Transaction Costs and Cost Mitigation in Option Investment Strategies *

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Abstract

We examine the impact of transaction costs on the profitability of long-short portfolios of delta-hedged option returns. Out of 24 variables studied, 17 generate positive and significant gross returns, but none remain profitable after accounting for trading costs. We explore cost-mitigation strategies and propose a novel approach that outperforms existing methods, restoring profitability to 7 long-short portfolios. Our findings emphasize the crucial role of implementation costs in assessing the investment opportunity set in equity-option markets and underscore the importance of incorporating transaction costs when evaluating option-based strategies.

Keywords: Asset-pricing, option returns, transaction costs, market frictions

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1 Introduction

Return measurement is one of the most fundamental elements of asset pricing. Although our objective is to measure the investment returns that would have been available to an investor in the past, various forms of bias can affect this measurement. For example, the data available to researchers may only keep observations for firms with particular features.[1] Even when the data is bias-free, return measurement is biased if trading costs are not accounted for. Transaction costs, which are unavoidable for real-world investors, represent a source of potentially biased measurement. As returns guide the design of theoretical models, empirical factor models, and real-world investment strategies, measuring returns net of sampling biases and transaction costs is an issue of first-order importance.

Measuring returns to investors in option markets is particularly challenging. Compared to equity markets, there are many more degrees of freedom in constructing of option strategies, such as the timing of entry, the frequency of delta hedging, the choice between exiting before expiration or holding until maturity, and the methods of accounting for transaction costs. Researchers employ different combinations of methods to measure returns. Furthermore, Duarte, Jones, Mo, and Khorram (2023) emphasize that some widely used sample construction techniques result in returns that are subject to a look-ahead bias. Due to different approaches used across studies for sample construction, measurement of returns, and adjustment for transaction costs, we do not have a comprehensive understanding of option strategy returns.

This paper sets out to answer three main questions. First, what are the returns to common option investment strategies after adjusting for look-ahead bias and transaction costs? Second, what are the time series and cross-sectional characteristics of option strategy transaction costs? Third, what transaction cost mitigation strategies can be used in the options market? Answering these questions is important to understand investor opportunity sets and market frictions. However, relative to the stock market, estimating the effects of transaction costs and designing cost mitigation strategies for options is more difficult because one must trade in both the option contract and the underlying stock. Furthermore, the literature on option portfolio returns has largely followed the equity-anomaly portfolio literature without designing portfolios and cost mitigation strategies tailored to the characteristics of option contracts.

We start by calculating the returns to long-short delta-hedged call option portfolios on a

[1] Fama and French (1992) point out that COMPUSTAT data pre-1962 is subject to a selection bias where large successful firms are retained, Shumway (1997) highlights a delisting bias in CRSP returns. Mutual fund data is also subject to survivorship bias (Elton, Gruber, and Blake, 1996) and incubation bias (Evans, 2010). McLean and Pontiff (2016) provide evidence that statistical biases affect the discovery of variables that predict stock returns.

sample of returns not subject to the look-ahead bias pointed out by Duarte et al. (2023). We focus on portfolios formed at the end of the month and held for one month as in Zhan, Han, Cao, and Tong (2022). We form a set of 24 potential predictor variables suggested by the literature and find that 17 of the 24 variables can be used to form portfolios with significant long-short portfolio returns. We then study the impact of stock and option transaction costs. Figure 1 shows the first main result. Under the conservative assumption that options traders pay approximately one-fifth of the quoted half spread for options and the effective half spread for stocks, we find that none of the strategy returns survive transaction costs. We find that look-ahead bias and transaction costs have an interactive effect on delta-hedged call option returns. While the bias on gross returns is upward, the bias for transaction costs is downward, meaning the bias is magnified for net returns. Together, look-ahead bias and transaction costs eliminate returns of common strategies and make understanding transaction costs and cost mitigation strategies of utmost importance.

In the second set of results, we investigate the properties of transaction costs. We start by investigating the cross-sectional relationship between portfolio sort variables and transaction costs. We find that transaction costs are persistent and that a large percentage of the cross-sectional variation in transaction costs can be predicted by variables related to size and volatility. Next, we construct a time series of the average transaction costs across strategies and decompose the series to understand the contribution of stock trading costs and option trading costs. We find that over 80% of the strategy trading costs come from the option transaction costs. Overall, transaction costs for trading the option portfolios we study have been increasing over time; this is in contrast to the trend in equity markets, where transaction costs have been decreasing over time (Jones, 2002; Angel, Harris, and Spatt, 2011). Finally, we investigate the time series determinants of transaction costs. The strongest predictors of average portfolio transaction costs are the VIX index, and the sentiment index of Baker and Wurgler (2006). These results suggest that transaction costs are particularly high when volatility and market sentiment are elevated and suggest that gross portfolio returns will be particularly high during these periods.

In the third set of results, we focus on cost-mitigation strategies. We find that cost mitigation strategies have a large impact on average returns. The returns of all strategies increase after cost mitigation. However, only a handful of strategy returns become significant. The most effective simple cost mitigation strategy, which uses 'hold-to-maturity' option returns that avoid paying transaction costs to exit the strategy, results in three significant long-short portfolios. When we combine this strategy with a limitation on the universe of investable options with relatively lower trading costs, we increase the number of significant anomalies to four.

We then show the returns to a novel cost mitigation strategy that relies on specific features of the options market. We provide analysis that motivates a focus on long-only portfolios; Figure 5 shows that, on average, across the 24 sorting variables, gross returns grow faster than transaction costs as we move from the bottom to the top decile. We examine long-only portfolios and portfolios that hedge the volatility risk in the long portfolio with a fixed position in market index volatility risk. This novel cost mitigation strategy is the most successful, increasing the number of significant long-short portfolios to seven. The return magnitudes are economically significant, ranging from 36bp to 114bp per month. These results emphasize the importance of applying cost mitigation strategies in general and tailoring these strategies to the specific features of option markets in particular.

Finally, we show that the decision of hedging frequency is crucial once we take stock-trading costs into account. Our main analysis uses strategies that delta-hedge once on the portfolio formation date and then focuses on the impact of varying the strategy entry date and holding period. We also show that holding the formation date and holding period constant, the decision of how frequently to delta hedge has a large impact on strategy return characteristics. Using a strategy that is delta-hedged daily until maturity, approximately 50% of the strategy trading costs come from the stock transaction costs. The key tradeoff is between strategy mean returns and variance. In the absence of transaction costs, delta-hedging daily typically increases Sharpe ratios through a reduction in variance. However, in the presence of stock trading costs, delta-hedging each day reduces the average returns to the point that it offsets the benefit of variance reduction. This highlights that transaction costs are a first-order consideration when measuring returns in option markets and that the impact of stock trading costs (rarely considered) depends on the return construction.

We contribute to the literature on asset pricing and transaction costs. A large literature focuses on the impact of trading costs on equity investment. Novy-Marx and Velikov (2016) show that transaction costs reduce all anomaly returns but that high-turnover strategies are impacted most heavily. Detzel, Novy-Marx, and Velikov (2023) show that transaction costs are essential for making sensible model comparisons, and DeMiguel, Martin-Utrera, Nogales, and Uppal (2020) show that transaction costs are essential for understanding the number of significant anomalies. Focusing on the short legs of anomalies, Stambaugh, Yu, and Yuan (2012) find higher returns following high periods of sentiment, suggesting that mispricing drives those returns. Muravyev, Pearson, and Pollet (2022) find that anomalies do not survive adjustments for the transaction costs associated with short-selling shares. Chen and Velikov (2023) find that adjustments for post-publication bias and transaction costs eliminate the returns on the average anomaly. Thus, transaction costs are an issue of first-order importance in many asset pricing contexts, and we contribute to this literature by analyzing the importance of transaction costs for option strategies.

Our work is related to a large body of literature on single stock option risk premia. Coval and Shumway (2001) is the seminal paper suggesting that known stock risks do not span option risk, and thus options provide exposure to a volatility risk factor. Carr and Wu (2004) show that both index options and single stock options contain a risk premium. Driessen and Maenhout (2007) show that options should be included in investor portfolios under quite general conditions. Goyal and Saretto (2009) are the first to show one can create long-short portfolios of delta-hedged option returns to capture risk premia. Cao and Han (2013) show that a stock market variable can be used to predict returns on single stock options, and Zhan et al. (2022) show generally that multiple variables can predict option returns. There is now a burgeoning literature documenting option return anomalies and suggesting factor models to explain those anomalies (Horenstein, Vasquez, and Xiao, 2022; Goyal and Saretto, 2022). The results in this paper help us understand whether these factors tell us about return patterns that are maintained because of friction or investor preferences. Furthermore, our work affects the design of empirical factor models; for example, whether we conclude that we have an emerging 'factor zoo' in option markets depends on how we account for implementation costs.

Empirical option researchers typically consider the impact of three frictions; the cost of trading the option, the cost of trading the stock, and margin costs. The impact on returns depends on which transaction costs are considered, the assumptions made, and sample construction details. For example, Neumann and Skiadopoulos (2013) find that the economic significance of an option strategy in S&P 500 index options disappears once they consider trading costs for the option contract. Furthermore, to avoid excessive stock transaction costs associated with delta hedging, Goyal and Saretto (2009), and others hold the option position for one month without rebalancing the delta hedges to limit the impact of transaction costs. Other studies consider different combinations of stock, option, and margin costs (Zhan et al., 2022; Heston, Jones, Khorram, Li, and Mo, 2023). Overall, different studies use different samples, different return construction methods, and different methods to adjust for transaction costs. We do not have a good understanding of which costs matter for which strategies and how costs vary over time and in the cross-section. We contribute to this literature by providing a comprehensive analysis of option returns after adjustment for transaction costs.

2 Data and Variables

This section introduces the data and key variables. Section 2.1 details the sample construction. Section 2.2 details the predictor variables used in the paper. Finally, Section 2.3 details how we construct the option returns and adjust them for transaction costs.

2.1 Sample construction

Data on end-of-day option prices, volume, and option risk characteristics come from Optionmetrics. Data on underlying stock prices, market capitalization, adjustments for stock splits, and dividends comes from the CRSP. We use the WRDS link table to merge Optionmetrics data with CRSP. Data on stock transaction costs comes from the TAQ database, and we use the WRDS link table to merge CRSP data with TAQ data. Our sample includes options on common stocks with CRSP share codes of 10 and 11 and a stock price of at least five dollars on the portfolio formation date. For the construction of some predictor variables, we use COMPUSTAT and I/B/E/S data.

Duarte et al. (2023) highlight that one of the most common sample construction techniques in the literature is subject to a look-ahead bias. In essence, the filters applied to option prices at the date of the strategy exit are correlated with strategy returns. Thus, we use their sample construction to avoid look-ahead bias.[2] At each month-end, we extract all call and put options for each optionable stock and then apply the following filters to these options in order to minimize the effect of erroneous recording: (1) Bid prices are positive; (2) The midpoint of the quoted bid and ask prices is at least \$1/8; (3) The midpoint of the quoted bid and ask prices do not violate no-arbitrage conditions; (4) The underlying stock does not pay a dividend during the remaining life of the option. This makes the early exercises of options suboptimal, so the investigated American options are effectively European options. To make this filter feasible, we only drop options whose dividend-paying declaration date is before the portfolio formation date, and the ex-distribution date lies between the portfolio formation date and the expiration date simultaneously; (5) We retain options with positive total trading volume in the month preceding the portfolio formation date to avoid extremely illiquid options; (6) We exclude options with bid price larger than or equal to the ask price at the portfolio formation date; (7) We retain options with moneyness between 0.8 and 1.2

[2] The look-ahead bias has two dimensions. First, common filters applied to data at the end of the holding period remove options that become deep in the money (ITM) or deep out of the money (OTM). These deep OTM/ITM options would have resulted in negative returns for delta-neutral call-writing strategies. Second, when used to form portfolios, characteristics associated with high stock-price volatility would systematically have more deep ITM/OTM options at the end of the portfolio period and thus result in portfolios that effectively sort on the bias.

where moneyness equals to stock price divided by the strike price.

After applying these filters to each extracted option at the month-end date, for each optionable stock, we choose a pair of options (one call and one put) that are closest to being at the money and have the shortest time to maturity among options with more than 30 days to expiration. The vast majority of options retained each month have the same maturity, so we drop options with maturity different from the majority. Finally, we only keep stocks with both call and put options available after the filtering process as the final sample.

After application of these filters, we have a sample of 255,240 observations. However, because our one-month (hold-to-maturity) returns require option price and stock price data (stock price data) one month later (on the maturity date), we would be subject to a subtle form of look-ahead-bias if we dropped stocks with missing data after the portfolio formation date. This look-ahead bias could be important for expected return measurement if the dropped observations were correlated with particular return realizations. We find that 676 (1,010) observations are missing when we attempt to calculate one-month (hold-to-maturity) returns. We use the delisting codes in CRSP and find that these missing returns are due to merger announcements, exchanges, and delistings. We then fill in returns using the following procedure. First, if a delisting price exists in CRSP, we use that price to calculate the option price at month's end (payoff at maturity). If the delisting price is missing, we use the last traded price multiplied by the delisting return. Finally, if the delisting returns are missing, we use the procedure of Fu (2014) and replace the missing return with the average returns for the same exchange and delisting reason. Filling in these missing stock prices allows us to calculate hold-to-maturity returns by calculating the exercise value. For one-month returns, we fill in option prices using the Black, Scholes, and Merton model price (using the option implied volatility at the portfolio formation date as an input) and the average option spread in that period.[3]

In some tests, we use an alternative strategy that involves forming portfolios on the third Friday of each month and holding the position until maturity (see Goyal and Saretto (2009); Heston et al. (2023)); this allows us to construct a monthly return that is held to maturity and avoids paying transaction costs to exit option positions. In contrast, the hold-to-maturity return formed at the end of each month would have a holding period longer than 30 days on average. For this sample, excepting the maturity filter, we use the same filters applied above.

Table 1 contains summary statistics of the options used in our study. Statistics for our main sample of buy-and-hold one-month returns are contained in Table 1 Panel A. We have a total of 255,240 observations spanning a time period from September 2003 to December 2021.

[3] Results are similar if we simply drop those missing values. In Table A1, we show the impact on portfolio returns of this potential look-ahead bias. The largest reduction in returns is 7bp for the IVOL portfolio.

The availability of the TAQ effective spread data limits the sample period. Our statistics are otherwise comparable with the literature. The monthly buy-and-hold return has a mean of 0.46%, with a large standard deviation of 8.9%. The maturities of selected options have a median of 50 days with a tight distribution (the 25th and 75th percentiles are 49 and 51, respectively). In particular, we note the large magnitude of quoted option bid-ask spreads. We show the spreads at the point of entry and exit of the buy-and-hold option position. The average spread at entry is 24% while the average spread at exit is 57%. This is because at entry, options are constrained to be at the money, while at exit, they can be very deep out-of-the-money with potentially large percentage spreads.[4] The average effective stock spread at entry and exit is 0.13%.[5] Panel B contains the summary statistics for buy-and-hold returns with the same portfolio formation date as Panel A but are held until option maturity rather than being exited after one month. Finally, Panel C contains summary statistics for the sample of returns that has a formation date on the third Friday of each month, where option positions are held to maturity.

2.2 Predictor variables

We use a comprehensive set of variables investigated by the literature. In total, we investigate the ability of 24 variables to predict equity-option returns. We start with the 13 variables investigated by Zhan et al. (2022). This includes ten stock characteristics and three additional control variables, which are the volatility mispricing measure from Goyal and Saretto (2009), idiosyncratic volatility as used in Cao and Han (2013), and the Amihud (2002) liquidity measure. We also include 11 other variables suggested by the option literature. We include volatility of volatility (Ruan, 2020), option price, option illiquidity (Christoffersen, Goyenko, Jacobs, and Karoui, 2018), risk-neutral skewness (Bali and Murray, 2013), and volatility term structure (Vasquez, 2017). We include option momentum and reversal, which are found to predict option returns in Heston et al. (2023).[6] Finally, we follow Horenstein et al. (2022) and include firm size, book-to-market-equity, momentum, and reversal because they are common predictors of stock returns. We provide a brief description of each variable here and provide

[4]This suggests another dimension to the look-ahead bias of Duarte et al. (2023); sample filters applied to future data that increase returns by removing deep ITM or OTM options will simultaneously reduce transaction costs at strategy exit. Thus, the impact of look-ahead bias should be even larger for net returns.

[5]We winsorize the measure of effective spread at the upper 99.5% of the distribution to deal with a limited number of outliers that seem to be recording errors. In cases where the TAQ effective spread is missing, we fill in those values using the quoted bid-ask spread from CRSP; if it is still missing, we use the average spread for that month.

[6]We note that the main results in Heston et al. (2023) focus on straddle returns and use an alternative filtering procedure to maximize the available data on past option returns. Thus we do not directly replicate their implementation, which is robust to the inclusion of transaction costs. We find that the option momentum strategy has positive and significant returns after transaction costs in Table 10.

detailed variable construction information in Appendix A.1.

1. CFV: Cash flow variance, calculated as the variance of the monthly ratio of cash flow to the market value of equity over the last 60 months as in Haugen and Baker (1996). Cash flow is net income plus depreciation and amortization, all scaled by market value of equity.

2. CH: The cash-to-assets ratio, computed as the value of corporate cash holdings over the value of the firm's total assets as in Palazzo (2012).

3. DISP: Analyst earnings forecast dispersion, computed as the standard deviation of annual earnings-per-share forecasts scaled by the absolute value of the average outstanding forecasts as in Diether, Malloy, and Scherbina (2002).

4. ISSUE_1Y: 1-year new issues, measured as the change in shares outstanding from 11 months ago as in Pontiff and Woodgate (2008).

5. ISSUE_5Y: 5-year new issues, measured as five-year composite change in number of shares outstanding as in Daniel and Titman (2006).

6. PM: Profit margin, calculated as earnings before interest and tax scaled by revenues as in Soliman (2008).

7. Ln(PRICE): The log of the stock price at the end of last month, as in Blume and Husic (1973).

8. PROFIT: Profitability, calculated as earnings divided by book equity, in which earnings are defined as income before extraordinary items as in Fama and French (2006).

9. TEF: Total external financing, calculated as net share issuance plus net debt issuance minus cash dividends, scaled by total assets as in Bradshaw, Richardson, and Sloan (2006).

10. ZS: Z-Score, (1.2×(Working Capital / Assets) + 1.4×(Retained Earnings / Assets) + 3.3×(EBIT / Assets) + 0.6×(Market Value of Equity / Book Value of Total Liabilities) + (Revenues / Assets)). Higher values of ZS indicate a lower probability of bankruptcy as in Dichev (1998).

11. VOL_deviation: Volatility mispricing, calculated as the log difference between the realized volatility and Black-Scholes implied volatility for at-the-money options as in Goyal and Saretto (2009).

12. IVOL: Idiosyncratic volatility, computed as the standard deviation of the regression residual of individual stock returns on the Fama and French (1993) three factors using daily data in the previous month as in Ang, Hodrick, Xing, and Zhang (2006) and Cao and Han (2013).

13. AMIHUD: The Amihud (2002) stock illiquidity measure, calculated as the average of the daily ratio of the absolute stock return to dollar volume over the previous month.

14. Size: the natural logarithm of the market value of the firm's equity as in Fama and French (1993).

15. BM: Book-to-market ratio, measured as the ratio of book equity to market equity as in Fama and French (1993).

16. Stock REV: Stock return reversal, measured as the lagged one-month return as in Jegadeesh and Titman (1993).

17. Stock MOM: Stock return momentum, the cumulative return on the stock over the 11 months ending at the beginning of the previous month as in Jegadeesh and Titman (1993).

18. VTS: The slope of the volatility term structure, measured as the difference between long-term and short-term implied volatilities as in Vasquez (2017).

19. VOV: Volatility of volatility, as in Ruan (2020). Measured as the standard deviation of implied volatility in the past month.

20. Option MOM: Option return momentum, calculated as the cumulative option return on the stock over the 11 months ending at the beginning of the previous month where there is no missing past return as in Heston et al. (2023).

21. Option REV: Option return reversal, measured as lagged one-month option return as in Heston et al. (2023).

22. Option Price: The option price.

23. ILLIQ: Option illiquidity as suggested in Christoffersen et al. (2018). This is measured using the quoted option bid-ask spread.

24. RN SKEW: Risk neutral skewness as in Bali and Murray (2013). We use the 30-day risk-neutral skewness. The construction follows Bakshi and Kapadia (2003).

2.3 Option returns calculation and adjustment for transaction costs

The basic unit of analysis is a delta-hedged position in a written call option. For each stock and each portfolio formation date, we calculate the returns to a strategy that sells one contract of the call option and hedges that position with a long position of delta shares of the underlying stock. The position is held for one month to compute the buy-and-hold return. Our return construction is standard in the literature (Goyal and Saretto, 2009; Zhan et al., 2022). Holding the position without rebalancing keeps the exposition simple and minimizes costs from adjusting the hedge. After constructing returns, we sort firms into decile portfolios depending on the levels of predictor variables. If portfolio returns decrease in a predictor variable, we sort on the negative value of the signal to make the long-short portfolio return positive.

Let $S(t)$ be the stock price at time t, $C(t)$ be the midpoint of the bid and ask prices for the call, Δ_t be the Black-Scholes delta of the option contract at time t, and K be the option strike price. The return to selling a delta-neutral call at time t and holding the position until time $t+1$, before accounting for transaction costs ('gross') is:

$$r_t^{gross} = \frac{\Delta_t S_{t+1} - C_{t+1}}{\Delta_t S_t - C_t} - 1.$$

We add transaction costs to this. We need to consider the transaction costs associated with the option position itself, and the stock trading for the delta-hedge. To operationalize the adjustment of option returns for transaction costs, we must make some assumptions. Boyer and Vorkink (2014) use trade and quote data for a small sample of exchange-traded options in 2011 and find that almost half of the trades occur at the ask price, suggesting investors incur high costs to trading options. On the other hand, Muravyev and Pearson (2020) find predictability in options quotes of options on S&P500 stocks, implying that informed traders can take liquidity at favorable prices. Because we don't have trade and quote data to estimate effective spreads for options, we follow Heston et al. (2023) and use the insight of Muravyev and Pearson (2020) that sophisticated option traders can time their execution to lower effective spreads and assume that option traders pay 20.3% of the quoted half spread for options. This is a conservative assumption and increases the possibility of portfolio returns surviving transaction costs.

The delta-hedged option position requires trading of the underlying stock. For stocks, we assume that traders pay half the effective spread when they enter or exit a position in the underlying stock. This is measured using the dollar-weighted effective daily spread from TAQ.

When we account for transaction costs for stock options in decile portfolios, we must account for the possibility that options on the same stock can enter the portfolio in consecutive months, which will mean some of the stock position for the delta hedge can be carried over. We give an overview of the formula here, assuming the stock is in the long decile portfolio so that on the formation date, the option is sold, and the stock is purchased. We provide additional details in Appendix B.

For an option in the long portfolio formed at the end of month t, and held until $t+1$, the total transaction costs equal:

$$\begin{aligned} TC_{t,t+1} &= StockBuyTC_t + StockSaleTC_{t+1} \\ &\quad + OptionSaleTC_t + OptionBuyTC_{t+1} \end{aligned}$$

and the portfolio formation cost with transaction costs equal to

$$FormCost_t = (\Delta_t S_t - C_t) + StockBuyTC_t + OptionSaleTC_t.$$

Therefore, the buy-and-hold one-month return of a written call position formed at the end of month t after accounting stock and option transaction costs ('net') can be written:

$$r_t^{net} = \frac{(\Delta_t S_{t+1} - C_t) - TC_{t,t+1}}{FormCost_t} - 1. \tag{1}$$

We note that the transaction costs have a similar form when we take a short position in a portfolio consisting of written and delta-hedged options. This trade involves buying a call and selling delta shares on the formation date, and then one month later selling the option and buying back delta shares to cover the short stock position.

If one writes a call option and holds it to maturity, one avoids paying the transaction costs required to exit the position (while potentially paying costs associated with the exercise of the option). This involves a slightly different accounting for transaction costs due to the possibility that an option expires in the money and shares may need to be delivered (received). We detail this accounting in Appendix B.4. The returns to this alternative strategy are explored in detail in Section 3.3.

3 Results

3.1 Long-short portfolio returns and transaction costs

In this section, we provide gross portfolio returns and returns that are net of transaction costs. We note, like Detzel et al. (2023), that even if portfolio returns net of transaction costs are insignificant, they can still reveal important information about frictions and investor behavioral biases. For example, if a strategy has high gross returns that do not survive adjustment costs, it suggests models of mispricing combined with limited arbitrage. On the other hand, strategies with high returns net of transaction costs suggest a different type of explanation, such as investor preferences to be compensated for marginal utility variation associated with the strategy.

We start by sorting firms into decile portfolios at each month-end based on the values of our 24 predictor variables. We then calculate the equally weighted average of buy-and-hold one-month option returns in these portfolios, as well as a long-short portfolio, which is long options in the top decile and short options in the bottom decile. Table 2 contains results. Looking at the results in column "$E[r^{gross}_{10-1}]$," we see that 17 of the 24 predictor variables give a significant long-short return spread. Some of these results are novel to the literature; Duarte et al. (2023) show the importance of a look-ahead bias adjustment for delta-hedged option returns using the 13 variables from Zhan et al. (2022).[7] One may worry that these returns compensate for well-understood risk factors documented in the equity market. Table A4 shows the factor returns adjusted for risk using the Fama and French (2015) five-factor model or a simple market (volatility) model. The risk adjustment does not impact the average excess return, suggesting that the excess returns earned by these strategies are not due to equity factor exposure or market volatility exposure. Next, we adjust these returns for transaction costs. Figure 1 helps to visualize the main results. Some long-short portfolios have insignificant returns even before accounting for transaction costs, so we do not show their returns after adjustment. The remaining long-short portfolios have significantly negative returns after adjustment. The column "$E[r^{net}_{10-1}]$" in Table 2 contains the results. The most striking result is that none of the long-short portfolios have a positive and significant return after adjustment for transaction costs, even given our conservative assumptions about transaction costs. In fact, only one variable, $VOL\_deviation$ provides a positive return after adjusting for transaction costs, owing to transaction costs, investors would lose money investing in these strategies. In Table 3, we show the contribution of different transaction costs for each anomaly. Although we don't include margin costs in the main analysis for brevity, we include them for reference. Stock transaction costs are typically two to four times the size of margin costs, and option transaction costs are six to ten times the magnitude of stock transaction costs. We note that the relatively lower importance of stock-transaction costs depends heavily on the return construction method - in Section 4, we show that stock-trading costs can account for over 50% of the strategy costs when we

[7] Our sample starts in September 2003, which is when the TAQ effective spread data becomes available. In Appendix Table A2, we show the impact of sample period selection on the results for gross returns.

delta-hedge daily and hold the option until maturity.

3.2 Analysis of transaction costs

Results in the preceding section reveal that transaction costs have a large impact on the profitability of option strategies. In this section, we investigate the cross-sectional and time series determinants of transaction costs.

To examine the cross-sectional relationship between predictive variables and transaction costs, we use Fama and MacBeth (1973) regressions of transaction costs on predictive variables. In particular, we use the regression specification:

$$TC_{i,t,t+1} = a + b \times TC_{i,t-1,t} + c \times X_{i,t} + \varepsilon_{i,t}, \quad t = 1, .., T$$

Where $TC_{i,t-1,t}$ is the lagged transaction costs for the buy-and-hold one-month return for the option on stock i, and X_t represents other variables that can potentially predict transaction costs. The transaction cost is defined as the stock transaction costs (effective bid-ask spreads) plus option transaction costs (effective bid-ask spreads equal to 20.3% times quoted bid-ask spreads) scaled by the formation costs accounting for position entry costs. Results are shown in Table 4. In the cross-section, lagged percentage transaction costs are the strongest predictor in terms of adjusted R-squared, which implies that costs are very persistent. This is important, as it means to the extent that costs are stable and expected returns change over time, there is a chance of finding strategies that avoid these costs. In univariate regressions, we find that firm size (in logs), idiosyncratic volatility, log price, and the volatility of implied volatility are significantly related to transaction costs.[8] This means options on small volatile stocks that are potentially difficult to price have the largest transaction costs. Looking at the adjusted R^2 in column (6), we can see that most of the univariate variables are significant predictors in a multivariate regression and that almost 50% of the cross-sectional variation in transaction costs can be explained by these variables. We note that the logarithm of market capitalization seems to drive out the economic significance of the log price predictor, and similarly, the sign on stock idiosyncratic volatility flips, and its economic magnitude diminishes in a multivariate regression. This suggests that the volatility of implied volatility is a more important predictor of transaction costs than stock idiosyncratic volatility. These results signal that any characteristics related to size, volatility, or pricing

[8] In untabulated results, we find that 23 of our 24 characteristics can significantly predict transaction costs in univariate regressions. For brevity, we focus on variables suggested by the literature that have predictive power after controlling for lagged transaction costs.

difficulty of options may relate to high gross returns without necessarily translating to high net-of-transaction cost returns.

To examine the time-series variation in transaction costs, we take an equal-weighted average of the transaction costs for the 17 significant portfolios in Table 2 to understand trading costs. In terms of the level of transaction costs, Figure 3 shows that overall, transaction costs for trading portfolios with high long-short returns have been increasing during our sample period. We note that trading costs spiked during the COVID-19 crisis. We also decompose the costs to highlight the contribution of stock and option-related trading costs. Figure 2 shows results. On average, over 80% of the costs can be attributed to the costs of trading the option and the remainder to stock trading costs.[9] These results suggest that the costs of trading long-short option portfolios have been increasing over our sample period. This is in contrast to trading costs in the stock market which have been decreasing over time (Jones, 2002; Angel et al., 2011).[10]

Understanding the time series properties of transaction costs is important. While the entry costs to a strategy can be decided ahead of time, the costs of exiting the strategy are unknown, and this will present a significant risk to delta-hedged option investors who plan to exit their position before maturity. We use time series regressions to understand the determinants of transaction costs. Table 5 contains estimation results of regressing the average transaction costs on lagged predictor variables. Lagged transaction costs are highly persistent. Other than lagged transaction costs, the level of the CBOE Volatility Index (VIX) and the market-wide sentiment index of Baker and Wurgler (2006) are the only other predictors with a significant relation to the time series of transaction costs. These results motivate our later analysis that explores the difference between buy-and-hold option returns that are rebalanced after one month and hold-to-maturity option returns that avoid this exit cost.

3.3 Cost-mitigation strategies

The previous section showed that transaction costs eliminate the returns to all option return strategies. However, these strategies were not designed with transaction costs in mind.

In this section, we investigate several cost mitigation strategies. Our buy-and-hold return,

[9]In Figure 6, we repeat the decomposition for strategies where the portfolio is delta-hedged daily and held for one month (Panel A) or until maturity (Panel B). We see that the relative importance of stock trading costs increases substantially.

[10]In Figure A1, we show the average transaction costs at the end of each month for our sample universe and find that option trading costs have increased significantly since around 2014. Thus, findings in Figure 2 of an increase in trading costs are not isolated to the trading costs of decile portfolios sorted on certain characteristics.

which delta-hedges the portfolio only once on the formation date, already applies some cost mitigation. We further note that cost-mitigation strategies cannot simply be adapted directly from the equity anomaly literature. For example, banding — which mitigates the transaction costs through reducing the turnover of stocks — is an effective cost mitigation strategy for equity trading strategies investigated in Novy-Marx and Velikov (2016) and Chen and Velikov (2023). However, because options expire, they must be re-purchased, so turnover (and transaction costs) may not be avoided. In the same vein, the strategy of rebalancing at a lower frequency (say quarterly rather than monthly) is not applicable to our options portfolios.

With this in mind, we adapt some strategies from the equity literature to our context and also analyze the returns on some novel transaction-cost mitigation strategies. First, we analyze filters that limit the universe of allowed options to those with low option transaction costs. Second, we analyze the returns of hold-to-maturity strategies, which avoid some option transaction costs by holding until the option maturity date. Finally, we analyze returns to novel cost mitigation strategies that involve long-only portfolios and portfolios that minimize the cost of hedging out market volatility risk.

3.3.1 Low-cost universe

Limiting the stock universe to those with low costs is an effective cost mitigation strategy as investigated in Novy-Marx and Velikov (2016) and Chen and Velikov (2023). The transaction costs of options are determined by bid-ask spread, so it is natural to restrict the option bid-ask spread below a predetermined threshold. Heston et al. (2023), for example, retain options with quoted bid-ask spread below 10% to form the low-cost universe. We note that because the average transaction cost is increasing over time, applying a filter based on the absolute level of the transaction cost may remove relatively more data from late in the sample. To deal with this, we apply a relative filter and keep stocks in the bottom four deciles of option transaction costs, which approximates the 10% filter while keeping a balanced sample over time. Once we have filtered out high option-transaction-cost stocks, we then construct the portfolios and adjust for transaction costs as before.

3.3.2 Hold-to-maturity

As shown in Figure 2, options trading costs account for the largest proportion of transaction costs of the delta-hedged call option writing strategy. In earlier sections, we used a strategy that held options for one month from the end of each formation month before rebalancing at the end of the next month. One transaction cost mitigation strategy suggested by Zhan et al.

(2022) is to hold each option in the portfolio until expiration. This means we can reduce the number of option trades required by half.

This hold-to-maturity strategy gives a continuous monthly series of returns. Because the maturity of these strategies will be longer than 30 days, we will adjust the returns to a 30-day basis. However, even with this adjustment, the average returns will not be directly comparable to the buy-and-hold option returns that hold options for one month. First, because each option has a median maturity of 50 days, from day 30 to day 50, we will potentially have two options for some stocks in the portfolio, and in general, we will invest in twice as many options for this period. Furthermore, the returns could be mechanically different because when held to maturity, the option gamma is higher when the option is close to maturity.[11]

3.3.3 Results of simple cost-mitigation strategies

The results can be seen in Table 6. For comparison, the column "$E[r_{all}^{mon}]$" displays the buy-and-hold one-month long-short portfolio returns adjusted for transaction costs as in Table 2. Because the hold-to-maturity strategies can have a different number of days to maturity, to make returns using different methods comparable, we rescale all returns to a 30-day basis in this section. First, we focus on cost-mitigation strategies applied to the one-month buy-and-hold return series that limit the universe of investable stock options before allocating stock options to portfolios. Looking at results in the column "$E[r_{lc}^{mon}]$", which contains returns when the universe of stocks is limited to those with lower option bid-ask spreads, we see (relative to the first column) large increases in returns. However, returns are still insignificant and typically negative after adjustment for transaction costs.

Next, we look at the hold-to-maturity returns, where returns are based on strategies formed at the end of the month or the third Friday of the month (columns "$E[r_{all}^{mat}]$" and "$E[r_{all}^{mat2}]$", respectively). These cost mitigation strategies avoid paying some transaction costs by holding the option to maturity. We first look at the hold-to-maturity returns of portfolios formed at the end of each month. Multiple long-short portfolios become significant using this cost mitigation strategy. The difference between implied and historical volatility from Goyal and Saretto (2009), the volatility of volatility from Ruan (2020), and Cash-to-assets (introduced by Zhan et al. (2022)) all become significant with this cost mitigation

[11] Dew-Becker, Giglio, Le, and Rodriguez (2017) highlight that for index options, the returns are relatively larger for short-maturity options with a relatively higher gamma.

strategy.[12] We noted earlier that the hold-to-maturity returns formed at the end of each month can result in overlapping option positions which might make the comparison with the one-month returns difficult. Thus in the column "$E[r_{all}^{mat2}]$" we focus on returns that are constructed on the third Friday of each month and held until maturity (approximately 30 days). For this return construction, the portfolios formed on VOV are no longer significant, but portfolios formed on $-VOL\_deviation$ and CH remain significant. Figure 4 helps to visualize the results for all of our 24 long-short portfolios; while the cost mitigation strategy helps to increase the returns of multiple anomalies, only two become statistically significant. These results underscore the importance of return construction for portfolio significance.

Next, we consider combinations of cost mitigation strategies. Namely, we combine hold-to-maturity returns with restrictions on the universe of investable stock options. First, we analyze hold-to-maturity returns with portfolios formed at the end of each month (column "$E[r_{lc}^{mat}]$"). This strategy has some moderate success; for example, the idiosyncratic volatility variable increases in magnitude and becomes significant when we combine hold-to-maturity returns with a constraint on options with relatively high bid-ask spreads. Next, we analyze returns of portfolios that are formed on the third Friday of each month and held until maturity (column "$E[r_{lc}^{mat2}]$"). For this cost mitigation strategy, we find the highest number of long-short portfolio returns that are significant at a 5% level. We find that $VOL\_deviation$, VOV, VTS, and CH are all significant with this cost mitigation strategy.

Overall, these results suggest that cost mitigation is an important consideration when designing option portfolio strategies to capture due to high transaction costs. Many strategies have high average returns after simple tweaks to the return construction or option contract selection rules. Nonetheless, depending on the cost mitigation strategy used we only find two to four long-short portfolios have significant returns. This means that the achievable investment opportunity set is quite small and can be explained by a low-dimensional factor model. Regarding consistency across methods, sorts on $VOL\_deviation$ are most consistent, with significant returns for four different cost mitigation strategies. VOV and CH are close behind with significant returns for three cost mitigation strategies. Sorts on variables like VTS and $IVOL$ are significant for one cost-mitigation strategy each, and, notably, they both rely on hold-to-maturity returns which both increase the overall gamma-exposure of the option positions and limit the transaction costs paid for trading the options.

[12] Goyal and Saretto (2024) find significant returns after transaction costs for long short portfolios formed using stock price and size, while we don't. We replicate their result and trace the difference to two crucial factors. Their sample includes firms with a stock price of less than 5 USD on the portfolio formation date, and they delta hedge the strategy daily without accounting for stock trading costs. In Table 10, we can see that delta hedging daily increases returns on these portfolios before accounting for stock transaction costs.

3.3.4 Low-cost (market) volatility neutral portfolios

In the equity market, long-short portfolios are typically constructed for three main reasons. First, we can generate a return series that does not load on market risk. In the context of equity anomalies, we typically have a zero market beta on the long-short portfolio returns. This implies that any positive average excess return must represent compensation for an additional risk-factor loading or market inefficiency. Second, the short portfolio can be used to take advantage of stock overpricing; indeed, Stambaugh et al. (2012) find that the returns to the short legs of anomaly strategies are more profitable following high sentiment periods, suggesting overpricing. Finally, long-short portfolios can, in theory, be constructed to be a zero-cost strategy if we assume the proceeds from short-selling stock can be used to invest in the long portfolio.

It's important to reconsider these motivations for forming long-short portfolios when analyzing equity-option returns. Figure 5 helps to visualize the main insight. When we average the gross returns, transaction costs, and net returns across decile portfolios for all the 24 sort variables, we see that gross returns increase faster than transaction costs as we move from the bottom to the top decile. This means that investments in low-decile portfolios, on average, will not contribute much to the long-short portfolio return. Table 7 contains results that help to analyze this issue for each individual portfolio sort variable. We calculate the pre- and post-transaction cost returns for the top and bottom decile portfolios, respectively. We note that as we go from the bottom to the top decile, the average returns grow faster than the transaction costs. For example, for the $VOL\_deviation$ portfolio sort, the returns increase by 210bp (from -19bp to 191bp), while the transaction costs only increase by 26bp (from 34bp to 60bp). This is a key insight because the transaction costs on this "short portfolio," which buys the option and sells the stock, can overwhelm any positive returns.

In this section, we suggest two novel cost mitigation strategies that take advantage of this insight. First, because Table 7 suggests that the call writing strategies have the highest returns in the top decile, we analyze the risk and returns of "long-only" option portfolios that involve a delta-hedged written option position. Second, to address the concern that this portfolio may represent compensation for loading on market volatility risk; we hedge this risk by taking a weighted short position in the market index options. If the only clear advantage of the short position in the long-short portfolio is creating neutrality to a market volatility risk factor, this strategy will provide a cost-effective way of achieving the same aim.

It's important to consider loadings of portfolios on market volatility risk because there is evidence that market volatility risk is priced. Bakshi and Kapadia (2003) show how delta-hedged gains can give qualitative information about market variance-risk-premia while Carr and Wu (2008) show how to quantify the variance risk premium. In the context of single stock options, Driessen, Maenhout, and Vilkov (2009) show the connection between individual stock and market volatility risk premium.

To achieve these aims, we calculate a time series of equity index option returns using delta-hedged buy-and-hold to maturity returns of written call options. We choose the SPX options on the Standard and Poor's 500 index as our proxy for options on the market. We hedge the position in this index by trading the SPY ETF. We can consider delta-hedged returns on these options as a proxy for the market variance risk premium. Table 8 shows summary statistics for delta-neutral call writing strategies on ATM index options with maturity matched to our single stock options. The summary statistics highlight the low transaction costs of trading (and delta-hedging) these options. The average quoted spread for these options is 4.16% which is one-sixth the average quoted spread for single stock options reported in Table 1.

The results are displayed in Table 9. As shown in Table A4, the returns on strategies that invest only in the top decile typically give high returns. One might be concerned that these high returns compensate for loading on some risk factor, typically hedged using the bottom decile portfolio. To analyze this issue we calculate market volatility loadings by regressing the return of the portfolios on index option returns. The first two columns contain the market-volatility loading for the bottom and top decile portfolio returns, respectively, and we confirm that they both have a relatively high loading on the return of a written option on the index. In the third column, we see that the long-short portfolio is often, but not always, neutral to the index option risk. We then consider a strategy that is long the top decile and short 0.9 units of the index option return. We find that the returns are approximately volatility-beta neutral, suggesting this strategy can net out some risk.

In the two columns "$Ret(\%)$", we show average returns to the investment in the top decile strategy and the strategy that is long the top decile and short 0.9 units of the index option. We find that returns are significant and positive for seven portfolio sort variables. In particular we note that profit margin and profit become significant using this strategy. However, one concern is that these strategies load on index option risk, which could be the source of the relatively higher returns. In the last two columns, we show estimates of strategy alphas. If the returns on the top decile portfolio are compensation for index-option risk, we can perform a risk adjustment by regressing their returns on the index-option returns. The alpha on the portfolio that is long the top decile is significant for an additional three variables, all three variables are related to issuance and external financing. In the last column, we show estimates for strategy alphas when we take a long position in the top decile and short 0.9 units of the index option. We do this because while returns to the top portfolio decile may not load on market risk, they will still have high volatility when market volatility is high. Portfolio sorts using option and stock-based characteristics provide significant returns using this cost mitigation strategy. For option characteristics, portfolios sorted on $VOL\_deviation$, VOV, and VTS have positive and significant returns. For stock characteristics, $IVOL$, CH, PM, and $PROFIT$ all have significant returns. The significance of PM and $PROFIT$ are particularly notable because cost mitigation strategies in Table 6 did not result in significant returns for these variables. Furthermore, this strategy is significantly simpler *logistically* as it replaces a position in a portfolio of single stock options with a position in one index option.

The overall message from these results is that the construction of portfolios to capture returns in equity options should not directly follow the methods used in the literature for stock returns. Regarding individual option characteristics, and depending on the cost mitigation strategy employed, we find up to 10 of the 24 characteristics provide valuable information for predicting option returns.

4 The impact of delta-hedge frequency

Throughout the paper, we use positions on options that are delta-hedged only once on the portfolio formation date. However, another popular approach in the literature is to use strategies that delta-hedge the option position once each day (Heston et al., 2023; Cao and Han, 2013; Goyal and Saretto, 2022). Delta-hedging daily has the benefit of decreasing the volatility of the investment by minimizing position volatility due to stock exposure (Tian and Wu, 2023). On the other hand, in the presence of transaction costs, daily trading of the stock may result in excessive transaction costs that can reduce the average return. In this section, we empirically investigate this tradeoff between volatility reduction and mean reduction of returns.

We start by considering the delta-hedged option gain following Bakshi and Kapadia (2003). We consider a position in a call option, hedged N times during a period $[t, t+\tau]$. The delta-hedge position can be rebalanced at the dates $t_n, n = 1, \ldots, N$ (where we define $t_0 = t, t_N = t+\tau$). The discrete delta-hedged call option gain over the period $[t, t+\tau]$ is

$$\Pi[t, t+\tau] = C_{t+\tau} - C_t + \sum_{n=0}^{N-1} \Delta_{c,t_n} \left[S(t_{n+1}) - S(t_n)\right] - \sum_{n=0}^{N-1} \frac{a_n r_{t_n}}{365} \left[C(t_n) - \Delta_{c,t_n} S(t_n)\right]$$

where a_n is the number of calendar days between t_n and t_{n+1} and r_{t_n} is the annualized risk free rate.

We scale this by $\Delta * S - C$ to calculate a return. To isolate the effects of hedging frequency, we consider a position formed at the end of each month and held until maturity. We then calculate returns where we hedge once, every ten trading days "Biweekly", every five trading days "Weekly," and every trading day "Daily." For these cases, Δ_{c,t_n} changes periodically, corresponding with the associated hedge frequency.[13] As before, we use characteristics to sort options into decile portfolios and calculate returns to a long-short decile portfolio. We also calculate the stock turnover per position in each portfolio to understand how hedge frequency affects the amount of stock traded.

To preview the importance of daily delta-hedging, we first take an average of transaction costs across all long-short portfolios and then decompose the cost into a part driven by stock trading costs and option trading costs. Figure 6 shows results. In Panel A we show the decomposition for the daily delta-hedge one-month returns. This can be compared to the decomposition in Figure 2, where we have the same strategy hedged only once on the formation date. The difference comes from the increased hedging frequency, which increases the relative importance of stock trading costs. In Panel B, we show the decomposition for the strategy used in this section, i.e., for portfolios formed at the end of the month and delta hedged until maturity. Delta hedging until the maturity date avoids paying option transaction costs to exit the option position, this increases the relative importance of stock trading costs which is now, on average, above 40% of the overall trading costs.

Results are contained in Table 10. For brevity, we report results for a subset of our full sample of variables (results for all variables can be found in Table A6). We report average returns, t-statistics, annual Sharpe ratios, and stock turnover for portfolios formed at the end of each month and held until maturity.[14] The first four columns assess the impact of more frequent hedging without transaction costs, and in the last four columns, we conduct the same analysis while accounting for transaction costs. Focusing first on turnover (the number in curly braces), we see that for all characteristics, the turnover more than doubles going from hedging once to daily hedging.[15]

Next, we focus on the effects of more frequent hedging in the absence of transaction costs. We see that for option characteristics, more frequent hedging has only a modest effect on strategy returns while decreasing strategy volatility significantly. For example, the Sharpe ratio on the long-short portfolio formed using VOV increases from 2.01 to 3.36 as we move from hedging once to hedging daily. For stock characteristics, it's notable that more frequent hedging can increase returns on portfolios formed on certain stock characteristics quite substantially: portfolios formed on $-LN(PRICE)$ and $-Size$ increase by approximately 50bp when we hedge daily relative to hedging once.

[13] If the value for delta is missing, we will forward the data from the last existing value to avoid any look-ahead bias.

[14] The statistics for the strategies with transaction costs that are delta hedged once are almost identical to those for '$E[r_{all}^{mat}]$' in Table 6, the slight difference comes from the fact that in this section we use the formula for a daily delta-hedged return which accounts for returns on a cash position.

[15] A turnover of 1 is consistent with buying 0.5 shares at the initiation and selling those shares at expiry (if delta does not change). Thus a turnover of 2 is expected for a long-short portfolio.

Next, we focus on the effects of hedging frequency after accounting for option transaction costs in the last four columns. Because we hold until maturity, the effects of the option transaction costs are the same for all strategies, allowing us to isolate the impact of stock transaction costs.

For option characteristics, we find it possible to increase Sharpe ratios even in the face of higher transaction costs due to stock turnover. For $OptionMOM$ we find significant portfolio returns when we delta-hedge weekly, and these returns do not survive the large increase in costs associated with the move from weekly to daily hedging. For portfolios formed on $-VOL\_deviation$ and VOV, we find Sharpe ratios sometimes increase with hedging frequency.

When we focus on portfolios formed using stock characteristics, results are in sharp contrast to those without transaction costs. Excepting the portfolio formed using CH, we do not find significant returns for any portfolios. We also find that the burden of stock adjustment costs overwhelms any benefit of variance reduction so that the increase in returns from daily hedging observed without transaction costs does not survive stock transaction costs. These results are important as researchers often make choices about which hedging frequency to use without considering the impact of transaction costs.

5 Robustness Tests

5.1 Alternative portfolio weighting schemes

Thus far, we have equally weighted returns in our decile portfolios. In the equity market, anomalies are well known to vary by stock size (Fama and French, 2008). Furthermore, signals that seem to predict returns may no longer be valuable after the smallest stocks are removed and returns are value-weighted (Hou, Xue, and Zhang, 2020). Researchers also place less weight on anomalies that are only present in equal-weighted returns because it is well-known that transaction costs are higher for these stocks. Our results in Table 4 similarly suggest that size is related to the cost of trading option anomalies. Thus, a weighting scheme that downweights returns on smaller stocks may improve the profitability of our long-short portfolios. In this section, we explore this idea in two ways. First, we use a value-weighting strategy which weights each stock using its market capitalization. Because option returns are decreasing in size (e.g., see the portfolio sorts on -SIZE in Table 2), this strategy will only increase returns after transaction costs if the reduction in returns due to putting more weight on options on larger stocks is offset by lower transaction costs for trading the options on those larger stocks. Second, we use “Option-Value-Weights,” which weighs returns by the market value of option open interest at the formation date (as used in Zhan et al. (2022)). These weights emphasize stock options likely to have more trading and potentially lower transaction costs.

Results are contained in Table A3. We apply different weighting schemes to two of our return strategies. The first three columns contain results for the buy-and-hold one-month returns with restrictions on the universe of investable options. The last three columns contain results for the hold-to-maturity returns, where portfolios are formed on the third Friday of each month.

Focusing first on the buy-and-hold one-month returns in the first three columns, we see that putting more weight on stock options with larger market-capitalization stocks or option open interest typically increases returns. However, it is only in the case of the idiosyncratic volatility and volatility deviation sorts that conclusions about the significance of long-short portfolio returns are changed. We note that these two variables are significant using multiple cost mitigation strategies. Looking at the results in the last three columns (which focus on the strategy formed on the third Friday and held until maturity), we come to a similar conclusion: reweighting portfolios towards larger stocks (or stocks with a higher market value of open interest) typically increases returns. Still, it does not change conclusions about the statistical significance of the strategies we analyze.

5.2 Adjustment for risk

In this section, we consider whether the portfolio returns we observe (prior to adjusting for transaction costs) could be compensation for well-documented risks in the equity market. Because we consider option returns that are delta-hedged only once, they could have stock exposure and potentially load on existing anomalies. Likewise, some of the option portfolios may provide compensation for market volatility risk. While there is no established factor model for risk adjustment in the context of delta-hedged single stock option returns, we adjust the returns using the five-factor model of Fama and French (2015) and a simple market volatility model by adjusting for the delta-hedged return on the S&P 500 index option. Table A4 contains results. We observe that the long-short portfolio return alphas are around the same magnitude as the unadjusted average returns.

5.3 Put options

Our main results focus on portfolios of delta-neutral call returns. One might wonder if our results are driven by the use of call options in particular. In this section, we replicate our main analysis in Table 2 using put options. Because our sample construction requires both a call and a put option with certain characteristics to exist on the portfolio formation date, our sample is identical. So, any difference in results will come from the difference in option type rather than the sample composition. For each characteristic, we sort firms into decile portfolios and then calculate the returns to investing in a long-short portfolio before and after accounting for transaction costs. As in Table 2, we use portfolios that are formed at month end and use buy-and-hold one-month returns accounting for stock and option transaction costs. The results are contained in Table A5. First, we note that 16 long-short portfolios are significant at a 5% level using put options, almost the same as the 17 significant long-short portfolios for call options. Second, we can see that the main qualitative result of the paper holds; that multiple characteristics that lead to significant long-short *gross* portfolio returns lead to negative *net* returns once we adjust for transaction costs.

6 Conclusion

This paper explores the impact of adjusting delta-hedged option returns for transaction costs and look-ahead bias. We study returns of long-short portfolios formed using 24 different variables, and 17 lead to significant gross portfolio returns. None of the studied long-short portfolios have significant returns after adjusting for transaction costs. Simple cost mitigation strategies can increase returns by a large margin and restore significance to some portfolios. We introduce a novel cost-mitigation strategy utilizing index options and find that it dominates existing cost-mitigation strategies. We show that daily-delta hedged strategies require significant additional trading, and while they reduce strategy variance, the reduction in average returns due to additional trading costs typically makes the strategy unattractive. Overall, considering transaction costs is essential for measuring option returns.

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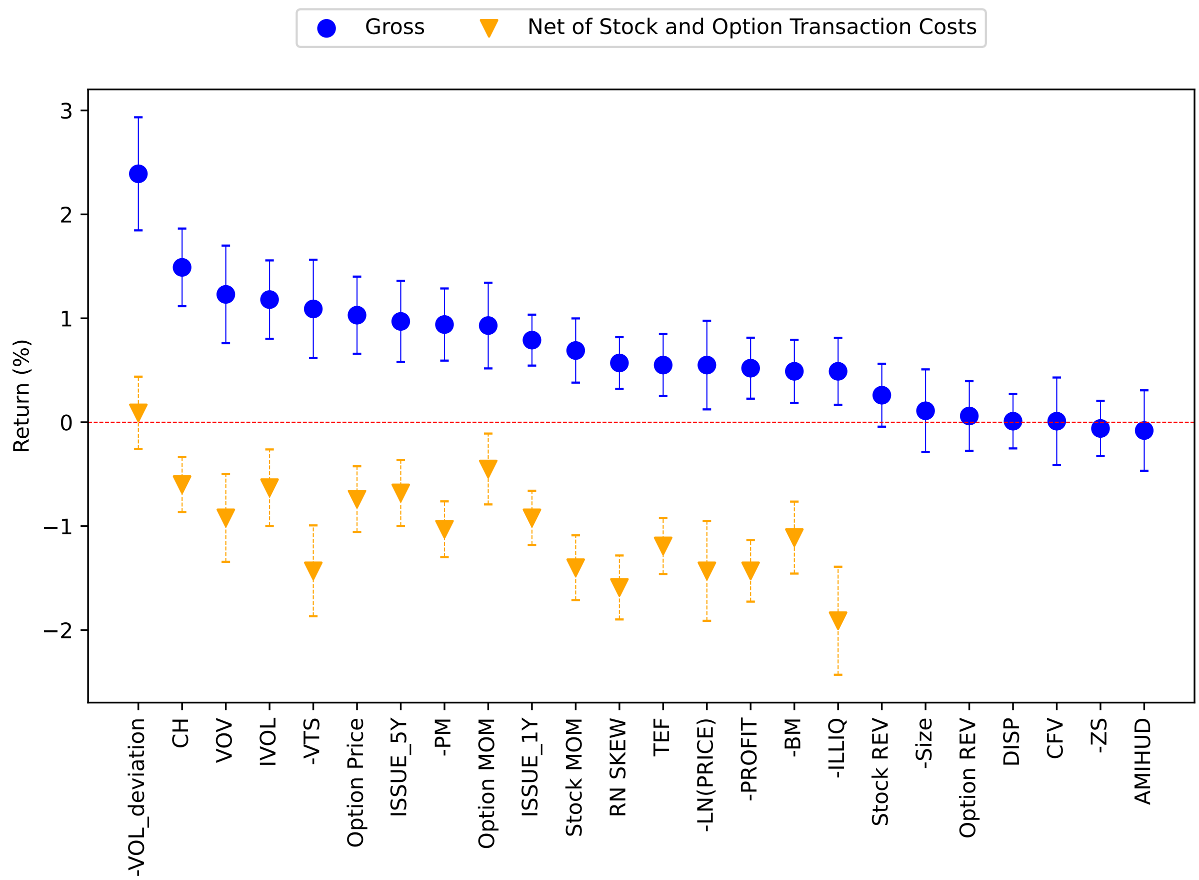

Figure 1: Equal-weighted long-short portfolio returns before and after accounting for transaction costs

This figure shows average returns on long-short portfolios of delta-hedged call option returns sorted by various characteristics. Portfolios are formed at the end of each month and held for one month. 'Gross' stands for long-short portfolio returns before accounting for transaction costs, and 'Net of Stock and Option Transaction Costs' stands for long-short portfolio return after accounting for transaction costs where the stock effective bid-ask spread is from the TAQ database and option effective bid-ask spread equals to 20.3% of the quoted bid-ask spread from OptionMetrics database. The error bars show two standard errors (using the Newey-West correction with six lags). When the portfolio gross return first becomes negative or insignificant, the portfolio performance with higher transaction costs is ignored since it must be negative or insignificant. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

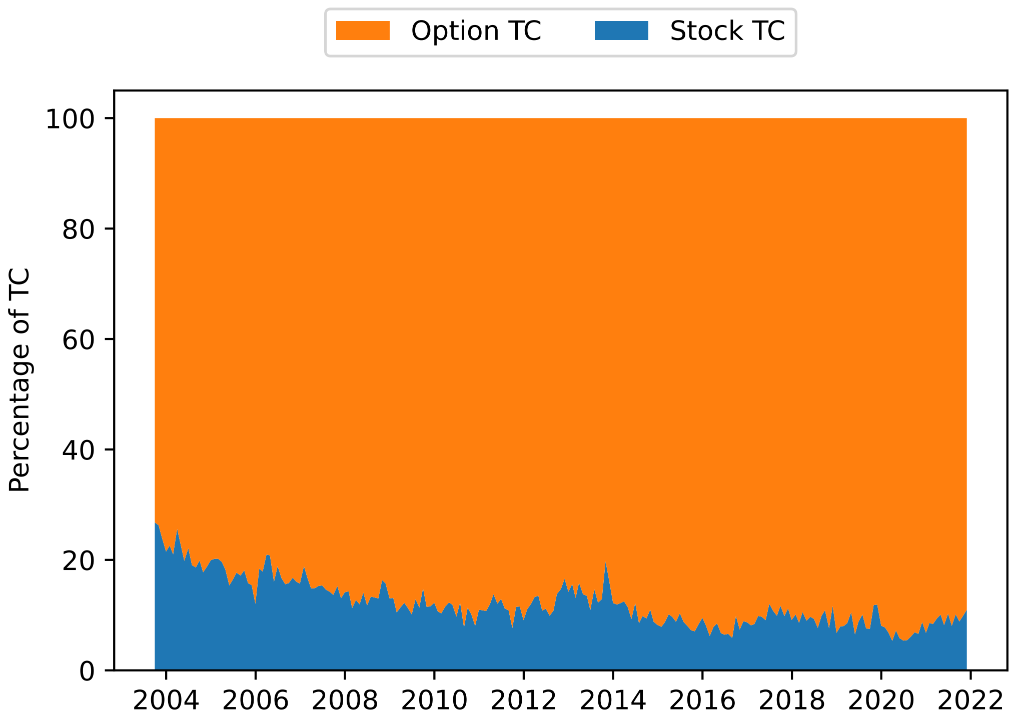

Figure 2: Decomposition of average long-short portfolio transaction costs in percent.
This figure shows a decomposition of average transaction costs across all the long-short portfolios in Figure 1. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% of the quoted bid-ask spread from the OptionMetrics database. The time period is between September 2003 and December 2021.

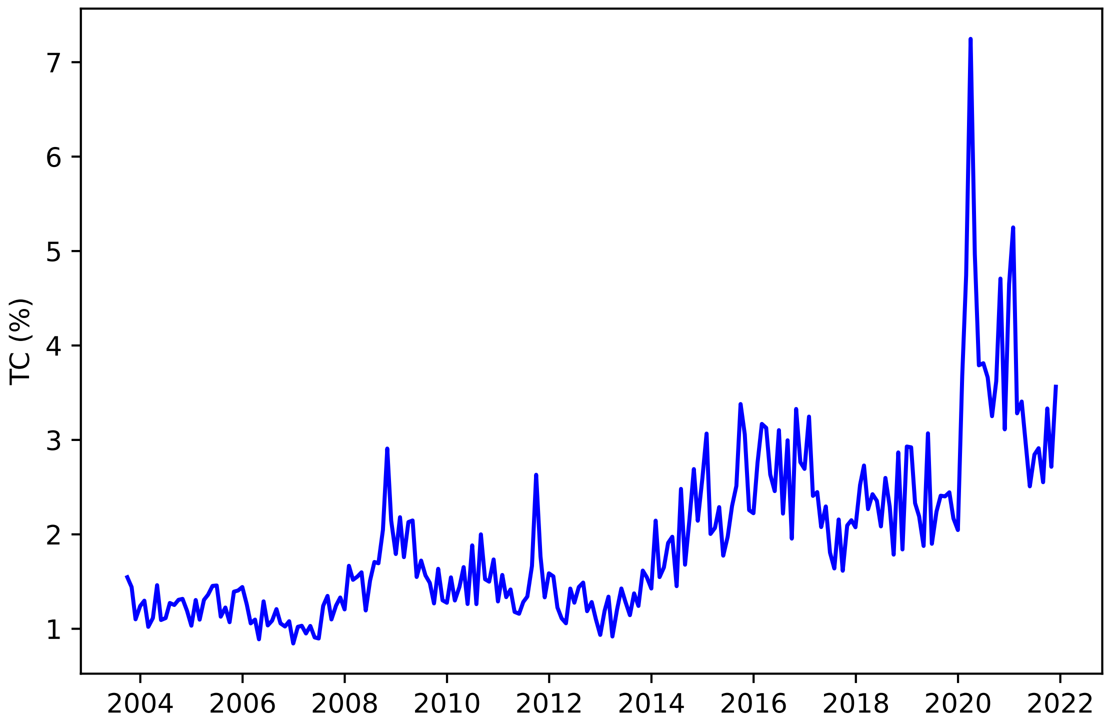

Figure 3: Time series of long-short portfolio transaction costs
This figure contains a graph of the time series of the cross-sectional average of long-short portfolio transaction costs of 17 significant anomalies from Table 2. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% of the quoted bid-ask spread from the OptionMetrics database. The time period is between September 2003 and December 2021.

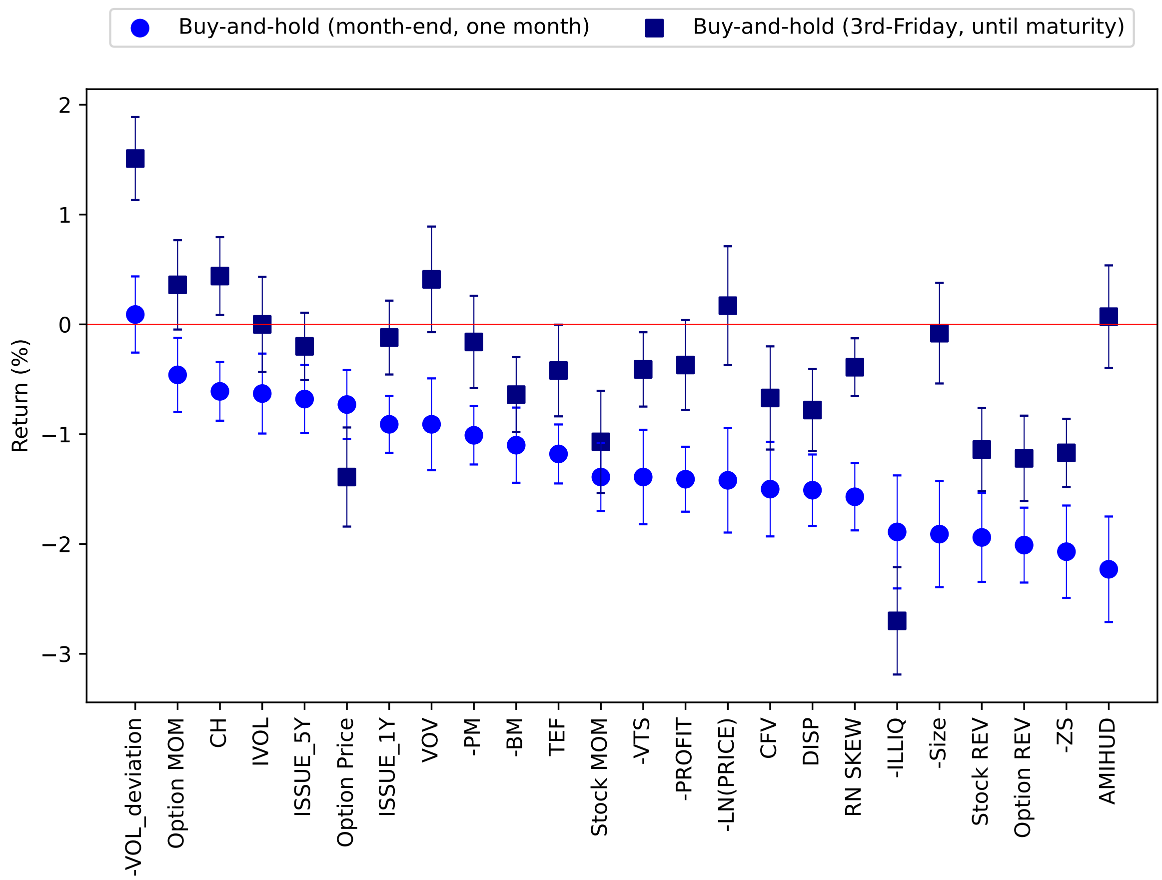

Figure 4: Equal-weighted long-short portfolio returns before and after applying cost-mitigation

This figure shows average returns on long-short portfolios of delta-hedged call option returns sorted by various characteristics with and without cost-mitigation. 'Buy-and-hold (month-end, one month)' refers to the option returns formed at the end of the month and held for one month. 'Buy-and-hold (3rd Friday, until maturity)' refers to the option returns formed on the third Friday of each month and held until maturity. Returns for the two strategies are scaled to be 30-day returns for comparability. Transaction costs are equal to stock trading costs (effective bid-ask spread from TAQ) plus option trading costs where effective bid-ask spread equals 20.3% of the quoted bid-ask spread from Optionmetrics. The error bars show two standard errors (using the Newey-West correction with six lags). Variables are described in Section A.1. The time period is between September 2003 and December 2021.

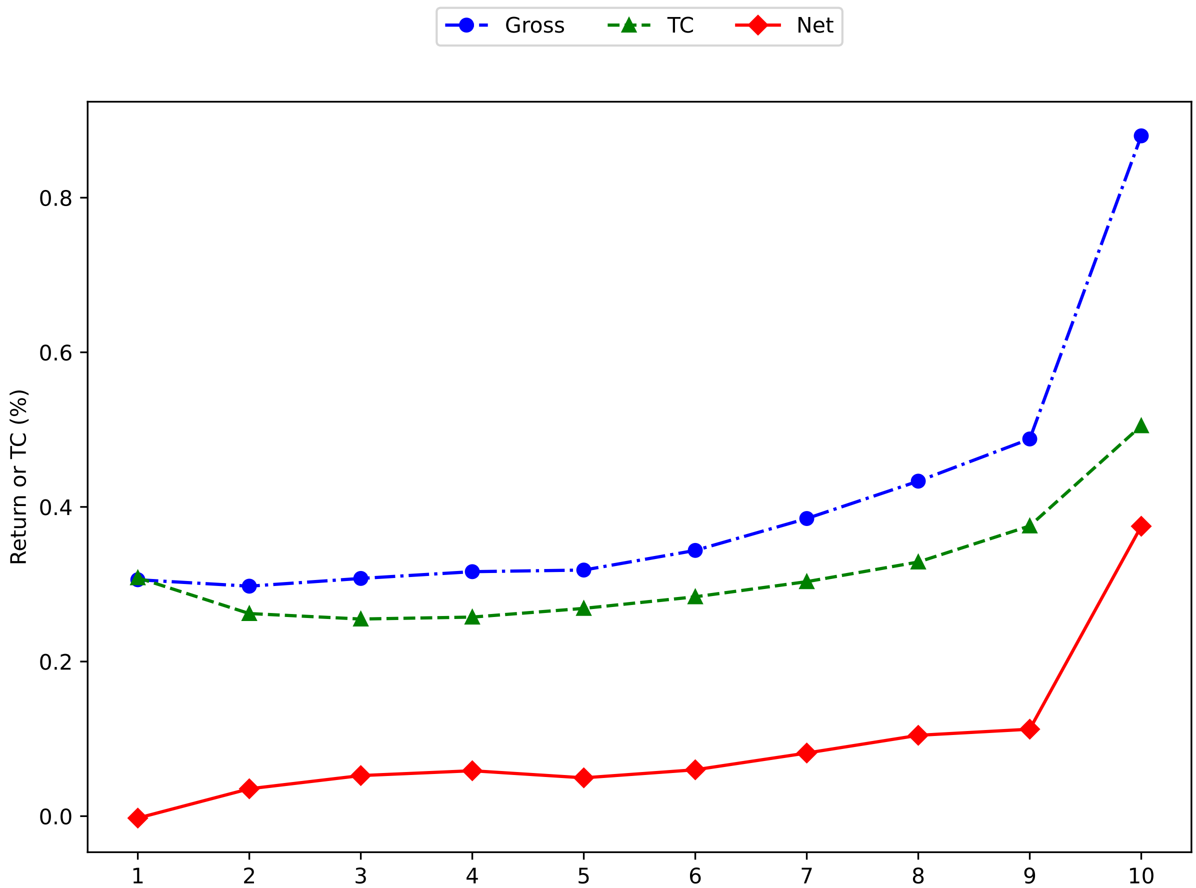

Figure 5: Average returns and transaction costs in decile portfolios
This graph shows statistics for decile portfolios averaged across all 24 portfolio sort variables. First, we sort into decile portfolios for each statistic and then average the characteristics across that decile for all 24 characteristics. The blue dots show gross returns for each decile. The green triangles show the average transaction costs for each decile (defined as the difference between gross and net returns). The red diamonds show net returns for each decile which are defined as the difference between gross returns and transaction costs. Transaction costs are equal to stock trading costs (effective bid-ask spread from TAQ) plus option trading costs where effective bid-ask spread equals 20.3% of the quoted bid-ask spread from Optionmetrics. The time period is between September 2003 and December 2021.

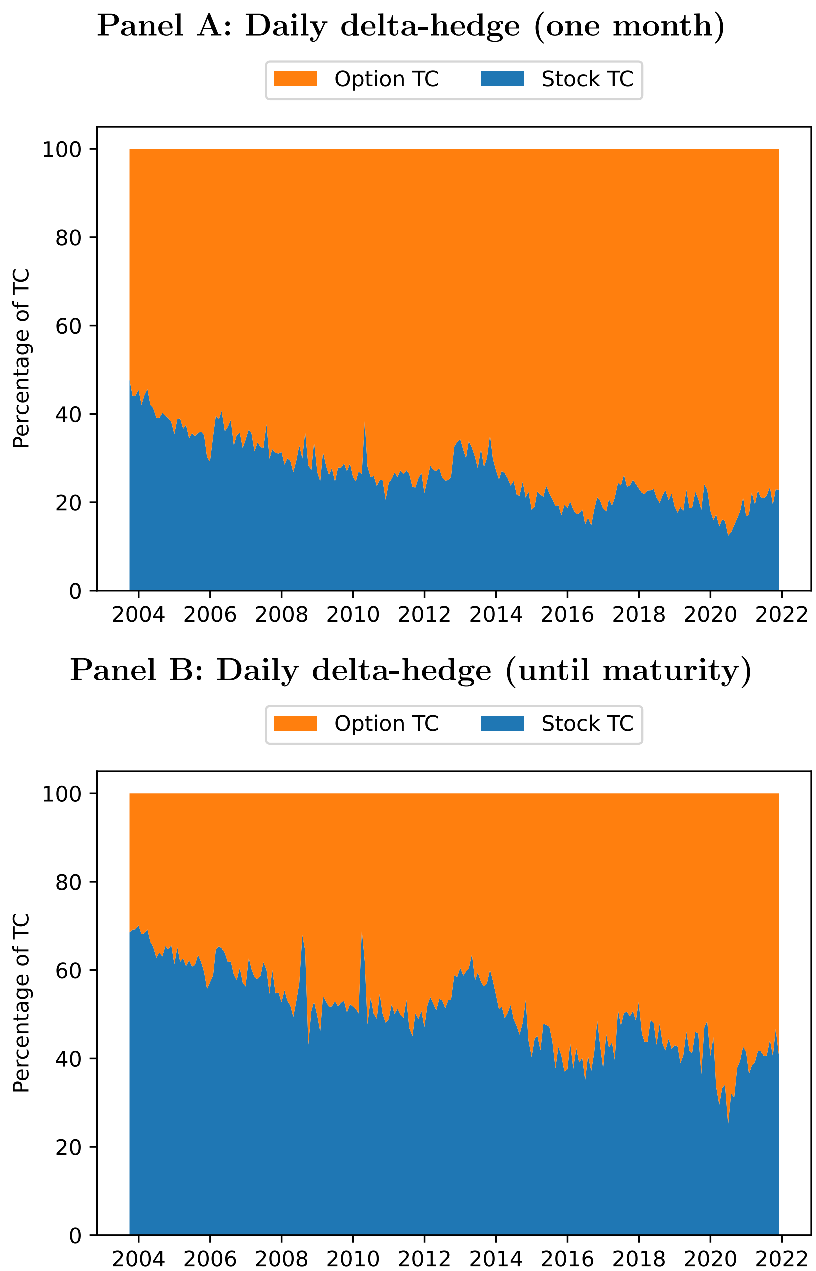

Figure 6: Decomposition of average long-short portfolio transaction costs in percent for the daily delta-hedged trading strategies

This figure shows a decomposition of transaction costs for long-short portfolios of daily delta-hedged call returns. Panel A (Panel B) contains the decomposition for a strategy formed at the end of each month, and delta hedged daily for one month (until maturity). The transaction costs are an average of the transaction costs across all 24 long-short portfolios. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% of the quoted bid-ask spread from the OptionMetrics database. The time period is between September 2003 and December 2021.

Table 1: Pooled summary statistics of delta-neutral call writing strategies for equity options.

The 'Buy-and-hold' returns in each panel refer to a delta-neutral call writing position, which involves selling one contract of an equity call and taking a long position of delta shares of the underlying stock. The position is held for one month (Panel A) or until option maturity (Panels B and C). Panel A contains statistics for a strategy formed at the end of each month and held until the end of the next month. Panel B contains statistics for the strategy formed at the end of each month and held until maturity. Panel C contains statistics for the strategy formed on the third Friday of each month and held until maturity (the third Friday of the following month). Stock and option trading costs are calculated at the initiation and conclusion of the strategy. "Entry" refers to a statistic on the formation date, and "Exit" refers to the associated exit date of the strategy. Days to maturity are the number of calendar days until the option expires. Vega is the Black-Scholes option vega scaled by the stock price. The time period is between September 2003 to December 2021.

Panel A: Buy-and-hold until month-end (formed at the month-end)

	mean	sd	p1	p10	p25	p50	p75	p90	p99
Buy & hold until month-end (%)	0.46	8.85	-31.56	-7.52	-1.55	1.83	4.32	7.30	16.59
Moneyness = S/K (%)	99.26	4.84	85.20	93.47	96.81	99.51	101.78	104.63	112.67
Days to maturity	49.60	2.08	44.00	46.00	49.00	50.00	51.00	52.00	53.00
Vega	0.14	0.01	0.09	0.13	0.14	0.14	0.15	0.15	0.15
Quoted option bid-ask spread of Entry (%)	23.90	26.54	1.83	5.41	8.70	15.05	28.04	51.85	142.86
Quoted option bid-ask spread of Exit (%)	57.07	66.39	2.00	5.94	11.20	25.26	66.67	200.00	200.00
Effective stock bid-ask spread of Entry(%)	0.13	0.12	0.02	0.04	0.05	0.09	0.16	0.25	0.61
Effective stock bid-ask spread of Exit(%)	0.13	0.12	0.02	0.04	0.05	0.09	0.16	0.25	0.62
Observations	255240								

Panel B: Buy-and-hold until maturity (formed at the month-end)

	mean	sd	p1	p10	p25	p50	p75	p90	p99
Buy & hold until maturity (%)	0.40	8.58	-28.75	-8.09	-2.35	1.43	4.62	8.02	17.54
Effective stock bid-ask spread at maturity(%)	0.20	0.30	0.02	0.04	0.07	0.12	0.22	0.41	1.40
Observations	255240								

Panel C: Buy-and-hold until maturity (formed on the third Friday)

	mean	sd	p1	p10	p25	p50	p75	p90	p99
Buy & hold until maturity (%)	0.75	10.89	-37.34	-9.27	-2.44	1.89	5.81	10.21	22.55
Moneyness = S/K (%)	99.75	4.56	87.10	94.40	97.36	99.84	102.09	105.00	112.93
Days to maturity	31.11	3.36	28.00	28.00	29.00	29.00	35.00	36.00	36.00
Vega	0.11	0.01	0.06	0.09	0.10	0.11	0.12	0.12	0.12
Quoted option bid-ask spread of Entry (%)	28.62	30.43	1.94	5.88	10.00	18.18	34.48	66.67	155.56
Effective stock bid-ask spread of Entry (%)	0.21	0.29	0.02	0.04	0.07	0.12	0.23	0.42	1.41
Effective stock bid-ask spread of Exit (%)	0.21	0.31	0.02	0.04	0.07	0.12	0.23	0.43	1.46
Observations	299755								

Table 2: Equal-weighted buy & hold option portfolio returns

This table contains buy & hold delta-hedged one-month call option portfolio returns and transaction costs for long-short portfolios sorted on various characteristics. Portfolios are formed at the end of each month and held for one month. Subscripts refer to portfolio deciles. Superscripts ‘net’ and ’gross’ refer to returns before and net-of transaction costs, respectively. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% times the quoted bid-ask spread from the OptionMetrics database. TC stands for portfolio transaction costs and is defined as the difference between gross and net returns. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Long-short portfolios with significant positive returns at a 5% level or above are indicated in bold. Variables are described in Section A.1. The sample period is from September 2003 to December 2021.

Panel A: Option Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
Option MOM	−0.02	0.91	**0.93**	1.38	−0.45
	(−0.09)	(4.41)	**(4.51)**		(−2.65)
Option REV	0.77	0.83	0.06	2.09	−2.03
	(3.18)	(3.77)	(0.34)		(−11.77)
-VOL_deviation	−0.28	2.11	**2.39**	2.30	0.09
	(−1.51)	(7.56)	**(8.78)**		(0.49)
VOV	0.13	1.36	**1.23**	2.15	−0.92
	(1.07)	(4.70)	**(5.24)**		(−4.33)
-VTS	0.41	1.50	**1.09**	2.52	−1.43
	(2.27)	(5.74)	**(4.61)**		(−6.53)
Option Price	−0.41	0.62	**1.03**	1.77	−0.74
	(−1.60)	(4.41)	**(5.57)**		(−4.69)
-ILLIQ	0.06	0.55	**0.49**	2.40	−1.91
	(0.27)	(3.32)	**(3.04)**		(−7.35)
RN SKEW	0.11	0.68	**0.57**	2.16	−1.59
	(0.82)	(3.02)	**(4.55)**		(−10.34)
Panel B: Stock Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
AMIHUD	0.49	0.41	−0.08	2.17	−2.25
	(3.83)	(1.63)	(−0.40)		(−9.36)
-LN(PRICE)	0.37	0.92	**0.55**	1.98	−1.43
	(2.80)	(3.23)	**(2.57)**		(−5.97)
-Size	0.54	0.64	0.11	2.04	−1.93
	(4.21)	(2.50)	(0.53)		(−7.98)

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	Before TC			After TC	
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
CFV	0.46	0.47	0.01	1.53	−1.52
	(3.93)	(1.79)	(0.03)		(−6.92)
DISP	0.39	0.40	0.01	1.54	−1.53
	(2.81)	(1.88)	(0.06)		(−9.23)
IVOL	0.18	1.36	**1.18**	1.81	−0.63
	(1.33)	(5.66)	**(6.26)**		(−3.43)
ISSUE_1Y	0.17	0.97	**0.79**	1.71	−0.92
	(1.01)	(4.56)	**(6.47)**		(−7.02)
ISSUE_5Y	0.05	1.02	**0.97**	1.65	−0.68
	(0.26)	(3.91)	**(5.00)**		(−4.28)
TEF	0.36	0.91	**0.55**	1.74	−1.19
	(2.56)	(4.74)	**(3.69)**		(−8.79)
-BM	0.17	0.66	**0.49**	1.60	−1.11
	(0.66)	(4.19)	**(3.26)**		(−6.40)
CH	0.06	1.55	**1.49**	2.09	−0.60
	(0.30)	(7.22)	**(7.95)**		(−4.56)
-PM	0.34	1.28	**0.94**	1.97	−1.03
	(1.84)	(5.77)	**(5.42)**		(−7.68)
-PROFIT	0.53	1.05	**0.52**	1.95	−1.43
	(3.38)	(4.44)	**(3.53)**		(−9.63)
-ZS	0.82	0.76	−0.06	2.03	−2.09
	(4.98)	(3.22)	(−0.42)		(−9.69)
Stock MOM	0.07	0.76	**0.69**	2.09	−1.40
	(0.30)	(3.53)	**(4.46)**		(−9.01)
Stock REV	0.46	0.72	0.26	2.21	−1.95
	(1.95)	(3.81)	(1.73)		(−9.50)

Table 3: Long-short decile portfolio returns before and after transaction costs This table contains buy & hold delta-hedged one-month call option portfolio returns and transaction costs for portfolios sorted on various characteristics. The superscript 'net' means net of a specific type of transaction cost, which is indicated in the subscript. Subscripts 'M,' 'Stk,' and 'Opt' refer to margin requirement, stock transaction costs, and option transaction costs, respectively. TC represents transaction costs and is defined as the difference between gross returns and returns net of the particular category of transaction costs indicated in the subscript. The option effective bid-ask spread equals 20.3% times the quoted option bid-ask spread. Variables are described in Section A.1. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Long-short portfolios with significant positive returns at a 5% level or above are indicated in bold. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics							
	$E[r^{gross}]$	TC_M	$E[r_M^{net}]$	TC_{Stk}	$E[r_{Stk}^{net}]$	TC_{Opt}	$E[r_{Opt}^{net}]$
Option MOM	**0.93**	0.08	**0.85**	0.11	**0.82**	1.27	−0.34
	(4.51)		**(4.11)**		**(3.99)**		(−2.00)
Option REV	0.06	0.07	−0.01	0.33	−0.27	1.76	−1.70
	(0.34)		(−0.06)		(−1.65)		(−10.04)
-VOL_deviation	**2.39**	0.09	**2.29**	0.26	**2.13**	2.04	0.34
	(8.78)		**(8.60)**		**(8.01)**		(1.93)
VOV	**1.23**	0.10	**1.13**	0.27	**0.97**	1.88	−0.65
	(5.24)		**(4.77)**		**(4.19)**		(−3.07)
-VTS	**1.09**	0.10	**1.00**	0.35	**0.74**	2.17	−1.08
	(4.61)		**(4.40)**		**(3.23)**		(−4.97)
Option Price	**1.03**	0.08	**0.95**	0.22	**0.82**	1.56	−0.52
	(5.57)		**(5.16)**		**(4.43)**		(−3.31)
-ILLIQ	**0.49**	0.07	**0.42**	0.25	0.24	2.15	−1.66
	(3.04)		**(2.56)**		(1.48)		(−6.47)
RN SKEW	**0.57**	0.08	**0.49**	0.29	**0.28**	1.87	−1.31
	(4.55)		**(3.72)**		**(2.31)**		(−8.56)

Panel B: Stock Characteristics							
	$E[r^{gross}]$	TC_M	$E[r_M^{net}]$	TC_{Stk}	$E[r_{Stk}^{net}]$	TC_{Opt}	$E[r_{Opt}^{net}]$
AMIHUD	−0.08	0.07	−0.15	0.28	−0.35	1.90	−1.98
	(−0.40)		(−0.78)		(−1.82)		(−8.34)
-LN(PRICE)	**0.55**	0.10	**0.45**	0.22	0.33	1.77	−1.22
	(2.57)		**(2.08)**		(1.57)		(−5.09)
-Size	0.11	0.10	0.01	0.24	−0.13	1.80	−1.70
	(0.53)		(0.03)		(−0.67)		(−7.09)

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	$E[r^{gross}]$	TC_M	$E[r^{net}_M]$	TC_{Stk}	$E[r^{net}_{Stk}]$	TC_{Opt}	$E[r^{net}_{Opt}]$
CFV	0.01	0.08	−0.08	0.13	−0.12	1.40	−1.40
	(0.03)		(−0.37)		(−0.57)		(−6.38)
DISP	0.01	0.04	−0.03	0.16	−0.16	1.37	−1.37
	(0.06)		(−0.26)		(−1.19)		(−8.29)
IVOL	**1.18**	0.08	**1.10**	0.25	**0.92**	1.56	−0.38
	(6.26)		**(5.81)**		**(5.04)**		(−2.04)
ISSUE_1Y	**0.79**	0.06	**0.73**	0.14	**0.66**	1.57	−0.78
	(6.47)		**(5.84)**		**(5.42)**		(−6.06)
ISSUE_5Y	**0.97**	0.05	**0.92**	0.17	**0.81**	1.49	−0.51
	(5.00)		**(4.62)**		**(4.18)**		(−3.21)
TEF	**0.55**	0.05	**0.50**	0.14	**0.41**	1.60	−1.05
	(3.69)		**(3.32)**		**(2.80)**		(−7.86)
-BM	**0.49**	0.09	**0.40**	0.14	**0.36**	1.47	−0.97
	(3.26)		**(2.62)**		**(2.38)**		(−5.63)
CH	**1.49**	0.08	**1.41**	0.16	**1.32**	1.93	−0.45
	(7.95)		**(7.19)**		**(7.25)**		(−3.35)
-PM	**0.94**	0.07	**0.87**	0.15	**0.79**	1.82	−0.88
	(5.42)		**(4.89)**		**(4.62)**		(−6.56)
-PROFIT	**0.52**	0.09	**0.43**	0.15	**0.37**	1.79	−1.28
	(3.53)		**(2.98)**		**(2.52)**		(−8.63)
-ZS	−0.06	0.07	−0.13	0.15	−0.21	1.89	−1.94
	(−0.42)		(−0.93)		(−1.56)		(−9.13)
Stock MOM	**0.69**	0.09	**0.60**	0.21	**0.48**	1.89	−1.20
	(4.46)		**(3.90)**		**(3.14)**		(−7.75)
Stock REV	0.26	0.11	0.16	0.35	−0.09	1.86	−1.60
	(1.73)		(1.00)		(−0.60)		(−8.03)

Table 4: Fama-MacBeth regressions: Transaction costs for individual delta-hedged call option writing

This table contains cross-sectional regressions of transaction costs on various predictor variables. The dependent variable (in percent) is stock transaction costs (effective bid-ask spreads come from the TAQ database) plus option transaction costs (effective bid-ask spreads equal to 20.3% times quoted bid-ask spreads) scaled by the formation costs accounting for position entry costs. All independent variables are cross-sectionally winsorized at the 0.5% and 99.5% percentile and standardized to have mean zero and unit standard deviation. We report t-statistics calculated using Newey-West standard errors with six lags in parentheses. Variables are described in Section A.1. The time period is between September 2003 and December 2021. *, **, *** stand for $p < 0.1, p < 0.05, p < 0.01$ respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Lagged TC (%)	0.59***					0.36***
	(37.48)					(30.30)
-Size		0.48***				0.23***
		(15.85)				(12.38)
IVOL			0.27***			−0.04***
			(13.22)			(−4.88)
-LN(PRICE)				0.41***		0.07***
				(17.55)		(8.09)
-VOV					0.38***	0.15***
					(10.45)	(7.61)
Constant	0.36***	0.85***	0.85***	0.85***	0.85***	0.55***
	(11.49)	(15.19)	(15.17)	(15.18)	(15.20)	(13.79)
Adjusted R^2	0.348	0.293	0.100	0.227	0.164	0.467

Table 5: Time-series regression of transaction costs on predictor variables
Time-series regression of the cross-sectional average of long-short portfolio return transaction costs on lagged state variables. The dependent variable is an equal-weighted average of the transaction costs for all the long-short portfolio returns in Table 2. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% times the quoted bid-ask spread from the OptionMetrics database. There are 219 observations from September 2003 to December 2021. *, **, *** stand for $p < 0.1, p < 0.05, p < 0.01$ respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged Cross-sectional Average Anomaly TC (%)	0.83***						0.84***
	(10.62)						(13.28)
VIX / 10		0.43***					0.14**
		(3.61)					(2.53)
VIX Log Difference			0.69*				1.27***
			(1.80)				(7.06)
TED Spread (%)				−0.10			−0.14*
				(−0.54)			(−1.78)
NBER Recession Indicator					0.34		−0.05
					(1.06)		(−0.34)
Sentiment						0.52***	0.06
						(4.95)	(0.89)
Constant	0.34**	1.12***	1.95***	1.99***	1.92***	2.01***	0.13
	(2.55)	(5.42)	(31.84)	(21.59)	(31.75)	(30.81)	(0.88)
Adjusted R^2	0.678	0.152	0.023	−0.003	0.007	0.057	0.787

Table 6: Cost mitigation performance on long-short portfolio returns with transaction costs

This table contains buy-and-hold option returns for long-short decile portfolios using various cost-mitigation strategies. The superscripts 'mon,' 'mat,' and 'mat2' refer to the buy-and-hold one-month return formed at the end of each month, the buy-and-hold to maturity return formed at the end of each month, and the buy-and-hold to-maturity return formed on the third Friday of each month, respectively. The subscripts 'all' and 'lc' refer to the full sample of firms and the subsample with firms in an option bid-ask spread decile below the 5th decile in each cross-section. Transaction costs equal stock trading costs (effective bid-ask spread from TAQ) plus option trading costs where effective bid-ask spread equals 20.3% times the quoted bid-ask spread. All returns are scaled to be 30-day returns for comparability. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Long-short portfolios with significant positive returns at a 5% level or above are indicated in bold. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics						
	Single Strategy				Combined Strategy	
	$E[r_{all}^{mon}]$	$E[r_{lc}^{mon}]$	$E[r_{all}^{mat}]$	$E[r_{all}^{mat2}]$	$E[r_{lc}^{mat}]$	$E[r_{lc}^{mat2}]$
Option MOM	−0.46	−0.41	0.21	0.36	−0.24	0.32
	(−2.72)	(−1.98)	(0.94)	(1.75)	(−1.11)	(1.72)
Option REV	−2.01	−1.17	−0.97	−1.22	−0.56	−0.73
	(−11.78)	(−7.39)	(−7.99)	(−6.26)	(−4.26)	(−2.76)
-VOL_deviation	0.09	0.11	**1.16**	**1.51**	**0.55**	**0.71**
	(0.52)	(0.48)	**(5.38)**	**(8.00)**	**(2.38)**	**(3.05)**
VOV	−0.91	0.26	**0.51**	0.41	**0.45**	**0.56**
	(−4.33)	(1.18)	**(2.77)**	(1.72)	**(2.48)**	**(2.23)**
-VTS	−1.39	−0.31	0.10	−0.41	0.31	**0.42**
	(−6.48)	(−1.37)	(0.52)	(−2.45)	(1.63)	**(2.02)**
Option Price	−0.73	−0.52	−0.67	−1.39	−0.33	−0.66
	(−4.66)	(−3.13)	(−5.22)	(−6.18)	(−2.10)	(−3.08)
-ILLIQ	−1.89	−0.59	−1.66	−2.70	−0.36	−0.52
	(−7.33)	(−5.58)	(−8.83)	(−11.04)	(−3.18)	(−4.65)
RN SKEW	−1.57	−0.38	−0.30	−0.39	0.06	−0.09
	(−10.25)	(−2.21)	(−3.64)	(−2.98)	(0.46)	(−0.62)
Panel B: Stock Characteristics						
	Single Strategy				Combined Strategy	
	$E[r_{all}^{mon}]$	$E[r_{lc}^{mon}]$	$E[r_{all}^{mat}]$	$E[r_{all}^{mat2}]$	$E[r_{lc}^{mat}]$	$E[r_{lc}^{mat2}]$
AMIHUD	−2.23	−0.67	−0.20	0.07	−0.05	0.16
	(−9.27)	(−3.59)	(−1.58)	(0.29)	(−0.40)	(0.69)
-LN(PRICE)	−1.42	−0.52	−0.10	0.17	−0.13	0.20
	(−5.96)	(−2.76)	(−0.55)	(0.63)	(−0.70)	(0.82)

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	Single Strategy				Combined Strategy	
	$E[r_{all}^{mon}]$	$E[r_{lc}^{mon}]$	$E[r_{all}^{mat}]$	$E[r_{all}^{mat2}]$	$E[r_{lc}^{mat}]$	$E[r_{lc}^{mat2}]$
-Size	−1.91	−0.63	−0.30	−0.08	−0.27	0.07
	(−7.90)	(−3.40)	(−1.97)	(−0.37)	(−1.66)	(0.27)
CFV	−1.50	−0.69	−0.71	−0.67	−0.37	−0.50
	(−6.96)	(−3.02)	(−4.21)	(−2.86)	(−2.03)	(−1.62)
DISP	−1.51	−0.58	−0.71	−0.78	−0.31	−0.41
	(−9.31)	(−3.58)	(−4.62)	(−4.18)	(−1.93)	(−1.90)
IVOL	−0.63	0.24	0.16	−0.00	**0.35**	0.35
	(−3.44)	(1.40)	(1.01)	(−0.01)	**(2.08)**	(1.56)
ISSUE_1Y	−0.91	−0.27	−0.03	−0.12	0.06	0.08
	(−7.01)	(−1.82)	(−0.23)	(−0.72)	(0.43)	(0.49)
ISSUE_5Y	−0.68	−0.17	0.11	−0.20	−0.11	−0.00
	(−4.39)	(−0.91)	(0.76)	(−1.34)	(−0.60)	(−0.01)
TEF	−1.18	−0.33	−0.22	−0.42	−0.08	−0.25
	(−8.77)	(−2.26)	(−1.31)	(−2.03)	(−0.57)	(−1.30)
-BM	−1.10	−0.46	−0.27	−0.64	−0.08	−0.38
	(−6.42)	(−2.89)	(−1.61)	(−3.77)	(−0.46)	(−1.80)
CH	−0.61	−0.12	**0.64**	**0.44**	0.18	**0.39**
	(−4.56)	(−0.71)	**(3.58)**	**(2.49)**	(0.87)	**(2.27)**
-PM	−1.01	−0.53	0.08	−0.16	−0.19	−0.17
	(−7.62)	(−3.64)	(0.56)	(−0.74)	(−1.16)	(−0.70)
-PROFIT	−1.41	−0.36	−0.14	−0.37	0.04	−0.18
	(−9.56)	(−2.84)	(−0.98)	(−1.80)	(0.25)	(−0.87)
-ZS	−2.07	−0.70	−1.02	−1.17	−0.38	−0.47
	(−9.85)	(−3.90)	(−7.24)	(−7.57)	(−2.03)	(−2.07)
Stock MOM	−1.39	−0.39	−0.40	−1.07	−0.17	−0.51
	(−8.97)	(−2.42)	(−2.03)	(−4.58)	(−0.79)	(−2.37)
Stock REV	−1.94	−0.83	−0.83	−1.14	−0.22	−0.38
	(−9.59)	(−4.71)	(−4.25)	(−6.03)	(−1.14)	(−1.83)

Table 7: Equal-weighted buy-and-hold until maturity returns for decile portfolios This table contains buy-and-hold option portfolio returns and transaction costs for portfolios sorted on various characteristics. Option returns are for delta-neutral call-writing strategies formed at the end of each month and held until maturity. Subscripts refer to portfolio deciles. Superscripts 'net' and 'gross' refer to returns before and net-of transaction costs, respectively. The transaction costs include stock transaction costs with the effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% times the quoted bid-ask spread from the OptionMetrics database. TC represents transaction costs and is defined as the difference between gross returns and returns net of the transaction costs. All returns are scaled to be 30-day returns for comparability. Variables are described in Section A.1. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics							
	$E[r_1^{gross}]$	TC_1	$E[r_1^{net}]$	$E[r_{10}^{gross}]$	TC_{10}	$E[r_{10}^{net}]$	$E[r_{10-1}^{net}]$
Option MOM	−0.17	0.27	−0.44	0.65	0.33	0.32	0.21
	(−0.73)		(−1.88)	(2.85)		(1.45)	(0.94)
Option REV	0.72	0.36	0.36	0.58	0.48	0.10	−0.97
	(2.98)		(1.47)	(2.49)		(0.43)	(−7.99)
-VOL_deviation	−0.19	0.34	−0.53	1.91	0.60	1.31	1.16
	(−0.92)		(−2.50)	(6.96)		(5.48)	(5.38)
VOV	0.11	0.16	−0.05	1.47	0.69	0.79	0.51
	(0.76)		(−0.36)	(5.40)		(3.21)	(2.77)
-VTS	0.40	0.40	−0.00	1.50	0.61	0.89	0.10
	(1.86)		(−0.01)	(5.68)		(3.66)	(0.52)
Option Price	0.25	0.53	−0.29	0.30	0.19	0.10	−0.67
	(1.04)		(−1.17)	(1.63)		(0.57)	(−5.22)
-ILLIQ	1.00	0.91	0.09	0.28	0.09	0.19	−1.66
	(4.09)		(0.39)	(1.50)		(1.00)	(−8.83)
RN SKEW	0.24	0.28	−0.04	0.76	0.54	0.22	−0.30
	(1.40)		(−0.25)	(3.62)		(1.05)	(−3.64)

Panel B: Stock Characteristics							
	$E[r_1^{gross}]$	TC_1	$E[r_1^{net}]$	$E[r_{10}^{gross}]$	TC_{10}	$E[r_{10}^{net}]$	$E[r_{10-1}^{net}]$
AMIHUD	0.29	0.09	0.20	1.01	0.83	0.18	−0.20
	(1.95)		(1.33)	(4.48)		(0.81)	(−1.58)
-LN(PRICE)	0.19	0.13	0.06	0.94	0.71	0.23	−0.10
	(1.21)		(0.36)	(3.55)		(0.86)	(−0.55)
-Size	0.33	0.09	0.24	0.91	0.79	0.13	−0.30
	(2.30)		(1.66)	(3.96)		(0.54)	(−1.97)

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	$E[r_1^{gross}]$	TC_1	$E[r_1^{net}]$	$E[r_{10}^{gross}]$	TC_{10}	$E[r_{10}^{net}]$	$E[r_{10-1}^{net}]$
CFV	0.46	0.19	0.27	0.39	0.45	−0.06	−0.71
	(3.50)		(2.02)	(1.56)		(−0.25)	(−4.21)
DISP	0.46	0.21	0.25	0.37	0.42	−0.05	−0.71
	(2.90)		(1.54)	(1.55)		(−0.19)	(−4.62)
IVOL	0.21	0.17	0.05	1.10	0.56	0.54	0.16
	(1.57)		(0.33)	(4.68)		(2.34)	(1.01)
ISSUE_1Y	0.19	0.23	−0.04	0.88	0.50	0.38	−0.03
	(1.06)		(−0.22)	(3.67)		(1.65)	(−0.23)
ISSUE_5Y	0.13	0.22	−0.09	0.92	0.47	0.46	0.11
	(0.71)		(−0.47)	(3.70)		(1.91)	(0.76)
TEF	0.39	0.25	0.13	0.91	0.50	0.42	−0.22
	(2.51)		(0.85)	(3.64)		(1.74)	(−1.31)
-BM	0.13	0.35	−0.23	0.54	0.33	0.21	−0.27
	(0.54)		(−0.94)	(2.87)		(1.10)	(−1.61)
CH	0.07	0.28	−0.21	1.60	0.62	0.99	0.64
	(0.33)		(−0.92)	(7.09)		(4.93)	(3.58)
-PM	0.30	0.25	0.05	1.23	0.60	0.63	0.08
	(1.42)		(0.22)	(4.99)		(2.69)	(0.56)
-PROFIT	0.40	0.30	0.10	1.10	0.56	0.54	−0.14
	(2.42)		(0.61)	(4.09)		(2.12)	(−0.98)
-ZS	0.87	0.43	0.44	0.73	0.47	0.26	−1.02
	(5.00)		(2.62)	(2.97)		(1.10)	(−7.24)
Stock MOM	0.08	0.48	−0.40	0.55	0.41	0.14	−0.40
	(0.31)		(−1.61)	(2.22)		(0.56)	(−2.03)
Stock REV	0.48	0.46	0.02	0.49	0.42	0.08	−0.83
	(1.73)		(0.07)	(2.26)		(0.35)	(−4.25)

Table 8: Pooled summary of returns to delta-neutral call writing strategy for S&P500 index options

This table contains summary statistics of delta-neutral call writing strategies on the SPX contract. The strategy involves selling one contract of an equity index call option and a long position of delta shares of the underlying index. The position is formed at the end of the month and held until maturity. The time period is between September 2003 to December 2021.

	mean	sd	p1	p10	p25	p50	p75	p90	p99
Buy & hold until maturity (TC, %)	0.08	2.43	-13.65	-2.11	-0.86	0.39	1.50	2.21	3.75
Moneyness = S/K (%)	99.99	0.13	99.58	99.86	99.93	100.01	100.07	100.13	100.30
Days to maturity	49.53	2.10	44.00	46.00	49.00	50.00	51.00	52.00	53.00
Vega	0.14	0.00	0.14	0.14	0.14	0.14	0.15	0.15	0.15
Quoted option bid-ask spread of Entry (%)	4.16	3.16	0.66	1.02	1.78	3.60	5.50	8.40	14.21
Effective index ETF bid-ask spread of Entry (%)	0.06	0.09	0.01	0.01	0.01	0.03	0.07	0.14	0.33
Effective index ETF bid-ask spread of Exit (%)	0.09	0.11	0.01	0.01	0.02	0.06	0.12	0.23	0.46
Observations	218								

Table 9: Market volatility neutral strategy characteristics

This table contains average returns, alphas, and beta of various equal-weighted portfolios after accounting for transaction costs for the buy-and-hold until maturity strategy. 1, 10, 10-1, and 10-0.9M refer to decile one, decile ten, the long-short portfolio of deciles ten and one, and the portfolio long decile ten and short 0.9 units of portfolio M. 'M' denotes the market factor, which is constructed as the delta-hedged buy-and-hold to maturity S&P 500 call option return after accounting for transaction costs. 'Beta' and 'Alpha' denote the regression coefficient and intercept from a univariate regression of option portfolio returns on the option market factor returns. The transaction costs include stock trading costs and option trading costs with effective bid-ask spread equal to dollar-weighted effective stock bid-ask spread from TAQ and 20.3% times quoted option bid-ask spread, respectively. The t-statistics are adjusted using the Newey-West method with six lags. Portfolios with significant positive returns (alphas) at a 5% level or above are indicated in bold. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics

	Beta				Ret (%)		Alpha (%)	
	1	10	10-1	10-0.9M	10	10-0.9M	10	10-0.9M
Option MOM	0.95 (11.07)	0.83 (9.89)	−0.11 (−1.63)	−0.06 (−0.76)	0.32 (1.45)	0.14 (0.75)	0.26 (1.35)	0.15 (0.78)
Option REV	1.03 (7.00)	0.98 (11.25)	−0.05 (−0.69)	0.08 (0.88)	0.10 (0.43)	−0.06 (−0.41)	0.04 (0.27)	−0.07 (−0.45)
-VOL_deviation	0.92 (9.83)	0.79 (8.02)	−0.12 (−2.33)	−0.11 (−1.07)	**1.31** **(5.48)**	**1.13** **(5.93)**	**1.25** **(6.41)**	**1.14** **(5.89)**
VOV	0.69 (8.18)	0.92 (7.40)	0.22 (1.65)	0.02 (0.18)	**0.79** **(3.21)**	**0.62** **(3.35)**	**0.74** **(3.85)**	**0.62** **(3.30)**
-VTS	0.87 (12.15)	0.87 (6.93)	0.00 (0.01)	−0.03 (−0.20)	**0.89** **(3.66)**	**0.71** **(3.92)**	**0.83** **(4.42)**	**0.72** **(3.87)**
Option Price	0.99 (10.16)	0.79 (6.18)	−0.21 (−2.47)	−0.11 (−0.86)	0.10 (0.57)	−0.06 (−0.55)	0.06 (0.47)	−0.06 (−0.44)
-ILLIQ	0.88 (9.40)	0.87 (12.08)	−0.01 (−0.33)	−0.02 (−0.34)	0.19 (1.00)	0.01 (0.10)	0.13 (1.12)	0.01 (0.11)
RN SKEW	0.78 (8.53)	0.96 (10.06)	0.19 (2.64)	0.06 (0.62)	0.22 (1.05)	0.03 (0.23)	0.14 (1.09)	0.02 (0.19)

Panel B: Stock Characteristics

	Beta				Ret (%)		Alpha (%)	
	1	10	10-1	10-0.9M	10	10-0.9M	10	10-0.9M
AMIHUD	0.74 (9.36)	0.90 (9.31)	0.16 (3.36)	0.00 (0.01)	0.18 (0.81)	0.00 (0.02)	0.12 (0.80)	0.00 (0.02)
-LN(PRICE)	0.72 (9.61)	1.03 (10.15)	0.31 (4.47)	0.13 (1.27)	0.23 (0.86)	0.07 (0.35)	0.17 (0.93)	0.06 (0.30)
-Size	0.77 (10.86)	0.92 (9.84)	0.15 (2.74)	0.02 (0.21)	0.13 (0.54)	−0.04 (−0.28)	0.07 (0.41)	−0.05 (−0.28)
CFV	0.64 (12.22)	1.14 (10.48)	0.49 (5.71)	0.24 (2.20)	−0.06 (−0.25)	−0.26 (−1.60)	−0.16 (−1.10)	−0.28 (−1.84)

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	Beta				Ret (%)		Alpha (%)	
	1	10	10-1	10-0.9M	10	10-0.9M	10	10-0.9M
DISP	0.82 (8.72)	0.98 (9.95)	0.15 (1.69)	0.08 (0.79)	−0.05 (−0.19)	−0.23 (−1.35)	−0.12 (−0.72)	−0.23 (−1.39)
IVOL	0.71 (10.04)	0.98 (7.79)	0.26 (2.14)	0.08 (0.63)	**0.54** **(2.34)**	**0.38** **(2.35)**	**0.49** **(2.99)**	**0.38** **(2.31)**
ISSUE_1Y	0.88 (8.70)	0.95 (8.63)	0.07 (0.78)	0.05 (0.46)	0.38 (1.65)	0.22 (1.36)	**0.33** **(2.02)**	0.22 (1.32)
ISSUE_5Y	0.89 (9.68)	0.93 (8.18)	0.04 (0.39)	0.03 (0.25)	0.46 (1.91)	0.29 (1.65)	**0.40** **(2.26)**	0.28 (1.61)
TEF	0.82 (10.43)	0.88 (6.32)	0.06 (0.58)	−0.02 (−0.13)	0.42 (1.74)	0.26 (1.45)	**0.37** **(2.03)**	0.26 (1.41)
-BM	1.00 (10.35)	0.81 (8.27)	−0.20 (−2.80)	−0.09 (−0.91)	0.21 (1.10)	0.04 (0.33)	0.16 (1.24)	0.05 (0.37)
CH	0.90 (8.30)	0.70 (9.51)	−0.21 (−3.02)	−0.20 (−2.68)	**0.99** **(4.93)**	**0.83** **(4.93)**	**0.96** **(5.61)**	**0.85** **(5.01)**
-PM	0.82 (8.70)	0.88 (7.23)	0.06 (0.45)	−0.01 (−0.10)	**0.63** **(2.69)**	**0.46** **(2.57)**	**0.58** **(3.12)**	**0.46** **(2.52)**
-PROFIT	0.86 (9.96)	1.01 (8.69)	0.14 (2.75)	0.11 (0.93)	**0.54** **(2.12)**	**0.37** **(1.99)**	**0.47** **(2.57)**	**0.36** **(1.96)**
-ZS	0.74 (9.34)	0.92 (8.77)	0.17 (3.94)	0.02 (0.21)	0.26 (1.10)	0.07 (0.45)	0.18 (1.13)	0.07 (0.43)
Stock MOM	1.01 (11.06)	0.91 (6.04)	−0.11 (−0.91)	0.01 (0.09)	0.14 (0.56)	−0.05 (−0.26)	0.06 (0.34)	−0.05 (−0.26)
Stock REV	1.05 (6.82)	0.90 (8.08)	−0.16 (−0.90)	0.00 (0.04)	0.08 (0.35)	−0.09 (−0.57)	0.03 (0.18)	−0.09 (−0.55)

Table 10: The impact of hedging frequency

This table contains a performance evaluation of equal-weighted decile portfolios of option returns with different delta-hedge frequencies. Portfolios are formed at the end of each month and held until maturity. 'Once' represents our buy-and-hold to maturity strategy, hedged at the portfolio formation date. 'Biweekly' represents the strategy which is re-hedged every two weeks, a 'Weekly' strategy is re-hedged every week, and the 'Daily' strategy is re-hedged every trading day. The number without parentheses shows the average return after transaction costs and t-statistics, annual Sharpe ratios, and turnover of stocks for the return after transaction costs time series are shown in the parentheses, bracket parentheses, and curly braces, respectively. All statistics for portfolios with significant positive returns at a 5% level or above are indicated in bold. t-statistics are calculated using Newey-West standard errors with six lags. For brevity, we only show returns on a subset of our full set of characteristics. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics								
	Before TC				After TC			
	Once	Biweekly	Weekly	Daily	Once	Biweekly	Weekly	Daily
Option MOM	**0.81**	**0.93**	**0.98**	**0.77**	0.21	0.32	**0.33**	−0.03
	(3.32)	**(5.06)**	**(5.51)**	**(5.23)**	(0.93)	(1.94)	**(2.09)**	(−0.23)
	[0.91]	**[1.55]**	**[1.80]**	**[1.72]**	[0.24]	[0.55]	**[0.63]**	[−0.07]
	{2.03}	**{2.41}**	**{2.76}**	**{4.44}**	{2.03}	{2.41}	**{2.76}**	{4.44}
-VOL_deviation	**2.06**	**1.93**	**1.90**	**1.97**	**1.16**	**1.02**	**0.94**	**0.83**
	(7.93)	**(9.06)**	**(9.99)**	**(9.09)**	**(5.38)**	**(6.01)**	**(6.51)**	**(5.06)**
	[2.98]	**[3.83]**	**[4.15]**	**[4.27]**	**[1.80]**	**[2.26]**	**[2.34]**	**[2.13]**
	{1.98}	**{2.36}**	**{2.71}**	**{4.41}**	**{1.98}**	**{2.36}**	**{2.71}**	**{4.41}**
VOV	**1.33**	**1.36**	**1.27**	**1.48**	**0.52**	**0.54**	**0.40**	**0.44**
	(6.09)	**(7.45)**	**(6.37)**	**(7.36)**	**(2.78)**	**(3.58)**	**(2.34)**	**(2.64)**
	[2.01]	**[2.94]**	**[2.80]**	**[3.36]**	**[0.82]**	**[1.28]**	**[0.97]**	**[1.12]**
	{1.98}	**{2.36}**	**{2.73}**	**{4.48}**	**{1.98}**	**{2.36}**	**{2.73}**	**{4.48}**
Panel B: Stock Characteristics								
	Before TC				After TC			
	Once	Biweekly	Weekly	Daily	Once	Biweekly	Weekly	Daily
-LN(PRICE)	**0.72**	**0.85**	**0.89**	**1.16**	−0.10	0.01	0.01	0.07
	(4.10)	**(4.79)**	**(4.66)**	**(7.16)**	(−0.54)	(0.06)	(0.03)	(0.45)
	[1.05]	**[1.77]**	**[2.02]**	**[2.99]**	[−0.14]	[0.02]	[0.01]	[0.18]
	{1.98}	**{2.36}**	**{2.72}**	**{4.45}**	{1.98}	{2.36}	{2.72}	{4.45}
-Size	**0.55**	**0.63**	**0.69**	**0.98**	−0.30	−0.23	−0.23	−0.16
	(3.72)	**(4.06)**	**(4.23)**	**(6.17)**	(−1.97)	(−1.59)	(−1.48)	(−1.16)
	[0.90]	**[1.40]**	**[1.61]**	**[2.43]**	[−0.49]	[−0.53]	[−0.55]	[−0.42]
	{1.98}	**{2.37}**	**{2.74}**	**{4.50}**	{1.98}	{2.37}	{2.74}	{4.50}
CH	**1.50**	**1.27**	**1.30**	**1.34**	**0.64**	**0.39**	**0.38**	**0.23**
	(6.93)	**(7.20)**	**(7.96)**	**(8.72)**	**(3.59)**	**(2.95)**	**(3.19)**	**(2.29)**
	[1.93]	**[2.66]**	**[3.07]**	**[3.61]**	**[0.85]**	**[0.91]**	**[1.00]**	**[0.72]**
	{1.98}	**{2.37}**	**{2.74}**	**{4.47}**	**{1.98}**	**{2.37}**	**{2.74}**	**{4.47}**

A Appendix

A.1 Description of variables

1. CFV: Cash flow variance, as in Haugen and Baker (1996), computed as the variance of the monthly ratio of annual cash flow to market value of equity over the last 60 months (at least 36 nonmissing monthly observations). Annual cash flow is Net Income (Compustat annual item NI) plus Depreciation and Amortization (item DP), all scaled by monthly updated market value of equity. We assume annual accounting items known publicly 4 months after the fiscal year end. To avoid stale information, we do not use annual accounting information from the fiscal year end that is older than 15 months.

2. CH: Following Palazzo (2012), we measure cash-to-assets, as cash holdings (Compustat quarterly item CHEQ) scaled by total assets (item ATQ). We assume quarterly accounting items known publicly 4 months after the fiscal quarter end. To avoid stale information, we do not use quarterly accounting information from the fiscal quarter end that is older than 6 months.

3. DISP: Analyst earnings forecast dispersion, as in Diether et al. (2002). We measure dispersion in analyst earnings forecasts as the ratio of the standard deviation of earnings forecasts (IBES unadjusted file, item STDEV) to the absolute value of the consensus mean forecast (unadjusted file, item MEANEST). We use the earnings forecasts for the current fiscal year (fiscal period indicator = 1), and we require them to be denominated in US dollars (currency code = USD). Stocks with a mean forecast of zero are assigned to the highest dispersion group. Firms with fewer than two forecasts are excluded.

4. ISSUE1Y: One-year new issues, as in Pontiff and Woodgate (2008), measured as the natural log of the ratio of the split-adjusted shares outstanding at one fiscal year end to the split-adjusted shares outstanding at the fiscal year-end 12 months ago. The split-adjusted shares outstanding are shares outstanding (Compustat annual item CSHO) times the adjustment factor (item AJEX). We assume annual accounting items are known publicly four months after the fiscal year-end. To avoid stale information, we do not use annual accounting information from the fiscal year end that is older than 15 months.

5. ISSUE5Y: Five-year new issues, as in Daniel and Titman (2006), for each month t, measured as the log growth rate in the market equity not attributable to stock return, log(Met/Met-60)-r(t-60, t). r(t-60, t) is the cumulative log stock return over the past

60 months, including month t, and Met is the market equity (from CRSP) on the last trading day of month t.

6. PM: Profit margin, as in Soliman (2008), calculated as Earnings Before Interest and Taxes (Compustat annual item EBIT) scaled by Revenue (item REVT). We assume annual accounting items are known publicly four months after the fiscal year-end. To avoid stale information, we do not use annual accounting information from the fiscal year end that is older than 15 months.

7. ln(PRICE): The log of the stock price at the end of last month, as in Blume and Husic (1973).

8. PROFIT: Profitability, as in Fama and French (2006), calculated as earnings divided by book equity (the denominator is current, not lagged, book equity), in which earnings is defined as Income Before Extraordinary Items (Compustat annual item IB). Book equity is stockholders' book equity, plus balance sheet deferred taxes and investment tax credit (item TXDITC) if available, minus the book value of preferred stock. Stockholders' equity is the value reported by Compustat (item SEQ), if it is available. If not, we measure stockholders' equity as the book value of common equity (item CEQ) plus the par value of preferred stock (item PSTK), or the book value of assets (item AT) minus total liabilities (item LT). Depending on availability, we use redemption (item PSTKRV), liquidating (item PSTKL), or par value (item PSTK) for the book value of preferred stock. We assume annual accounting items are known publicly four months after the fiscal year end. To avoid stale information, we do not use annual accounting information from the fiscal year end that is older than 15 months.

9. TEF: Total external financing, as in Bradshaw et al. (2006), for one fiscal year-end, scaled by the average of total assets (Compustat annual item AT) at the same fiscal year-end and the prior fiscal year-end. Total external financing is the sum of net equity financing and net debt financing. Net equity financing is the proceeds from the sale of common and preferred stocks (Compustat annual item SSTK), less cash payments for the repurchases of common and preferred stocks (item PRSTKC), and less cash payments for dividends (item DV). Net debt financing is the cash proceeds from the issuance of long-term debt (item DLTIS) less cash payments for long-term debt reductions (item DLTR) plus the net changes in current debt (item DLCCH, zero if missing). We assume annual accounting items are known publicly four months after the fiscal year end. To avoid stale information, we do not use annual accounting information from the fiscal year end that is older than 15 months.

10. ZS: Z-score. We follow Dichev (1998) to construct the Z-score (Dichev (1998)): Z = 1.2×WCTA + 1.4×RETA + 3.3×EBITTA + 0.6×METL + SALETA, in which WCTA is working capital (Compustat annual item ACT minus item LCT) divided by total assets (item AT), RETA is retained earnings (item RE) divided by total assets, EBITTA is earnings before interest and taxes (item OIADP) divided by total assets, METL is the market equity (from CRSP, at fiscal year end) divided by total liabilities (item LT), and SALETA is sales (item SALE) divided by total assets. For firms with more than 1 share class, we merge the market equity for all share classes before computing Z.

11. VOL_deviation: Volatility mispricing measure as in Goyal and Saretto (2009), calculated as the log difference between the realized volatility and Black-Scholes implied volatility for at-the-money options at the end of the last month.

12. IVOL: Idiosyncratic volatility, as in Ang et al. (2006) and Cao and Han (2013), computed as the standard deviation of the regression residual of individual stock returns on the Fama and French (1993) three factors using daily data in the previous month.

13. AMIHUD: The Amihud (2002) stock illiquidity measure (calculated as the average of the daily ratio of the absolute stock return to dollar volume over the previous month).

14. Size: the natural logarithm of the market value of the firm's equity as in Fama and French (1993).

15. BM: Book-to-market ratio, measured as the ratio of book equity to market equity as in Fama and French (1993).

16. Stock REV: Stock return reversal, measured as lagged one-month return as in Jegadeesh and Titman (1993).

17. Stock MOM: Stock return momentum, the cumulative return on the stock over the 11 months ending at the beginning of the previous month as in Jegadeesh and Titman (1993).

18. VTS: The slope of the volatility term structure, measured as the difference between long-term and short-term implied volatilities as in Vasquez (2017).

19. VOV: Volatility of volatility, measured as the standard deviation of implied volatility in the past month as Ruan (2020).

20. Option Momentum: Option return momentum, calculated as the cumulative option return on the stock over the 11 months ending at the beginning of the previous month as in Heston et al. (2023).

21. Option REV: Option return reversal, measured as lagged one-month option return as in Heston et al. (2023).

22. Option Price: The option price.

23. ILLIQ: Option illiquidity as suggested in Christoffersen et al. (2018). This is measured using the quoted option bid-ask spread.

24. RN SKEW: Risk neutral skewness as in (Bali and Murray, 2013). We use the 30-day risk-neutral skewness. The construction follows Bakshi and Kapadia (2003). We thank Grigory Vilkov for making his code available online at https://osf.io/z2486/

A.2 Figures and Tables

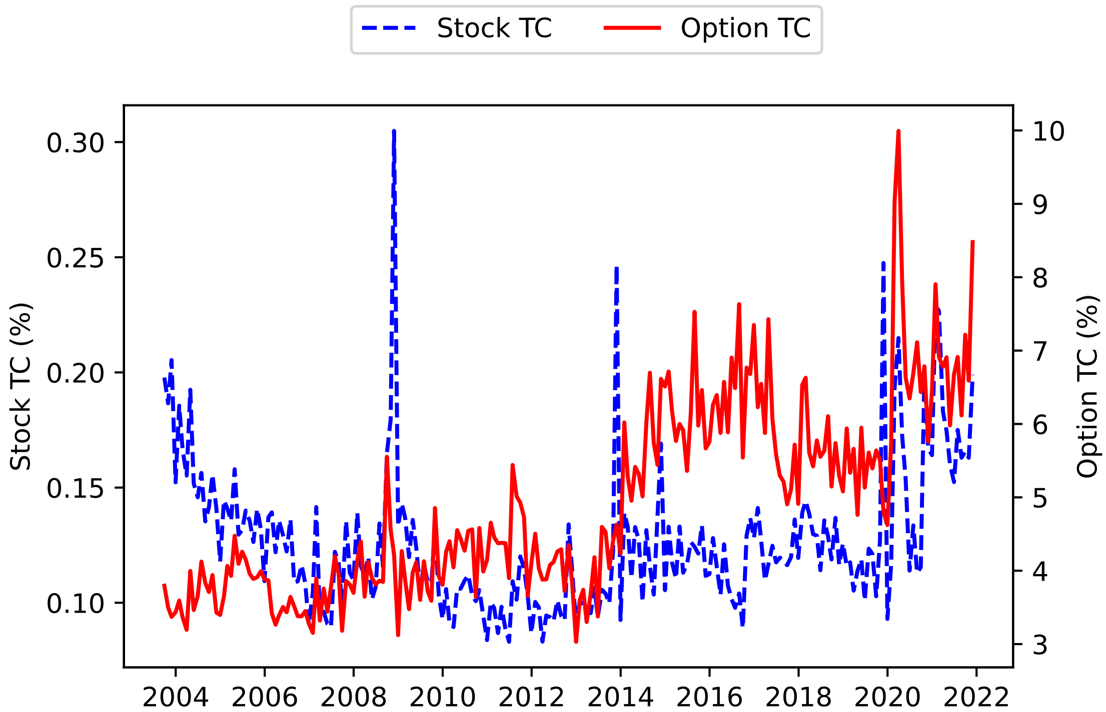

Figure A1: Time series of average transaction costs - sample universe
This figure contains a graph of the average transaction costs in the time series for our sample universe. The average cost (in %) is calculated at the end of each month in our sample (corresponding to portfolio formation dates). 'Stock TC' denotes the stock transaction cost defined as the percentage dollar-weighted effective spread from the TAQ database. 'Option TC' denotes the option transaction cost defined as 20.3% of the percentage quoted bid-ask spread from the OptionMetrics database. The time period is between September 2003 and December 2021.

Table A1: The impact of filling missing values on portfolio returns

This table contains equal-weighted delta-hedged option portfolio returns sorted by various characteristics using samples with and without filling of missing data. Portfolios are formed at the end of each month and held for one month. 'Option' denotes the option sample without filling of price data; 'Option Fill' denotes the option sample with filling of price data; 'Difference' represents the difference in returns (after transaction costs) between the 'Option' and 'Option Fill' samples. The first three columns show the long-short portfolio return without transaction costs, and the last three columns show the long-short portfolio return after transaction costs. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Variables are described in Section A.1. The sample period is from September 2003 to December 2021.

Panel A: Option Characteristics						
	Before TC			After TC		
	Option	Option Fill	Difference	Option	Option Fill	Difference
Option MOM	0.94	0.93	0.01	−0.43	−0.45	0.02
	(4.33)	(4.51)	(0.39)	(−2.41)	(−2.65)	(0.54)
Option REV	0.07	0.06	0.01	−2.02	−2.03	0.01
	(0.41)	(0.34)	(0.85)	(−11.94)	(−11.77)	(0.84)
-VOL_deviation	2.44	2.39	0.06	0.15	0.09	0.06
	(8.92)	(8.78)	(2.86)	(0.84)	(0.49)	(2.93)
VOV	1.28	1.23	0.04	−0.87	−0.92	0.04
	(5.42)	(5.24)	(2.35)	(−4.13)	(−4.33)	(2.29)
-VTS	1.14	1.09	0.05	−1.38	−1.43	0.05
	(4.83)	(4.61)	(2.35)	(−6.31)	(−6.53)	(2.25)
Option Price	1.04	1.03	0.00	−0.73	−0.74	0.01
	(5.68)	(5.57)	(0.22)	(−4.72)	(−4.69)	(0.46)
-ILLIQ	0.49	0.49	−0.00	−1.91	−1.91	0.00
	(2.99)	(3.04)	(−0.17)	(−7.27)	(−7.35)	(0.09)
RN SKEW	0.58	0.57	0.01	−1.57	−1.59	0.02
	(4.63)	(4.55)	(0.88)	(−10.39)	(−10.34)	(1.14)
Panel B: Stock Characteristics						
	Before TC			After TC		
	Option	Option Fill	Diff	Option	Option Fill	Diff
AMIHUD	−0.02	−0.08	0.06	−2.19	−2.25	0.06
	(−0.10)	(−0.40)	(3.89)	(−9.20)	(−9.36)	(3.96)
-LN(PRICE)	0.60	0.55	0.05	−1.38	−1.43	0.05
	(2.83)	(2.57)	(2.70)	(−5.76)	(−5.97)	(2.74)
-Size	0.17	0.11	0.06	−1.87	−1.93	0.06
	(0.83)	(0.53)	(3.56)	(−7.74)	(−7.98)	(3.66)

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	Before TC			After TC		
	Option	Option Fill	Difference	Option	Option Fill	Difference
CFV	0.01	0.01	0.01	−1.51	−1.52	0.01
	(0.05)	(0.03)	(0.32)	(−6.77)	(−6.92)	(0.71)
DISP	0.01	0.01	0.00	−1.52	−1.53	0.00
	(0.09)	(0.06)	(0.78)	(−9.19)	(−9.23)	(0.84)
IVOL	1.25	1.18	0.07	−0.56	−0.63	0.07
	(6.58)	(6.26)	(4.22)	(−3.04)	(−3.43)	(4.25)
ISSUE_1Y	0.82	0.79	0.02	−0.89	−0.92	0.03
	(6.60)	(6.47)	(1.43)	(−7.07)	(−7.02)	(1.59)
ISSUE_5Y	0.97	0.97	−0.01	−0.68	−0.68	−0.00
	(5.06)	(5.00)	(−0.42)	(−4.45)	(−4.28)	(−0.20)
TEF	0.58	0.55	0.03	−1.15	−1.19	0.03
	(3.92)	(3.69)	(2.69)	(−8.65)	(−8.79)	(2.82)
-BM	0.49	0.49	−0.01	−1.11	−1.11	−0.01
	(3.24)	(3.26)	(−0.89)	(−6.44)	(−6.40)	(−0.57)
CH	1.49	1.49	0.00	−0.60	−0.60	0.00
	(7.90)	(7.95)	(0.41)	(−4.51)	(−4.56)	(0.53)
-PM	0.95	0.94	0.01	−1.02	−1.03	0.01
	(5.30)	(5.42)	(0.51)	(−7.55)	(−7.68)	(0.52)
-PROFIT	0.53	0.52	0.01	−1.42	−1.43	0.01
	(3.58)	(3.53)	(0.57)	(−9.69)	(−9.63)	(0.62)
-ZS	−0.04	−0.06	0.02	−2.07	−2.09	0.02
	(−0.28)	(−0.42)	(0.81)	(−9.61)	(−9.69)	(0.92)
Stock MOM	0.67	0.69	−0.02	−1.42	−1.40	−0.01
	(4.31)	(4.46)	(−1.13)	(−9.15)	(−9.01)	(−0.88)
Stock REV	0.29	0.26	0.03	−1.92	−1.95	0.03
	(1.90)	(1.73)	(1.82)	(−9.42)	(−9.50)	(1.91)

Table A2: The impact of sample period on portfolio returns

This table contains equal-weighted delta-hedged option portfolio returns sorted by various characteristics using different sample periods. Long-short decile portfolios are formed at the end of each month and held for one month. All returns are gross returns before transaction costs. '96-16' denotes the sample from January 1996 to April 2016; '03-21' denotes the sample from September 2003 to December 2021; '96-03' denotes the sample from January 1996 to August 2003; and '16-21' denotes for the sample from May 2003 to December 2021. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags and Sharpe ratios in bracket parentheses. Variables are described in Section A.1.

Panel A: Option Characteristics				
	96-16	03-21	96-03	16-21
Option MOM	0.72	0.93	1.00	1.78
	(2.48)	(4.51)	(1.34)	(4.42)
	[0.58]	[1.05]	[0.55]	[1.64]
Option REV	−0.34	0.06	−0.78	0.40
	(−1.61)	(0.34)	(−1.62)	(1.02)
	[−0.38]	[0.08]	[−0.62]	[0.43]
-VOL_deviation	2.83	2.39	4.27	3.35
	(10.02)	(8.78)	(9.12)	(4.84)
	[3.64]	[3.23]	[4.85]	[3.49]
VOV	0.95	1.23	0.97	1.86
	(5.80)	(5.24)	(2.64)	(2.91)
	[1.01]	[1.70]	[0.72]	[2.01]
-VTS	1.31	1.09	1.88	1.37
	(7.61)	(4.61)	(5.72)	(2.00)
	[1.56]	[1.55]	[1.62]	[1.40]
Option Price	0.76	1.03	0.52	1.26
	(3.02)	(5.57)	(0.88)	(2.88)
	[0.75]	[1.49]	[0.35]	[1.36]
-ILLIQ	0.62	0.49	0.55	0.05
	(3.19)	(3.04)	(1.37)	(0.18)
	[0.81]	[0.81]	[0.55]	[0.07]
RN SKEW	0.55	0.57	0.24	0.59
	(6.02)	(4.55)	(0.54)	(1.67)
	[1.37]	[1.01]	[0.39]	[0.71]

Panel B: Stock Characteristics				
	96-16	03-21	96-03	16-21
AMIHUD	0.13	−0.08	0.51	0.01
	(0.67)	(−0.40)	(1.43)	(0.03)
	[0.18]	[−0.12]	[0.60]	[0.02]

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	96-16	03-21	96-03	16-21
-LN(PRICE)	0.66	0.55	1.00	0.81
	(2.69)	(2.57)	(1.73)	(1.39)
	[0.75]	[0.74]	[0.83]	[0.82]
-Size	0.24	0.11	0.53	0.25
	(1.21)	(0.53)	(1.24)	(0.48)
	[0.33]	[0.14]	[0.58]	[0.24]
CFV	−0.15	0.01	−0.07	0.57
	(−0.97)	(0.03)	(−0.21)	(1.00)
	[−0.24]	[0.01]	[−0.09]	[0.61]
DISP	−0.17	0.01	−0.32	0.24
	(−1.02)	(0.06)	(−0.88)	(0.95)
	[−0.25]	[0.02]	[−0.35]	[0.42]
IVOL	0.77	1.18	0.52	1.66
	(3.57)	(6.26)	(1.02)	(3.57)
	[0.80]	[1.73]	[0.37]	[1.91]
ISSUE_1Y	0.24	0.79	−0.27	1.27
	(1.71)	(6.47)	(−0.95)	(4.97)
	[0.35]	[1.44]	[−0.30]	[2.02]
ISSUE_5Y	0.36	0.97	−0.07	1.73
	(2.42)	(5.00)	(−0.25)	(3.90)
	[0.54]	[1.54]	[−0.08]	[2.15]
TEF	0.08	0.55	−0.23	1.10
	(0.51)	(3.69)	(−0.63)	(3.72)
	[0.11]	[1.04]	[−0.22]	[1.80]
-BM	0.30	0.49	−0.29	0.05
	(1.31)	(3.26)	(−0.58)	(0.13)
	[0.32]	[0.74]	[−0.22]	[0.05]
CH	0.63	1.49	−0.25	2.14
	(2.42)	(7.95)	(−0.45)	(5.77)
	[0.65]	[2.04]	[−0.19]	[2.29]
-PM	0.24	0.94	−0.23	1.83
	(1.29)	(5.42)	(−0.54)	(5.61)
	[0.29]	[1.34]	[−0.19]	[1.96]
-PROFIT	0.17	0.52	−0.00	1.07
	(1.14)	(3.53)	(−0.01)	(3.81)
	[0.27]	[0.88]	[−0.01]	[1.73]
-ZS	0.18	−0.06	0.62	0.10
	(0.92)	(−0.42)	(1.38)	(0.33)
	[0.21]	[−0.09]	[0.48]	[0.12]
Stock MOM	0.30	0.69	0.01	1.15
	(1.26)	(4.46)	(0.02)	(5.06)
	[0.33]	[0.97]	[0.01]	[1.48]
Stock REV	0.12	0.26	−0.29	−0.00
	(0.53)	(1.73)	(−0.59)	(−0.02)
	[0.15]	[0.41]	[−0.27]	[−0.01]

Table A3: The impact of portfolio weights on returns

Long-short delta-hedged option portfolio returns after transaction costs under stock value-weighted, equal-weighted, and option value-weighted weighting schemes. 'Stock-VW' refers to a portfolio that weights each return using its stock market capitalization at the portfolio formation date, 'EW' refers to equal weights, and 'Option-Value-Weights' weighs by the market value of option open interest at the formation date. All returns are net of transaction costs. The transaction costs include stock trading costs and option trading costs with effective bid-ask spread equal to dollar-weighted effective stock bid-ask spread from TAQ and 20.3% times quoted option bid-ask spread, respectively. The superscripts 'mon' and 'mat2' refer to the buy-and-hold one-month return formed at the end of each month and the buy-and-hold to-maturity return formed on the third Friday of each month, respectively. The subscripts 'all' and 'lc' refer to the full sample of firms and the subsample with firms in an option bid-ask spread decile below the 5th decile in each cross-section. Portfolios with significant positive returns at a 5% level or above are indicated in bold. The t-statistics are adjusted using the Newey-West method with six lags. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics						
	$E[r_{lc}^{mon}]$			$E[r_{all}^{mat2}]$		
	Stock-VW	EW	Option-VW	Stock-VW	EW	Option-VW
Option MOM	−0.38	−0.41	−0.41	0.30	0.36	0.33
	(−1.91)	(−1.98)	(−0.62)	(1.49)	(1.75)	(0.71)
Option REV	−0.80	−1.17	−0.85	−1.02	−1.22	−1.36
	(−5.13)	(−7.39)	(−2.27)	(−4.78)	(−6.26)	(−4.24)
-VOL_deviation	0.40	0.11	**1.05**	**1.29**	**1.51**	**1.68**
	(1.93)	(0.48)	**(2.34)**	**(5.79)**	**(8.00)**	**(4.78)**
VOV	0.28	0.26	0.32	0.19	0.41	0.15
	(1.21)	(1.18)	(0.96)	(0.53)	(1.72)	(0.42)
-VTS	0.23	−0.31	0.39	0.45	−0.41	0.05
	(0.92)	(−1.37)	(0.83)	(1.74)	(−2.45)	(0.14)
Option Price	−0.08	−0.52	−0.72	−0.89	−1.39	−1.14
	(−0.59)	(−3.13)	(−1.97)	(−4.30)	(−6.18)	(−3.60)
-ILLIQ	−0.29	−0.59	−0.44	−1.81	−2.70	−2.52
	(−2.77)	(−5.58)	(−1.96)	(−10.66)	(−11.04)	(−6.78)
RN SKEW	−0.14	−0.38	0.06	−0.30	−0.39	0.29
	(−0.86)	(−2.21)	(0.19)	(−2.00)	(−2.98)	(0.96)

Panel B: Stock Characteristics						
	$E[r_{lc}^{mon}]$			$E[r_{all}^{mat2}]$		
	Stock-VW	EW	Option-VW	Stock-VW	EW	Option-VW
AMIHUD	−0.73	−0.67	−0.75	0.01	0.07	0.35
	(−3.78)	(−3.59)	(−1.44)	(0.03)	(0.29)	(0.80)
-LN(PRICE)	−0.41	−0.52	−0.57	−0.02	0.17	0.47
	(−2.20)	(−2.76)	(−1.60)	(−0.07)	(0.63)	(1.49)
-Size	−0.66	−0.63	−1.09	−0.15	−0.08	−0.03
	(−3.37)	(−3.40)	(−2.18)	(−0.68)	(−0.37)	(−0.08)
CFV	−0.53	−0.69	−0.65	−0.30	−0.67	−0.18
	(−2.61)	(−3.02)	(−1.79)	(−1.52)	(−2.86)	(−0.58)

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	$E[r_{lc}^{mon}]$			$E[r_{all}^{mat2}]$		
	Stock-VW	EW	Option-VW	Stock-VW	EW	Option-VW
DISP	−0.52 (−2.52)	−0.58 (−3.58)	−0.18 (−0.63)	−0.53 (−2.06)	−0.78 (−4.18)	−0.09 (−0.34)
IVOL	**0.43** **(2.38)**	0.24 (1.40)	−0.04 (−0.10)	−0.01 (−0.04)	−0.00 (−0.01)	0.38 (1.30)
ISSUE_1Y	−0.21 (−1.49)	−0.27 (−1.82)	−0.09 (−0.25)	−0.26 (−1.83)	−0.12 (−0.72)	−0.26 (−0.96)
ISSUE_5Y	−0.22 (−1.40)	−0.17 (−0.91)	0.15 (0.37)	−0.36 (−2.34)	−0.20 (−1.34)	−0.16 (−0.64)
TEF	−0.28 (−2.13)	−0.33 (−2.26)	−0.10 (−0.23)	−0.41 (−1.74)	−0.42 (−2.03)	−0.06 (−0.26)
-BM	−0.13 (−0.73)	−0.46 (−2.89)	−0.51 (−1.69)	−0.27 (−1.40)	−0.64 (−3.77)	−0.14 (−0.49)
CH	−0.42 (−3.06)	−0.12 (−0.71)	−0.45 (−1.12)	−0.06 (−0.27)	**0.44** **(2.49)**	**0.82** **(2.69)**
-PM	−0.25 (−1.66)	−0.53 (−3.64)	−0.59 (−1.33)	−0.01 (−0.06)	−0.16 (−0.74)	0.50 (1.93)
-PROFIT	−0.23 (−1.81)	−0.36 (−2.84)	−0.41 (−1.19)	−0.03 (−0.16)	−0.37 (−1.80)	0.16 (0.60)
-ZS	−0.28 (−1.99)	−0.70 (−3.90)	−0.70 (−1.25)	−0.34 (−2.04)	−1.17 (−7.57)	−0.46 (−1.59)
Stock MOM	−0.02 (−0.11)	−0.39 (−2.42)	−0.83 (−2.14)	−0.70 (−2.84)	−1.07 (−4.58)	−1.17 (−3.28)
Stock REV	−0.33 (−1.71)	−0.83 (−4.71)	−1.34 (−2.99)	−0.36 (−1.60)	−1.14 (−6.03)	−0.76 (−2.30)

Table A4: Risk-adjustment of portfolio returns
This table contains equal-weighted delta-hedged option portfolio returns sorted on various characteristics with risk adjustment. Portfolios are formed at the end of each month and held for one month. Subscripts refer to portfolio deciles. Superscripts 'net' and 'gross' refer to returns before and net-of transaction costs, respectively. Column 'α_{FF5}' contains the alpha relative to the Fama and French five-factor model. Column 'α_{SP500}' contains the alphas relative to the delta-hedged SP500 option return. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Variables are described in Section A.1. The time period is between September 2003 and December 2021. The sample period is from September 2003 to December 2021.

Panel A: Option Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	α_{FF5}	α_{SP500}
Option MOM	−0.02	0.91	**0.93**	**0.93**	**0.99**
	(−0.09)	(4.41)	**(4.51)**	**(4.70)**	**(4.28)**
Option REV	0.77	0.83	0.06	0.06	0.11
	(3.18)	(3.77)	(0.34)	(0.37)	(0.52)
-VOL_deviation	−0.28	2.11	**2.39**	**2.34**	**2.41**
	(−1.51)	(7.56)	**(8.78)**	**(10.10)**	**(9.26)**
VOV	0.13	1.36	**1.23**	**1.10**	**1.08**
	(1.07)	(4.70)	**(5.24)**	**(5.41)**	**(4.55)**
-VTS	0.41	1.50	**1.09**	**1.02**	**1.05**
	(2.27)	(5.74)	**(4.61)**	**(5.11)**	**(4.36)**
Option Price	−0.41	0.62	**1.03**	**1.17**	**1.21**
	(−1.60)	(4.41)	**(5.57)**	**(7.78)**	**(5.60)**
-ILLIQ	0.06	0.55	**0.49**	**0.64**	**0.48**
	(0.27)	(3.32)	**(3.04)**	**(5.31)**	**(3.10)**
RN SKEW	0.11	0.68	**0.57**	**0.57**	**0.44**
	(0.82)	(3.02)	**(4.55)**	**(4.29)**	**(3.51)**
Panel B: Stock Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	α_{FF5}	α_{SP500}
AMIHUD	0.49	0.41	−0.08	−0.15	−0.18
	(3.83)	(1.63)	(−0.40)	(−0.97)	(−0.93)
-LN(PRICE)	0.37	0.92	**0.55**	**0.44**	0.42
	(2.80)	(3.23)	**(2.57)**	**(2.71)**	(1.84)
-Size	0.54	0.64	0.11	0.03	0.04
	(4.21)	(2.50)	(0.53)	(0.21)	(0.17)
CFV	0.46	0.47	0.01	−0.18	−0.22
	(3.93)	(1.79)	(0.03)	(−1.05)	(−0.90)

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	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	α_{FF5}	α_{SP500}
DISP	0.39	0.40	0.01	−0.04	−0.07
	(2.81)	(1.88)	(0.06)	(−0.32)	(−0.52)
IVOL	0.18	1.36	**1.18**	**1.16**	**1.06**
	(1.33)	(5.66)	**(6.26)**	**(6.47)**	**(5.68)**
ISSUE_1Y	0.17	0.97	**0.79**	**0.76**	**0.80**
	(1.01)	(4.56)	**(6.47)**	**(5.94)**	**(5.88)**
ISSUE_5Y	0.05	1.02	**0.97**	**0.88**	**0.97**
	(0.26)	(3.91)	**(5.00)**	**(5.13)**	**(4.49)**
TEF	0.36	0.91	**0.55**	**0.49**	**0.49**
	(2.56)	(4.74)	**(3.69)**	**(3.24)**	**(2.88)**
-BM	0.17	0.66	**0.49**	**0.68**	**0.67**
	(0.66)	(4.19)	**(3.26)**	**(5.48)**	**(3.90)**
CH	0.06	1.55	**1.49**	**1.49**	**1.64**
	(0.30)	(7.22)	**(7.95)**	**(7.66)**	**(7.40)**
-PM	0.34	1.28	**0.94**	**0.96**	**0.99**
	(1.84)	(5.77)	**(5.42)**	**(4.58)**	**(4.38)**
-PROFIT	0.53	1.05	**0.52**	**0.38**	**0.44**
	(3.38)	(4.44)	**(3.53)**	**(2.89)**	**(2.63)**
-ZS	0.82	0.76	−0.06	−0.14	−0.16
	(4.98)	(3.22)	(−0.42)	(−1.11)	(−1.14)
Stock MOM	0.07	0.76	**0.69**	**0.66**	**0.76**
	(0.30)	(3.53)	**(4.46)**	**(4.21)**	**(4.31)**
Stock REV	0.46	0.72	0.26	**0.35**	0.35
	(1.95)	(3.81)	(1.73)	**(2.28)**	(1.84)

Table A5: Equal-weighted buy & hold option portfolio returns - put options
This table contains buy & hold delta-hedged put option portfolio returns and transaction costs for long-short portfolios sorted on various characteristics. Portfolios are formed at the end of each month and held for one month. Subscripts refer to portfolio deciles. Superscripts 'net' and 'gross' refer to returns before and net-of transaction costs, respectively. TC stands for portfolio transaction costs and is defined as the difference between gross and net returns. The transaction costs include stock transaction costs with an effective bid-ask spread from the TAQ database and option transaction costs with an effective bid-ask spread equal to 20.3% times the quoted bid-ask spread from the OptionMetrics database. We report t-statistics in parentheses calculated using Newey-West standard errors with six lags. Variables are described in Section A.1. The sample period is from September 2003 to December 2021.

Panel A: Option Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
-Option MOM	−0.09	−0.55	−0.45	1.11	−1.57
	(−0.53)	(−3.20)	(−3.19)		(−9.02)
-Option REV	−0.54	−0.75	−0.21	1.67	−1.88
	(−2.71)	(−4.58)	(−1.58)		(−8.97)
VOL_deviation	−1.46	0.23	**1.70**	1.92	−0.22
	(−6.89)	(1.68)	**(9.30)**		(−1.55)
-VOV	−1.01	−0.04	**0.97**	1.80	−0.82
	(−5.29)	(−0.34)	**(7.12)**		(−5.58)
VTS	−1.16	−0.20	**0.96**	2.09	−1.13
	(−6.11)	(−1.34)	**(5.89)**		(−6.03)
-Option Price	−0.37	0.39	**0.75**	1.67	−0.92
	(−2.91)	(1.63)	**(4.19)**		(−6.04)
ILLIQ	−0.31	0.10	**0.41**	2.15	−1.74
	(−2.16)	(0.60)	**(4.21)**		(−9.46)
RN SKEW	−0.18	0.06	**0.24**	1.84	−1.60
	(−1.28)	(0.34)	**(2.21)**		(−10.95)
Panel B: Stock Characteristics					
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
-AMIHUD	−0.36	−0.31	0.05	1.80	−1.74
	(−2.05)	(−2.69)	(0.41)		(−10.65)
LN(PRICE)	−0.61	−0.20	**0.41**	1.67	−1.26
	(−2.96)	(−1.52)	**(2.82)**		(−7.30)
Size	−0.52	−0.34	0.18	1.68	−1.50
	(−2.82)	(−2.93)	(1.35)		(−8.96)
-CFV	−0.30	−0.24	0.05	1.30	−1.25
	(−1.42)	(−2.15)	(0.33)		(−7.40)

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	Before TC			After TC	
	$E[r_1^{gross}]$	$E[r_{10}^{gross}]$	$E[r_{10-1}^{gross}]$	TC	$E[r_{10-1}^{net}]$
-DISP	−0.34	−0.22	0.12	1.31	−1.19
	(−2.12)	(−1.85)	(1.30)		(−9.74)
-IVOL	−1.14	−0.08	**1.06**	1.52	−0.46
	(−6.72)	(−0.69)	**(8.64)**		(−3.34)
-ISSUE_1Y	−0.70	−0.10	**0.60**	1.44	−0.84
	(−4.34)	(−0.69)	**(7.20)**		(−7.22)
-ISSUE_5Y	−0.69	−0.06	**0.63**	1.40	−0.78
	(−3.47)	(−0.40)	**(4.68)**		(−6.28)
-TEF	−0.62	−0.23	**0.39**	1.46	−1.07
	(−4.14)	(−1.97)	**(3.58)**		(−8.98)
BM	−0.45	−0.11	**0.35**	1.36	−1.01
	(−3.33)	(−0.56)	**(2.87)**		(−7.37)
-CH	−1.05	−0.02	**1.03**	1.75	−0.72
	(−6.62)	(−0.10)	**(8.25)**		(−5.98)
PM	−0.87	−0.31	**0.56**	1.67	−1.11
	(−5.68)	(−2.12)	**(5.26)**		(−8.47)
PROFIT	−0.73	−0.42	**0.31**	1.64	−1.32
	(−4.29)	(−3.00)	**(3.01)**		(−9.16)
-ZS	−0.63	−0.50	0.13	1.71	−1.59
	(−4.56)	(−2.81)	(1.38)		(−9.42)
-Stock MOM	−0.49	−0.05	**0.44**	1.74	−1.30
	(−2.72)	(−0.26)	**(3.52)**		(−9.31)
-Stock REV	−0.53	−0.32	0.21	1.82	−1.61
	(−3.17)	(−1.79)	(1.63)		(−8.83)

Table A6: The impact of hedging frequency - all variables

This table contains a performance evaluation of equal-weighted long-short decile portfolios with four kinds of hedging frequency. 'Once' represents the buy-and-hold to maturity strategy, hedged at the portfolio formation date. 'Biweekly' represents the strategy which is re-hedged every two weeks, a 'Weekly' strategy is re-hedged every week, and the 'Daily' strategy is re-hedged every trading day. The number without parentheses shows the average return after transaction costs and t-statistics, annual Sharpe ratios, and turnover of stocks for the return after transaction costs time series are shown in the parentheses, bracket parentheses, and curly braces, respectively. All statistics for portfolios with significant positive returns at a 5% level or above are indicated in bold. t-statistics are calculated using Newey-West standard errors with six lags. For brevity, we only show returns on a subset of our full set of characteristics. Variables are described in Section A.1. The time period is between September 2003 and December 2021.

Panel A: Option Characteristics								
	Before Transaction Costs				After Transaction Costs			
	Once	Half-Monthly	Weekly	Daily	Once	Half-Monthly	Weekly	Daily
Option MOM	**0.81**	**0.93**	**0.98**	**0.77**	0.21	0.32	**0.33**	−0.03
	(3.32)	**(5.06)**	**(5.51)**	**(5.23)**	(0.93)	(1.94)	**(2.09)**	(−0.23)
	[0.91]	**[1.55]**	**[1.80]**	**[1.72]**	[0.24]	[0.55]	**[0.63]**	[−0.07]
	{2.03}	**{2.41}**	**{2.76}**	**{4.44}**	{2.03}	{2.41}	**{2.76}**	{4.44}
Option REV	−0.14	**0.24**	**0.40**	**0.63**	−0.97	−0.60	−0.49	−0.46
	(−1.07)	**(2.05)**	**(3.42)**	**(6.37)**	(−7.99)	(−5.96)	(−5.08)	(−5.62)
	[−0.22]	**[0.56]**	**[0.99]**	**[1.95]**	[−1.52]	[−1.42]	[−1.31]	[−1.47]
	{2.00}	**{2.39}**	**{2.75}**	**{4.47}**	{2.00}	{2.39}	{2.75}	{4.47}
-VOL_deviation	**2.06**	**1.93**	**1.90**	**1.97**	**1.16**	**1.02**	**0.94**	**0.83**
	(7.93)	**(9.06)**	**(9.99)**	**(9.09)**	**(5.38)**	**(6.01)**	**(6.51)**	**(5.06)**
	[2.98]	**[3.83]**	**[4.15]**	**[4.27]**	**[1.80]**	**[2.26]**	**[2.34]**	**[2.13]**
	{1.98}	**{2.36}**	**{2.71}**	**{4.41}**	**{1.98}**	**{2.36}**	**{2.71}**	**{4.41}**
VOV	**1.33**	**1.36**	**1.27**	**1.48**	**0.52**	**0.54**	**0.40**	**0.44**
	(6.09)	**(7.45)**	**(6.37)**	**(7.36)**	**(2.78)**	**(3.58)**	**(2.34)**	**(2.64)**
	[2.01]	**[2.94]**	**[2.80]**	**[3.36]**	**[0.82]**	**[1.28]**	**[0.97]**	**[1.12]**
	{1.98}	**{2.36}**	**{2.73}**	**{4.48}**	**{1.98}**	**{2.36}**	**{2.73}**	**{4.48}**
-VTS	**1.08**	**0.92**	**0.84**	**0.86**	0.10	−0.07	−0.19	−0.39
	(4.85)	**(6.14)**	**(5.98)**	**(6.28)**	(0.53)	(−0.49)	(−1.49)	(−3.46)
	[1.71]	**[2.01]**	**[1.95]**	**[2.21]**	[0.17]	[−0.15]	[−0.47]	[−1.09]
	{2.00}	**{2.37}**	**{2.72}**	**{4.41}**	{2.00}	{2.37}	{2.72}	{4.41}
Option Price	0.05	−0.02	−0.06	−0.16	−0.67	−0.76	−0.84	−1.15
	(0.37)	(−0.18)	(−0.39)	(−1.36)	(−5.22)	(−5.80)	(−6.06)	(−10.18)
	[0.09]	[−0.06]	[−0.14]	[−0.44]	[−1.22]	[−1.74]	[−2.09]	[−3.18]
	{1.82}	{2.19}	{2.55}	{4.23}	{1.82}	{2.19}	{2.55}	{4.23}
-ILLIQ	−0.69	−0.68	−0.66	−0.69	−1.66	−1.66	−1.68	−1.91
	(−4.92)	(−5.38)	(−5.39)	(−5.50)	(−8.84)	(−9.61)	(−9.85)	(−10.78)
	[−1.40]	[−1.76]	[−1.81]	[−1.98]	[−3.08]	[−3.78]	[−3.99]	[−4.64]
	{1.85}	{2.24}	{2.60}	{4.33}	{1.85}	{2.24}	{2.60}	{4.33}
RN SKEW	**0.50**	**0.62**	**0.65**	**0.79**	−0.30	−0.19	−0.20	−0.25
	(5.53)	**(5.63)**	**(6.76)**	**(7.56)**	(−3.64)	(−2.11)	(−2.46)	(−3.08)
	[1.04]	**[1.78]**	**[2.23]**	**[2.90]**	[−0.63]	[−0.58]	[−0.71]	[−1.00]
	{1.95}	**{2.34}**	**{2.71}**	**{4.50}**	{1.95}	{2.34}	{2.71}	{4.50}

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Panel B: Stock Characteristics								
	Before Transaction Costs				After Transaction Costs			
	Once	Half-Monthly	Weekly	Daily	Once	Half-Monthly	Weekly	Daily
AMIHUD	**0.69**	**0.66**	**0.71**	**0.92**	−0.20	−0.25	−0.25	−0.27
	(5.00)	**(4.42)**	**(4.72)**	**(6.33)**	(−1.57)	(−1.78)	(−1.79)	(−2.21)
	[1.32]	**[1.53]**	**[1.74]**	**[2.47]**	[−0.39]	[−0.60]	[−0.64]	[−0.79]
	{1.97}	**{2.36}**	**{2.72}**	**{4.49}**	{1.97}	{2.36}	{2.72}	{4.49}
-LN(PRICE)	**0.72**	**0.85**	**0.89**	**1.16**	−0.10	0.01	0.01	0.07
	(4.10)	**(4.79)**	**(4.66)**	**(7.16)**	(−0.54)	(0.06)	(0.03)	(0.45)
	[1.05]	**[1.77]**	**[2.02]**	**[2.99]**	[−0.14]	[0.02]	[0.01]	[0.18]
	{1.98}	**{2.36}**	**{2.72}**	**{4.45}**	{1.98}	{2.36}	{2.72}	{4.45}
-Size	**0.55**	**0.63**	**0.69**	**0.98**	−0.30	−0.23	−0.23	−0.16
	(3.72)	**(4.06)**	**(4.23)**	**(6.17)**	(−1.97)	(−1.59)	(−1.48)	(−1.16)
	[0.90]	**[1.40]**	**[1.61]**	**[2.43]**	[−0.49]	[−0.53]	[−0.55]	[−0.42]
	{1.98}	**{2.37}**	**{2.74}**	**{4.50}**	{1.98}	{2.37}	{2.74}	{4.50}
CFV	−0.08	0.24	0.27	**0.56**	−0.71	−0.40	−0.41	−0.28
	(−0.47)	(1.42)	(1.65)	**(4.08)**	(−4.21)	(−2.52)	(−2.57)	(−2.37)
	[−0.12]	[0.51]	[0.65]	**[1.71]**	[−1.02]	[−0.89]	[−0.98]	[−0.93]
	{1.98}	{2.37}	{2.74}	**{4.49}**	{1.98}	{2.37}	{2.74}	{4.49}
DISP	−0.09	0.07	0.07	**0.30**	−0.71	−0.56	−0.59	−0.53
	(−0.61)	(0.69)	(0.64)	**(3.30)**	(−4.62)	(−5.14)	(−4.94)	(−5.64)
	[−0.16]	[0.22]	[0.23]	**[1.12]**	[−1.30]	[−1.67]	[−1.87]	[−1.99]
	{1.97}	{2.36}	{2.73}	**{4.51}**	{1.97}	{2.36}	{2.73}	{4.51}
IVOL	**0.87**	**0.85**	**0.75**	**0.97**	0.17	0.13	−0.01	0.04
	(5.06)	**(5.20)**	**(4.41)**	**(6.00)**	(1.02)	(0.88)	(−0.07)	(0.29)
	[1.27]	**[1.84]**	**[1.80]**	**[2.55]**	[0.25]	[0.30]	[−0.03]	[0.11]
	{1.98}	**{2.37}**	**{2.74}**	**{4.50}**	{1.98}	{2.37}	{2.74}	{4.50}
ISSUE_1Y	**0.67**	**0.69**	**0.69**	**0.88**	−0.03	−0.02	−0.07	−0.05
	(4.39)	**(4.97)**	**(5.52)**	**(6.79)**	(−0.22)	(−0.19)	(−0.66)	(−0.51)
	[1.20]	**[1.78]**	**[2.04]**	**[2.92]**	[−0.06]	[−0.06]	[−0.21]	[−0.19]
	{1.98}	**{2.36}**	**{2.73}**	**{4.46}**	{1.98}	{2.36}	{2.73}	{4.46}
ISSUE_5Y	**0.78**	**0.72**	**0.68**	**0.85**	0.11	0.05	−0.04	−0.03
	(4.78)	**(4.56)**	**(4.84)**	**(6.18)**	(0.76)	(0.34)	(−0.31)	(−0.28)
	[1.22]	**[1.67]**	**[1.82]**	**[2.60]**	[0.18]	[0.11]	[−0.10]	[−0.10]
	{1.98}	**{2.37}**	**{2.74}**	**{4.48}**	{1.98}	{2.37}	{2.74}	{4.48}
TEF	**0.51**	**0.48**	**0.47**	**0.66**	−0.21	−0.26	−0.31	−0.30
	(2.77)	**(2.96)**	**(3.35)**	**(5.05)**	(−1.30)	(−1.84)	(−2.64)	(−2.86)
	[0.93]	**[1.15]**	**[1.30]**	**[2.10]**	[−0.40]	[−0.66]	[−0.92]	[−1.03]
	{1.98}	**{2.37}**	**{2.73}**	**{4.46}**	{1.98}	{2.37}	{2.73}	{4.46}
-BM	**0.41**	**0.26**	**0.32**	**0.27**	−0.27	−0.42	−0.40	−0.63
	(2.45)	**(2.03)**	**(2.39)**	**(2.72)**	(−1.61)	(−3.33)	(−3.17)	(−6.50)
	[0.58]	**[0.62]**	**[0.82]**	**[0.93]**	[−0.38]	[−0.99]	[−1.04]	[−2.12]
	{1.98}	**{2.37}**	**{2.74}**	**{4.48}**	{1.98}	{2.37}	{2.74}	{4.48}
CH	**1.50**	**1.27**	**1.30**	**1.34**	**0.64**	**0.39**	**0.38**	**0.23**
	(6.93)	**(7.20)**	**(7.96)**	**(8.72)**	**(3.59)**	**(2.95)**	**(3.19)**	**(2.29)**
	[1.93]	**[2.66]**	**[3.07]**	**[3.61]**	**[0.85]**	**[0.91]**	**[1.00]**	**[0.72]**
	{1.98}	**{2.37}**	**{2.74}**	**{4.47}**	**{1.98}**	**{2.37}**	**{2.74}**	**{4.47}**
-PM	**0.91**	**1.00**	**1.08**	**1.23**	0.08	0.16	0.19	0.15
	(5.19)	**(5.68)**	**(6.51)**	**(7.60)**	(0.56)	(1.18)	(1.56)	(1.30)
	[1.21]	**[2.12]**	**[2.59]**	**[3.21]**	[0.11]	[0.38]	[0.52]	[0.46]
	{1.99}	**{2.38}**	**{2.75}**	**{4.49}**	{1.99}	{2.38}	{2.75}	{4.49}

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Continued from the previous page								
	Before Transaction Costs				After Transaction Costs			
	Once	Biweekly	Weekly	Daily	Once	Biweekly	Weekly	Daily
-PROFIT	**0.68**	**0.67**	**0.71**	**0.82**	−0.14	−0.16	−0.18	−0.25
	(4.26)	**(4.35)**	**(5.23)**	**(6.78)**	(−0.98)	(−1.21)	(−1.55)	(−2.71)
	[1.32]	**[1.66]**	**[1.98]**	**[2.72]**	[−0.28]	[−0.43]	[−0.53]	[−0.94]
	{2.00}	**{2.38}**	**{2.73}**	**{4.44}**	{2.00}	{2.38}	{2.73}	{4.44}
-ZS	−0.15	0.12	0.20	**0.30**	−1.02	−0.76	−0.73	−0.82
	(−1.17)	(1.06)	(1.94)	**(3.52)**	(−7.24)	(−6.59)	(−6.76)	(−9.90)
	[−0.29]	[0.30]	[0.61]	**[1.15]**	[−1.89]	[−1.96]	[−2.20]	[−3.24]
	{2.00}	{2.38}	{2.74}	**{4.44}**	{2.00}	{2.38}	{2.74}	{4.44}
Stock MOM	**0.47**	**0.38**	**0.37**	**0.25**	−0.40	−0.50	−0.56	−0.90
	(2.29)	**(3.00)**	**(2.70)**	**(2.42)**	(−2.03)	(−4.28)	(−4.39)	(−9.35)
	[0.60]	**[0.82]**	**[0.86]**	**[0.73]**	[−0.52]	[−1.10]	[−1.29]	[−2.59]
	{2.00}	**{2.39}**	**{2.75}**	**{4.44}**	{2.00}	{2.39}	{2.75}	{4.44}
Stock REV	0.02	0.16	0.15	0.13	−0.83	−0.71	−0.77	−1.00
	(0.11)	(1.39)	(1.19)	(1.35)	(−4.24)	(−6.13)	(−5.94)	(−10.14)
	[0.03]	[0.39]	[0.39]	[0.42]	[−1.16]	[−1.73]	[−1.96]	[−3.22]
	{1.99}	{2.39}	{2.75}	{4.47}	{1.99}	{2.39}	{2.75}	{4.47}

B Accounting for transaction costs

In the following sections, we detail how we adjust returns for transaction costs.

B.1 Stock transaction costs

To construct a delta-hedged option return on a written option, delta shares of the stock must be bought at initiation. Because we form portfolios that are rebalanced monthly, an option written on the same stock can enter the same portfolio in consecutive months. Therefore, we account for the possibility of already having an existing stock position when we rebalance.

For decile portfolio k with a written option on stock i at the end of month t, one needs to buy $b^k_{i,t}$ shares of stock i, which is determined by

$$b^k_{i,t} = \max\{\Delta^k_{i,t} - \Delta^k_{i,t-1}, 0\},$$

where $\Delta^k_{i,t}$ denotes the delta on stock i added to portfolio k at time t. $\Delta^k_{i,t-1}$ captures any pre-existing stock position. If an option on stock i is not included in portfolio k at the end of month $t-1$, $\Delta^k_{i,t-1}$ equals zero. Specifically, at the first portfolio formation date $t = 1$, one has to buy the $\Delta^k_{i,1}$ shares of the stock i for the portfolio k, hence $\Delta^k_{i,0} = 0$.

Rebalancing after the one-month holding period may require selling shares used to hedge to an option position. After holding the stock i in the portfolio k formed at the end of the month t for one month, one needs to sell $s^k_{i,t}$ shares of stock;

$$s^k_{i,t} = \max\{\Delta^k_{i,t} - \Delta^k_{i,t+1}, 0\}$$

where $\Delta^k_{i,t}$ denotes the delta shares of stocks needed for the portfolio k at time t. As before, if the stock i is not included in the portfolio k at the end of the month $t+1$, $\Delta^k_{i,t+1}$ equals zero. In particular, at the end of the sample period $t = T$, one has to sell the $\Delta^k_{i,T}$ shares of the stock i for the portfolio k, hence $\Delta^k_{i,T+1} = 0$.

Thus, the overall transaction costs for trading shares on stock i for the portfolio k formed at the end of the month t contains two parts, the buying cost and selling cost, which can be written as:

$$StockBuyTC^k_{i,t} = b^k_{i,t} \times S_{i,t} \times 0.5 \times StockSpread_{i,t},$$

and

$$StockSaleTC^k_{i,t} = s^k_{i,t} \times S_{i,t+1} \times 0.5 \times StockSpread_{i,t+1}.$$

where $StockSpread_{i,t}$ denotes the effective bid-ask spread of the stock i at time t. We assume that half of the effective bid-ask spread is paid in the trading of stocks.

B.2 Option transaction costs

We also need to consider the transaction costs of buying and selling options. We denote this cost as $OptionSpread_{i,t}$ and note that effective bid-ask spreads of buying and selling options are approximated by a proportion of quoted option bid-ask spreads, i.e., $OptionSpread_{i,t} = 0.203 \times QuotedSpread_{i,t}$. For the specific portfolio k, if the call option i is assigned to the portfolio k at the end of month t, one needs to sell a contract, and the associated transaction cost can be written:

$$OptionSaleTC^k_{i,t} = 0.5 \times OptionSpread_{i,t} \times C_{i,t}$$

After holding for one month, the option i moves out of the portfolio k, and we buy back the written option at a cost of:

$$OptionBuyTC^k_{i,t} = 0.5 \times OptionSpread_{i,t+1} \times C_{i,t+1}.$$

We assume that the effective option spread is 20.3% of the quoted spread as in Heston et al. (2023) and that traders pay the effective half-spread to enter or exit a position.

B.3 Option return adjusted for transaction costs

Putting the costs together, for an option i in portfolio k formed at the end of month t, and held until $t+1$, the total transaction costs equal:

$$\begin{aligned} TC^{k,long}_{i,t,t+1} = {} & StockBuyTC^k_{i,t} + StockSaleTC^k_{i,t+1} \\ & + OptionSaleTC^k_{i,t} + OptionBuyTC^k_{i,t+1} \end{aligned}$$

and the portfolio formation cost with transaction costs equal to

$$FormCost^k_{i,t} = (\Delta^k_t S_{i,t} - C_{i,t}) + StockBuyTC^k_{i,t} + OptionSaleTC^k_{i,t}.$$

Therefore, the buy-and-hold one-month return of a written call position in stock i in portfolio k formed at the end of month t after accounting stock and option transaction costs (‘net’) can be written:

$$r_{i,t}^{k,long-TC-Adjusted} = \frac{(\Delta_t^k S_{i,t+1} - C_{i,t}) - TC_{i,t}^{k,long}}{FormCost_{i,t}^k} - 1. \tag{2}$$

We note that the transaction costs have a similar form when we take a short position in a portfolio consisting of written and delta-hedged options. This trade involves buying a call and selling delta shares on the formation date, and then one month later selling the option and buying back delta shares to cover the short stock position.

and can be written:

$$TC_{i,t,t+1}^{k,short} = ShortSaleTC_{i,t} + StockBuyTC_{i,t}^k + StockSaleTC_{i,t}^k \tag{3}$$
$$+ OptionSaleTC_{i,t}^k + OptionBuyTC_{i,t}^k \tag{4}$$

$$TC_{i,t,t+1}^{k,short} = StockSaleTC_{i,t}^k StockBuyTC_{i,t+1}^k + \tag{5}$$
$$OptionBuyTC_{i,t}^k + OptionSaleTC_{i,t+1}^k \tag{6}$$

and the portfolio formation cost with transaction costs equals to

$$FormCost_{i,t}^k = (\Delta_t^k S_{i,t} - C_{i,t}) + StockSellTC_{i,t}^k + OptionBuyTC_{i,t}^k \tag{7}$$

Accordingly, the corresponding transaction costs adjusted for the short position equals to

$$HPR_{i,t}^{k,short-TC-Adjusted} = -\frac{(\Delta_t^k S_{i,t+1} - C_{i,t}) + TC_{i,t}^{k,short}}{FormCost_{i,t}^k}. \tag{8}$$

B.4 Transaction costs for hold-to-maturity returns

We use two types of hold-to-maturity returns in the paper. For one strategy, we form portfolios at the end of the month; for the second, we form portfolios on the third Friday of each month. The option positions are then delta-hedged once at formation and held to maturity. Because options on the same stock can enter a portfolio on consecutive formation dates, we need to do some accounting for the position in delta shares. The accounting is slightly different for portfolios formed on the third Friday of each month and portfolios formed at the end of each month, and we detail the accounting here.

B.4.1 Formation on the third Friday

We detail the costs for a position which consists of a short position in the option and a long position in delta shares to hedge that position.

Δ_t denotes the amount of stock needed to hedge the option position at time t, S_t denotes the market price of the stock at time t and O_t denotes the market price of the option with the stock as the underlying asset, K_t denotes the strike price of the option at time t, SS_t (OS_t) denotes the effective bid-ask spread of the stock (option) at time t. At time t, suppose we have an existing short option position expiring, and an option on the same stock enters the portfolio. There will be η_t shares of stock held already. We need to buy $\Delta_t - \eta_t$ shares of the stock and sell one option contract, so the transaction costs of this entry is

$$(\Delta_t - \eta_t) \times S_t \times 0.5 \times SS_t + O_t \times 0.5 \times OS_t. \tag{9}$$

At time $t+1$, the position formed at time t matures, and if it is in the money, we buy extra $1-\Delta_t$ to clear the short option position, and we are left with no stock position, i.e., $\eta_{t+1} = 0$; if it is out the money, it will not be exercised, and we sell $\max\{\Delta_t - \Delta_{t+1}, 0\}$ shares of stock to exit the position and the remaining stock position, η_{t+1} is $\min\{\Delta_{t+1}, \Delta_t\}$. Therefore, the transaction costs of the exit of the portfolio formed at time t is

$$\begin{cases} (1 - \Delta_t) \times S_{t+1} \times 0.5 \times SS_{t+1} \text{ If } S_{t+1} > K_t, \\ \max\{\Delta_t - \Delta_{t+1}, 0\} \times S_{t+1} \times 0.5 \times SS_{t+1} \text{ If } S_{t+1} <= K_t. \end{cases} \tag{10}$$

B.4.2 Formation at month-end

The key difference between portfolios of option positions formed at month-end and held for one month and with option positions held to maturity is the possibility of option positions overlapping. For example, because the maturity of the position is approximately 50 days, at the end of the next month, we can have two options on the same stock assigned to a portfolio. We typically have twice the number of options assigned to the portfolio between the month's end and maturity (i.e., approximately days 30-50).

In this case, we do not attempt to avoid transaction costs by netting off positions in the delta-hedge portfolio. That is, we track each option until maturity and pay any transaction costs associated with the initial delta-hedge and option exercise.

B.5 Margin costs

We measure the margin requirement following the CBOE initial margin requirement for a naked short position, which is “100% of option proceeds plus 20% of underlying security / index value less out-of-the-money amount, if any, to a minimum for calls of option proceeds plus 10% of the underlying security / index value, and a minimum for puts of option proceeds plus 10% of the put’s exercise price.” [16] Hence, the margin requirement for the short position of a call option i at time t is determined by

$$M_{i,t} = \max\{C_{i,t} + 20\% \times S_{i,t} - \max\{K_i - S_{i,t}, 0\}, C_{i,t} + 10\% \times S_{i,t}\} \tag{11}$$

where K_i stands for the strike price of the option i. Following Zhan et al. (2022), we measure the margin cost as the cost of borrowing additional capital to meet the margin requirement over the holding period, i.e., $MTC_{i,t} = r_t \times \tau_{i,t} \times M_{i,t}$ where r_t denotes the option-maturity matched annual LIBOR rate and $\tau_{i,t}$ denotes the holding time of the option i in year units.

[16] Website: https://cdn.cboe.com/resources/membership/Margin_Manual.pdf