 (0.0339)	-0.0171 (0.0285)	-0.00850 (0.0183)	-0.0227 (0.0263)	-0.0643 (0.0926)
<b>Confidence</b>	-0.0554 (0.0343)	-0.0507 (0.0354)	-0.0446 (0.0289)	0.00673 (0.0197)	-0.0439* (0.0234)	-0.0837 (0.0976)
<b>Difficulty recognizing errors</b>	0.0878*** (0.0295)	0.0790*** (0.0294)	0.0705*** (0.0270)	0.0381** (0.0152)	0.0538*** (0.0205)	0.169** (0.0711)
<b>Competitiveness</b>	0.0448 (0.0392)	0.0443 (0.0399)	0.0382 (0.0335)	-0.00289 (0.0194)	0.0328 (0.0276)	0.135 (0.108)
<b>Enjoys Winning</b>	-0.0481 (0.0298)	-0.0635* (0.0353)	-0.0361 (0.0263)	-0.0139 (0.0153)	-0.0480** (0.0211)	-0.145* (0.0865)
<b>Decisiveness</b>	-0.0153 (0.0355)	0.00198 (0.0361)	-0.0162 (0.0320)	-0.0142 (0.0167)	-0.0332 (0.0263)	-0.0666 (0.0851)
<b>Self-control</b>	0.0593 (0.0410)	0.0430 (0.0354)	-0.0506 (0.0387)	-0.0221 (0.0226)	0.0509 (0.0315)	0.108 (0.109)
<b>High Confidence</b>	-0.00963 (0.0222)	0.0138 (0.0243)	-0.00754 (0.0214)	-0.00178 (0.0160)	0.00842 (0.0190)	0.0437 (0.0542)
<b>High Financial Literacy</b>	-0.0331 (0.0385)	-0.0343 (0.0327)	-0.0263 (0.0327)	0.0113 (0.0213)	-0.0155 (0.0240)	-0.0415 (0.0728)
<b>High Grades</b>	-0.00124 (0.0365)	0.0288 (0.0361)	-0.00559 (0.0331)	-0.0110 (0.0189)	-0.00813 (0.0260)	-0.00627 (0.0881)
<b>&gt;1 Switches</b>	0.0108 (0.0384)	0.0141 (0.0348)	0.00223 (0.0322)	0.0166 (0.0179)	0.0154 (0.0298)	-0.0342 (0.107)

<b>Neuroticism</b>	0.0145 (0.0174)	0.0205 (0.0184)	0.0182 (0.0169)	0.00143 (0.00981)	0.0176 (0.0133)	0.0573 (0.0476)
<b>Extraversion</b>	0.0163 (0.0139)	-0.000608 (0.0137)	0.0194 (0.0124)	0.0111 (0.00819)	0.0173 (0.0110)	0.00396 (0.0461)
<b>Agreeableness</b>	-0.0144 (0.0178)	-0.0162 (0.0181)	-0.0189 (0.0151)	-0.0115 (0.00737)	-0.00905 (0.0126)	0.00542 (0.0389)
<b>Openness</b>	0.0236* (0.0139)	0.0301** (0.0140)	0.0210* (0.0122)	0.00169 (0.00727)	0.0115 (0.0100)	0.0403 (0.0315)
<b>Conscientiousness</b>	-0.00417 (0.0196)	0.00333 (0.0155)	-0.00436 (0.0177)	-0.00469 (0.00810)	-0.00644 (0.0138)	-0.0261 (0.0451)
<b>Art</b>	-0.0150 (0.0460)	0.0402 (0.0435)	-0.0144 (0.0405)	-0.0119 (0.0215)	-0.0105 (0.0400)	-0.0532 (0.111)
<b>Health</b>	0.0313 (0.0448)	-0.000513 (0.0395)	0.0148 (0.0388)	-0.0192 (0.0240)	0.00622 (0.0303)	0.0602 (0.104)
<b>Science</b>	0.0256 (0.0494)	-0.00936 (0.0461)	0.0130 (0.0438)	-0.0294* (0.0173)	0.00594 (0.0382)	0.117 (0.144)
<b>Engineering</b>	-0.0984** (0.0477)	-0.103** (0.0424)	-0.0803*** (0.0307)	-0.0314 (0.0239)	-0.0671** (0.0293)	-0.146 (0.130)
<b>Constant</b>	0.0514 (0.0846)	-0.0407 (0.0772)	0.162** (0.0768)	0.0686* (0.0370)	0.134** (0.0638)	0.152 (0.214)
<b>Observations</b>	706	668	719	612	723	687
<b>Number of id</b>	192	192	192	191	192	192

Note: We show the coefficients of six different regressions in which the dependent variables is DE. We use a different definition of reference price in each case. The set of regressors is the same in the six regressions. All variables except Female, Treatment and Experience standardized to zero mean and unit standard deviation. Robust standard errors clustered by group and session in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table B3.** Proportion of Gains Realized (PGR) according to each reference price

VARIABLES	Average Price	Initial Price	FIFO	LIFO	Last Price
<b>Female</b>	-0.0459 (0.0315)	-0.0254 (0.0321)	-0.0378 (0.0313)	0.00757 (0.0231)	-0.0414 (0.0296)
<b>C</b>	0.00172 (0.0245)	-0.0230 (0.0213)	-0.0111 (0.0234)	0.0177 (0.0179)	-0.0176 (0.0232)
<b>T</b>	-0.0584** (0.0296)	-0.0636*** (0.0227)	-0.0506* (0.0293)	0.0163 (0.0231)	-0.0775*** (0.0234)
<b>CT</b>	-0.0916*** (0.0262)	-0.0708*** (0.0225)	-0.0878*** (0.0256)	-0.0148 (0.0228)	-0.0985*** (0.0209)
<b>Female*C</b>	0.0203 (0.0288)	0.0260 (0.0290)	0.0330 (0.0264)	-0.0294 (0.0236)	0.0282 (0.0278)
<b>Female*T</b>	0.0598* (0.0350)	0.0557* (0.0290)	0.0528 (0.0337)	0.0253 (0.0271)	0.0691** (0.0280)
<b>Female*CT</b>	0.0809*** (0.0294)	0.0504 (0.0308)	0.0790*** (0.0285)	0.0117 (0.0300)	0.0837*** (0.0264)
<b>Experience2</b>	-0.0193 (0.0196)	-0.0129 (0.0141)	-0.0181 (0.0193)	-0.0297** (0.0138)	-0.0234 (0.0160)
<b>Experience3</b>	-0.0198 (0.0199)	-0.0176 (0.0135)	-0.0199 (0.0193)	-0.00249 (0.0167)	-0.0379** (0.0175)
<b>Experience4</b>	-0.0507*** (0.0157)	-0.0356*** (0.0134)	-0.0508*** (0.0161)	-0.0349** (0.0166)	-0.0631*** (0.0140)
<b>Optimism</b>	0.00993 (0.0350)	0.00687 (0.0327)	0.0135 (0.0339)	-0.00102 (0.0163)	0.00473 (0.0274)
<b>Risk</b>	-0.0213 (0.0311)	-0.0193 (0.0298)	-0.0177 (0.0298)	0.00903 (0.0153)	-0.0162 (0.0267)
<b>Confidence</b>	-0.00764 (0.0346)	0.00687 (0.0332)	-0.00381 (0.0343)	0.0166 (0.0184)	-0.00208 (0.0293)
<b>Difficulty recognizing errors</b>	0.0344 (0.0300)	0.0226 (0.0275)	0.0303 (0.0298)	0.0247** (0.0124)	0.0143 (0.0239)
<b>Competitiveness</b>	0.0141 (0.0290)	-0.00819 (0.0261)	0.0109 (0.0291)	-0.0156 (0.0142)	0.00632 (0.0232)
<b>Enjoys Winning</b>	-0.0396 (0.0258)	-0.0329 (0.0257)	-0.0364 (0.0272)	-0.0237** (0.0118)	-0.0417** (0.0196)
<b>Decisiveness</b>	-0.0274 (0.0358)	-0.00560 (0.0349)	-0.0247 (0.0359)	-0.0174 (0.0149)	-0.0319 (0.0302)
<b>Self-control</b>	0.0575* (0.0307)	0.0485* (0.0254)	-0.0358 (0.0345)	-0.00314 (0.0193)	0.0390 (0.0249)
<b>High Confidence</b>	-0.0142 (0.0193)	0.0126 (0.0154)	-0.00737 (0.0186)	-0.0105 (0.0136)	-0.00885 (0.0147)
<b>High Financial Literacy</b>	-0.0193 (0.0333)	-0.0293 (0.0258)	-0.0235 (0.0320)	0.0114 (0.0173)	-0.0209 (0.0243)
<b>High Grades</b>	-0.00268 (0.0322)	0.00982 (0.0277)	-0.00240 (0.0326)	-0.0133 (0.0175)	-0.00742 (0.0251)
<b>&gt;1 Switches</b>	0.00885 (0.0291)	0.0142 (0.0246)	0.00359 (0.0284)	0.0101 (0.0154)	0.0129 (0.0248)

<b>Neuroticism</b>	0.0189 (0.0180)	0.0196 (0.0172)	0.0174 (0.0178)	0.000643 (0.00835)	0.0167 (0.0144)
<b>Extraversion</b>	0.0149 (0.0153)	0.00319 (0.0137)	0.0154 (0.0145)	-0.00189 (0.00672)	0.0111 (0.0130)
<b>Agreeableness</b>	-0.0193 (0.0160)	-0.0123 (0.0151)	-0.0208 (0.0162)	-0.00519 (0.00659)	-0.0112 (0.0131)
<b>Openness</b>	0.0207 (0.0132)	0.0191 (0.0119)	0.0177 (0.0126)	0.00266 (0.00521)	0.0135 (0.0117)
<b>Conscientiousness</b>	-0.00800 (0.0167)	-0.00488 (0.0125)	-0.00425 (0.0165)	-0.00260 (0.00802)	-0.00596 (0.0129)
<b>Art</b>	-0.0538 (0.0462)	-0.0339 (0.0359)	-0.0576 (0.0462)	-0.0275 (0.0195)	-0.0540 (0.0380)
<b>Health</b>	-0.0210 (0.0387)	-0.0157 (0.0295)	-0.0269 (0.0383)	-0.0201 (0.0196)	-0.0400 (0.0291)
<b>Science</b>	-0.0503 (0.0386)	-0.0527 (0.0329)	-0.0545 (0.0403)	-0.0537*** (0.0150)	-0.0612* (0.0324)
<b>Engineering</b>	-0.106*** (0.0351)	-0.0887** (0.0373)	-0.101*** (0.0338)	-0.0327** (0.0160)	-0.0935*** (0.0312)
<b>Constant</b>	0.331*** (0.0724)	0.273*** (0.0564)	0.366*** (0.0720)	0.136*** (0.0280)	0.336*** (0.0604)
<b>Observations</b>	720	719	720	612	727
<b>Number of id</b>	192	192	192	191	192

Note: We show the coefficients of six different regressions in which the dependent variables is PGR. We use a different definition of reference price in each case. The set of regressors is the same in the six regressions. All variables except Female, Treatment and Experience standardized to zero mean and unit standard deviation. Robust standard errors clustered by group and session in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table B4.** Proportion of Losses Realized (PLR) according to each reference price

VARIABLES	Average Price	Initial Price	FIFO	LIFO	Last Price
<b>Female</b>	-0.0557** (0.0223)	-0.0800** (0.0315)	-0.0534*** (0.0191)	0.0103 (0.0195)	-0.0536*** (0.0186)
<b>C</b>	-0.00147 (0.0201)	0.00277 (0.0344)	0.00846 (0.0187)	0.0116 (0.0166)	0.0178 (0.0183)
<b>T</b>	-0.0903*** (0.0235)	-0.0792** (0.0358)	-0.0805*** (0.0198)	-0.0337** (0.0145)	-0.0649*** (0.0189)
<b>CT</b>	-0.0878*** (0.0208)	-0.0630 (0.0413)	-0.0650*** (0.0175)	-0.0190 (0.0178)	-0.0446** (0.0175)
<b>Female*C</b>	0.00794 (0.0291)	0.00290 (0.0412)	0.0163 (0.0271)	-0.0205 (0.0245)	0.0138 (0.0278)
<b>Female*T</b>	0.0462* (0.0250)	0.0376 (0.0368)	0.0595*** (0.0215)	-0.00639 (0.0227)	0.0524** (0.0206)
<b>Female*CT</b>	0.0614*** (0.0197)	0.0287 (0.0437)	0.0636*** (0.0220)	-0.0153 (0.0265)	0.0410* (0.0224)
<b>Experience2</b>	0.0175 (0.0111)	0.0168 (0.0193)	0.0106 (0.00803)	0.00825 (0.0109)	0.0215*** (0.00826)
<b>Experience3</b>	0.00804 (0.0195)	0.0336 (0.0311)	0.00844 (0.0124)	0.00927 (0.0102)	0.0165 (0.0141)
<b>Experience4</b>	0.0172 (0.0154)	0.0284 (0.0236)	0.00471 (0.0116)	0.0122 (0.00785)	0.0166 (0.0130)
<b>Optimism</b>	-0.0614** (0.0268)	-0.0819*** (0.0284)	-0.0359** (0.0174)	-0.00870 (0.00935)	-0.0363* (0.0186)
<b>Risk</b>	0.00758 (0.0189)	0.0219 (0.0233)	-0.00447 (0.0132)	0.0136 (0.00993)	-0.000174 (0.0130)
<b>Confidence</b>	0.0440 (0.0269)	0.0572* (0.0311)	0.0344* (0.0189)	0.00528 (0.0110)	0.0332* (0.0190)
<b>Difficulty recognizing errors</b>	-0.0569*** (0.0167)	-0.0573*** (0.0213)	-0.0425*** (0.0123)	-0.0116 (0.0103)	-0.0399*** (0.0123)
<b>Competitiveness</b>	-0.0286 (0.0235)	-0.0558* (0.0306)	-0.0259 (0.0164)	-0.0121 (0.0105)	-0.0247 (0.0158)
<b>Enjoys Winning</b>	0.00958 (0.0223)	0.0309 (0.0292)	0.00346 (0.0154)	-0.00663 (0.00948)	0.0102 (0.0164)
<b>Decisiveness</b>	-0.0144 (0.0184)	-0.0175 (0.0207)	-0.00711 (0.0140)	-0.00276 (0.00865)	0.00767 (0.0131)
<b>Self-control</b>	-0.00518 (0.0251)	0.00397 (0.0282)	0.0175 (0.0182)	0.0169 (0.0118)	-0.0152 (0.0174)
<b>High Confidence</b>	-0.00366 (0.0135)	0.000361 (0.0225)	0.00426 (0.00999)	-0.00911 (0.00863)	-0.00749 (0.0110)
<b>High Financial Literacy</b>	0.0120 (0.0237)	0.00353 (0.0268)	0.00275 (0.0149)	0.00131 (0.0113)	-0.00638 (0.0142)
<b>High Grades</b>	-0.00247 (0.0212)	-0.0223 (0.0240)	0.00106 (0.0153)	-0.00224 (0.00820)	-0.00139 (0.0154)
<b>&gt;1 Switches</b>	-0.00364 (0.0219)	-0.00456 (0.0235)	0.00647 (0.0142)	-0.00209 (0.00813)	0.00133 (0.0144)

<b>Neuroticism</b>	0.00313 (0.0122)	-0.00150 (0.0147)	6.54e-05 (0.00836)	-0.00276 (0.00434)	-0.000140 (0.00834)
<b>Extraversion</b>	-0.00238 (0.0114)	0.00222 (0.0133)	-0.00457 (0.00818)	-0.0108** (0.00452)	-0.00672 (0.00781)
<b>Agreeableness</b>	-0.000641 (0.00950)	0.00321 (0.0139)	0.00120 (0.00682)	0.00590 (0.00435)	0.00104 (0.00746)
<b>Openness</b>	-0.00445 (0.00887)	-0.0118 (0.0117)	-0.00317 (0.00643)	0.00145 (0.00417)	0.00140 (0.00612)
<b>Conscientiousness</b>	-0.00412 (0.0116)	-0.00818 (0.00977)	5.25e-05 (0.00723)	0.00110 (0.00320)	-0.000251 (0.00813)
<b>Art</b>	-0.0385 (0.0293)	-0.0722** (0.0343)	-0.0399** (0.0193)	-0.0152 (0.0121)	-0.0391* (0.0212)
<b>Health</b>	-0.0534** (0.0222)	-0.0141 (0.0286)	-0.0404** (0.0171)	-0.00451 (0.0107)	-0.0405** (0.0166)
<b>Science</b>	-0.0778** (0.0307)	-0.0422 (0.0299)	-0.0671*** (0.0199)	-0.0273*** (0.0105)	-0.0668*** (0.0230)
<b>Engineering</b>	-0.00988 (0.0374)	0.0115 (0.0406)	-0.0274 (0.0212)	-0.00470 (0.0159)	-0.0344 (0.0218)
<b>Constant</b>	0.288*** (0.0363)	0.330*** (0.0492)	0.204*** (0.0306)	0.0671*** (0.0230)	0.200*** (0.0286)
<b>Observations</b>	710	673	732	660	729
<b>Number of id</b>	192	192	192	191	192

Note: We show the coefficients of six different regressions in which the dependent variable is PLR. We use a different definition of reference price in each case. The set of regressors is the same in the six regressions. All variables except Female, Treatment and Experience standardized to zero mean and unit standard deviation.

Robust standard errors clustered by group and session in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table B5.** Gender differences in DE, PGR, PLR and alpha in the baseline treatment.

		Average	Initial	Reference Prices			Alpha	N
				FIFO	LIFO	Last		
DE	diff	0.0544 (0.0455)	0.0476 (0.0523)	0.0502 (0.0414)	0.0106 (0.0387)	0.0355 (0.0361)	0.0007 (0.0916)	42
	p-value	0.3581	0.2883	0.3516	0.6374	0.5610	0.9751	
PGR	diff	-0.0092 (0.0345)	0.0013 (0.0317)	-0.0062 (0.0335)	0.0263 (0.0340)	-0.0162 (0.0301)		42
	p-value	0.5526	0.7977	0.7029	0.9711	0.4645		
PLR	diff	-0.0678 (0.0236)	-0.0528 (0.0316)	-0.0580 (0.0184)	0.0079 (0.0209)	-0.0535 (0.0172)		42
	p-value	<b>0.0054</b>	<b>0.0903</b>	<b>0.0012</b>	0.4491	<b>0.0026</b>		

Note: Subjects were allocated to groups of 4 participants (2 women, 2 men) who experienced identical prices. We averaged each measure for each group and gender so that  $\sum_n(\text{mean}(DE_n^{fem}) - \text{mean}(DE_n^{male}))/N$ , where  $N$  is the number of groups ( $N = 42$ ). Standard errors in parentheses, p-values from Wilcoxon signed-rank tests, where the null hypothesis is  $\text{diff} = 0$ .

**Table B6.** Marginal effects of gender from Table 6.

VARIABLES	DE	PGR	PLR
<b>(overall) female = 1</b>	0.0216 (0.0347)	-0.00424 (0.0282)	-0.0262 (0.0199)
<b>(B) female = 1</b>	0.00666 (0.0391)	-0.0459 (0.0315)	-0.0557** (0.0223)
<b>(C) female = 1</b>	0.0233 (0.0433)	-0.0257 (0.0346)	-0.0478* (0.0270)
<b>(T) female = 1</b>	0.0333 (0.0434)	0.0139 (0.0344)	-0.00951 (0.0260)
<b>(CT) female = 1</b>	0.0219 (0.0476)	0.0350 (0.0364)	0.00562 (0.0278)
<b>Observations</b>	706	720	710

We run three regressions in which the dependent variables are DE, PGR and PLR, respectively. The first line shows the overall marginal effect of female, pooled across the four treatments. The remaining lines show the marginal effect of female, disaggregated by treatment. Standard errors in parentheses, \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

**Table B7.** Mean DE, PGR and PLR in the Baseline and Rebates treatments.

	Average Price Reference		
	DE	PGR	PLR
<i>Baseline</i>	0.107*** (0.024)	0.238 (0.018)	0.131 (0.014)
<i>N</i>	96	96	96
<i>Rebates</i>	0.109*** (0.025)	0.223 (0.021)	0.113 (0.014)
<i>N</i>	96	96	96
<i>p-value</i>	0.767	0.217	0.100

Standard errors in parentheses. p-values from Wilcoxon signed-rank tests of treatment effects. \*\*\*DE is significantly different from 0 in both treatments (p<0.001, Wilcoxon signed-rank test)

## **Appendix C. Experiment instructions (FOR ONLINE PUBLICATION)**

### **Questionnaire (translated from Spanish)**

- Are you an optimistic or a pessimistic person?
- Are you a person willing to take risks or do you try to avoid risks?
- Are you a confident person?
- I find it hard to recognize my errors
- I am a very competitive person
- I enjoy very much winning in a game
- After making a decision, I do not worry about it or regret it

**Reference prices question (translated from Spanish)**

1. In the following table, we present the hypothetical evolution of the price of an asset, your transactions and your portfolio:

	Period 1	Period 2	Period 3	Period 4	Period 5
Price	100	80	60	40	20
Buy/Sell	+1	+1	+2	-1	
Portfolio	1	2	4	3	

Imagine that in period 5 you decide to sell one unit of the asset. Express your degree of agreement or disagreement with the following ways to account for your losses in this transaction:

- A. I lose 80 in this transaction, because the initial price of the asset was 100 ( $20 - 100 = -80$ ).
- B. I lose 60 in this transaction, because the first unit I bought (at 100) I sold it in period 4, and this unit I bought it at 80 in period 2 ( $20 - 80 = -60$ ).
- C. I lose 55 in this transaction, because the average purchase price is  $(100+80+60 \times 2)/4 = 75$ . ( $20 - 75 = -55$ )
- D. I lose 40 in this transaction, because the price of the last unit I bought is 60 ( $20 - 60 = -40$ ).
- E. I lose 20 in this transaction, because the last price of the asset is 40 ( $20 - 40 = -20$ ).

Seven possible answers form 1 = “completely disagree” to 7 = “completely agree.”

2. In the following table, we present the hypothetical evolution of the price of an asset, your transactions and your portfolio:

	Period 1	Period 2	Period 3	Period 4	Period 5
Price	100	120	140	160	180
Buy/Sell	+1	+1	+2	-1	
Portfolio	1	2	4	3	

Imagine that in period 5 you decide to sell one unit of the asset. Express your degree of agreement or disagreement with the following ways to account for your gains in this transaction:

- A. I gain 80 in this transaction, because the initial price of the asset was 100 ( $180 - 100 = 80$ ).
- B. I gain 60 in this transaction, because the first unit I bought (at 100) I sold it in period 4, and this unit I bought it at 120 in period 2 ( $180 - 120 = 60$ ).
- C. I gain 55 in this transaction, because the average purchase price is  $(100+120+140 \times 2)/4 = 125$ . ( $180 - 125 = 55$ )
- D. I gain 40 in this transaction, because the price of the last unit I bought is 140 ( $180 - 140 = 40$ ).
- E. I gain 20 in this transaction, because the last price of the asset is 160 ( $180 - 160 = 20$ ).

## Study 1 Instructions

Welcome to the experiment. This is an experiment to study how individuals make decisions. We are only interested in what individuals do on average. Do not think that any particular behavior is expected from you.

Please read these instructions carefully. Throughout the experiment you will be able to buy and sell assets using experimental currency. To simplify the presentation, we will use *pesetas* as experimental currency. The amount of pesetas you can earn depends on the decisions you make and, in some cases, the decisions made by other participants. At the end of the experiment you will be asked to fill in a short questionnaire.

Once you finish the experiment you will be paid privately and in cash the earnings you have obtained in the experiment.

The exchange rate is 1000 pesetas = 1 €

Please, it is important that you make all decisions privately. Therefore, do not talk to other participants during the experiment. You cannot use mobile phones during the experiment. If you need help, raise your hand and remain silent. We will answer your question as soon as possible.

The experiment lasts approximately 2 hours and consists of four rounds and a warm-up round. Each round consists of 14 periods (from -3 to 10). In periods -3 to 0 you will receive information on the prices of 6 assets (A, B, C, D, E and F), although you will not be able to buy or sell. In period 1 of each round you will receive an endowment of 5000 pesetas that you can use to buy and sell units of the 6 assets for the next 9 periods (period 1 to 9).

### LOTTERY ROUND

You have 21 decisions between a fixed payment and a lottery. The lottery is always the same: there is a 50 % chance of winning 5000 pesetas and a 50 % chance of winning nothing. At the end of the experiment we will randomly select one of the 21 decisions. If in that decision you chose the safe payment, you will be paid that amount. If you chose the lottery, the computer will “flip a coin”: if heads you will get 5000 pesetas and if tails you will get nothing.

## FIRST ROUND

In this round, you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. The 4 members in the group participate in a small financial market consisting of 6 assets. All assets have the same initial price (in period -3) of 100 pesetas. From there, the price of each asset will change: it will go up by 6% or down by 5%. The probability of a price increase may be different for each asset but is constant for the same asset over each round. At the beginning of each round, the computer randomly chooses new probabilities of up or down for each asset, which will remain constant for that round. That means that the same asset can have a very high probability of rising in a round, and very low in another.

Suppose, for example, that an asset has a probability of price increase of 0.55 (i.e. 55%). This means that in each period, the current price can go up a 6% with a probability of 55%, or down a 5% with a probability of 45% (= 100% -55%).

This means that, if in a given period the price of an asset is 113.9 pesetas, its price in the next period will rise by 6% to 120.7 pesetas (=  $113.9 \times (1 + 0.06)$ ) with probability 0.55 or will fall 5% to 108.2 pesetas (=  $113.9 \times (1 - 0.05)$ ) with probability  $1 - 0.55 = 0.45$ .

These probabilities will be unknown for you. However, remember that they will not change within each round. In addition, price changes are independent of each other and independent of your trading decisions. They are also independent of the decisions of others.

In each of the periods from period 1 to period 9 you can buy or sell assets. In the figure below you can see the computer screen. At the top you can see the prices of assets A-F throughout the round. In this case we only show prices up to period 5.

Periodo		5 de 10										Tiempo restante [sec]: 9	
		Per. -3	Per. -2	Per. -1	Per. 0	Per. 1	Per. 2	Per. 3	Per. 4	Per. 5			
Activo A	Precio: Comp./Vend. (+/-)	100 ---	96 ---	92 ---	98 ---	104 3	110 -2	116 0	122 0	116 0			
Activo B	Precio: Comp./Vend. (+/-)	100 ---	106 ---	100 ---	96 ---	102 4	96 0	92 -2	88 0	84 0			
Activo C	Precio: Comp./Vend. (+/-)	100 ---	96 ---	92 ---	98 ---	94 6	100 0	96 8	92 0	98 0			
Activo D	Precio: Comp./Vend. (+/-)	100 ---	106 ---	100 ---	96 ---	102 8	108 -2	102 -2	96 0	102 0			
Activo E	Precio: Comp./Vend. (+/-)	100 ---	106 ---	112 ---	118 ---	126 4	134 0	142 -1	150 0	160 0			
Activo F	Precio: Comp./Vend. (+/-)	100 ---	96 ---	92 ---	98 ---	94 7	90 7	86 -1	82 0	78 0			

En mi cartera		Precio Actual			
Activo A	1	116		Compra 1	Vende 1
Activo B	2	84		Compra 1	Vende 1
Activo C	14	98		Compra 1	Vende 1
Activo D	4	102		Compra 1	Vende 1
Activo E	3	160		Compra 1	Vende 1
Activo F	13	78		Compra 1	Vende 1
SALDO:		392			

The top of the screen shows the evolution of the prices of the six assets A-F from period -3, and all the transactions you have already made.<sup>31</sup> Since in periods -3, -2, -1 and 0 you cannot buy or sell, the number of transactions for these periods is always 0. Purchases from period 1 onwards are represented by positive numbers and sales by negative numbers.

The bottom of the screen contains your transactions. Here you can decide whether to buy or sell one or more units of assets A-F. The column "En mi cartera" indicates the number of units of each asset you own. The column "Precio actual" means the price you pay for each additional unit you want to buy and also the price you receive for each unit you want to sell. You can also see how many pesetas you still have available under "SALDO".

If you want to buy an asset, you have to pay for each unit the current price of the asset. You can never spend more money than you have available (your "SALDO"). To purchase an asset, you have to click the "Compra 1" button. If you want to buy more than one unit, you simply have to click as many times as units you want to buy.

Example: Suppose we are in period 5 and Asset A has a price of 116 pesetas, as in the figure above. If you decide to buy 3 units of A, you will have to click three times on the "Compra 1" button. You will spend  $3 \times 116 = 348$  pesetas in this transaction. This amount is subtracted from your SALDO.

If you own units of an asset, then you have the option to sell these units. For each unit you sell you will receive the current price of the asset. The number of units you sell cannot exceed the number of units you own.

Example: Suppose we are in period 5 and Asset C has a price of 98 pesetas, as in the figure above. You have 14 units of C and you want to sell 3 of them. To do this you have to click 3 times on the "Vende 1" button. You will receive  $3 \times 98 = 294$  pesetas that will be added to your SALDO.

In each period you have a limited time to make your decisions. This time will be one minute. You will see the remaining time in red on the top right corner of the screen.

The round ends in period 10. In period 10 you will not be able to buy or sell assets. The prices of period 10 will determine the final value of your portfolio. The value of the portfolio will be added automatically to your "SALDO" and will be part of your earnings.

At the beginning and end of the round we will ask you to tell us what position you believe you will be in terms of profits within the group of 4 people to which you belong. Every time you guess

---

<sup>31</sup> Due to a small programming error, prices were rounded to the nearest even number, rather than to the nearest integer. No subject seemed to notice this otherwise inconsequential fact.

correctly, you will be paid 100 pesetas.

Also, before periods 1, 6 and 10 we will ask you to guess, which one of the 6 assets is the best (i.e., the one whose probability of price increase is highest), which one is the second best, which one is the worst (the one whose probability of price increase is the lowest) and which one is the second worst. Each time you guess correctly the four questions, you will receive an additional 100 pesetas. For these two decisions there is no time limit. However, we ask you not to take too long because the round cannot continue until you make your decision.

In short, your gains in this first round are:

Your SALDO

- + The value of the assets in your portfolio
- + What you have earned guessing your position
- + What you have earned guessing the assets

To familiarize yourself with the mechanics of the experiment, we will start with a small trial practice.

## SECOND ROUND

This second round is similar to the first, with a variation. As in the first round you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate. The difference with the previous round has to do with the profits you can get. Specifically, your earnings in this round are:

If you are the winner in your group of 4 (i.e., if at the end of the round the value of your assets plus your “SALDO” is greater than those of the other 3 members of your group), you will receive:

(The value of the assets in your portfolio + your “SALDO”) × 2

- + What you have earned guessing your position
- + What you have earned guessing the assets

If you are not the winner in your group of 4, then you will receive:

- + What you have earned guessing your position
- + What you have earned guessing the assets

### THIRD ROUND

This third round is similar to the first round, with a variation. As in the first round you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate. The difference is that each time you buy or sell an asset, you will have to pay a fee that is a percentage of the value of the asset. The fee is the same for all members of each group, although it can vary across groups. At the bottom of the screen you will see the amount of the fee.

Example: We are in period 3 and asset A has a price of 130 pesetas. The fee applied to transactions is 1%. If you want to buy 4 units of A you have to pay  $4 \times 130 = 520$  pesetas plus  $4 \times 130 \times 0.01 = 5.2$  pesetas in fees. In total this transaction has a cost of  $520 + 5.2 = 525.2$  pesetas. This amount is subtracted from your "SALDO".

Example: We are in period 8 and asset E has a price of 90 pesetas. The fee is 4%. Suppose you own 5 units of E and you decide to sell 3 of them. By selling those 3 units you receive  $3 \times 90 = 270$  pesetas, but you have to pay fees of  $3 \times 90 \times 0.04 = 10.8$  pesetas, so your net revenue will be  $270 - 10.8 = 259.2$  pesetas that will be added to your "SALDO".

IMPORTANT: The fee will be charged automatically each time you press the "Compra 1" or "Vende 1" button. You must be careful because if you buy a unit of an asset and sell it within the same period, you will pay the fee twice.

Your earnings in this round are:

Your SALDO

- + The value of the assets in your portfolio
- + What you have earned guessing your position
- + What you have earned guessing the assets

## FOURTH ROUND

This fourth and final round is similar to the second round, but also as in the third round each time you buy or sell an asset, you will have to pay a fee that is a percentage of the value of the asset. The fee is the same for all members of each group, although it can vary across groups. At the bottom of the screen you will see the amount of the fee. As in previous rounds you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate.

Your earnings in this round are:

If you are the winner in your group of 4 (i.e., if at the end of the round the value of your assets plus your “SALDO” is greater than those of the other 3 members of your group), you will receive:

(The value of the assets in your portfolio + your “SALDO”) × 2  
+ What you have earned guessing your position  
+ What you have earned guessing the assets

If you are not the winner in your group of 4, then you will receive:

+ What you have earned guessing your position  
+ What you have earned guessing the assets

Once you finish the four rounds, your total earnings will be the sum of the earnings of the four rounds plus the result of the lottery round.

To finish we ask you to answer a short questionnaire. Once you finish you can leave the room and wait outside. Do not forget to pick up your ID number. We will call you to come in to collect your earnings.

Thank you all!

## Study 2 Instructions

### LOTTERY AND FIRST ROUND

Exactly as in the first experiment.

### SECOND ROUND

This second round is similar to the first, with a variation. As in the first round you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate. The difference with the first round is that each time you buy or sell an asset, you will have to pay a fee that is a percentage of the value of the asset. The fee is the same for all members of each group, although it can vary across groups. At the bottom of the screen you will see the amount of the fee. Additionally, at the end of the round we will refund you 50% of the fees corresponding to sales of losing assets

Example: We are in period 3 and asset A has a price of 130 pesetas. The fee applied to transactions is 1%. If you want to buy 4 units of A you have to pay  $4 \times 130 = 520$  pesetas plus  $4 \times 130 \times 0.01 = 5.2$  pesetas in fees. In total, this transaction has a cost of  $520 + 5.2 = 525.2$  pesetas. This amount is subtracted from your "SALDO".

Example: We are in period 8 and asset E has a price of 90 pesetas. The fee is 4%. Suppose you own 5 units of E and you decide to sell 3 of them. By selling those 3 units you receive  $3 \times 90 = 270$  pesetas, but you have to pay fees of  $3 \times 90 \times 0.04 = 10.8$  pesetas, so your net revenue will be  $270 - 10.8 = 259.2$  pesetas that will be added to your "SALDO". As explained above, if this is a losing asset (imagine you paid 100 pesetas for each of the three units), we will refund you 50% of the fees you paid at the end. In this case the refund would be 5.4 pesetas.

IMPORTANT: The fee will be charged automatically each time you press the "Compra 1" or "Vende 1" button. You must be careful because if you buy a unit of an asset and sell it within the same period, you will pay the fee twice.

Your earnings in this round are:

Your SALDO

- + The value of the assets in your portfolio
- + What you have earned guessing your position
- + What you have earned guessing the assets
- + 50% of the fees corresponding to sales of losing assets

## THIRD ROUND

This third round is different from the previous rounds. As in the previous rounds you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate.

In this round you have to take two types of decisions:

1) During periods 1 to 9 you should try to guess, for each of the six assets, if in the next period the price of the asset will go UP or DOWN. You simply have to press the corresponding button (UP or DOWN) that you will see next to each asset. Remember that you have to make a prediction for each of the six assets. Each time you guess correctly you will receive 100 pesetas. In each period you have a time limit of one minute to make this decisions. Please try not to exceed this time, since the other participants will have to wait for you. The remaining time will be shown in red at the top right corner of the screen.

2) In period 5 we will randomly choose 3 assets and we will buy 10 units of each one of them for you. These assets will be the same for all members in your group. In the screen you will see the assets that you own in green. The purchase value will be deducted from your SALDO. Only in period 9 you will have the opportunity to sell these assets. You can sell all your assets, part of them or even sell nothing. To do this you simply have to press the "Sell 1" button of the corresponding asset as many times as you want. You can always correct your decision by pressing the "Cancel 1" button. In this round you will not have to pay any fees when selling your assets. You have one minute to make this decision. Please try not to exceed this time, since the other participants will have to wait for you. The remaining time will be shown in red at the top right of the screen.

Your earnings in this round are:

Your SALDO

- + The value of the assets that you have not sold (at period 10 prices)
- + What you have earned guessing if prices go UP or DOWN
- + What you have earned guessing your position

## FOURTH ROUND

This fourth and last round is similar to the third round with one modification. As in the previous rounds you will be in a group of 4 randomly selected participants. You will never know who is in your group, and no one will know if you are in his/her group, neither during nor after the experiment. Again you will have an initial endowment of 5000 pesetas to participate.

In this round you have to take three types of decisions:

1) Exactly the same as in Round 3.

2) In period 5 you will have to choose 3 assets from which you will have to buy exactly 10 units of each. To do it, you will have to press the button "Buy 10" next to the three assets you have chosen. You can always correct your decision by pressing the "Cancel" button. Once you have taken your decision you have to press the button "OK". The purchase value will be deducted from your SALDO. In the screen you will see in green color the three assets you have chosen. You have one minute to make this decision. Please try not to exceed this time, since the other participants will have to wait for you. The remaining time will be shown in red at the top right corner of the screen.

3) Only in period 9 you will have the opportunity to sell these assets. You can sell all your assets, part of them or even sell nothing. To do this you simply have to press the "Sell 1" button of the corresponding asset as many times as you want. You can always correct your decision by pressing the "Cancel 1" button. In this round you will not have to pay any fees when selling your assets. You have one minute to make this decision. Please try not to exceed this time, since the other participants will have to wait for you. The remaining time will be shown in red at the top right of the screen.

Your earnings in this round are:

Your SALDO

+ The value of the assets that you have not solved (at period 10 prices)

+ What you have earned guessing if prices go UP or DOWN

+ What you have earned guessing your position

Once you finish the four rounds, your total earnings will be the sum of the earnings of the four rounds plus the result of the lottery round.



**Ivie**

Guardia Civil, 22 - Esc. 2, 1º  
46020 Valencia - Spain  
Phone: +34 963 190 050  
Fax: +34 963 190 055

**Website:** [www.ivie.es](http://www.ivie.es)  
**E-mail:** [publicaciones@ivie.es](mailto:publicaciones@ivie.es)