Investment Targets as Reference Points

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Abstract

We provide the first evidence of forward-looking reference points in investor behavior. Combining administrative data on option traders with a stacked difference-in-differences design, we show that investors' propensity to sell options spikes precisely when the underlying asset crosses the strike price, which retail investors frequently select to match their target price. The effect is difficult to explain using the standard disposition effect, nominal returns, salience, option Greeks, or complex option trading strategies. Moreover, the effect is present only for options bought out of the money, for which the strike price acts as a natural target, but absent for options bought in the money, for which it cannot. The evidence is most consistent with investors evaluating gains and losses relative to a forward-looking target, in sharp contrast with the backward-looking purchase price widely used in the disposition effect literature. Our findings help reconcile conflicting empirical evidence on investors' reluctance to realize losses.

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1 Introduction

The most widely studied form of reference dependence in finance and economics is the disposition effect, or the tendency to sell gains while holding on to losses.[1] This large empirical and theoretical literature has almost exclusively assumed that the reference point from which investors evaluate gains and losses is an asset's purchase price.[2] Much less is known about how investors' selling decisions respond to forward-looking reference points based on expectations or investment targets (Barberis, 2018, p. 148), as opposed to the backward-looking purchase price. The idea that "there are situations in which gains and losses are coded relative to an aspiration level" is as old as prospect theory (Kahneman and Tversky, 1979, p. 286)[3] and has received some support in labor economics. For example, cab drivers may stop working after reaching their daily income target.[4]

Because investment decisions are inherently forward-looking, many investors likely hold aspirations beyond the purchase price. They may therefore exit positions once their objectives are reached, instead of evaluating portfolios based on final expected wealth as in standard expected utility theory. Yet, providing compelling evidence of such forward-looking reference points has proven extremely difficult due to data limitations. To study the topic, a researcher would need to combine comprehensive data on the trading activity of investors with information on the goals or targets that investors had in mind when entering each position. Moreover, the data should be sufficiently rich to support credible causal inference and be accurately reported to avoid selection or reporting biases.

In this paper, we fill this gap by exploiting a unique feature of options—the strike price—which provides observable variation in investors' forward-looking motives. Widespread anecdotal evidence

[1] Since it was first documented by Shefrin and Statman (1985), the disposition effect has been studied by Odean (1998), Grinblatt and Keloharju (2001), Calvet, Campbell, and Sodini (2009a), Ben-David and Hirshleifer (2012), Heimer (2016), and Frydman and Wang (2020), among many others—see Barber and Odean (2013) and Gomes, Haliassos, and Ramadorai (2021) for surveys. According to the bibliometric analysis by Paule-Vianez, Gómez-Martínez, and Prado-Román (2020), the disposition effect is the second most actively studied topic in behavioral finance.

[2] An exception is Barberis and Xiong (2009, 2012), who model the reference point as the purchase price compounded at the risk-free rate, arguing that an investor may not view an investment as successful if its return is lower than that of the risk-free asset. We review other types of reference points in Section 5.

[3] See also "Goals are Reference Points" in Kahneman (2011). A formal theory of expectations-based reference points is developed by Kőszegi and Rabin (2006, 2007).

[4] See Camerer, Babcock, Loewenstein, and Thaler (1997), Crawford and Meng (2011), and Thakral and Tô (2021). In related work, Mas (2006) shows that employees become dissatisfied when they receive a wage increase that is smaller than they expected.

from brokers, trading-related websites, and social media posts shows that investors often select an option's strike price to match their target price for the underlying asset.[5] Combining 17 years of population-level administrative data with a stacked difference-in-differences design, we show that investors' propensity to sell options purchased out of the money spikes when the underlying asset crosses the strike price. We then conduct placebo tests using options purchased in the money for which the strike price cannot serve as a forward-looking target, since reaching the strike would represent a loss relative to the purchase price, and find no corresponding spike. Overall, selling behavior responds to the strike price in a manner consistent with investment targets acting as forward-looking reference points, but inconsistent with alternative explanations, including the standard disposition effect, nominal returns, salience, rational rebalancing, hedging, liquidity needs, transaction costs, complex option trades, or option Greeks.

We begin our empirical analyses by plotting the aggregate propensity to sell options as a function of moneyness, defined as the relative distance of the price of the underlying asset from the strike price. We find that the propensity to sell has an inverse V shape that peaks at the strike price and then declines for options that are in or out of the money. The peak in selling propensity at the strike persists even after flexibly controlling for holding period returns and holding periods. Because returns are smooth around the strike price, controlling for holding period returns has little effect on the results. The inverse V shape therefore cannot be explained by the standard disposition effect, which links selling decisions to holding period returns.

An obvious concern with interpreting these results is that the strike price may be proxying for other covariates that affect the propensity to sell. For example, the option Greeks gamma and vega peak at the strike, so excess selling at the strike could be explained by investors using them to manage price and volatility risk, or as part of a sophisticated option trading strategy. Similarly, the strike price may serve as a purely salient reference point (O'Donoghue and Sprenger, 2018), rather than reflecting investors' forward-looking targets. Rather than attempting to control for all possible covariates, our preferred approach is to design placebo tests using options that were purchased in the money. Unlike the out-of-the-money option purchases used in our main analyses, the strike

[5] See Tables IA.1 and IA.2 for a list of representative quotes from articles and social media posts that relate an option's strike price to an investor's target price.

price cannot serve as a forward-looking target for in-the-money purchases, since reaching the strike would represent a loss relative to the purchase price. If investors respond to the strike price because of option Greeks, salience, or other factors, then this sample should also exhibit a spike in selling propensity at the strike price. This is not what we find: there is no increase in selling propensity at the strike price for options purchased in the money, which is inconsistent with such alternative explanations.

Perhaps the cleanest way to identify the effect that the strike price has on selling behavior is to examine within-option and within-investor selling decisions around the precise moment the underlying stock crosses the strike price. Using a stacked difference-in-differences design, we begin by comparing options that cross the strike to options that remain out of the money over the entire event window of ± 5 days. In the days before a strike price crossing, the estimated coefficients are all statistically indistinguishable from zero, indicating parallel trends in the selling of treated and control options. On the strike crossing day, we observe a sharp spike in selling propensity of over 12 percentage points relative to the previous day, which corresponds to a 65% increase in selling propensity relative to the unconditional average.

We then exploit the full granularity of our data by implementing a difference-in-differences design at the individual position level. This design compares an investor's selling decision for a given option around the strike crossing to otherwise comparable positions with the same option type and underlying asset that have not yet crossed the strike. This position-level design allows us to control directly for the holding period return, gain status, holding period, and time to expiry, thereby separating the effect of the strike price from the standard disposition effect and other return-based motives. Moreover, we include underlying-by-day fixed effects, thereby separating the strike effect from earnings announcements and other attention-grabbing events. Consistent with the option-level results, we find a pronounced spike in selling on the strike crossing day, corresponding to a 70% increase relative to the unconditional probability of sale.

As before, the effects are confined to options purchased out of the money and are absent in placebo tests using in-the-money purchases. These placebo tests use the same difference-in-differences design but replace options purchased out of the money with in-the-money purchases for which the

strike price cannot plausibly serve as an investment target. In stark contrast to our main results, we find no increase in selling propensity when in-the-money options cross the strike and fall out of the money. This asymmetry strongly supports the interpretation that the observed selling behavior for out-of-the-money options is driven by target attainment rather than salience, option Greeks, or other strike-related characteristics.

The literature on the disposition effect has primarily considered two explanations for this stylized fact: (i) reference-dependent preferences (e.g., realization utility; Barberis and Xiong, 2012), and (ii) belief-based mechanisms, such as a belief in mean reversion (Odean, 1998). We next examine whether the strike-related selling behavior we document can be explained by belief-based mechanisms or instead reflects reference-dependent preferences. To do so, we exploit settings in which investors simultaneously hold multiple options on the same underlying asset, so that their beliefs about the future price path of the underlying are plausibly constant across positions. Even in these restrictive settings, investors are significantly more likely to sell in-the-money options than otherwise identical out-of-the-money options. This pattern is difficult to reconcile with belief-based explanations. For example, a belief in mean reversion would predict correlated selling across all options of the same type written on the same underlying. Instead, the evidence points to reference dependence centered on forward-looking targets.

We consider and rule out several additional alternative explanations. Our findings are difficult to reconcile with skewness preferences, the rank effect (Hartzmark, 2015), complex option strategies, rational rebalancing or rollover behavior, hedging motives, transaction costs, liquidity needs, taxes, or ex post rationalization. For example, the effect of strike crossing on selling remains qualitatively and quantitatively unchanged after controlling for the rank of positions within investor portfolios. Skewness preferences are also unlikely to explain the results, as they would predict symmetric behavior for out-of-the-money and in-the-money purchases, which we fail to find. Finally, investors would have earned positive returns by holding their positions after strike-price crossing, which is inconsistent with ex post rationalization based on subsequent return reversals.

Our main contribution is to provide evidence that investors use investment targets as reference points—an example of forward-looking reference points that have received little attention in finance.

Barberis (2018) notes that most implementations of prospect theory in finance adopt "backward-looking" reference points. In contrast, Kőszegi and Rabin (2006, 2007) advocate "forward-looking" reference points, under which investors evaluate gains and losses relative to the wealth they expected to have at a given time. Bordalo, Gennaioli, and Shleifer (2019) (see also Bordalo, Gennaioli, and Shleifer, 2020) model reference points using associative memory which mixes both forward- and backward-looking reference points. Our evidence provides new support for models that incorporate forward-looking reference points, although our results do not require the reference point to coincide with an investor's expectation, but rather with an aspiration or target—a related yet distinct concept. This reference point is also distinct from salient thresholds such as round numbers or 52-week highs (e.g., George and Hwang, 2004; Pope and Simonsohn, 2011; Pope and Schweitzer, 2011). Our results thus enrich our understanding of reference-dependent behavior in the context of investment decisions.

The vast majority of the empirical literature on the disposition effect relies on data from stock investors (e.g., Ivković, Poterba, and Weisbenner, 2005; Grinblatt and Han, 2005; Calvet, Campbell, and Sodini, 2009b; Linnainmaa, 2010; Birru, 2015; An, 2016; Chang, Solomon, and Westerfield, 2016; An, Engelberg, Henriksson, Wang, and Williams, 2024).[6] An active literature also studies the role of reference dependence in housing markets (e.g., Genesove and Mayer, 2001; Andersen, Badarinza, Liu, Marx, and Ramadorai, 2022; Badarinza, Ramadorai, Siljander, and Tripathy, 2024). We extend this literature by exploiting a new laboratory—option traders—to demonstrate how the unique features of this market can be used to construct novel tests of reference dependence in investment behavior.

Our results also have the potential to reconcile some of the conflicting evidence in the disposition effect literature. Specifically, Ben-David and Hirshleifer (2012) find that the propensity to sell stocks is V-shaped with respect to nominal gains and displays little discontinuity at zero, arguing that the evidence is inconsistent with investors being reluctant to realize losses. If many investors instead have reference-dependent preferences around their targets rather than the purchase price, we should

[6] See also Heimer (2016) and Heimer and Imas (2022) for evidence from forex traders, Ivković and Weisbenner (2009) for evidence from mutual fund flows, Fischbacher, Hoffmann, and Schudy (2017) and Aristidou, Giga, Lee, and Zapatero (2025) for laboratory experiments, and Andrikogiannopoulou and Papakonstantinou (2020) for evidence from sports bettors. See also Heimer, Iliewa, Imas, and Weber (2025).

not necessarily expect a sharp break in selling behavior around the purchase price. Our results thus highlight that the commonly applied tests of discontinuity in selling around the purchase price[7] are misspecified for investors with different reference points, such as their target prices. More broadly, these results underscore that any test of reference-dependent utility is a joint test of the reference point and the utility specification.

2 Data

2.1 Data Sources

Euroclear Finland. Our main data source is Euroclear Finland, which acts as the official registry of stock and option holdings in Finland. The data include comprehensive daily holdings and changes in holdings of all stocks and options in Finland from December 2000 to December 2017. We identify retail investors in the data by using the retail investor flag provided by Euroclear Finland. Earlier versions of the data from Euroclear Finland or its predecessor, the Finnish Central Securities Depository, have been used in studies of retail stock investments (Grinblatt and Keloharju, 2000, 2001; Grinblatt, Keloharju, and Linnainmaa, 2012) and employee derivative trading (Vacca, 2026).[8] By contrast, the present study leverages the full sample of retail option trades in Finland.

Technically, the options in our data set are bank-issued warrants. The term "warrant" can be misleading because it typically refers to call options issued on the primary market by firms which, if exercised, lead to the issuance of new shares. By contrast, the warrants in our data set are exchange-traded, European-style vanilla call or put options issued by banks and marketed specifically to retail investors.[9] To avoid any confusion in terminology, throughout the paper, we refer to the warrants in our data set as options. Unlike in the United States, retail investors in Finland are not permitted to write (short sell) options, and all options are cash-settled at expiry, eliminating the risk of physical settlement.

The data set includes 15 752 unique options written on 42 underlying assets: 27 Finnish stocks, 7

[7] See Grinblatt and Keloharju (2001), Kaustia (2010), and Ben-David and Hirshleifer (2012).

[8] See also Kaustia and Knüpfer (2008), Kaustia (2010), and Kaustia and Knüpfer (2012).

[9] The issuing banks are also required to act as designated market makers, thus guaranteeing liquidity. Table IA.3 shows that over 90% of bid-ask spreads at market close are either one or two cents, which is on the lower end of bid-ask spreads observed in U.S. option markets (Hendershott, Khan, and Riordan, 2022).

stock indices, and 8 commodities or exchange rates. Stock options account for 85% of all observations, index options for 14%, and the remaining options for 1%.

Stock Exchange Releases. The data from Euroclear Finland do not contain information on option characteristics, such as the expiration date, strike price, underlying asset, or whether an option is a call or a put, so we manually collect data on option characteristics from stock exchange releases prepared by the issuing banks. An excerpt from a representative stock exchange release is presented in Figure IA.1. Due to the limited availability of older stock exchange releases, the proportion of options for which we have data on characteristics increases over time, rising to over 90% in 2010–2013 and reaching 100% in 2014–2017.

Helsinki Stock Exchange. The data from Euroclear Finland also do not contain transaction prices, so we use the price of the asset at market close as the transaction price. Both the option prices and the prices of their underlying assets are from the Helsinki Stock Exchange.

2.2 Terminology and Definitions

We now define key terms and variables that we use throughout the paper. At the outset, we note that many of the variables are calculated at the round-trip level. If an investor combines multiple purchases of the same option within a single round-trip, we calculate the variables using weights based on the euro value of each separate purchase.

Option Variables. We define the moneyness of a call option as the price of the underlying asset minus the strike price, divided by the strike price. The moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. We say that an option is out of the money if its moneyness is less than zero, and in the money if its moneyness is greater than or equal to zero. Option returns are calculated from the respective option close prices, and all return and moneyness variables are adjusted for capital events, such as stock splits. We define the main outcome variable, $Sale_{ijt}$, as an indicator equal to one if investor i sells option j on day t, and zero otherwise. Hence, the sale variable covers both full and partial sales of a position.

Event Days. In our stacked difference-in-differences analyses, we use the terms "strike price crossings" or "strike crossing days" to refer to days on which an option crosses from out of the money

to in the money, or from in the money to out of the money, for the first time. We operationalize this definition at two different units of observation. First, in the option-level design, the unit is an option-day, so we assign each option j an event date E_j. The dependent variable $Sale_{jt}$ is then measured after aggregating investor-level selling behavior to the option-day level. Second, in the position-level design, the unit is an investor-option-day, so we treat each investor's holding of a given option as a distinct position. The dependent variable $Sale_{ijt}$ is measured at the holding level, allowing the same option-day to contribute a separate observation for each investor holding that option on that day.

Samples. For our analyses, we generally use two samples of observations. The main sample covers all round-trips that are out of the money at the initial purchase. Conversely, the placebo sample covers all round-trips that are in the money at the initial purchase. Hence, the placebo sample covers positions for which the strike price cannot act as a target price, as it would imply a negative target return.

2.3 Summary Statistics

Table 1 presents summary statistics on our main sample of out-of-the-money purchases, our placebo sample of in-the-money purchases, the investors, and the data set.

In total, the sample contains 18 570 investors, of whom 10% are female. The average (median) investor is a 38-year-old (36-year-old) male with one year (two months) of option trading experience and 51 (9) executed trades. Consistent with the evidence on retail option trading in the United States presented by Bryzgalova, Pavlova, and Sikorskaya (2023) and Bogousslavsky and Muravyev (2024), we find that retail investors prefer calls over puts, with 80% of out-of-the-money purchases and 73% of in-the-money purchases being calls, and prefer out-of-the-money options to in-the-money options, with 73% of all purchases being out of the money. Compared to options purchased in the money, out-of-the-money option purchases are smaller in value, further away from zero moneyness at the time of purchase, held for longer, and have lower returns.

3 The Propensity to Sell Around the Strike Price

In this section, we examine aggregate patterns in selling behavior around the strike price of an option. Using our main sample of out-of-the-money option purchases, we show that the propensity to sell options as a function of moneyness has an inverse V-shape that peaks at the strike price, consistent with investors using the strike price as a target for their out-of-the-money option purchases. We then rule out potential confounding factors and alternative explanations by controlling for the effect that the holding period and holding period return have on selling decisions, and by performing placebo tests with options purchased in the money, for which the strike price cannot act as a target.

3.1 The Inverse V-Shaped Relation Between Option Sales and Moneyness

We begin our examination of whether investors use the strike price of an option as a target for their out-of-the-money option purchases by regressing investors' selling decisions on dummy variables for different levels of option moneyness. Our empirical approach is comparable to the propensity to sell functions estimated for stock trades by Ben-David and Hirshleifer (2012) and for real estate transactions by Andersen et al. (2022), except that we plot the selling propensity as a function of moneyness and not as a function of holding period returns.

Formally, we use our main sample of out-of-the-money purchases to estimate the linear probability model

$$Sale_{ijt} = \alpha + \sum_{k=1}^{100} \beta_k \mathbb{1}\{\phi(m_{jt}) = k\} + \varepsilon_{ijt}. \tag{1}$$

The dependent variable $Sale_{ijt}$ is a dummy variable that equals one if investor i sells option j on day t. The moneyness m_{jt} of option j on day t is discretized into percentile bins using the bin assignment function $\phi(\cdot)$. The indicator $\mathbb{1}\{\phi(m_{jt}) = k\}$ equals one if an option-day observation falls in moneyness percentile bin k, and zero otherwise. Standard errors are clustered by investor and day.

The estimated selling propensities and their 95% confidence intervals are plotted in Figure 1. Consistent with investors using the strike price of an option as a target for their out-of-the-money option purchases, the propensity to sell is close to zero for options that are deep out of the money,

increases sharply as the price of the underlying asset approaches the strike price, and then decreases again for options that are in the money. In contrast to the V-shaped propensity to sell for holding period returns documented by Ben-David and Hirshleifer (2012), the propensity to sell for moneyness exhibits an inverse V-shape that peaks at the strike price.

A potential concern with the results presented in Figure 1 is that investors' selling decisions around the strike price could be driven by factors other than moneyness that are known to influence selling behavior, such as a position's holding period or its holding period return (e.g., Ben-David and Hirshleifer, 2012). As a first piece of evidence against this possibility, in Figures IA.2 and IA.3 we plot average holding period returns and average holding periods for different levels of option moneyness. Neither holding periods nor holding period returns exhibit an inverse V-shaped relation with moneyness, nor do they exhibit any discontinuous behavior at the strike price that could generate the relation observed in Figure 1. As a result, we would not expect the peak in selling propensity at the strike price to be explained by holding periods or holding period returns.

Nonetheless, to rule out this possibility more directly, we rerun the regression specification from Equation 1 with flexible and granular controls for the holding period and holding period return of the position. This empirical approach allows us to isolate the effect that option moneyness has on the propensity to sell in excess of what would be expected purely based on a position's holding period and holding period return.

Specifically, using the same sample of out-of-the-money purchases, we estimate the linear probability model

$$Sale_{ijt} = \alpha + \sum_{k=1}^{100} \beta_k \mathbb{1}\{\phi(m_{jt}) = k\} + \sum_{q=1}^{100}\sum_{p=1}^{20} \gamma_{qp} \mathbb{1}\{\pi(r_{ijt}) = q\}\mathbb{1}\{h_{ijt} = p\} + \varepsilon_{ijt}, \tag{2}$$

where r_{ijt} denotes the holding period return of investor i's position in option j on day t, and h_{ijt} denotes the holding period of the same position. As before, we discretize the holding period return into percentile bins with the bin assignment function $\pi(\cdot)$. The holding period is measured in trading days and is thus already discrete.[10] The interaction indicators $\mathbb{1}\{\pi(r_{ijt}) = q\}\mathbb{1}\{h_{ijt} = p\}$ therefore

[10] We winsorize the holding period at 20 days to reduce the risk of overfitting, as our data show that the probability of selling declines steadily from 1 to 20 holding days but remains flat thereafter.

provide a complete set of return-percentile-by-holding-period controls. Standard errors are again clustered by investor and day.

The estimated selling propensities in excess of what would be expected purely based on a position's holding period and holding period return are plotted in Figure 2. Consistent with the strike price exerting a significant influence on the sales of out-of-the-money option purchases, the excess selling propensity again peaks at the strike price and retains the same inverse V-shape as in Figure 1. Holding periods and holding period returns thus do not explain the peak in selling propensity at the strike price.

The results in Figure 2 are estimated using our main sample of out-of-the-money option purchases, so they do not distinguish between options purchased deep out of the money and options purchased only slightly out of the money. To examine whether the strike price has a consistent effect on the selling of out-of-the-money options with different levels of moneyness at purchase, in Figure IA.4 we plot the results of a subsample analysis where we estimate the model from Equation 2 separately for options purchased between 0% and 10% out of the money and for options purchased more than 10% out of the money. The cutoff of 10% is very close to the median moneyness at purchase of out-of-the-money option purchases in our data set. Although the inverse V-shape is most prominent for options purchased closer to the strike price, in both subsamples we continue to observe a peak in excess selling propensity at the strike price. The strike price thus seems to have a consistent effect on investors' sales of options purchased out of the money, regardless of the precise level of moneyness at purchase, consistent with investors using the strike price as a target.

3.2 Placebo Tests Using In-the-Money Options

The analyses presented above have been performed on our main sample of out-of-the-money option purchases, since these are the option purchases for which the strike price can serve as an explicit forward-looking target that investors use. Although the results are consistent with this interpretation, similar results could plausibly be generated by other attributes that can be associated with the strike price. For example, the strike price could be a round number or an otherwise salient price to which investors react, even if they do not use it as an ex ante target (e.g., Pope and

Simonsohn, 2011; Frydman and Wang, 2020). Alternatively, investors could be selling at the strike price because they use sophisticated option trading strategies involving option Greeks like gamma and vega, which peak at the strike price.

To rule out these alternative explanations, we repeat the same analyses using our placebo sample of in-the-money option purchases. The attractive feature of these purchases is that the strike price cannot serve as a target price, since reaching the strike would represent a loss relative to the purchase price. As a result, if the peak in selling at the strike for options purchased out of the money is the result of investors using the strike price as a target, then we would not expect to observe a similar peak for options purchased in the money. By contrast, if the peak in selling is driven by other attributes associated with the strike price, such as salience or option Greeks, then we would expect to observe a peak at the strike for options purchased in the money.

Figure 3 plots the selling propensities and their 95% confidence intervals derived from estimating Equation 1 with our placebo sample of in-the-money option purchases. For options purchased in the money, the selling propensity is maximized when options remain approximately 3–8% in the money, but decreases sharply when an option approaches the strike price and falls out of the money. In contrast to options purchased out of the money, the selling propensity does not peak at the strike price, consistent with the peak for out-of-the-money options being the result of investors using the strike as a target, but inconsistent with the peak being driven by attributes such as salience or option Greeks, which should result in an identical peak for options purchased in the money.

Figure IA.5 plots the excess selling propensities controlling for a position's holding period and holding period return, and Figure IA.6 plots the results separately for options purchased between 0% and 10% in the money and for options purchased more than 10% in the money. In both figures, the excess selling propensity is highest for options that remain moderately in the money before decreasing as options approach the strike price and fall out of the money. The subsample plots show that the peak in excess selling propensity does not coincide with the strike price but instead occurs for options whose moneyness has decreased slightly from what it was when the option was purchased.

4 The Propensity to Sell When Crossing the Strike Price

If investors use the strike price of an option as a forward-looking target for their out-of-the-money option purchases, then we would expect to observe a clustering of sales on days when an option first crosses the strike price and investors sell to lock in their profits once their target has been reached.[11] In this section, we present evidence of such clustering from two stacked difference-in-differences designs (e.g., Gormley and Matsa, 2011; Cengiz, Dube, Lindner, and Zipperer, 2019), which are particularly appropriate for analyzing staggered treatments as they rely on clean control observations within the treatment window (i.e., not-yet-treated or never-treated units). We show that there is a significant spike in selling on days when an option purchased out of the money crosses the strike for the first time, but no corresponding spike when in-the-money purchases cross the strike, consistent with investors using the strike price of an option as a target price.

4.1 The Clustering of Sales on Strike Price Crossings

To see how investors respond to strike price crossings, we begin by examining selling behavior at the option-day level. Focusing on options that were issued out of the money, we test whether the probability of selling spikes when options cross from out of the money to in the money for the first time, relative to options issued out of the money that remain out of the money. For each strike price crossing date, we identify a cohort of treated options that cross the strike and control options that do not. We then stack the data across crossing events and estimate the average treatment effect.

Formally, we estimate the option-panel regression

$$Sale_{jt} = \alpha_{jc} + \lambda_{tc} + \sum_{\tau=-5}^{-2} \mu_\tau D_{jt}^\tau + \sum_{\tau=0}^{5} \mu_\tau D_{jt}^\tau + \varepsilon_{jt}, \tag{3}$$

where $Sale_{jt}$ is the fraction of option holders who sell option j on day t, and $D_{jt}^k = \mathbb{1}[t - E_j = k]$ is an indicator for option j in cohort E_j (i.e., the strike price crossing day) being k days away from the crossing. The standard two-way fixed effects are at the option-cohort level, α_{jc}, and day-cohort

[11] Similar examples of clustering around targets have been documented in other settings. For example, Allen, Dechow, Pope, and Wu (2017) document significant clustering in marathon runners' finishing times around commonly used target times.

level, λ_{tc}. The parameters of interest are the μ_τ, which identify the differences in selling probabilities between options that cross the strike price for the first time on $\tau = 0$ and options that remain out of the money throughout the entire treatment window. Standard errors are clustered by investor and day.

The estimates of the μ_τ and their 95% confidence intervals are plotted in Figure 4. In the days before a strike price crossing, the estimated coefficients are all statistically indistinguishable from zero, indicating parallel trends in the selling of treated and control options. On the strike crossing day, the probability of selling spikes to over 12% relative to the previous day, which is both statistically and economically significant, corresponding to a 65% increase in selling propensity relative to the unconditional average of the dependent variable aggregated at the option-day level. We thus find significant excess selling of options issued out of the money precisely on the day when they first cross the strike price, consistent with investors selling to lock in their profits as soon as their target has been reached.

The option-level design presented in Equation 3 closely mirrors the structure of the traditional stacked difference-in-differences approach (e.g., Baker, Larcker, and Wang, 2022), but by aggregating the analysis to the option level, it does not fully exploit the richness of our individual holding-level data. In the following analysis, we apply the difference-in-differences approach at the position level, which provides two distinct advantages over the option-level design. First, the increased granularity of the data enables us to construct highly comparable cohorts using control observations that match both the option type and the underlying asset of a given treated observation. Second, it allows us to more precisely control for additional factors that are known to influence selling decisions, such as the holding period return, holding period, and time to expiry of an option position.

Formally, we estimate the holding-panel regression

$$Sale_{ijt} = \alpha_{ijc} + \lambda_{tc} + \gamma X_{ijt} + \sum_{\tau=-5}^{-2} \mu_\tau D_{ijt}^\tau + \sum_{\tau=0}^{5} \mu_\tau D_{ijt}^\tau + \varepsilon_{ijt}, \tag{4}$$

where $Sale_{ijt}$ is a dummy variable that equals one if investor i sells option j on day t, and D_{ijt}^k is an indicator for option j held by investor i being k days away from the crossing. The two-way fixed

effects are at the investor-option-cohort level, α_{ijc}, and the day-cohort level, λ_{tc}. X_{ijt} are additional control variables. The standard errors are again clustered by investor and day.

As in the option-level design, we require that control observations remain untreated throughout the treatment window, meaning they are either not yet treated or never treated. We further restrict control observations to those with the same option type and the same underlying asset as those in the corresponding treated group. This approach allows us to form highly homogeneous cohorts defined by option type, underlying asset, and trading day.

The results from the position-level design are presented in Table 2. In Column (1), we augment the two-way fixed effects with direct controls for the holding period return and a dummy variable *Gain* that equals one if the position of investor i in option j on day t is trading at a gain relative to the purchase price. We find that the probability of selling on strike crossing days spikes by 4.1% relative to the previous day. Although the magnitude of the effect size is smaller than in the option-level design, the economic significance of the effect remains similar, representing a 70% increase in selling propensity relative to the unconditional mean of the dependent variable in the full stacked sample.

In Column (2), we control for the holding period return and gain status using fixed effects, by discretizing the holding period return into bins with a width of 5% and by interacting both variables with the corresponding strike-crossing cohort indicator. In Column (3), we present our most demanding specification, adding cohort-specific fixed effects for holding days and time to expiry. In both specifications, the spike in selling on the strike crossing day remains positive and highly statistically significant, and even in the most demanding specification represents an economically significant 47% increase in selling propensity relative to the unconditional baseline.

4.2 Placebo Tests Using In-the-Money Options

The results of the stacked difference-in-differences analyses presented above are consistent with the interpretation that investors use the strike price of an option as a target price. However, as with the propensity to sell functions estimated for out-of-the-money purchases in Section 3, the results could plausibly be generated by other attributes associated with the strike price. We thus

adopt the same approach as before and perform placebo tests with options that cross the strike price from in the money to out of the money.

Figure 5 plots the results from the option-level design in Equation 3. The treated options are those that cross the strike price and fall out of the money for the first time, while the control options remain in the money throughout the entire treatment window. The results show that there is no spike in selling propensity when crossing the strike from in the money to out of the money, which is not what we would expect if the clustering of sales around strike price crossings were driven by salience, option Greeks, or other alternative explanations. Instead, the results are consistent with investors using the strike price of an option as a target for their out-of-the-money option purchases.

Table 3 presents the results from the corresponding position-level design, using individual holding-level data to control for the holding period return, holding period, and time to expiry. Consistent with the results from the option-level design, we find no evidence of a spike in selling propensity on days when an in-the-money option crosses the strike and falls out of the money for the first time.

5 Interpretation

5.1 Reference-Dependent Preferences

The economic literature has considered three types of reference points in models of reference-dependent preferences: backward-looking, forward-looking, and salience-based (see O'Donoghue and Sprenger (2018) for a review). Perhaps the most widespread is the use of the status quo, a type of exogenous and backward-looking reference point (Tversky and Kahneman, 1991). The effects of status quo reference points have been well-documented in the housing market (Andersen et al., 2022), labor supply decisions (Camerer et al., 1997; Crawford and Meng, 2011; Thakral and Tô, 2021), and trading decisions in financial markets (Odean, 1998; Barberis and Xiong, 2012; Ben-David and Hirshleifer, 2012).

Our results are inconsistent with purely backward-looking or salience-based reference points. The status quo interpretation in our setting would imply that investors use the purchase price as a

reference point and react to nominal losses disproportionately more than nominal gains. Yet, we show that nominal gains are smooth around the strike price and that across the empirical designs we consider, the results are insensitive to the inclusion of highly flexible controls for nominal gains. The salience-based interpretation of our results implies that investors react to the strike price because of its prominence. For example, some online brokers use different colors to display in-the-money options compared to out-of-the-money options, making their moneyness more salient. However, our placebo tests rule out salience as an explanation for our results, since the salience of the strike price should be the same, regardless of whether an option was purchased in the money or out of the money.

Instead, the evidence we present is most consistent with investors using investment targets as forward-looking reference points, and evaluating the success of their trading episodes relative to the goal or target they have set for themselves.

The finance theories most related to our work are models of realization utility (Barberis and Xiong, 2012) where the act of selling an asset triggers an instantaneous burst of utility relative to a reference point. The sharp increase in selling propensity at the strike price we document is broadly consistent with the mechanism of realization utility, albeit with a more nuanced specification of the reference point. Most models of realization utility assume a status quo reference point or its variant inflated by the risk-free rate. Our results are most consistent with the idea that investors have investment-specific targets. Hence, our results suggest that a fruitful direction for future research is to explore models of realization utility with forward-looking and endogenous reference points.

5.2 Belief-Based Explanations

An alternative class of explanations considered in the literature on the disposition effect is based on belief-based mechanisms. Under this interpretation, investors may be more likely to sell options that are in the money because they believe the price of the underlying asset may mean-revert and drop below the strike price, rendering the position worthless at expiry.

Disentangling preference- and belief-based explanations is challenging because beliefs are typically unobserved by the researcher. Perhaps the most compelling evidence against the belief-based

explanations comes from laboratory studies that automatically liquidate positions while attempting to hold beliefs fixed (Weber and Camerer, 1998). Although the observation that subjects are less likely to repurchase losing stocks after forced liquidation is inconsistent with a belief-based explanation, these results are difficult to interpret because of the potentially confounding effect that ownership has on valuations and belief formation (Hartzmark, Hirshman, and Imas, 2021), and the evidence that buying and selling decisions are governed by different mental processes (Barber and Odean, 2013).

In this section, we exploit the unique features of options to design a novel test of reference-dependent selling in a setting where we can plausibly keep beliefs fixed, even without observing them directly. The test we propose takes advantage of the fact that an investor can simultaneously hold multiple options with the same underlying asset. The setting is as follows. On a specific day t, a specific investor i simultaneously holds two call options or two put options with the same underlying asset and the same time to expiry. To restrict the setting even further, we can require that the options were purchased on the same day, so that they also have the same holding period. The attractive feature of fixing the holding period, time to expiry, and underlying asset is that both the price path of the underlying asset during the holding period and the investor's belief about the future price path until the time of expiry are the same for both option positions. As a result, if investors' reference-dependent selling decisions are driven by their beliefs, we should observe selling behavior that is consistent across the two positions, regardless of whether the positions are in the money or out of the money. As we show below, this is not what we observe.

Although the setting we exploit is highly restrictive, our data set includes 530 518 investor-option-days that satisfy the option type, underlying asset, and time to expiry requirements, and 76 070 investor-option-days that meet the additional holding period requirement. In total, 2 118 investors—or roughly one in every nine retail option traders in Finland—simultaneously hold two options of the same type with the same underlying asset and the same time to expiry at least once during our sample period. Summary statistics about these investors and their trades in this restricted setting are presented in Table IA.4.

Inspired by the disposition effect tests of Chang et al. (2016), we test whether an option position

being in the money or out of the money influences investors' selling decisions by using the following linear probability model specifications:

$$Sale_{ijt} = \beta_0 + \beta_1 ITM_{jt} + \varepsilon_{ijt}, \tag{5}$$

$$Sale_{ijt} = \beta_0 + \beta_1 ITM_{jt} + \beta_2 Gain_{ijt} + \varepsilon_{ijt}. \tag{6}$$

ITM_{jt} is a dummy variable that equals one if option j is in the money on day t. $Gain_{ijt}$ is a dummy variable that equals one if the position of investor i in option j on day t is trading at a gain relative to the purchase price. In both specifications, standard errors are clustered by investor and day.

Both specifications are estimated with two sets of fixed effects corresponding to the restricted setting described above. The first set consists of fixed effects at the investor by day by underlying asset by time to expiry level. The identifying variation with these fixed effects comes from situations where one of two options with the same underlying asset and the same time to expiry held by an investor is in the money, while the other is out of the money. The second set consists of fixed effects at the investor by day by underlying asset by time to expiry by holding period level. With these fixed effects, the source of identifying variation is the same as before, except for the additional holding period requirement.

The results from the baseline specification in Equation 5 are presented in Columns (1) and (2) of Table 4. In both settings, the coefficient on the ITM dummy variable is positive and statistically significant, indicating that investors use the strike price of an option as a reference point and are more likely to sell in-the-money options, even in this setting where investors' beliefs for the in-the-money position and the out-of-the-money position should be the same. The ITM coefficients remain positive and statistically significant when controlling for the gain or loss status of a position in Columns (3) and (4) of Table 4, so the effect that the strike price has on selling decisions is distinct from the effect that returns have on selling decisions. Overall, these results are consistent with preference-based explanations for reference-dependent selling but inconsistent with a purely belief-based explanation.

5.2.1 The Subjective Expected Returns Implied by In-the-Money Option Sales

The results of Table 4 show that in situations where an investor simultaneously holds two options of the same type with the same underlying asset and the same time to expiration, with one of the options being in the money and the other out of the money, they are more likely to sell the in-the-money option. Specifically, when an investor sells one of the options but not the other, 78.55% of the time they sell the in-the-money option. Could these sales of in-the-money options be rationalized by investors' beliefs, and what do they reveal about the determinants of investors' selling decisions? To shed light on these questions, we study whether selling in-the-money options is consistent with the beliefs implied by the fact that investors continue to hold their out-of-the-money options.

For simplicity, assume that when an investor sells the in-the-money option, they plan to hold the unsold out-of-the-money option until it expires.[12] It follows that the investor must believe that the out-of-the-money option will expire in the money, since if they did not, then their expected terminal payoff would be equal to zero, and they would be better off selling the option immediately. The strike price of the out-of-the-money option thus represents a lower bound on the investor's belief about the price of the underlying asset at the time of expiry. As a result, the difference between the strike price of the unsold out-of-the-money option and the strike price of the sold in-the-money option also represents a lower bound, this time on the investor's belief about the terminal payoff of the in-the-money option. Given this expected payoff, the subjective expected return of holding the in-the-money option until expiry that is implied by the investor's belief, and which the investor chooses to forgo by selling the option, is given by:

$$E[r_t^{ITM}] = \frac{\text{Payoff}_T^{ITM} \mid S_T = K^{OTM}}{P_t^{ITM}} - 1, \tag{7}$$

where the numerator is the terminal payoff conditional on the price of the underlying asset being equal to the strike price of the out-of-the-money option, and the denominator is the current price of

[12] This assumption simplifies the subsequent calculations, but qualitatively similar conclusions hold for other assumptions about the investment horizon. Empirically, we find that 52.29% of the unsold out-of-the-money positions are held until expiry.

the in-the-money option.[13]

Table 5 reports summary statistics of the subjective expected returns implied by investors' sales of in-the-money options in this restricted setting and in subsamples based on option type, trade size, time to expiry, and moneyness. In each instance, the forgone expected returns implied by investors' selling decisions are extraordinarily high. Across all options, the average (median) forgone return is 1243.95% (650.00%) over an average investment horizon of 33 days. Investors thus seem to be making highly contradictory trading decisions when selling in-the-money positions and continuing to hold out-of-the-money positions. These decisions are very difficult to reconcile with a purely belief-based explanation for investors' reference-dependent selling decisions.

6 Alternative Explanations

The results presented above are consistent with investors buying options with a specific target price in mind, and then making their selling decisions by evaluating their performance relative to this forward-looking reference point. In this section, we rule out alternative explanations for our results and provide additional evidence in support of this interpretation.

6.1 Ex Post Rationality

Investors may sell options crossing from out of the money to in the money because they believe prices tend to mean revert (e.g., Odean, 1998). Although we cannot directly observe whether investors hold such beliefs, we can evaluate whether such beliefs would be justified by the ex post performance of the options.

Figure 6 reports average cumulative option returns and their corresponding 95% confidence intervals for the ten days following the crossing of an option from out of the money to in the money. The average 1-day (10-day) option return is 2.8% (4.4%), so investors are forgoing highly attractive short-term returns by selling on strike crossing days. If investors' sales are explained by a belief in mean reversion, then, on average, the investors' beliefs are incorrect.

[13] For example, if an investor sells an in-the-money call with a price of 10 and a strike of 100 while holding an out-of-the-money call with a strike of 120, then the subjective expected return of continuing to hold the in-the-money option implied by the investor's actions is $(120 - 100)/10 - 1 = 100\%$.

A similar picture emerges in the subsample that we use to test belief-based explanations for reference-dependent selling, when an investor decides to sell an in-the-money option while continuing to hold an out-of-the-money option. Ex post returns calculated from the date on which the in-the-money option was sold to the expiry date of the options show that the out-of-the-money option would have outperformed the in-the-money option in only 10% of cases. Overall, the median return from continuing to hold the in-the-money option until expiry would have been 295%, whereas the median return from the out-of-the-money option would have been -100%.

Overall, if investors' selling and holding decisions are driven by their beliefs, then these beliefs are not justified by the ex post performance of their trades.

6.2 The Rank Effect

Hartzmark (2015) shows that investor selling behavior is influenced by the relative performance of holdings within an investor's portfolio, with the best- and worst-performing holdings having higher selling propensities. Since options that cross the strike tend to have more extreme returns than options that do not, the selling behavior around the strike that we document could potentially be driven by this rank effect. To rule out this possibility, Table IA.5 augments the position-level difference-in-differences design with cohort-specific fixed effects for the best- and worst-performing holdings within an investor's portfolio. The estimated effects associated with strike price crossings remain statistically and economically significant, suggesting that our findings are not driven by relative performance.

6.3 Skewness Preferences

Selling in-the-money options and holding out-of-the-money options could be consistent with investors having a preference for skewness, since out-of-the-money options have more skewed return distributions than in-the-money options. However, we consider it unlikely that skewness preferences are a major driver of our results for two reasons. First, it is not clear why skewness preferences would generate a spike in selling when out-of-the-money options cross the strike price, but have no effect when in-the-money options cross the strike. If selling on strike crossing days is explained by

the skewness of the option position changing, then we would expect to observe a decrease in selling propensity for crossings from in the money to out of the money, but we actually observe neither a decrease nor an increase.

Second, in the subsample that we use to test belief-based explanations for reference-dependent selling, when an investor chooses to sell an in-the-money option while continuing to hold an out-of-the-money option, in 93% of cases the sale occurs when the investor also holds other assets in their portfolio. In particular, in 64% of cases the investor also holds one or more stocks. If selling decisions are driven by a preference for skewness, then it is unclear why investors choose to sell in-the-money options rather than stocks, which exhibit considerably less skewed returns.

6.4 Rational Rebalancing or Rollover Strategies

Reinvestment or rollover strategies, defined as sales that are shortly followed by new purchases (e.g., Grinblatt et al., 2012; Muravyev, 2016), are also unlikely to be driving our results. As shown in Table IA.6, our position-level difference-in-differences results continue to hold even when we exclude investors who purchase an option on the strike crossing day or one day after the strike price crossing.

A similar pattern emerges in the tests of belief-based explanations for reference-dependent selling. In that setting, a higher propensity to sell in-the-money options could be rational if investors sell with the intention of reinvesting the proceeds of the sale into positions with even higher expected returns given the investor's implied beliefs, such as an option on the same underlying asset with a lower moneyness than the sold option. However, we find that after 69% of in-the-money option sales, there is no direct repurchase of another option position on the same day, and 84% of in-the-money option sales are not followed by any rebalancing into an option of the same type and on the same underlying asset that has a lower moneyness than the sold option. Rational rebalancing into options with even higher implied expected returns thus cannot explain the vast majority of the in-the-money option sales we document.

6.5 Transaction Costs

Since out-of-the-money options have lower prices than in-the-money options, fixed transaction costs could discourage investors from selling out-of-the-money options. Although we do not have data on historical transaction costs, we would expect transaction costs to matter most for small positions and deep out-of-the-money options, while options that are crossing or close to the strike price—and which are the main focus of our empirical analyses—should be less affected. For example, in the subsample that we use to test belief-based explanations for reference-dependent selling, the average value of unsold out-of-the-money option positions is €1 735, compared to which fixed transaction costs are likely to be small. Tables IA.7 and IA.8 confirm that our main results are robust to excluding small option positions, following the definition of Fecht, Hackethal, and Karabulut (2018), for which transaction costs are more likely to influence investment decisions.

6.6 Liquidity Needs

Investors may sell in-the-money options because they have a pressing need for liquidity. Although it is not clear why the need for liquidity would spike precisely on days when out-of-the-money options cross the strike for the first time, but not on days when in-the-money options cross the strike, Tables IA.9 and IA.10 confirm that our main results continue to hold in situations where an investor also holds other assets in their portfolio at the time of selling. In these situations, an investor with a need for liquidity has multiple assets to choose from when making their selling decision. Given the positive average returns of continuing to hold in-the-money options sold on strike crossing days reported in Figure 6, and given the extremely high subjective expected returns of continuing to hold in-the-money options reported in Table 5, it seems less likely that investors would choose to sell these options for liquidity purposes when they could instead sell other assets with lower expected returns.

6.7 Taxes

While tax motives could influence investors' propensity to sell in-the-money options, three pieces of evidence make it unlikely that this is a significant driver of our results. First, 83% of

in-the-money options sold on strike crossing days result in realized gains, thus incurring tax liabilities instead of tax benefits. Second, in the subsample that we use to test belief-based explanations for reference-dependent selling, a further 80% of in-the-money options are sold at a gain, again incurring tax liabilities. Moreover, when an in-the-money option is sold at a loss, 93% of the corresponding out-of-the-money options are also trading at a loss, and thus could have been sold instead. Finally, we observe no clustering of in-the-money option sales in December, a month typically associated with tax-loss selling behavior (Grinblatt and Keloharju, 2004). Overall, we find little evidence that tax motives are a significant driver of our results.

6.8 Hedging Motives

The literature on option trading by retail investors has shown that hedging does not seem to be a primary motivation behind retail investors' option trades (Lakonishok, Lee, Pearson, and Poteshman, 2007). For example, Bogousslavsky and Muravyev (2024) find that only 0.1% of the option trades in their sample are protective puts, which can be used to limit the downside risk of a long stock position. Table IA.11 shows that protective puts are also very uncommon in our sample: when an investor purchases an option while already owning the underlying stock, 92% of the time they purchase a call option. In other words, investors are far more likely to leverage their long exposure with a call than to limit their downside risk with a put. In total, protective puts make up only 3% of all stock option purchases in our sample. The results are similar if we consider the total euro value of stock option purchases, as opposed to the number of purchases. Overall, these results are consistent with the view that hedging is not a primary concern for the investors in our sample.

Nonetheless, to examine whether hedging-motivated trading drives our results, we repeat our analyses excluding put options. Since short selling stocks is very uncommon among retail investors in Finland (e.g., Grinblatt and Keloharju, 2001), it is highly unlikely that call options are purchased for the purposes of hedging. If our results are driven by hedging motives, then we would expect them to disappear when excluding puts. Tables IA.12 and IA.13 show that this is not the case.

6.9 Avoiding Settlement

An important reason why investors may prefer to sell in-the-money options is to avoid settlement-related frictions, such as the possibility of delivery of the underlying asset or the need to fund an exercise payment. This mechanism, however, does not apply to our setting because all of the options in our data set are cash-settled. For cash-settled contracts, expiration does not require delivery of the underlying asset and does not mechanically trigger a position in the underlying. Instead, the payoff is realized through a cash transfer equal to the contract's intrinsic value. As a result, there is no need for the investors in our data set to "avoid" settlement by selling their options.

6.10 Complex Option Trades

Three pieces of evidence speak against our results being attributable to complex option trades. First, because the options in our data set are issued by banks, the investors in our sample cannot write options, which considerably limits their ability to construct complex option trades.[14]

Second, while the simultaneous option holdings used in our tests of belief-based explanations for reference-dependent selling could be complex option trades, most option pairs in that sample were purchased on different days. This makes the option pairs less likely to have been purchased as part of a deliberate complex trading strategy.

Finally, we also estimate the position-level difference-in-differences design excluding investors who own more than one option on a given underlying asset or the underlying asset itself. Table IA.14 shows that excluding positions that could be part of a complex option trade actually makes the effect of the strike price crossing even stronger.

6.11 Pinning Risk

Investors could sell around strike price crossings because of pinning risk (e.g., Golez and Jackwerth, 2012). If the price of the underlying asset tends to be pulled toward option strike prices close to option expiration, then small moves in the underlying can generate large changes in an option's delta and value. This could, in turn, lead investors to reduce exposure by selling as the price of the

[14] Li, Musto, and Pearson (2022) find that between 70% and 85% of complex option trading volume in the U.S. comes from trades that include at least one written option.

underlying asset approaches the strike.

If investors' selling decisions are explained by their concern over pinning risk, then we would expect our main results to be driven by options close to expiry, for which pinning is most relevant. However, Tables IA.15 and IA.16 show that our main results continue to hold even after excluding options with five or fewer days to expiry. Pinning risk thus does not seem to be a significant driver of our results.

6.12 Option-Level Beliefs

The test we design in Section 5.2 to disentangle preference- and belief-based explanations for reference-dependent selling exploits the fact that an investor can simultaneously hold multiple options on the same underlying asset. Since option prices are a function of the prices and volatilities of their underlying assets, we argue that the beliefs investors hold about different options with the same underlying asset should be internally consistent, thus allowing us to plausibly keep beliefs fixed, even without observing them directly.

A potential concern with this empirical strategy is that investors may actually form option-level beliefs that are independent of their beliefs about other options with the same underlying asset. For example, retail investors may not understand that an option is linked to an underlying asset, which could lead to very different beliefs for different options on the same underlying. However, the very fact that investors' selling decisions are influenced by an option's strike price, which is directly related to the price of the underlying asset, rules out this extreme degree of financial illiteracy.

Alternatively, investors may form beliefs about expected option returns based on an option's moneyness, which could generate inconsistent beliefs for in-the-money and out-of-the-money options. Although we cannot directly observe whether investors hold such beliefs, we can examine trading behavior in closely related option pairs to see whether selling decisions are consistent with expected returns being a function of moneyness. Specifically, we consider investors who simultaneously hold two options with the same moneyness and underlying asset, but with different times to expiry. If beliefs are determined by option moneyness, we would expect the sales of these pairs to occur simultaneously. However, of the 12 097 selling days in our data set that satisfy these criteria, 82%

are days on which only one of the two options is sold, which is inconsistent with investors forming option-level beliefs in this way.

Finally, we note that if investors held highly divergent beliefs about options with different strike prices but the same underlying asset, then this would imply very large and unrealistic differences in implied volatilities across different strike prices.

6.13 Placebo Tests

Our primary empirical strategy for ruling out alternative explanations has been to perform placebo tests using in-the-money options, since these are options for which the strike price cannot act as a target price. If the results of the main tests and the placebo tests were similar, then that would be inconsistent with the target price mechanism. By contrast, if the results were different, then that would rule out any explanation based on attributes associated with the strike price that are identical for out-of-the-money and in-the-money options, such as salience, round number focality, or option Greeks.

A potential concern with the placebo test approach is that the investors who purchase in-the-money options may be fundamentally different from those who purchase out-of-the-money options, and that this difference may be systematically related to the strike price, thus rendering the placebo tests a poor comparison for the main tests. To address this concern, in Table IA.17 we present the placebo test results for the position-level difference-in-differences design excluding investors who never purchase an out-of-the-money option. The results confirm that this kind of investor sorting is not driving the results of the placebo tests.

7 Conclusion

Most empirical work on reference dependence in trading implicitly treats the purchase price as the benchmark against which investors evaluate gains and losses. This paper points to a different, inherently forward-looking benchmark: investor targets. We exploit a distinctive feature of retail option trading in which investors can choose a strike that maps naturally into a target price for the underlying asset. Using population-level administrative holdings data and stacked difference-

in-differences designs, we document a sharp increase in the propensity to sell precisely when the underlying first crosses the strike price.

Our results support a target-based interpretation. The discontinuity is difficult to reconcile with other mechanisms, such as salience or option Greeks. Most importantly, the effect is absent in placebo settings in which the strike price cannot plausibly represent a gain target, namely options purchased in the money. In addition, within-investor tests that hold the underlying, option type, and time to expiry fixed are hard to square with belief-based explanations, but align with investors evaluating outcomes relative to a position-specific aspiration level. Taken together, our results are most consistent with reference-dependent preferences organized around forward-looking targets, rather than solely around backward-looking purchase prices.

Beyond documenting target-based reference points, the paper clarifies why reference point formation is central for inference in behavioral finance. When investors trade with heterogeneous benchmarks, standard diagnostics that focus on behavior around the purchase price, such as discontinuities at zero gains or V-shaped selling propensities, need not be informative about reluctance to realize losses because the relevant zero is not pinned down by the transaction price. More broadly, tests of reference-dependent utility are unavoidably joint tests of the reference point and the utility specification. The option market provides a setting in which the strike price delivers unusually sharp, falsifiable predictions about where reference dependence should and should not appear, offering a disciplined laboratory for modeling endogenous, forward-looking benchmarks in trading decisions.

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Figure 1. Propensity to Sell Options by Moneyness: Out-of-the-Money Purchases.
Plotted is the propensity to sell function estimated by regressing the dummy variable *Sale* on a set of dummy variables corresponding to moneyness percentile bins. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

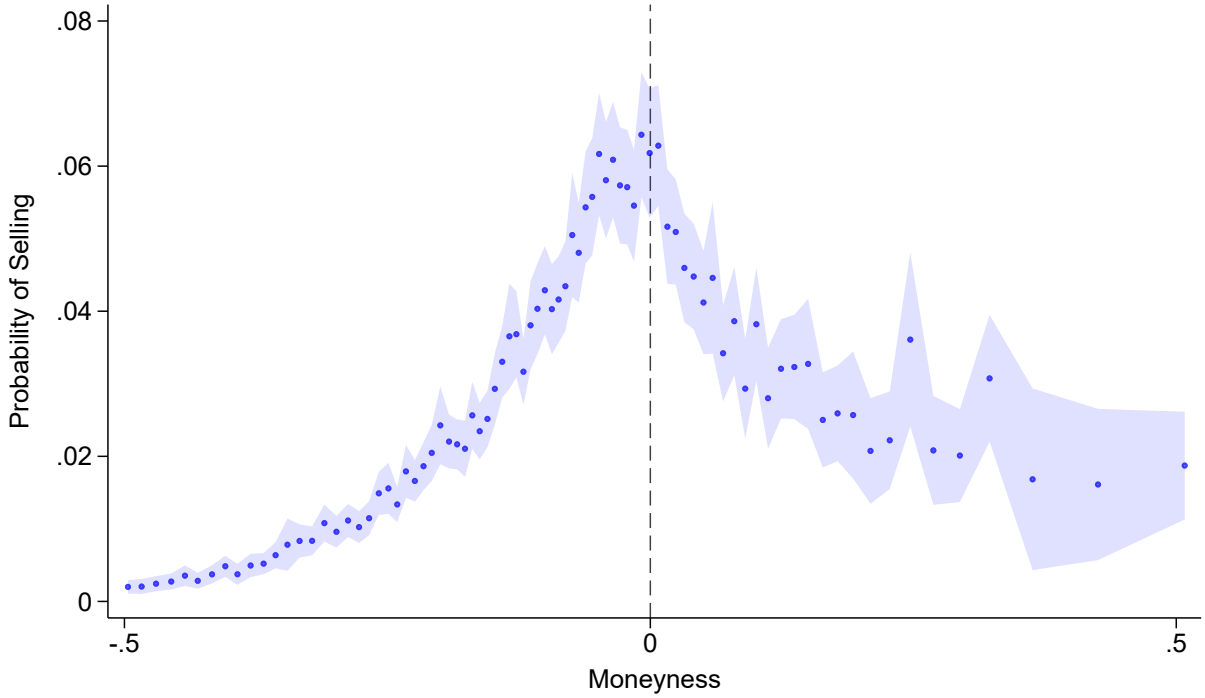


Figure 2. Excess Propensity to Sell Options by Moneyness: Out-of-the-Money Purchases.
Plotted is the excess propensity to sell function estimated by regressing the dummy variable *Sale* on a set of dummy variables corresponding to moneyness percentile bins and on interacted controls for holding period return percentile bins and the holding period. The holding periods are winsorized at 20 days. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

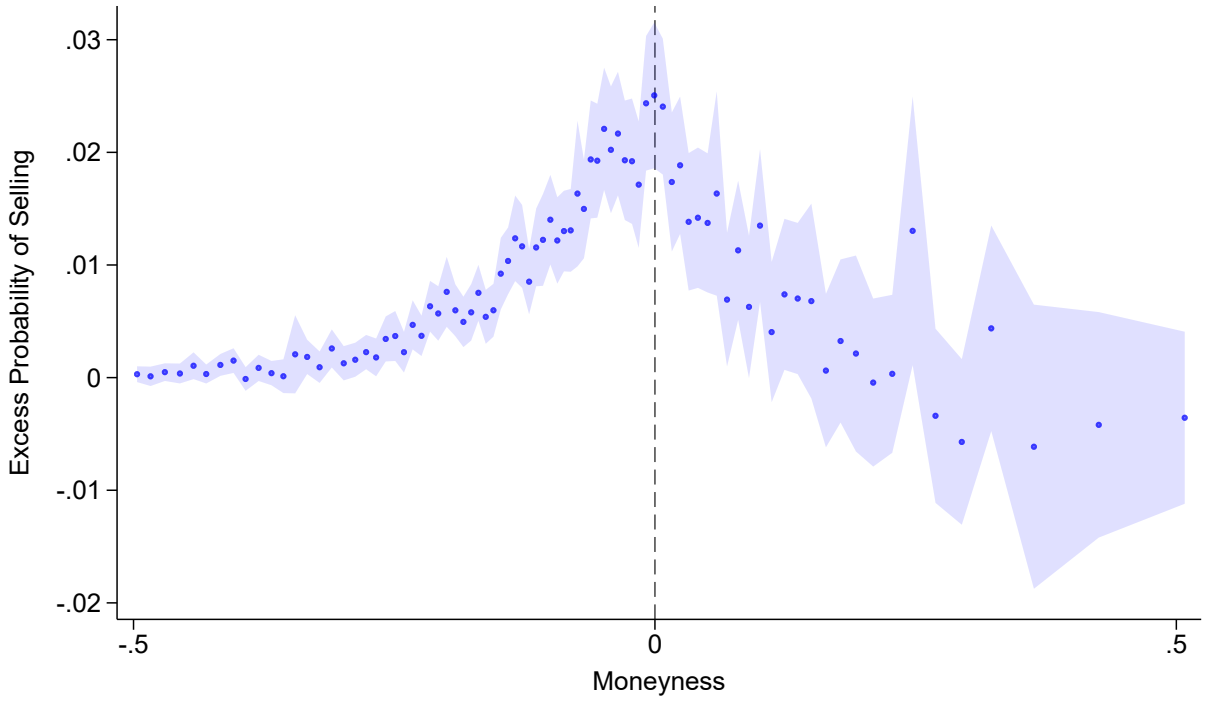


Figure 3. Propensity to Sell Options by Moneyness: In-the-Money Purchases.
Plotted is the propensity to sell function estimated by regressing the dummy variable *Sale* on a set of dummy variables corresponding to moneyness percentile bins. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all in-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

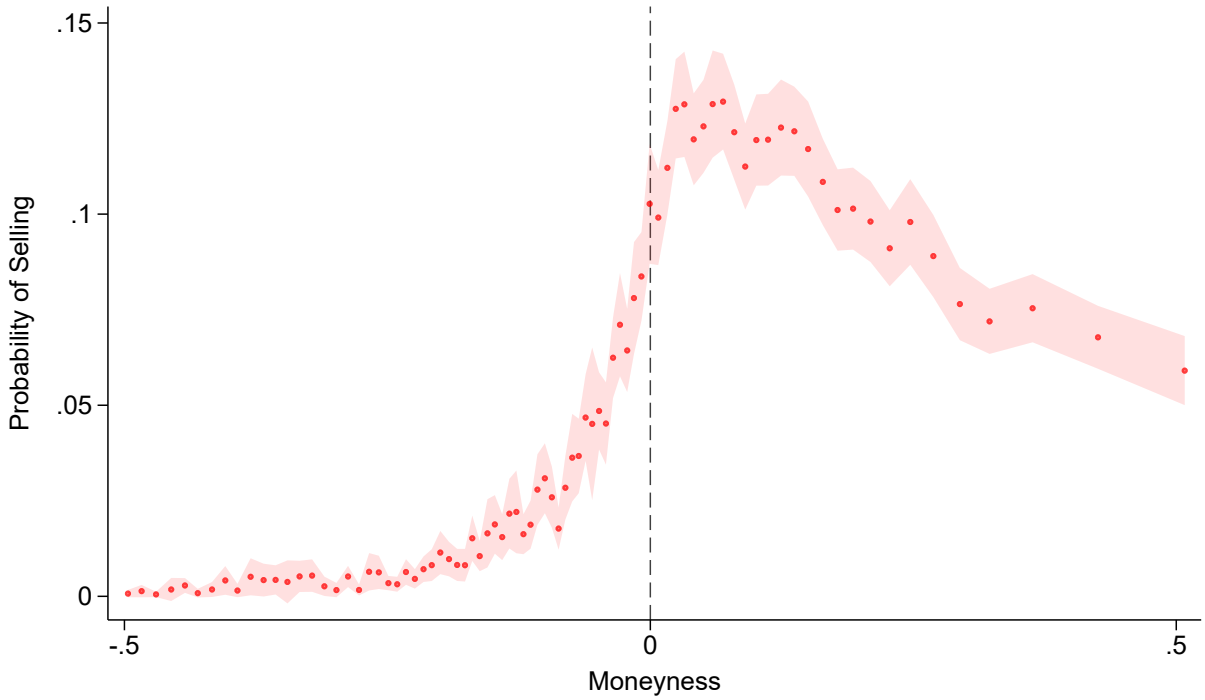


Figure 4. Propensity to Sell Options Around Strike Price Crossings: OTM to ITM.
Plotted is the propensity to sell options around strike price crossings from out of the money to in the money estimated using a stacked difference-in-differences approach with two-way fixed effects at the option-cohort and day-cohort levels. Each cohort is identified at the strike price crossing day. The unit of analysis is an option-day and the dependent variable is the fraction of option holders who sell on a given day. Option-days are weighted based on the number of investors holding an option on a given day. The sample is constructed from our data set which contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

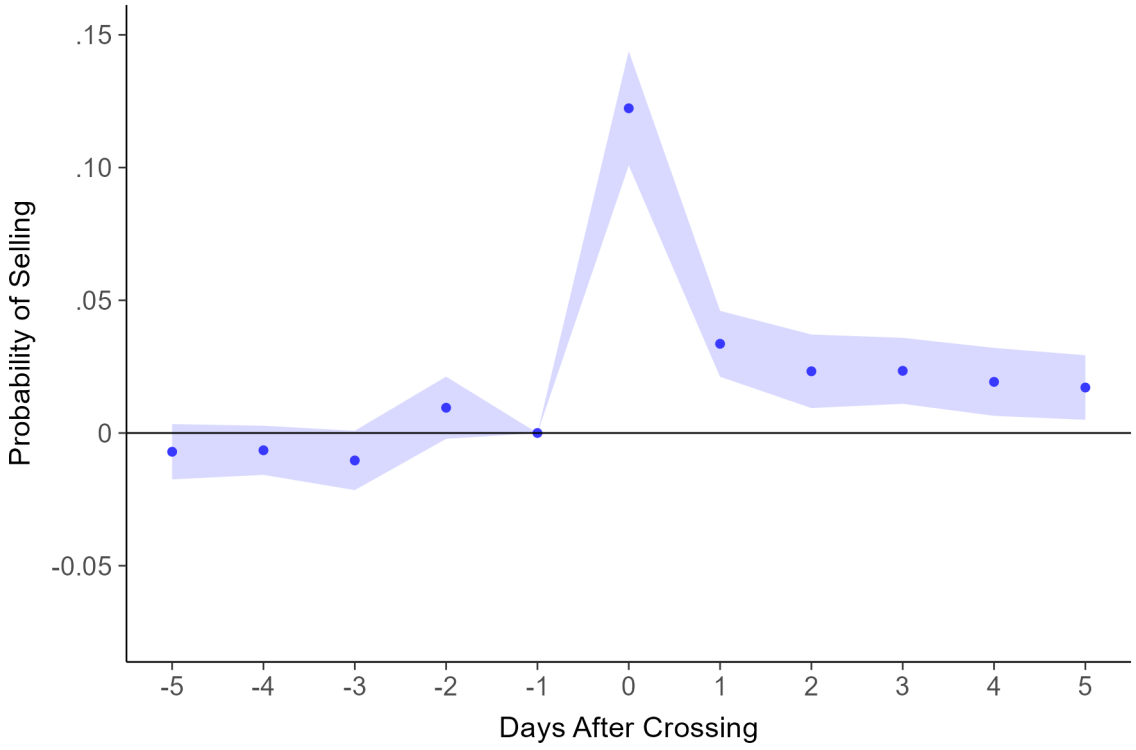


Figure 5. Propensity to Sell Options Around Strike Price Crossings: ITM to OTM.
Plotted is the propensity to sell options around strike price crossings from in the money to out of the money estimated using a stacked difference-in-differences approach with two-way fixed effects at the option-cohort and day-cohort levels. Each cohort is identified at the strike price crossing day. The unit of analysis is an option-day and the dependent variable is the fraction of option holders who sell on a given day. Observations are weighted based on the number of investors holding an option on a given day. The sample is constructed from our data set which contains all in-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

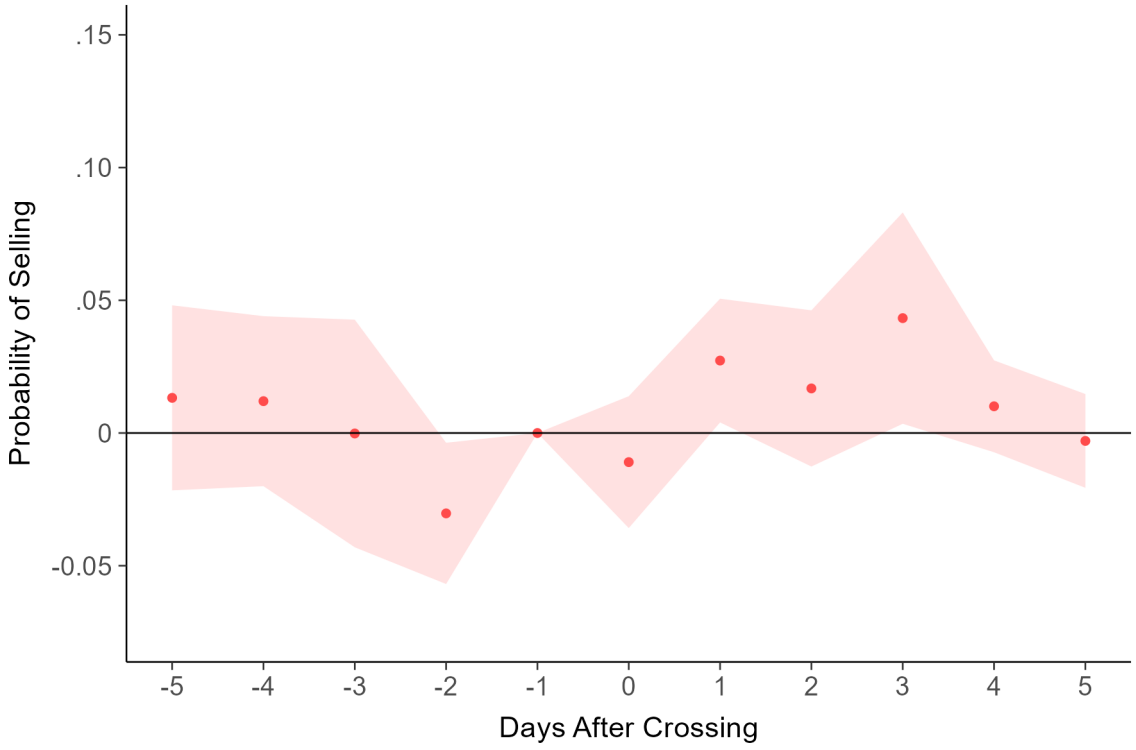


Figure 6. Realized Option Returns After Strike Price Crossings.
Plotted are the average cumulative returns of holding an option for one to ten days after it crosses from out of the money to in the money for the first time. The sample is constructed from our data set which contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by underlying asset and day.

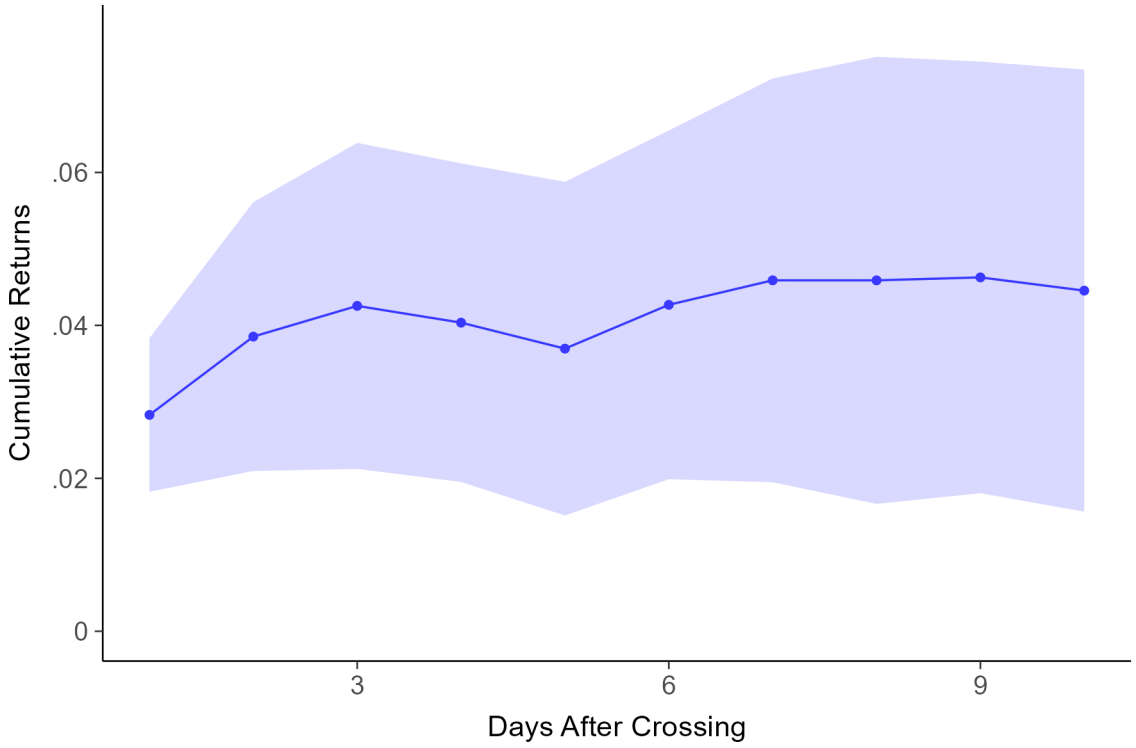


Table 1. Summary Statistics.
Reported are summary statistics about out-of-the-money purchases, in-the-money purchases, investors, and the data set. For the investor characteristics, we first calculate the average value of a characteristic separately for each investor and then report the distribution of the investor-level averages, with investor age and trading experience measured at the beginning of each new trade. The daily selling probability is the unconditional probability that an investor sells an option on a given day. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The round-trip return is the total return from the first purchase which opens a new position to the final sale which fully closes the position. The data set contains the option trades of all retail investors in Finland from Dec-2000 to Dec-2017.

Panel A: Main Sample — Out-of-the-Money Purchases

	Mean	SD	25^{th} Pct.	Median	75^{th} Pct.
Call Option (%)	80.34				
Daily Selling Probability (%)	2.62				
Moneyness at Purchase (%)	-12.77	11.28	-17.50	-9.73	-4.67
Days to Expiry at Purchase	94.32	131.80	26.00	49.00	93.00
Value at Purchase (euros)	1 352	4 860	200	500	1 200
Round-Trip Return (%)	-11.68	90.56	-100.00	-6.67	26.51
Holding Period (days)	45.65	92.83	3.00	13.00	45.00

Panel B: Placebo Sample — In-the-Money Purchases

	Mean	SD	25^{th} Pct.	Median	75^{th} Pct.
Call Option (%)	72.81				
Daily Selling Probability (%)	5.88				
Moneyness at Purchase (%)	9.34	20.61	2.41	5.78	11.78
Days to Expiry at Purchase	54.85	80.46	17.00	34.00	59.00
Value at Purchase (euros)	2 171	7 385	300	750	1 950
Round-Trip Return (%)	-3.79	61.71	-37.08	2.33	23.53
Holding Period (days)	19.50	44.48	2.00	5.00	19.00

Panel C: Investor Characteristics

	Mean	SD	25^{th} Pct.	Median	75^{th} Pct.
Female (%)	10.46				
Age (years)	37.88	13.04	28.50	35.50	45.94
Experience (years)	1.00	1.64	0.00	0.17	1.34
Total Trades	51.38	175.51	3.00	9.00	33.00

Panel D: Data Set Characteristics

	N
Investors	18 570
Out-of-the-Money Purchases	122 525
In-the-Money Purchases	44 556

Table 2. Option Sales Around Strike Price Crossings: OTM to ITM.
Reported are the probabilities of selling options around strike price crossings from out of the money to in the money estimated using a stacked difference-in-differences approach with two-way fixed effects at the investor-option-cohort and day-cohort levels. Each cohort is identified at the strike price crossing day, with control observations having the same option type and underlying asset. The unit of analysis is an investor-option-day and the dependent variable *Sale* equals one if investor i sells option j on day t. All fixed effects are interacted with the corresponding strike-crossing cohort indicator. Return bins have a width of 5%. The sample is constructed from our data set which contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. Standard errors clustered by option and day are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0059	-0.0020	0.0056
	(0.0043)	(0.0041)	(0.0050)
t_{-4}	-0.0096**	-0.0071*	-0.0013
	(0.0039)	(0.0037)	(0.0045)
t_{-3}	-0.0089**	-0.0028	-0.0059
	(0.0037)	(0.0034)	(0.0036)
t_{-2}	-0.0065	-0.0022	-0.0016
	(0.0039)	(0.0035)	(0.0045)
t_0	0.0406***	0.0316***	0.0270***
	(0.0081)	(0.0068)	(0.0082)
t_1	0.0023	-0.0048	0.0045
	(0.0048)	(0.0048)	(0.0059)
t_2	0.0052	0.0019	-0.0029
	(0.0049)	(0.0049)	(0.0055)
t_3	0.0031	-0.0006	-0.0029
	(0.0046)	(0.0045)	(0.0056)
t_4	0.0052	0.0025	0.0018
	(0.0043)	(0.0040)	(0.0045)
t_5	0.0087**	0.0059	0.0039
	(0.0043)	(0.0037)	(0.0046)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 425 521	2 418 874	2 380 183
Adjusted R^2	0.2872	0.3209	0.3388

Table 3. Option Sales Around Strike Price Crossings: ITM to OTM.
Reported are the probabilities of selling options around strike price crossings from in the money to out of the money estimated using a stacked difference-in-differences approach with two-way fixed effects at the investor-option-cohort and day-cohort levels. Each cohort is identified at the strike price crossing day, with control observations having the same option type and underlying asset. The unit of analysis is an investor-option-day and the dependent variable *Sale* equals one if investor i sells option j on day t. All fixed effects are interacted with the corresponding strike-crossing cohort indicator. Return bins have a width of 5%. The sample is constructed from our data set which contains all in-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. Standard errors clustered by option and day are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0151	0.0018	0.0031
	(0.0157)	(0.0154)	(0.0157)
t_{-4}	-0.0051	0.0100	0.0178
	(0.0164)	(0.0152)	(0.0138)
t_{-3}	-0.0202	-0.0101	-0.0089
	(0.0162)	(0.0136)	(0.0122)
t_{-2}	-0.0440***	-0.0292**	-0.0062
	(0.0120)	(0.0124)	(0.0114)
t_0	0.0075	0.0058	0.0143
	(0.0147)	(0.0125)	(0.0139)
t_1	-0.0411***	-0.0303***	-0.0129
	(0.0082)	(0.0074)	(0.0088)
t_2	-0.0199*	-0.0090	0.0010
	(0.0116)	(0.0085)	(0.0110)
t_3	-0.0076	-0.0026	0.0053
	(0.0097)	(0.0066)	(0.0073)
t_4	-0.0101	-0.0070	-0.0019
	(0.0070)	(0.0063)	(0.0073)
t_5	-0.0132**	-0.0086	-0.0043
	(0.0063)	(0.0059)	(0.0069)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 481 568	2 479 248	2 454 191
Adjusted R^2	0.3047	0.3329	0.3569

Table 4. Option Sales by Moneyness When Investor Beliefs are Fixed.
Reported are the results from regressing the dependent variable *Sale* on dummy variables for the moneyness status and gain status of an option in situations where a given investor on a given day simultaneously holds two options of the same type with the same underlying asset, the same time to expiry, and, in a second specification, the same holding period. The sample is constructed from our data set which contains the option trades of all retail investors in Finland from Dec-2000 to Dec-2017. Standard errors clustered by investor and day are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable: Sale			
	(1)	(2)	(3)	(4)
ITM	0.0204***	0.0261***	0.0084***	0.0190***
	(0.0018)	(0.0046)	(0.0017)	(0.0045)
Gain			0.0281***	0.0373***
			(0.0029)	(0.0065)
	Fixed Effects			
Investor × Day × Underlying × Expiry	Yes	No	Yes	No
Investor × Day × Underlying × Expiry × Hold	No	Yes	No	Yes
Observations	530 518	76 070	530 518	76 070
Adjusted R^2	0.3406	0.5309	0.3446	0.5334

Table 5. Subjective Expected Returns Implied by In-the-Money Option Sales.
Reported are summary statistics on the subjective expected returns implied by investors' sales of in-the-money options while continuing to hold out-of-the-money options in the sample of option trades where investors' beliefs are fixed described in Section 5.2. The sample is constructed from our data set which contains the option trades of all retail investors in Finland from Dec-2000 to Dec-2017.

Characteristic	Category	N	Mean	St. Dev.	25th Pct.	Median	75th Pct.
All Options	–	1 340	1 243.95%	3 144.45%	400.00%	650.00%	1 233.33%
Option Type	Call	1 238	1 240.38%	3 050.09%	400.00%	650.00%	1 233.33%
	Put	102	1 287.34%	4 140.24%	337.20%	669.23%	925.86%
Trade Size	Below 250	141	1 697.12%	3 572.78%	376.19%	809.09%	1 566.67%
(euros)	250–1 000	364	1 325.59%	2 636.01%	391.18%	677.78%	1 400.00%
	1 000–10 000	649	1 192.40%	3 625.95%	408.47%	650.00%	1 180.00%
	Above 10 000	186	920.55%	1 390.89%	404.31%	531.91%	823.02%
Time to Expiry	0–5 days	239	1 579.89%	2 712.57%	559.42%	900.00%	1 900.00%
	1–4 weeks	302	1 257.71%	2 985.26%	400.00%	614.29%	1 150.00%
	1–3 months	374	772.73%	1 011.90%	294.12%	500.00%	891.94%
	3–12 months	299	1 726.68%	5 234.00%	478.27%	680.49%	1 453.98%
Moneyness	Above 10%	527	834.77%	1 997.26%	387.15%	525.00%	763.47%
	1% to 10%	704	1 488.30%	3 904.41%	433.33%	769.57%	1 400.00%
	0% to 1%	109	1 644.13%	1 600.36%	525.00%	1 100.00%	2 087.50%

Internet Appendix to

Investment Targets as Reference Points

Aleksi Pitkäjärvi, Matteo Vacca, Petra Vokata

February 12, 2026

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Figure IA.1. Excerpt From a Representative Stock Exchange Release.
Presented is an excerpt from a stock exchange release by Nordea Bank AB dated 10 February 2009. For each option issued by a bank, the stock exchange release generally contains information on option characteristics such as the expiration date, strike price, underlying asset, and whether the option is a call or a put. For illustrative purposes we only include the first two rows from each table. In this example, the stock exchange release was retrieved from GlobeNewsWire.

Nordea Bank AB (publ) issues 77 new warrant series on 10 February 2009

February 09, 2009 05:00 ET| Source: **Nordea Bank AB (publ.)** Follow

Nordea Bank AB (publ) will launch 77 new warrant series on 10 February 2009 under its warrant programme. The underlying asset of the warrants is the Fortum Oyj (FUM1V), Metso Oyj (MEO1V), Nordea Bank AB (NDA1V), Neste Oil Oyj (NES1V), Nokian Renkaat Oyj (NRE1V), Outotec Oyj (OTE1V), Outokumpu Oyj (OUT1V), Sampo Oyj (SAMAS), Stora Enso Oyj (STERV), UPM-Kymmene Oyj (UPM1V), Wärtsilä Oyj (WRT1V), Nokia Oyj (NOK1V) shares and Dow Jones Euro Stoxx 50-index and OMXH25-index. The warrants are call and put warrants. The warrants are redeemed by cash payment. Upon expiry of a warrant, the possible net value is paid in cash to the holder of the warrant.

Warrant specific terms and conditions

All Warrants are issued under the warrant programme of Nordea Bank AB (publ) dated 6 October 2008. The base prospectus for the warrant programme and the final terms for each warrant serie are available at the issuer's website: www.nordea.fi/warrantit. The following terms only summarize the final terms and the base prospectus.

Table 1

Warrant Trading code	Warrant ISIN code	Underlying instrument	Underlying instrument ISIN code	Underlying Currency	Additional Information on the underlying
9RFUMEW130	FI0009654149	Fortum Oyj	FI0009007132	EUR	www.fortum.com
9RFU1EW150	FI0009654156	Fortum Oyj	FI0009007132	EUR	www.fortum.com

Table 2

Warrant Trading code	Strike price	Type	Multiplier	Total number of warrants	Issue date	Expiration Date	Settlement Date
9RFUMEW130	13	P	0,2	1 500 000	10.2.2009	18.6.2009	26.6.2009
9RFU1EW150	15	P	0,2	1 500 000	10.2.2009	18.6.2009	26.6.2009

Figure IA.2. Average Holding Period Returns by Moneyness.
Plotted are the average holding period returns of option positions within moneyness percentile bins. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness.

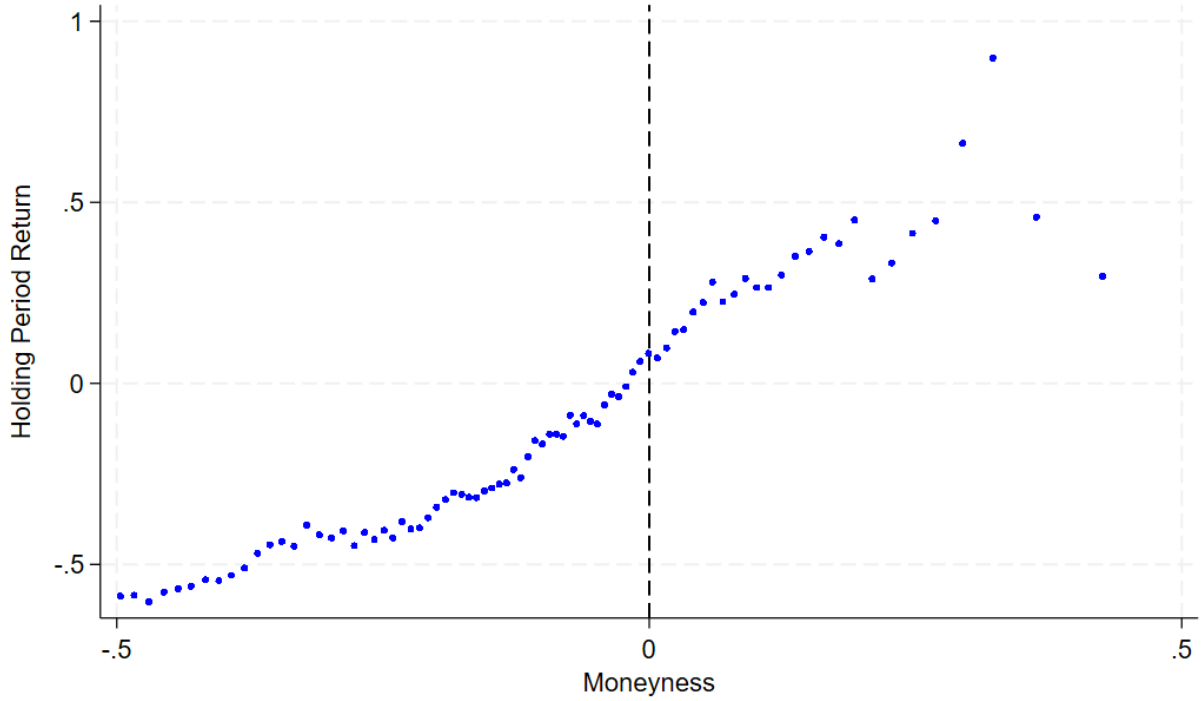


Figure IA.3. Average Holding Periods by Moneyness.
Plotted are the average holding periods of option positions within moneyness percentile bins. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all out-of-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness.

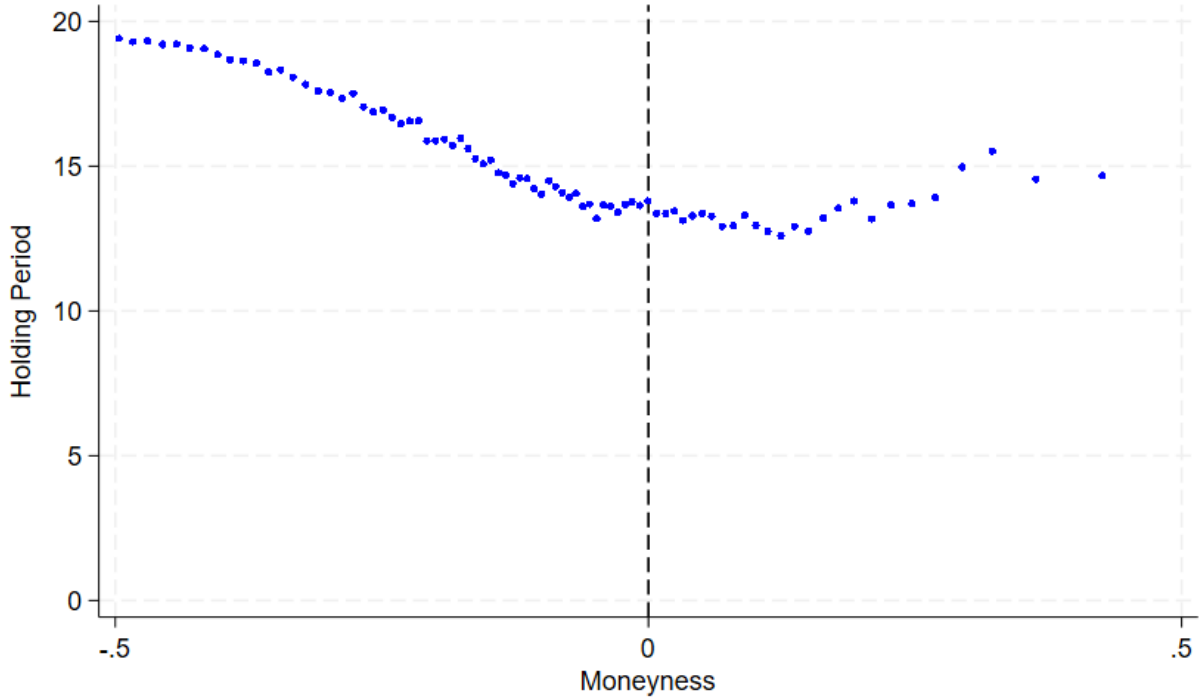
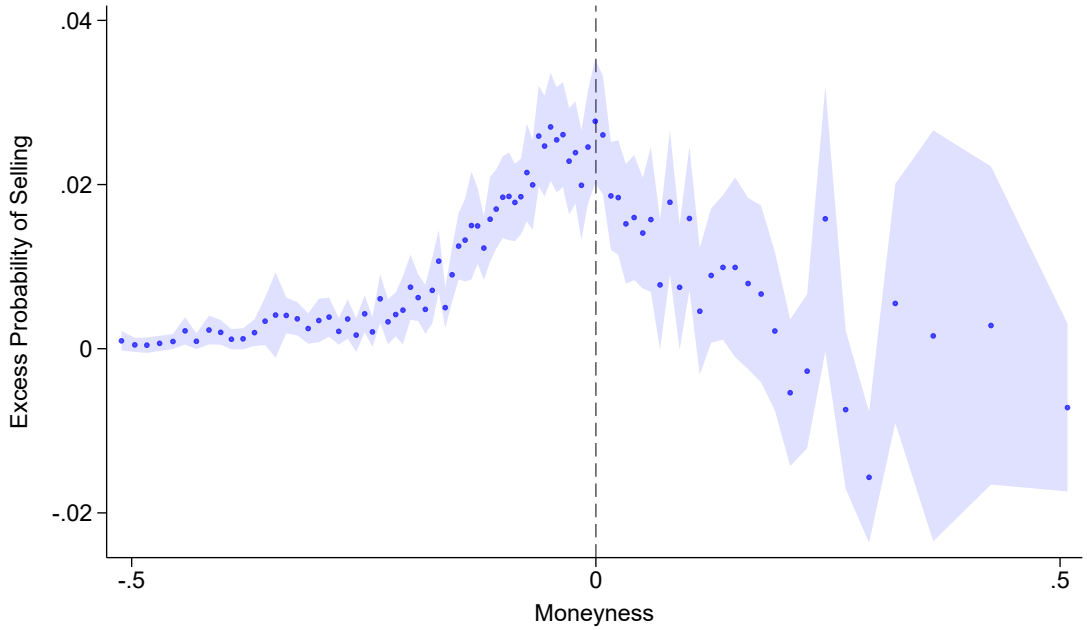


Figure IA.4. Excess Propensity to Sell Options by Moneyness: Out-of-the-Money Subsamples. Plotted are subsample analyses corresponding to Figure 2 for options purchased (a) between 0% and 10% out of the money and (b) more than 10% out of the money. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

(a) Options Purchased 0–10% Out of the Money



(b) Options Purchased More Than 10% Out of the Money

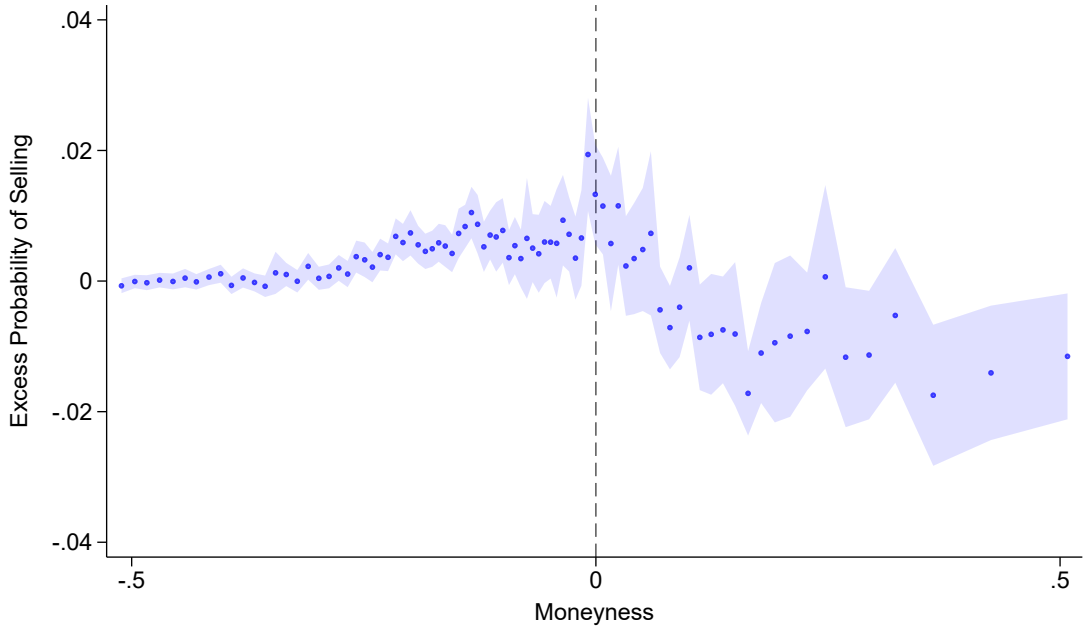


Figure IA.5. Excess Propensity to Sell Options by Moneyness: In-the-Money Purchases.
Plotted is the excess propensity to sell function estimated by regressing the dummy variable *Sale* on a set of dummy variables corresponding to moneyness percentile bins and on interacted controls for holding period return percentile bins and the holding period. The holding periods are winsorized at 20 days. The moneyness of a call option is the price of the underlying asset minus the strike price, divided by the strike price, and the moneyness of a put option is the strike price minus the price of the underlying, divided by the strike price. The sample contains all in-the-money option purchases by retail investors in Finland from Dec-2000 to Dec-2017, in those options for which we can determine the moneyness. The shaded areas represent 95% confidence intervals based on standard errors clustered by investor and day.

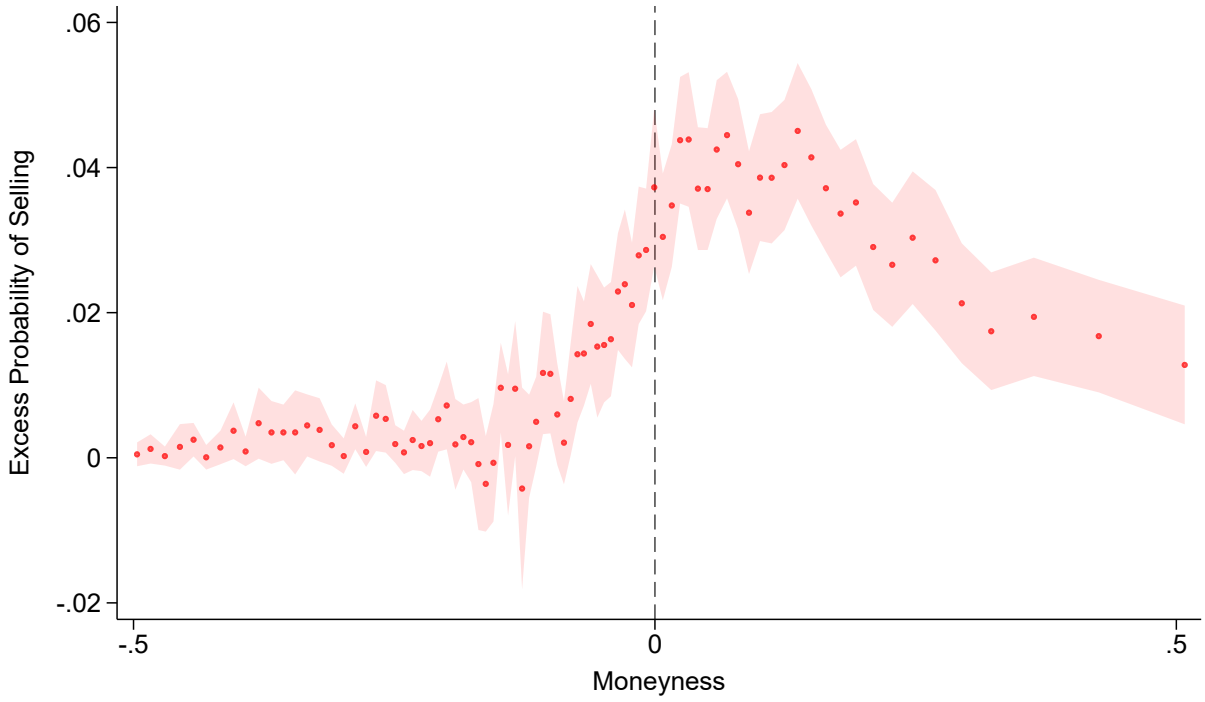
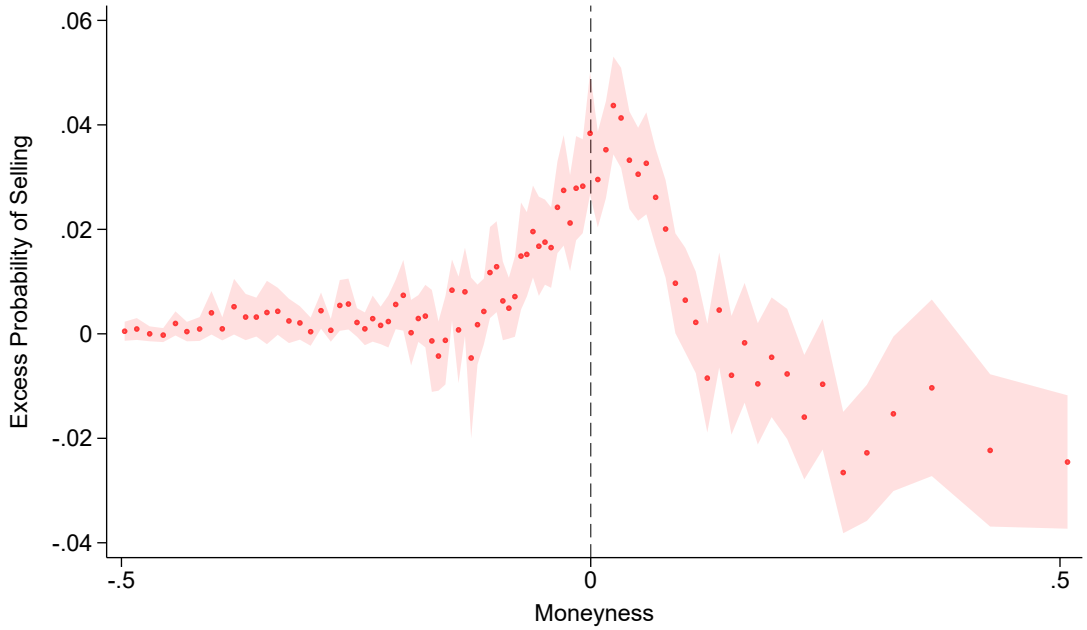


Figure IA.6. Excess Propensity to Sell Options by Moneyness: In-the-Money Subsamples. Plotted are subsample analyses corresponding to Figure IA.5 for options purchased (a) between 0% and 10% in the money and (b) more than 10% in the money. 95% confidence intervals are based on standard errors clustered by investor and day.

(a) Options Purchased 0–10% in the Money



(b) Options Purchased More Than 10% in the Money

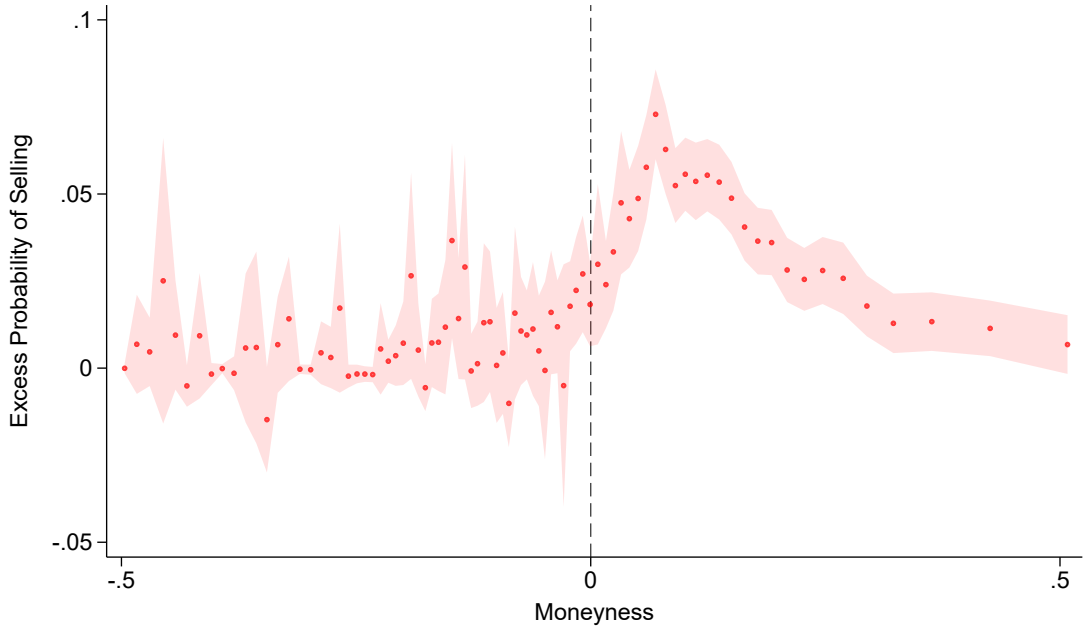


Table IA.1. Illustrative Social Media Posts on Strike Prices as Targets.
Reported are examples of retail option traders' social media posts that treat the strike price of an option as a target price for the underlying asset. Excerpts were retrieved in February 2026.

ID	Source	Excerpt
1	EliteTrader	"For certain moves (i.e. range bound oscillation) I will purchase an OTM strike that is my target price to sell when it is ATM."
2	EliteTrader	"The [special] Elite Trader who always times everything perfectly should buy the OTM strike near the target price and enjoy the leveraged return."
3	EliteTrader	"[...] if that's your modus operandi, the most bang for the buck will come from the call with the closest expiration and just under your target price."
4	Reddit	"For me I'll usually buy calls with a strike price just above the current price and sell when it hits my strike. [...] When price hits that target sell. [...] I make my targets based off the underlying asset price, not the option price."
5	Reddit	"Typically you buy a few strikes OTM and sell as the price approaches the strike."
6	Reddit	"Always buy the nearest ITM of your expected value. For example, if you buy at $600 and expect a $20 move buy the $615 call."
7	Reddit	"Are there any cons to selling right away once strike price is reached, before expiration? Say a $40 stock call is bought for $50 on 12/1 with expiry 12/18. Are there any cons to selling the call right away once it hits $50.2 [on] 12/5?"
8	Reddit	"Let's assume a stock is currently trading at $250 and you believe the stock will reach $300 (ignore theta for now). My understanding is that it's most efficient to buy the $300 OTM call when when the underlying is $250 and sell it when the underlying's price is near the strike ($300) to maximize the change in delta."
9	X (formerly Twitter)	"I target a strike that coincides with my chart level target price or I trade in the money."
10	Worden forum	"If [I am] expecting a big move, [I will] normally buy out the money by 1 strike, ABC is at $100 and [I am] expecting a move to $110 today, [I] would look to buy the 110 calls.. if [I] expect a move to 106, i would probably buy the 105 calls"

Table IA.2. Illustrative Online Articles on Strike Prices as Targets.
Reported are examples of articles that treat the strike price of an option as a target price for the underlying asset. Excerpts were retrieved in February 2026.

ID	Source	Excerpt
11	B2Prime	"The strike price is just the target price for the stock."
12	CBOE	"Suppose each of the stocks A, B, C, D, and E were trading at €100/share, and we expect that at least one of these five stocks will rise to at least €150/share by the Dec 2025 expiry date."
13	Forex.com	"You will need to choose a strike price close to where you expect the stock to trade by expiration."
14	IndiaBulls Securities	"The strike price is the cost at which the buyer of the option can buy (in a call option) or sell (in a put option) the underlying asset. You can think of it as a price target."
15	Insider Finance	"For a Long Call, select a strike price based on your price target for the stock and an expiration date that gives the stock enough time to move."
16	Interactive Brokers	"Are you expecting the price of a security to rise, and you have a target price in mind? In this article, you will learn how to choose the right strike price to optimize your return if the security reaches your target price by the time your call option expires."
17	Investing Daily	"People trade options with a price target in mind. That price target is the strike price."
18	National Bank Direct Brokerage	"When you turn on a GPS, you must tell it where you want to go and then it will give you the optimal route. The same thing is true of options (this applies to calls and puts): you need to have an expected target price."
19	Option Samurai	"To make the most of a strike price in options, align it with: • Your price target • The time you expect the move to happen • Current volatility conditions"
20	Saxo Bank	"After the stock has moved to your target level, the sooner you sell the put option then the more money you will be able receive for it, as you are minimizing time decay."

Table IA.3. Distribution of Bid-Ask Spreads.
Reported is the distribution of bid-ask spreads at market close for 749 067 option-day observations. The data set contains all options traded in Finland from Dec-2000 to Dec-2017.

Bid-Ask Spread (€)	N	Proportion
0.01	511 981	68.35%
0.02	168 575	22.50%
0.03	35 194	4.70%
0.04	13 858	1.85%
0.05	6 952	0.93%
> 0.05	12 507	1.67%

Table IA.4. Summary Statistics for the Sample with Fixed Beliefs.
Reported are summary statistics about investor, trade, and sample characteristics for the sample of option trades where investors' beliefs are fixed described in Section 5.2. The sample is constructed from our data set which contains the option trades of all retail investors in Finland from Dec-2000 to Dec-2017.

Panel A: Investor Characteristics

	Mean	SD	25th Pct.	Median	75th Pct.
Female (%)	5.20				
Age (years)	41.02	12.28	32.00	39.50	49.59
Experience (years)	2.43	2.21	0.76	1.83	3.59
Total Trades	224.35	438.31	31.00	81.00	232.00

Panel B: Trade Characteristics

	Mean	SD	25^{th} Pct.	Median	75^{th} Pct.
Call Option (%)	88.86				
Value at Purchase (euros)	1 400	3 504	224	530	1 266
Days to Expiry at Purchase	100.04	148.53	18.00	40.00	92.00
Holding Period (days)	74.35	105.04	10.75	31.00	88.00

Panel C: Sample Characteristics

	N
Investors	2 118
Observations	530 518

Table IA.5. Option Sales Around Strike Price Crossings: Rank Effect.
Reported are analyses corresponding to Table 2 with additional controls for the rank effect. *Best* and *Worst* are fixed effects for the best and worst performing assets in an investor's portfolio, interacted with the corresponding strike-crossing cohort indicator.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0055	-0.0022	0.0053
	(0.0043)	(0.0041)	(0.0050)
t_{-4}	-0.0091**	-0.0069*	-0.0013
	(0.0039)	(0.0037)	(0.0045)
t_{-3}	-0.0089**	-0.0030	-0.0058
	(0.0037)	(0.0034)	(0.0036)
t_{-2}	-0.0061	-0.0022	-0.0016
	(0.0039)	(0.0035)	(0.0045)
t_0	0.0398***	0.0320***	0.0272***
	(0.0079)	(0.0069)	(0.0082)
t_1	0.0020	-0.0048	0.0044
	(0.0048)	(0.0048)	(0.0059)
t_2	0.0051	0.0020	-0.0026
	(0.0049)	(0.0049)	(0.0055)
t_3	0.0026	-0.0005	-0.0025
	(0.0045)	(0.0045)	(0.0056)
t_4	0.0041	0.0022	0.0014
	(0.0042)	(0.0040)	(0.0045)
t_5	0.0081*	0.0056	0.0035
	(0.0042)	(0.0037)	(0.0046)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Best	Yes	Yes	Yes
Worst	Yes	Yes	Yes
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 425 398	2 418 773	2 380 058
Adjusted R^2	0.2895	0.3219	0.3394

Table IA.6. Option Sales Around Strike Price Crossings: Rollover Strategies.
Reported are analyses corresponding to Table 2 excluding investors who purchase an option on t_0 or t_1.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0062	-0.0038	0.0008
	(0.0038)	(0.0036)	(0.0043)
t_{-4}	-0.0061	-0.0038	0.0007
	(0.0037)	(0.0036)	(0.0046)
t_{-3}	-0.0047	0.0014	-0.0046
	(0.0035)	(0.0032)	(0.0037)
t_{-2}	-0.0047	-0.0013	-0.0006
	(0.0041)	(0.0039)	(0.0050)
t_0	0.0416***	0.0335***	0.0291***
	(0.0083)	(0.0072)	(0.0088)
t_1	0.0065	0.0012	0.0057
	(0.0049)	(0.0049)	(0.0060)
t_2	0.0058	0.0019	-0.0028
	(0.0041)	(0.0041)	(0.0048)
t_3	0.0068	0.0048	0.0009
	(0.0048)	(0.0048)	(0.0060)
t_4	0.0067*	0.0039	0.0015
	(0.0040)	(0.0038)	(0.0045)
t_5	0.0081*	0.0058	0.0051
	(0.0042)	(0.0039)	(0.0050)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 255 274	2 248 780	2 210 939
Adjusted R^2	0.2926	0.3250	0.3419

Table IA.7. Option Sales Around Strike Price Crossings: Excluding Small Positions.
Reported are analyses corresponding to Table 2 excluding option positions worth less than €100.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0054	-0.0019	0.0066
	(0.0047)	(0.0045)	(0.0053)
t_{-4}	-0.0101**	-0.0077**	-0.0000
	(0.0041)	(0.0038)	(0.0049)
t_{-3}	-0.0099**	-0.0035	-0.0057
	(0.0039)	(0.0036)	(0.0040)
t_{-2}	-0.0057	-0.0020	-0.0006
	(0.0043)	(0.0039)	(0.0050)
t_0	0.0320***	0.0241***	0.0177**
	(0.0078)	(0.0068)	(0.0080)
t_1	0.0027	-0.0051	0.0042
	(0.0050)	(0.0049)	(0.0058)
t_2	0.0066	0.0023	-0.0012
	(0.0051)	(0.0051)	(0.0053)
t_3	0.0021	-0.0017	-0.0032
	(0.0048)	(0.0047)	(0.0058)
t_4	0.0032	0.0025	0.0029
	(0.0045)	(0.0042)	(0.0048)
t_5	0.0087*	0.0065	0.0042
	(0.0046)	(0.0040)	(0.0052)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	1 865 883	1 859 385	1 822 379
Adjusted R^2	0.2985	0.3304	0.3448

Table IA.8. Option Sales by Moneyness When Investor Beliefs are Fixed: Excluding Small Positions. Reported are analyses corresponding to Table 4 excluding option positions worth less than €100.

	Dependent Variable: Sale			
	(1)	(2)	(3)	(4)
ITM	0.0181***	0.0248***	0.0074***	0.0177***
	(0.0017)	(0.0049)	(0.0018)	(0.0048)
Gain			0.0255***	0.0368***
			(0.0029)	(0.0072)
	Fixed Effects			
Investor × Day × Underlying × Expiry	Yes	No	Yes	No
Investor × Day × Underlying × Expiry × Hold	No	Yes	No	Yes
Observations	429 509	59 550	429 509	59 550
Adjusted R^2	0.3557	0.5325	0.3591	0.5348

Table IA.9. Option Sales Around Strike Price Crossings: Liquidity.
Reported are analyses corresponding to Table 2 excluding investors who hold no other assets in their portfolio.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0036	0.0001	0.0076
	(0.0043)	(0.0041)	(0.0050)
t_{-4}	-0.0109***	-0.0082**	-0.0048
	(0.0038)	(0.0036)	(0.0045)
t_{-3}	-0.0093**	-0.0029	-0.0052
	(0.0039)	(0.0035)	(0.0038)
t_{-2}	-0.0065*	-0.0023	-0.0033
	(0.0038)	(0.0034)	(0.0044)
t_0	0.0380***	0.0292***	0.0225***
	(0.0083)	(0.0069)	(0.0083)
t_1	0.0026	-0.0034	0.0022
	(0.0047)	(0.0047)	(0.0058)
t_2	0.0037	0.0006	-0.0045
	(0.0045)	(0.0046)	(0.0054)
t_3	0.0040	0.0002	-0.0010
	(0.0047)	(0.0045)	(0.0059)
t_4	0.0044	0.0031	0.0032
	(0.0044)	(0.0041)	(0.0046)
t_5	0.0067	0.0039	0.0033
	(0.0041)	(0.0036)	(0.0044)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 263 401	2 256 804	2 217 761
Adjusted R^2	0.2878	0.3228	0.3404

Table IA.10. Option Sales by Moneyness When Investor Beliefs are Fixed: Liquidity.
Reported are analyses corresponding to Table 4 excluding investors who hold no other assets in their portfolio.

	Dependent Variable: Sale			
	(1)	(2)	(3)	(4)
ITM	0.0197***	0.0262***	0.0081***	0.0191***
	(0.0018)	(0.0049)	(0.0018)	(0.0047)
Gain			0.0272***	0.0358***
			(0.0030)	(0.0065)
	Fixed Effects			
Investor × Day × Underlying × Expiry	Yes	No	Yes	No
Investor × Day × Underlying × Expiry × Hold	No	Yes	No	Yes
Observations	500 104	70 958	500 104	70 958
Adjusted R^2	0.3418	0.5295	0.3457	0.5320

Table IA.11. Stock Option Purchases and Ownership of the Underlying Stock.
Reported are the total number of purchases of calls and puts, and the total euro value of call and put purchases, based on whether an investor owns the underlying stock at the time of purchase or not. The data set contains the stock option purchases of all retail investors in Finland from Dec-2000 to Dec-2017 for which we can determine the underlying stock.

	Purchases		Value (€)	
	Call	Put	Call	Put
Owns Underlying	47 190	4 350	63 579 058	4 559 199
Does Not Own Underlying	88 891	26 691	144 477 833	38 048 115

Table IA.12. Option Sales Around Strike Price Crossings: Hedging.
Reported are analyses corresponding to Table 2 excluding put options.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0027	0.0005	0.0080
	(0.0044)	(0.0043)	(0.0051)
t_{-4}	-0.0099**	-0.0071*	-0.0038
	(0.0040)	(0.0038)	(0.0044)
t_{-3}	-0.0119***	-0.0073**	-0.0074**
	(0.0038)	(0.0033)	(0.0037)
t_{-2}	-0.0034	-0.0032	-0.0023
	(0.0041)	(0.0035)	(0.0045)
t_0	0.0437***	0.0350***	0.0281***
	(0.0087)	(0.0072)	(0.0083)
t_1	0.0017	-0.0050	0.0025
	(0.0048)	(0.0049)	(0.0061)
t_2	0.0055	0.0018	-0.0041
	(0.0051)	(0.0051)	(0.0056)
t_3	0.0035	-0.0015	-0.0042
	(0.0047)	(0.0046)	(0.0057)
t_4	0.0052	0.0016	0.0013
	(0.0045)	(0.0041)	(0.0045)
t_5	0.0105**	0.0065	0.0046
	(0.0045)	(0.0040)	(0.0048)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 339 276	2 335 242	2 309 501
Adjusted R^2	0.2611	0.2896	0.3041

Table IA.13. Option Sales by Moneyness When Investor Beliefs are Fixed: Hedging.
Reported are analyses corresponding to Table 4 excluding put options.

	Dependent Variable: Sale			
	(1)	(2)	(3)	(4)
ITM	0.0192***	0.0220***	0.0078***	0.0156***
	(0.0018)	(0.0044)	(0.0017)	(0.0043)
Gain			0.0266***	0.0323***
			(0.0028)	(0.0062)
	Fixed Effects			
Investor × Day × Underlying × Expiry	Yes	No	Yes	No
Investor × Day × Underlying × Expiry × Hold	No	Yes	No	Yes
Observations	513 548	72 178	513 548	72 178
Adjusted R^2	0.3238	0.5166	0.3277	0.5188

Table IA.14. Option Sales Around Strike Price Crossings: Complex Strategies.
Reported are analyses corresponding to Table 2 excluding investors who own more than one option on a given underlying asset or the underlying asset itself.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0109	-0.0033	0.0015
	(0.0072)	(0.0080)	(0.0119)
t_{-4}	-0.0111*	-0.0065	0.0009
	(0.0067)	(0.0064)	(0.0088)
t_{-3}	-0.0158**	-0.0033	-0.0203**
	(0.0064)	(0.0064)	(0.0095)
t_{-2}	-0.0084	-0.0012	-0.0047
	(0.0071)	(0.0069)	(0.0112)
t_0	0.0512***	0.0436***	0.0516***
	(0.0120)	(0.0126)	(0.0178)
t_1	-0.0001	-0.0092	0.0010
	(0.0086)	(0.0090)	(0.0128)
t_2	-0.0005	0.0003	0.0080
	(0.0083)	(0.0083)	(0.0125)
t_3	0.0041	0.0032	-0.0062
	(0.0072)	(0.0077)	(0.0117)
t_4	0.0060	-0.0003	0.0006
	(0.0072)	(0.0081)	(0.0114)
t_5	0.0117	0.0131*	-0.0017
	(0.0074)	(0.0072)	(0.0102)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	620 434	614 101	575 418
Adjusted R^2	0.3345	0.3833	0.3713

Table IA.15. Option Sales Around Strike Price Crossings: Pinning Risk.
Reported are analyses corresponding to Table 2 excluding options with five or fewer days to expiry.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0046	-0.0022	0.0072
	(0.0043)	(0.0041)	(0.0049)
t_{-4}	-0.0080**	-0.0066*	-0.0008
	(0.0038)	(0.0037)	(0.0045)
t_{-3}	-0.0064*	-0.0007	-0.0034
	(0.0039)	(0.0036)	(0.0038)
t_{-2}	-0.0028	-0.0001	-0.0016
	(0.0042)	(0.0037)	(0.0047)
t_0	0.0363***	0.0279***	0.0230***
	(0.0080)	(0.0068)	(0.0080)
t_1	-0.0033	-0.0110**	-0.0003
	(0.0044)	(0.0044)	(0.0050)
t_2	-0.0001	-0.0051	-0.0059
	(0.0041)	(0.0042)	(0.0051)
t_3	-0.0005	-0.0045	-0.0046
	(0.0043)	(0.0042)	(0.0054)
t_4	0.0032	0.0009	0.0029
	(0.0041)	(0.0040)	(0.0045)
t_5	0.0086**	0.0058	0.0046
	(0.0043)	(0.0039)	(0.0047)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2 338 910	2 332 477	2 300 120
Adjusted R^2	0.2878	0.3212	0.3372

Table IA.16. Option Sales by Moneyness When Investor Beliefs are Fixed: Pinning Risk.
Reported are analyses corresponding to Table 4 excluding options with five or fewer days to expiry.

	Dependent Variable: Sale			
	(1)	(2)	(3)	(4)
ITM	0.0163***	0.0217***	0.0051***	0.0152***
	(0.0016)	(0.0042)	(0.0016)	(0.0041)
Gain			0.0262***	0.0354***
			(0.0028)	(0.0066)
	Fixed Effects			
Investor × Day × Underlying × Expiry	Yes	No	Yes	No
Investor × Day × Underlying × Expiry × Hold	No	Yes	No	Yes
Observations	509 072	71 982	509 072	71 982
Adjusted R^2	0.3427	0.5296	0.3464	0.5321

Table IA.17. Option Sales Around Strike Price Crossings: Out-of-the-Money Buyers.
Reported are analyses corresponding to Table 3 excluding investors who never purchase an out-of-the-money option.

	Dependent Variable: Sale		
	(1)	(2)	(3)
t_{-5}	-0.0060	-0.0018	0.0061
	(0.0043)	(0.0041)	(0.0050)
t_{-4}	-0.0093**	-0.0069*	-0.0009
	(0.0039)	(0.0037)	(0.0046)
t_{-3}	-0.0096***	-0.0035	-0.0066*
	(0.0037)	(0.0034)	(0.0037)
t_{-2}	-0.0061	-0.0022	-0.0018
	(0.0039)	(0.0035)	(0.0045)
t_0	0.0406***	0.0314***	0.0255***
	(0.0081)	(0.0069)	(0.0082)
t_1	0.0030	-0.0042	0.0046
	(0.0048)	(0.0048)	(0.0060)
t_2	0.0056	0.0023	-0.0035
	(0.0049)	(0.0049)	(0.0055)
t_3	0.0032	-0.0006	-0.0038
	(0.0046)	(0.0044)	(0.0055)
t_4	0.0056	0.0026	0.0016
	(0.0043)	(0.0040)	(0.0045)
t_5	0.0086**	0.0053	0.0037
	(0.0043)	(0.0037)	(0.0047)
	Controls		
Return	Yes	No	No
Gain	Yes	No	No
	Fixed Effects		
Investor × Option	Yes	Yes	Yes
Day	Yes	Yes	Yes
Return Bin	No	Yes	Yes
Gain	No	Yes	Yes
Holding Period	No	No	Yes
Time to Expiry	No	No	Yes
Observations	2,411,937	2,405,326	2,366,485
Adjusted R^2	0.2862	0.3199	0.3377