Intraday Option Reversals: Return Predictability and Market Efficiency

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Abstract

We uncover the first intraday option reversals: zero-delta straddles exhibit systematic half-hour return reversals that are economically and statistically significant, robust to transaction costs, and distinct from cross-day momentum. The evidence points to inventory-based pricing—market makers absorb demand imbalances and earn compensation as prices revert. Three independent demand proxies support this mechanism: implied-volatility changes, bid-ask spread variations, and volume sorting all reveal monotonic reversal patterns. Crucially, symmetric demand shocks reverse in options but not underlying stocks, isolating the options-specific mechanism. These effects persist after excluding major market events, confirming that short-term demand pressure drives predictable intraday option returns even in highly liquid and diversified markets.

Keywords: Intraday, stock options, reversal, delta hedging, straddle.

JEL classification: G11, G12, G14.

1. Introduction

Intraday asset prices are fundamental to understanding return dynamics across horizons and the origins of many asset pricing anomalies. Although intraday equity returns have been extensively studied (see, e.g., Bogousslavsky, 2016; Gao, Han, Li, and Zhou, 2018; Bogousslavsky, 2021), research on intraday option returns remains limited. An important exception is the contemporaneous study of Da, Goyenko, and Zhang (2025), who document cross-day option momentum. At the monthly level, Han, He, Rapach, and Zhou (2024) show that short-term reversal and trend factors dominate among more than 200 stock return predictors. Yet, whether such dynamics, especially *reversals*, also appear within the trading day for options remains unexplored.

In this paper, we address a notable gap in the literature by demonstrating, for the first time, the existence of reversal patterns in intraday option returns. We focus on the zero-delta straddle (ZDS) portfolios of at-the-money (ATM) options. Sorting options by their ZDS return over the past half-hour, we find that the spread portfolio of buying the lowest quintile and shorting the highest earns consistent abnormal returns, from 10:30 to 16:00. The Sharpe ratios are significantly positive across the 30-minute time intervals. Interestingly, the most pronounced returns occur between 14:00 and 14:30, likely reflecting the impact of scheduled market events such as earnings announcements or FOMC meetings, which can introduce substantial volatility. Indeed, markets often respond to news delivered on a routine daily schedule. Scheduled events, such as FOMC meetings and earnings calls, can prompt traders to either overreact or underreact due to cognitive biases (Tversky and Kahneman, 1974), which may contribute to patterns of intraday return periodicity.

The strategy typically generates significantly positive Sharpe ratios for low-minus-high portfolios across most time intervals, with values ranging from 0.83 to 1.83, peaking at 1.83 around noon. Although the strategy performs worse between 14:00 and 14:30, it rebounds sharply at 15:00, and the Sharpe ratios for the final two half-hour intervals remain positive at 1.69 and 1.13, respectively.

We also examine whether stock and option characteristics influence the profitability of intraday option reversals by performing Fama and MacBeth (1973) cross-sectional regressions of option returns on reversal strategies and various control variables. Our analysis reveals that the previous half-hour option returns are strong negative predictors of future half-hour returns across all intervals, except for the 10:00–10:30 period, which shows a positive and statistically significant relationship with the prior day's last half-hour return. Despite including control variables such as implied volatility and bid-ask spreads, we find that these characteristics do not explain the reversal strategy's profitability. Overall, our findings provide compelling evidence of significant intraday option reversals, demonstrating the strategy's economic value, especially during periods such as noon and the intervals between 14:30 and 15:30, which show the highest returns.

We also investigate whether the overnight return, measured from the previous trading day's close to the current day's 10:00, can predict the half-hour intraday return. The results reveal that the spread portfolios sorted by overnight performance show a strong negative return of -3.69% from 10:00 to 10:30, with a highly significant t-statistic of -10.67. The negative returns persist until noon but gradually lose significance in the afternoon, except for the last half-hour (15:30–16:00). Unlike intraday stock momentum (Gao et al., 2018), overnight zero-delta straddle returns predict a reversal pattern in the last half-hour return. We also perform cross-sectional regressions, where we control for variables such as implied volatility and bid-ask spreads. Our results confirm that the overnight reversal effect remains significant from 10:00 to 11:30, even after controlling for these characteristics, while exhibiting a strong daily-level momentum with a t-statistic of 6.83.

We investigate how our intraday option reversal strategy relates to the cross-day option momentum documented by Da et al. (2025). Consistent with broader anomaly patterns, intraday reversals and cross-day momentum coexist. In line with their findings, we observe no reversals during the 10:00–10:30 interval, since our strategy depends on returns from the preceding half-hour within the same trading day. To further explore this connection, we run cross-sectional regressions including returns from the same half-hour interval

on the previous trading day. We find a significant negative relationship between previous and current half-hour returns during the morning and noon sessions, yet the coefficients for our reversal strategy remain largely unchanged after controlling for cross-day momentum, indicating that intraday reversals are not driven by cross-day effects. These patterns persist throughout later hours, further confirming that cross-day momentum is concentrated at the market open and close.

To explain the observed intraday options reversals, we build on the stock market reversal framework of Nagel (2012) and incorporate the demand-driven option pricing approach of Garleanu, Pedersen, and Poteshman (2008). This combined model considers three types of participants in the options market: informed traders, market makers, and liquidity traders, with the latter trading a predetermined amount of options at each time. Market makers are especially concerned about volatility-related private information from informed traders, as incorrect implied volatility may present trading opportunities for them. Our findings confirm significant negative returns for both delta-hedged call and put options, with spread portfolios based on prior half-hour returns showing dollar returns between -$8.93 to -$13.02 for calls and -$9.10 to -$12.79 for puts during the intraday session, and even stronger negative returns overnight. In addition, we investigate zero-delta straddle portfolios, which isolate delta risk over short intervals. The model suggests that reversals are driven by demand imbalances between informed and liquidity traders, which we proxy using implied volatility changes as our primary measure and trading volume as a complementary indicator of activity intensity. The significant reversal patterns observed in delta-hedged calls and puts, combined with evidence that higher trading volume predicts stronger reversals, support the conclusion that these reversals are primarily driven by short-term demand pressures measurable through both implied volatility fluctuations and trading intensity.

To further explore the demand-based explanation, we construct portfolios double-sorted by changes in call and put implied volatility over the previous half-hour, expecting that portfolios with smaller changes in volatility will yield higher returns, while those with larger changes will show lower returns. Our findings provide strong support for

this demand-based explanation, as portfolios with smaller changes in both call and put volatility consistently generate higher returns, with diagonal portfolio returns decreasing monotonically from 2.65% to -1.57%. This pattern holds across all time intervals, and the distribution of firms suggests that the observed volatility changes reflect demand pressures rather than violations of put-call parity. We validate these results using two alternative demand proxies. First, changes in quoted bid-ask spreads produce qualitatively similar patterns with spread returns ranging from -0.47% to -1.54% intraday and -3.98% overnight. Second, portfolios sorted by trading volume exhibit negative high-minus-low returns across most intervals, ranging from -0.18% to -0.34% during regular hours and reaching -5.44% overnight, consistent with higher trading activity signaling larger inventory imbalances requiring greater compensation. We use unsigned volume rather than signed trades because retail trading exceeds 60% of market volume after 2020 (Bryzgalova, Pavlova, and Sikorskaya, 2023), and standard trade classification achieves only 55.82% accuracy in recent data Gao, Tang, Zhou, and Zhou (2025).

We also explore whether the straddle reversal is influenced by movements in the underlying stock, focusing on how market makers adjust quotes based on demand. Our demand-based explanation suggests that when calls and puts experience similar directional demand, market makers face net-zero delta order flows, resulting in no significant abnormal returns for the underlying stock. Conversely, asymmetric demand flows—such as buying calls and selling puts—can indicate short-term changes in the stock's value. Using independent double-sorting to construct 3×3 portfolios of the underlying stocks based on volatility changes, we observe no significant returns for portfolios with small or large volatility changes, with the spread portfolio generating only 0.40 basis points ($t = 2.08$). However, within each tertile, increased call demand correlates with positive returns, while higher put demand corresponds with negative returns. An off-diagonal spread portfolio, capturing these directional patterns, generates a significant return of 1.69 basis points with a t-statistic of 7.46, supporting the influence of directional option demand on underlying stock returns while confirming that symmetric demand shocks drive option return reversals without affecting the underlying asset.

To ensure the robustness of our findings, we systematically exclude dates surrounding Federal Open Market Committee (FOMC) meetings, earnings announcements, option expiration dates, and the onset of the COVID-19 pandemic. These exclusions help mitigate potential distortions in market dynamics, resulting in consistent and statistically significant results. Specifically, FOMC meeting dates, periods of heightened market volatility during the COVID period, option expiration dates, and earnings announcements are controlled for to ensure the reliability of our analyses. In all cases, our findings remain robust, demonstrating the consistency and validity of our strategy. The only exception is the 10:00 to 10:30 interval, where we observe weak positive continuation (rather than reversal), which becomes insignificant after eliminating earnings announcements. However, the option reversal strategy remains highly negative and significant across all other time periods.

Our paper adds to the literature on the predictability of (equity) option returns: Cao and Han (2013) establish a link to the idiosyncratic volatility of the underlying. More recently, Bali, Beckmeyer, Moerke, and Weigert (2023) show that equity option returns are predictable by a vast array of characteristics of the option and its underlying when deployed jointly with modern methods from machine learning.

Our paper contributes to the literature on the predictability of (equity) option returns. Cao and Han (2013) establish a link to the idiosyncratic volatility of the underlying. The literature has also documented the existence of a factor structure in (equity) option returns Christoffersen, Fournier, and Jacobs (2018); Büchner and Kelly (2022); Goyal and Saretto (2025), and Heston, Jones, Khorram, Li, and Mo (2023) and Beckmeyer, Beckmeyer, Filippou, and Zhou (2023) show that the well-documented momentum anomaly (e.g., Asness, Moskowitz, and Pedersen, 2013) also extends to the equity options market at the monthly frequency. Substantially less is known about the *intraday* dynamics of option returns. While an increased availability of granular price data has motivated several studies on intraday patterns in the equity market Gao et al. (2018); Lou, Polk, and Skouras (2019); Li, Yuan, and Zhou (Forthcoming), few studies investigate intraday patterns in the equity *options* market.

In their contemporaneous study, Da et al. (2025) discover an option momentum effect across adjacent days. We add to this strand of the literature by demonstrating the existence of highly significant and persistent reversal patterns in the intraday returns of equity option contracts. Our study and theirs are complementary: they show that cross-day momentum concentrates at market open and close, while we document intraday reversals throughout the trading day based on returns from the previous half-hour within the same day. These findings collectively demonstrate that momentum and reversal coexist in option markets at different frequencies, consistent with similar patterns documented at the monthly level. Recently, Bali, Goyal, Moerke, and Weigert (2025) divide the trading day into halves, documenting cross-day momentum together with intraday reversals, thereby combining our findings with those of Da et al. (2025) at a lower frequency.

The rest of the paper is organized as follows: Section 2 provides a description of the data. Section 3 offers the main empirical results. Section 4 provides an economic explanation of the findings. Section 5 shows robustness checks. Section 6 concludes.

2. Data and Variable Construction

In this section, we describe the options data used in our analysis and the construction of delta-hedged returns and zero-delta straddle returns.

2.1. Data source and sample construction

We use tick-by-tick data from the Options Price Reporting Authority (OPRA), obtained via ThetaData, covering the period from January 2020 to December 2023. This dataset includes bid and ask quotes for all equity options traded in the U.S. at a 1-minute frequency. To align with existing studies on the intraday predictability of stock returns, we extract the last available quote in each 30-minute interval during the trading day, beginning at 10:00 AM and ending at 4:00 PM. The dataset also includes high-frequency

prices of the underlying stocks, as well as implied volatilities and Greeks of the options.[1] We merge information about stock splits and ticker changes from CRSP, which allows us to track the individual option contracts over time.

To ensure that our findings on the intraday predictability of option returns are not driven by market liquidity issues, we focus exclusively on the most liquid option contracts. Specifically, we select option chains for underlying stocks that actively quote weekly options. We further examine the intraday return patterns of at-the-money (ATM) options, which generally exhibit the highest liquidity. Each day at 10:00 AM, we identify the put and call pair with a strike price closest to the current price of the underlying stock. These options are then tracked throughout their lifetime, with particular attention to their return predictability over the subsequent trading day and the following overnight period. This approach ensures that an investor operating in the options market could have selected the contracts in real-time. Notably, our findings are robust to the specific choice of contract and remain consistent across a range of options quoted near the current value of the underlying stock. Finally, we check if the documented predictability survives the consideration of transaction costs in the equity options market. For this, we consider the high-frequency bid-ask spread of the individual contracts.

In our empirical analysis, we focus on the shortest-dated options (excluding 0DTE). As Andersen, Fusari, and Todorov (2017) point out, short-dated option pricing is closely tied to the underlying asset's return process, but this link weakens for longer maturities. Furthermore, because these contracts are near expiration, the relative prices of deep out-of-the-money (DOTM) options become largely independent of diffusive volatility and instead reflect the characteristics of the risk-neutral jump process. Meanwhile, the pricing of short-dated ATM options depends primarily on the current spot volatility.

[1]Calculated using the Black and Scholes (1973) model. Muravyev and Pearson (2020) use the same model and note that the impact of considering dividends and possible early exercise are negligible.

2.2. Delta Hedging and Zero-Delta Straddle

To assure that our results on the intraday predictability of equity option returns are not plagued by their mechanical link to the underlying stocks, we perform a high-frequency hedging approach. We investigate straddle portfolios, which combine a position in the atm put and call contract. We follow the definition of Coval and Shumway (2001), with the delta-hedged straddle return given by:

$$r^{STR}_{hh,i,t} = w_c \times \frac{C_{hh,i,t} - C_{hh-1,t,i}}{C_{hh-1,t,i}} + (1 - w_c) \times \frac{P_{hh,i,t} - P_{hh-1,t,i}}{P_{hh-1,t,i}}, \tag{1}$$

$w_c = -\Delta_p/(\Delta_c - \Delta_p)$ assures that the position is initially delta-neutral, such that all three option positions (delta-hedged calls, puts, and straddles) assure that any intraday predictability that we find is not merely a reiteration of intraday stock return predictability.

When investigating individual long call and put option returns over a 30-minute interval, we follow Duarte, Jones, Mo, and Khorram (2023) to set up a hedge portfolio in the underlying, of Δ units. The 30-minute delta-hedged returns are consequently given by:

$$r^{O}_{hh,i,t} = \frac{O_{hh,i,t} - O_{hh-1,t,i} - \Delta_{hh-1,i,t} \times (S_{hh,i,t} - S_{hh-1,i,t})}{|O_{hh-1,t,i} - \Delta_{hh-1,i,t} S_{hh-1,i,t}|}, \tag{2}$$

Where hh denotes the respective 30-minute period, O is the mid-price of option contract i, which can be the atm call or put, and S is the current price of the underlying stock. We scale the delta-hedged dollar gain of the position by the initial amount invested.

Moreover, we examine the dollar returns in both zero-delta straddle and delta hedging in a manner akin to Nagel (2012), which explores short-term reversal strategies in equity

markets:

$$
\begin{aligned}
R^{O}_{hh,i,t} &= O_{hh,i,t} - O_{hh-1,t,i} - \Delta_{hh-1,i,t} \times (S_{hh,i,t} - S_{hh-1,i,t}) \\
&\text{and} \\
R^{STR}_{hh,i,t} &= w_c(C_{hh,i,t} - C_{hh-1,t,i}) + (1 - w_c)(P_{hh,i,t} - P_{hh-1,t,i}) \\
&= w_c R^{C}_{hh,i,t} + (1 - w_c) R^{P}_{hh,i,t}.
\end{aligned}
\tag{3}
$$

Interestingly, the dollar returns in a zero-delta straddle can be perfectly decomposed into the dollar returns from call delta-hedging and put delta-hedging. Theoretically, option delta-hedging returns should depend only on changes in implied volatility, changes in the underlying stock price, and time decay. Due to put-call parity, previous studies typically assume that changes in implied volatility are identical for calls and puts. However, our high-frequency empirical analysis shows that implied volatility changes differ significantly between calls and puts. This finding suggests that market makers adjust call and put quotes asymmetrically, implying that the reversal pattern observed in a zero-delta straddle may also manifest in the delta-hedging returns of calls and puts. Moreover, these asymmetric quote adjustments provide a clear explanation for the intraday option reversals observed in the market.

3. Empirical Results

In this section, we present summary statistics for the intraday option reversal strategy and explore its relationship with both intraday and overnight returns. Additionally, we compare these findings to established momentum and seasonality patterns.

3.1. Intraday Option Reversals

Univariate Sorts. Table 1 presents the average returns and t-statistics for zero-delta straddles, sorted based on the percentage returns and dollar returns from the previous half-hour. The only exception is the return from 10:00 to 10:30 which is sorted into

portfolios based on the last half-hour return (15:30 to 16:00) of the previous day. We show the average returns of quintile portfolios as well as the return of a spread portfolio that buys the high past return portfolio and sells the low past return portfolio. The holding and formation periods are half an hour. The last column shows Newey and West (1987) t-statistics with 6 lags. Panel A reports the percentage return, Panel B reports the dollar returns expressed in dollars per contract.

We find that the spread portfolios consistently yield negative returns, which are statistically significant across both sorting methods. In the percentage return sorting (Panel A), the returns range from -3.56% to -4.96%. The only exception is the return from 10:00 to 10:30, which is sorted based on the last half-hour return (15:30-16:00) of the previous day, where the return is positive and statistically significant. This may reflect momentum from the previous day. The most negative returns occur from 14:00 to 14:30, potentially linked to scheduled events such as earnings announcements or FOMC meetings. Panel B of Table 1 shows consistent results for dollar returns.

Sharpe Ratios. We also calculate the Sharpe ratio for each time interval. As shown in Figure 1, the strategy generally exhibits significantly positive Sharpe ratios across all intervals, except for the return from 10:00 to 10:30. In these cases, we present the Sharpe ratios with the opposite sign. In a subsequent section, we show that sorting based on the overnight return from 16:00 the previous day to 10:00 results in a negative and statistically significant return. For the remaining intervals, Sharpe ratios are positive, ranging from 0.83 to 1.83. Notably, the ratios increase steadily from 10:30 to 13:00, peaking at 1.83 at noon. After this peak, the strategy underperforms until 14:30, but it rebounds sharply at 15:00. The Sharpe ratios for the final two half-hour intervals of the day are 1.69 and 1.13, respectively.

Cross-sectional Regressions. We also investigate whether various stock and option characteristics influence our results. To this end, we perform cross-sectional regressions of option returns on the reversal, as well as stock and option characteristics, following

the methodology of Fama and MacBeth (1973). Table 2 presents the results of these regressions, where delta-neutral straddle returns are regressed on the previous half-hour return along with a set of control variables. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility (IV) and the bid-ask (BA) spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). Panel A presents the results for half-hour returns from 10:00 to 13:30, while Panel B shows the results for half-hour returns from 13:30 to 16:00, along with the overnight return from 16:00 to 10:00 the following day. Our analysis reveals that the coefficients of the previous half-hour option returns serve as strong negative predictors for the next half-hour returns across all intervals. The only exception is the coefficient for the 10:00 to 10:30 return, which is both positive and statistically significant. The predictor for this return is the last half-hour return from the previous day. Additionally, in a later section, we demonstrate that the overnight return from 16:00 to 10:00 strongly negatively predicts the 10:00 to 10:30 option return. The R-squares range from 5.8% for the interval from 10:00 to 10:30 to 14.2% for the interval from 14:00 to 14:30 when the returns of the strategy are more negative.

Overall, we find compelling evidence of intraday option reversals that are not explained by stock and option characteristics. The strategy demonstrates significant economic value, as evidenced by the high Sharpe ratios observed around noon and during the half-hour intervals between 14:30 and 15:00, as well as from 15:00 to 15:30.

3.2. Intraday and Overnight Option Reversals

In the previous section, we found that intraday option returns provide valuable information about the corresponding intraday return. Specifically, the option return from 15:30 to 16:00 serves as a strong predictor of the overnight return from 16:00 to 10:00 the following day. In this section, we explore whether the overnight return can, in turn, predict the half-hour intraday return on the following day.

Table 3 presents the results of spread portfolios sorted by their overnight performance, measured from the previous trading day's market close to the current day's 10:00. Notably, the half-hour return from 10:00 to 10:30 is -3.69%, with a highly significant t-statistic of -10.67. After 10:30, the spread returns remain significantly negative until noon, although their t-statistics steadily decline. During the afternoon, the spread returns become insignificant, except for the final half-hour (15:30–16:00). Unlike the stock intraday momentum documented in Gao et al. (2018), overnight zero-delta straddle returns predict the last half-hour zero-delta straddle returns in a reversal pattern rather than momentum. Furthermore, overnight returns exhibit a strong daily-level momentum: the spread portfolio held from 16:00 to the following 10:00 consistently generates significant positive returns.

To ensure that our results are not driven by other stock and option characteristics, we also run cross-sectional regressions of half-hour option returns on the overnight return from 16:00 the previous day to 10:00, along with a set of control variables. The results are presented in Table 4. The cross-sectional model is specified as follows:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{16:00-(N)10:00,t-1:t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility (IV) and the bid-ask (BA) spreads of call and put options for stock i during the previous half-hour period on day t.

Panel A presents the results for half-hour returns from 10:00 to 13:30, while Panel B shows the results for half-hour returns from 13:30 to 16:00, along with the overnight return from 16:00 to 10:00 the following day. Our regression analysis confirms this finding in Table 3. Even after controlling for implied volatility and the options' liquidity, the overnight reversal effect remains significant from 10:00 to 11:30, evidenced by negative coefficients in Table 4. In the afternoon, however, these coefficients turn positive. Moreover, the overnight returns exhibit a robust daily-level momentum in the cross-section, with a t-statistic of 6.83.

3.3. Comparison with Intraday Momentum and Seasonality

Heston, Korajczyk, and Sadka (2010) demonstrate that stock returns in a specific 30-minute window can predict returns in the same window on subsequent days. Da et al. (2025) extend this cross-day momentum concept to the options market and show that it is significant only at market open and close. To determine whether our intraday options reversal captures information similar to cross-day options momentum, we run cross-sectional regressions that include returns from the same time interval on the previous trading day.

In Table 5, we show cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 r_{hh,i,t-1} + \beta_3 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t and $r_{hh,i,t-1}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day $t-1$. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t.

We find that, even after controlling for the same half-hour return from the previous day,

there remains a significantly negative relationship between the returns from the previous half-hour and the current half-hour during the morning and noon sessions. Additionally, the returns from the same interval on the previous trading day are only significant for 10:00–10:30, which is consistent with Da et al. (2025). A comparison with the coefficients in Table 2 shows that, after controlling for cross-day momentum, the coefficients for the reversal strategy remain largely unchanged. This suggests that our intraday reversal patterns are uncorrelated with cross-day momentum. Similar results are observed in the later hours, as reported in Panel B of Table 5.

As shown in Table 5, our reversal patterns remain robust even after controlling for cross-day options momentum. Moreover, using a recent dataset, we confirm Da et al. (2025)'s finding that cross-day options momentum is only significant in the first and last half-hour of trading.

4. Economic Explanation

To explain these robust intraday options reversals, we integrate the stock market reversal model from Nagel (2012) with the demand-based option pricing framework of Garleanu et al. (2008).

Following Nagel (2012), we assume that the options market comprises three types of participants: informed traders, market makers, and liquidity traders. The latter group trades an exogenous amount z_t at time t. Because implied volatility maps directly to option prices, market makers are particularly concerned about informed traders who possess private information on volatility. Setting the wrong implied volatility can create profitable trading opportunities for these informed traders. To isolate volatility-based risk from delta risk, we consider a zero-delta straddle portfolio, which removes the delta component over short intervals. The value of this zero-delta portfolio's at time T is given by:

$$v_T = v_0 + \sum_{t=1}^{T} \delta_t + \sum_{t=1}^{T} \xi_t, \tag{4}$$

where δ_t, ξ_t and z_t are jointly normal, IID across time, mutually uncorrelated, and have variances $\sigma_\delta^2, \sigma_\xi^2$, and σ_z^2, respectively. The signal ξ_t is public and observed at time t by all market participants. In contrast, δ_t becomes public information at t, but is known one period earlier to informed traders through a private signal $s_{t-1} = \delta_t$. In equilibrium, following Nagel (2012)'s model, the dollar returns $R_{t+1} \equiv P_{t+1} - P_t$ follow

$$R_{t+1} = \xi_{t+1} + \delta_{t+1} + \left(\frac{1}{\gamma} + \phi\right) x_{t+1} - \left(\frac{1}{\gamma}\right) x_t, \tag{5}$$

where x_t is the total demand imbalance from informed and liquidity traders absorbed by the market makers, γ is the slope of total demand and ϕ captures the informativeness of x_t.

Equation (5) shows that the zero-delta straddle returns are predictable because of the last component ($-\left(\frac{1}{\gamma}\right) x_t$), which compensates options market makers for inventory risk. When options market makers are long the zero-delta straddle ($x_t < 0$), the conditional expected return at $t+1$ is positive.

It is difficult to directly measure x_t, the high-frequency demand for zero-delta straddle, in practice. Therefore, following Garleanu et al. (2008), we use changes in implied volatility as an empirical proxy for x_t. Specifically, Garleanu et al. (2008) develop an option pricing model demonstrating that option demand pressure increases both option prices and implied volatility in proportion to the unhedgeable risk. Hence, the high-frequency demand is linearly related to changes in implied volatility, making implied volatility changes an ideal proxy for x_t. To sum up, we argue that the predictable reversals primarily arise from short-term end-users demand, which is effectively captured by the change in implied volatility.

4.1. Reversal Pattern in Delta Hedging Call and Put

The zero-delta straddle's dollar return is a linear combination of the dollar returns from delta-hedged calls and puts; likewise, its demand can be decomposed into call and put

demands. Hence, if our explanation holds, we should observe a significant reversal pattern in the dollar returns of delta-hedged calls and puts, as indicated by equation (5).

Table 6 presents the dollar returns from call delta-hedging, sorted by the previous half-hour returns. The spread dollar returns range from -$8.93 per contract to -$13.02 per contract during the intraday session, and -$27.39 per contract overnight. Returns for all time intervals are economically and statistically significant, with similar t-statistics. Thus, we also find strong evidence of intraday option reversals in delta-hedged call option returns.

Table 7 shows similar results for delta-hedged put options. Specifically, we show portfolio sorts based on the previous half-hour delta-hedged put option return. The spread dollar returns range from -$9.10 per contract to -$12.79 per contract during the intraday session, and -$29.24 per contract overnight. The returns for all time intervals are economically and statistically significant.

4.2. Demand-based Explanation

As discussed earlier, the demand for a zero-delta straddle can be captured by the sum of the changes in call and put implied volatility. In this section, we construct portfolios that are independently double-sorted by the changes in call and put implied volatility over the previous half-hour. Given the large number of firms, we focus on 3×3 portfolios. If our demand-based explanation holds, we expect the straddle portfolio with the smallest changes in both call and put implied volatilities to exhibit the highest returns over the next 30 minutes, while the portfolio with the largest changes in both call and put implied volatilities should show the lowest returns.

Table 8 provides strong evidence in support of our demand-based explanations. Panel A of Table 8 reports the average independent double-sorted zero-delta straddle returns across all 30-minute intervals in the sample. For each tertile of the change in call implied volatility, zero-delta straddle returns are highest for small changes in put volatility and lowest for large changes in put volatility. A similar pattern is observed for each tertile of

the change in put implied volatility. Average returns along the diagonal monotonically decrease from 2.65% to -1.57%, consistent with stronger reversal effects following higher volatility demand shocks. All these numbers are significantly different from zero.

Furthermore, we observe that changes in call volatility and put volatility are weakly correlated, as shown in Panel B of Table 8. According to put-call parity, the magnitude of volatility changes should be similar for call and put options on the same underlying asset, meaning most firms should fall into diagonal portfolios. However, the average number of firms in these 3×3 portfolios is relatively balanced, ranging from 52 to 103. This finding does not suggest that put-call parity fails to hold in the options market. On the contrary, we offer an alternative explanation related to the large bid-ask spreads in the options market, as discussed in Muravyev and Pearson (2020). Options market makers adjust the midpoints of call and put options based on demand. To prevent arbitrage opportunities, they must widen the bid-ask spread, thereby increasing transaction costs for arbitrageurs.

To further validate that our demand-based explanation holds across all time intervals, we report the returns for the three diagonal portfolios in each half-hour interval in Table 9. Consistent with our explanation, portfolios with small changes in volatility exhibit positive returns ranging from 1.54% to 4.23% during intraday periods and 8.85% overnight, whereas portfolios with large changes in volatility show negative returns across all intervals except 15:30-16:00. Moreover, the returns of the three diagonal portfolios decrease monotonically across all time intervals, and the spread returns range from -2.97% to -4.65% during intraday and -11.41% overnight. These spread returns are both economically and statistically significant, with similar t-statistics.

To confirm the robustness of our demand-based explanation, we employ an alternative proxy for short-term demand pressure, the change in the quoted spread. This measure is well-motivated, as shown by Stoll (1978) and Ho and Stoll (1981), market makers widen quoted spread when facing inventory imbalances to manage risk. Table 10 reports the returns of the three diagonal portfolios obtained from the independent double-sorting on

call ATM dollar quoted spread and put ATM dollar quoted spread across all half-hour intervals. Consistent with the patterns observed using change in implied volatility, the returns of the three diagonal portfolios decrease monotonically across all time intervals. The spread returns are significantly negative, ranging from -0.47% to -1.54% during intraday periods and -3.98% overnight, with similar t-statistics.

We also examine whether the straddle reversal is driven by movements in the underlying stock. Our demand-based explanation suggests that options market makers adjust quotes in response to the demand for specific contracts. When calls and puts experience similar directional demand (both being bought or sold), it implies that investors lack a strong directional view on the underlying asset. In such cases, the corresponding order flows generate a net-zero delta for market makers, resulting in no significant abnormal returns for the underlying stock.

In contrast, if order flows indicate a substantial demand for buying calls and selling puts, this is typically reflected in a marked increase in call implied volatility, accompanied by a smaller change in put implied volatility. Such a pattern suggests a potential short-term increase in the underlying stock's value. Conversely, larger order flows favoring selling calls and buying puts lead to a modest change in call implied volatility and a more pronounced increase in put implied volatility, signaling a potential short-term decrease in the underlying stock.

To test these hypotheses, we conduct the same independent double-sorting procedure as before but construct portfolios based on the underlying asset rather than the zero-delta straddle. As previously discussed, if our demand-based explanation holds, we should not observe significant abnormal returns in these portfolios. Table 11 reports the average returns for the resulting 3×3 underlying portfolios.

The results confirm our expectations. The portfolio with small changes in volatility yields a return of –0.34 basis points over the next half-hour, while the portfolio with large changes in volatility generates 0.06 basis points. Both are statistically insignificant, with t-statistics below one. The spread portfolio, defined as the return difference between large

and small volatility changes, shows a positive and marginally significant return of 0.40 basis points ($t = 2.08$).

Within each tertile of call volatility changes, returns decrease as put volatility changes become larger. This pattern suggests that increased buying of put options induces market makers to raise put implied volatilities, resulting in a negative relationship between put volatility changes and subsequent underlying returns. Conversely, within each tertile of put volatility changes, returns increase with the magnitude of call volatility changes, consistent with stronger call buying pressure predicting short-term positive moves in the underlying asset.

Finally, the off-diagonal spread portfolio—long the portfolio with large call and small put volatility changes and short the portfolio with small call and large put volatility changes—produces a return of 1.69 basis points with a t-statistic of 7.46. This finding reinforces that directional demand asymmetries between calls and puts are informative about short-term underlying price movements, whereas symmetric demand shocks (affecting both equally) primarily drive the observed reversals in option returns.

Overall, these findings confirm that the observed intraday reversals arise from demand imbalances in the options market, rather than from contemporaneous movements in the underlying asset. This evidence reinforces our interpretation that short-term end-user demand pressure, rather than fundamental news, drives predictable reversals in option returns.

5. Robustness

To ensure the robustness of our findings, we systematically exclude dates surrounding Federal Open Market Committee (FOMC) meetings, earnings announcements, option expiration dates, and the onset of the COVID-19 pandemic. This approach helps eliminate potential distortions in market dynamics, resulting in consistent and statistically significant results.

FOMC Meetings. To confirm the robustness of our findings, we exclude Federal Open Market Committee (FOMC) meeting dates from our sample.[2] These meetings often result in significant market activity as investors adjust their portfolios in anticipation of potential policy announcements, which could influence our results.

Table 12 reports cross-sectional regressions of half-hour straddle returns on prior half-hour returns, controlling for various factors. The results remain robust and consistent, with no material changes in the magnitude or significance of our key coefficients. Notably, the return reversal observed in the 14:00–14:30 window persists with strong statistical significance, confirming that the performance of our strategy is not driven by FOMC-related trading patterns.

COVID Period. We further exclude March 2020, the onset of the COVID-19 pandemic, to address the heightened market volatility and surge in retail trading activity during this period. These factors could potentially distort our findings. As shown in Table A1 of the Internet Appendix, our results remain consistent when March 2020 is excluded.[3]

Option Expiration Dates. The expiration of options is commonly linked to increased volatility. To examine whether our findings are affected by the near-expiration effect, we exclude all expiration dates from the analysis. Table A2 in the Internet Appendix presents cross-sectional regressions of half-hour returns on the preceding half-hour return, along with a set of controls. Our results remain consistent even after excluding expiration dates.

Earnings Announcements. We investigate whether our results are driven by earnings announcements. To address this, we exclude all earnings announcement days from our sample. Table A3 in the Internet Appendix presents cross-sectional regressions of half-hour returns on the previous half-hour return, along with a set of controls. Notably, we

[2]The complete list of FOMC dates is publicly available at https://www.federalreserve.gov/monetarypolicy/fomc_historical_year.htm. We exclude the dates of the scheduled, canceled and unscheduled meetings.

[3]The results also remain robust when we exclude the months of March, April, and May 2020.

observe that the coefficient for the half-hour return from 15:30 to 16:00 of the previous day is positive but not statistically significant. This finding suggests that the momentum observed from 10:00 to 10:30 is largely driven by earnings announcements. Moreover, we find that our reversal strategy remains highly positive and statistically significant. Specifically, the coefficients for all other hours remain negative and statistically significant, highlighting the robustness of our results.

Trading Volume. While implied volatility changes provide our primary measure of demand pressure, we also examine whether option volume—a simpler measure of trading intensity—exhibits patterns consistent with our demand-based framework. Table B4 presents zero-delta straddle returns sorted by previous half-hour option volume. Specifically, we construct quintile portfolios at the start of each 30-minute holding period based on stock options volume from the preceding half-hour.

The results support our theoretical predictions. The HML portfolio (high minus low volume) generates significantly negative returns across most time intervals, ranging from -0.18% to -0.34% during regular trading hours, with the strongest reversals occurring at market close (-3.04%, t-statistic $= -9.74$) and overnight (-5.44%, t-statistic $= -9.38$). Ten out of 13 time periods exhibit statistically significant negative spreads.

This pattern aligns with our model's inventory risk mechanism from Equation (5). High volume periods likely coincide with larger absolute demand imbalances $|x_t|$ that market makers must absorb. According to our framework, when market makers hold larger inventory positions (regardless of direction), they require greater compensation, leading to stronger reversals captured by the term $-\left(\frac{1}{\gamma}\right) x_t$. However, since volume is an unsigned measure, it cannot distinguish between buying and selling pressure, making it a coarser proxy than implied volatility changes. Nevertheless, these results provide complementary evidence that trading intensity—a correlate of demand shocks—predicts subsequent option return reversals consistent with inventory-based pricing.

We do not use signed volume as a demand measure due to severe trade direction misclassification in our sample period. After 2020, retail option trading accounts for

over 60% of total market volume (Bryzgalova et al., 2023), and wholesalers frequently offer prices better than the midpoint through competitive auctions. Gao et al. (2025) show that the standard midpoint rule correctly identifies trade direction only 55.82% of the time in recent data—barely better than random. This measurement error reinforces our choice to use implied volatility changes, which directly reflect market maker quote adjustments without requiring trade classification.

Transaction Costs. The results presented so far are based on returns computed using mid-point prices. Trading at this price, however, may not always be feasible due to liquidity constraints (Ofek, Richardson, and Whitelaw, 2004; Muravyev and Pearson, 2020). To examine the impact of transaction costs, Table 13 reports reversal profits under effective spreads set at 25%, 50%, 75%, and 100% of the quoted spread, following Goyal and Saretto (2009). As expected, reversal profits decline as transaction costs increase: the average half-hour return falls from –3.92% (from 10:30 to 16:00) when trading at the mid-point to –1.15% at the worst quoted price. Nevertheless, most half-hour returns remain statistically significant at the 0.01 level. In particular, under the 75% spread scenario, all twelve half-hour periods yield significant returns at the 0.01 level, while under the 100% spread scenario, significance emerges starting at 11:30. Overall, these results suggest that intraday reversals are not solely an artifact of trading at mid-quote prices and remain economically meaningful even after accounting for transaction costs.

6. Conclusion

This paper contributes to the literature on intraday option return dynamics by uncovering the first significant reversal pattern throughout the trading day. Focusing on zero-delta straddle portfolios of at-the-money options, we document that buying past half-hour losers and selling past winners generates Sharpe ratios ranging from 0.83 to 1.83 across most 30-minute intervals. These reversals remain robust after controlling for transaction costs, implied volatility fluctuations, and various market conditions.

We trace these reversals to demand-based pricing mechanisms by integrating the stock market reversal framework of Nagel (2012) with the demand-driven option pricing approach of Garleanu et al. (2008). Our theoretical model identifies market maker inventory risk as the primary driver: when liquidity traders generate demand imbalances, market makers absorb these positions and subsequently earn compensation as prices revert. We validate this mechanism using three independent demand proxies. Portfolios double-sorted by changes in call and put implied volatility exhibit monotonically decreasing returns from 2.65% to -1.57%, confirming that symmetric demand shocks drive option reversals without affecting underlying stock prices. Alternative proxies based on quoted bid-ask spreads and trading volume produce qualitatively similar patterns, with spread returns ranging from -0.47% to -1.54% intraday (spreads) and -0.18% to -0.34% (volume), strengthening to -3.98% and -5.44% overnight, respectively. The convergence of these distinct measures provides compelling evidence that short-term demand pressure, rather than information or mechanical effects, drives predictable reversals in option returns. Results remain robust when excluding FOMC meetings, earnings announcements, option expirations, and the COVID-19 period.

Our findings uncover economically significant, exploitable patterns that yield substantial risk-adjusted returns, showing that inventory-based pricing remains a key driver of short-horizon option returns. The documented asymmetries—where symmetric demand shocks reverse in options but not in underlying stocks, while directional shocks forecast underlying returns—shed new light on how demand pressure transmits across interconnected securities. These results deepen our understanding of market microstructure and high-frequency dynamics in derivative markets, highlighting that even in highly liquid settings, short-term frictions and inventory adjustments play a central role in shaping return predictability and cross-asset linkages.

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Table 1: **Average Return of Zero-Delta Straddle Portfolios Sorted by Previous Half-Hour Zero-Delta Straddle Return**

This table presents the average returns of portfolios sorted by zero-delta straddle performance. These 30-minute portfolios are constructed according to the zero-delta straddle returns from previous half-hour zero-delta straddle returns. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the performance from the previous trading day's 15:30 to market close. Panel A reports the percentage return, Panel B reports the dollar returns expressed in dollars per contract. The adjusted t-statistics, as described by Newey and West (1987), are reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Low	2	3	4	High	HML	t-stat
Panel A: Results for Percentage Returns (Unit: %)							
10:00-10:30	1.91	0.77	1.10	1.21	4.37	2.49***	(8.44)
10:30-11:00	2.32	0.25	-0.01	-0.40	-2.13	-4.44***	(-11.11)
11:00-11:30	1.98	0.26	-0.02	-0.25	-1.57	-3.56***	(-11.54)
11:30-12:00	2.05	0.20	-0.05	-0.28	-1.62	-3.67***	(-11.51)
12:00-12:30	2.09	0.26	0.03	-0.19	-1.61	-3.70***	(-11.44)
12:30-13:00	2.32	0.40	0.19	-0.04	-1.27	-3.59***	(-10.90)
13:00-13:30	2.10	0.26	-0.01	-0.23	-1.57	-3.67***	(-11.09)
13:30-14:00	3.00	0.56	0.51	0.20	-0.84	-3.84***	(-11.28)
14:00-14:30	2.51	0.33	0.04	-0.35	-2.44	-4.96***	(-11.02)
14:30-15:00	1.97	0.22	0.02	-0.20	-1.55	-3.53***	(-11.40)
15:00-15:30	2.08	0.24	0.11	-0.20	-1.61	-3.70***	(-11.37)
15:30-16:00	5.17	1.31	1.19	1.14	0.67	-4.50***	(-10.94)
Panel B: Results for Dollar Returns (Unit: $/contract)							
10:00-10:30	8.19	1.82	1.64	2.85	22.32	14.26***	(3.93)
10:30-11:00	5.58	0.18	-0.29	-0.82	-10.22	-15.80***	(-9.28)
11:00-11:30	4.26	0.33	-0.06	-0.60	-7.47	-11.73***	(-10.15)
11:30-12:00	4.20	0.19	-0.34	-0.73	-7.43	-11.63***	(-10.24)
12:00-12:30	5.24	0.37	0.08	-0.50	-6.98	-12.23***	(-9.92)
12:30-13:00	5.67	0.78	0.26	-0.01	-6.08	-11.75***	(-10.44)
13:00-13:30	5.32	0.39	-0.22	-0.77	-6.55	-11.87***	(-8.51)
13:30-14:00	10.42	1.19	0.53	0.20	-4.55	-14.97***	(-6.61)
14:00-14:30	33.67	0.62	0.02	-0.87	-10.61	-44.34*	(-1.68)
14:30-15:00	5.50	0.50	0.01	-0.47	-7.30	-12.85***	(-10.45)
15:00-15:30	6.36	0.36	0.00	-0.65	-7.01	-13.41***	(-9.31)
15:30-16:00	21.76	2.93	1.76	1.65	8.59	-13.12***	(-3.59)

Table 2: **Cross-sectional Regressions: Intraday Option Reversals**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in percentages. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.013**						
	(2.16)						
$r_{10:00-10:30,t}$		-0.195***					
		(-33.50)					
$r_{10:30-11:00,t}$			-0.206***				
			(-39.05)				
$r_{11:00-11:30,t}$				-0.256***			
				(-40.21)			
$r_{11:30-12:00,t}$					-0.270***		
					(-44.26)		
$r_{12:00-12:30,t}$						-0.279***	
						(-29.13)	
$r_{12:30-13:00,t}$							-0.282***
							(-46.84)
constant	0.014***	0.004***	0.005***	0.004***	0.004***	0.007**	0.004***
	(12.14)	(2.62)	(6.65)	(6.48)	(7.94)	(2.25)	(9.18)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.058	0.102	0.096	0.109	0.112	0.111	0.112

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.296***					
	(-29.18)					
$r_{13:30-14:00,t}$		-0.291***				
		(-43.08)				
$r_{14:00-14:30,t}$			-0.268***			
			(-46.03)			
$r_{14:30-15:00,t}$				-0.293***		
				(-36.11)		
$r_{15:00-15:30,t}$					-0.350***	
					(-21.72)	
$r_{15:30-16:00,t}$						-0.381***
						(-30.41)
constant	0.011***	0.004***	0.003***	0.004***	0.018***	0.052***
	(8.67)	(6.97)	(6.49)	(5.88)	(9.70)	(10.76)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.114	0.142	0.114	0.121	0.059	0.063

Table 3: **Average Return of Zero-Delta Straddle Portfolios Sorted by Overnight Zero-Delta Straddle Return**

This table presents the average returns of portfolios sorted by zero-delta straddle performance. These 30-minute portfolios are constructed according to the zero-delta straddle returns from the last overnight zero-delta straddle returns. The returns are expressed in percentages. The adjusted t-statistics, as described by Newey and West (1987), are reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Low	2	3	4	High	HML	t-stat
10:00-10:30	1.75	0.04	-0.11	-0.48	-1.94	-3.69***	(-10.67)
10:30-11:00	0.36	-0.06	0.06	-0.08	-0.26	-0.62***	(-7.01)
11:00-11:30	0.26	0.01	-0.03	0.04	0.07	-0.19***	(-3.14)
11:30-12:00	0.22	-0.06	-0.02	0.02	0.12	-0.11**	(-2.05)
12:00-12:30	0.29	-0.02	0.03	0.08	0.20	-0.08	(-0.97)
12:30-13:00	0.46	0.17	0.20	0.23	0.53	0.07	(0.81)
13:00-13:30	0.22	0.02	0.02	0.05	0.22	0.00	(-0.01)
13:30-14:00	1.07	0.38	0.38	0.54	1.08	0.01	(0.10)
14:00-14:30	0.04	-0.07	-0.01	0.01	0.08	0.04	(0.83)
14:30-15:00	0.15	0.02	0.02	0.06	0.20	0.05	(1.03)
15:00-15:30	0.19	0.02	0.04	0.05	0.26	0.07	(1.03)
15:30-16:00	3.14	1.15	1.01	1.23	2.70	-0.44**	(-2.55)
16:00-(N)10:00	4.16	1.87	1.82	2.27	5.46	1.29***	(3.02)

Table 4: **Cross-sectional Regressions: Intraday and Overnight Option Reversals**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{16:00-(N)10:00,t-1:t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. The return is measured in dollars per contract. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{16:00-(N)10:00,t-1:t}$	-0.051***	-0.008***	-0.003***	0.000	-0.001	0.003	0.004***
	(-25.87)	(-4.59)	(-2.69)	(0.05)	(-0.41)	(1.59)	(3.06)
constant	0.012***	0.008***	0.007***	0.006***	0.006***	0.009***	0.006***
	(11.23)	(6.05)	(9.41)	(9.40)	(10.33)	(2.77)	(12.67)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.067	0.045	0.041	0.037	0.038	0.034	0.036

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{16:00-(N)10:00,t-1:t}$	0.006**	0.003**	0.003**	0.006	0.003	0.060***
	(1.98)	(2.15)	(2.49)	(1.09)	(0.97)	(6.83)
constant	0.012***	0.008***	0.005***	0.006***	0.021***	0.059***
	(10.15)	(12.38)	(9.12)	(9.86)	(11.44)	(12.17)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.035	0.041	0.036	0.035	0.036	0.048

Table 5: **Cross-sectional Regressions: Intraday Option Reversals and Seasonality**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 r_{hh,i,t-1} + \beta_3 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t and $r_{hh,i,t-1}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day $t-1$. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in dollars per contract. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.013**						
	(2.20)						
$r_{10:00-10:30,t-1}$	0.017***						
	(3.73)						
$r_{10:00-10:30,t}$		-0.193***					
		(-33.46)					
$r_{10:30-11:00,t-1}$		0.001					
		(0.16)					
$r_{10:30-11:00,t}$			-0.204***				
			(-39.87)				
$r_{11:00-11:30,t-1}$			0.002				
			(0.46)				
$r_{11:00-11:30,t}$				-0.256***			
				(-41.86)			
$r_{11:30-12:00,t-1}$				0.011			
				(1.40)			
$r_{11:30-12:00,t}$					-0.269***		
					(-45.40)		
$r_{12:00-12:30,t-1}$					0.008		
					(1.40)		
$r_{12:00-12:30,t}$						-0.278***	
						(-29.93)	
$r_{12:30-13:00,t-1}$						0.006	
						(1.25)	
$r_{12:30-13:00,t}$							-0.282***
							(-47.72)
$r_{13:00-13:30,t-1}$							0.014**
							(2.14)
constant	0.014***	0.004***	0.005***	0.004***	0.004***	0.007**	0.004***
	(12.34)	(2.71)	(6.68)	(6.21)	(7.83)	(2.24)	(9.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.068	0.112	0.106	0.119	0.122	0.122	0.123

Table 5: **Cross-sectional Regressions: Intraday Option Reversals and Seasonality** (Continued)

Panel B: Late Hours						
Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.299***					
	(-29.99)					
$r_{13:30-14:00,t-1}$	-0.014					
	(-0.82)					
$r_{13:30-14:00,t}$		-0.292***				
		(-43.90)				
$r_{14:00-14:30,t-1}$		0.003				
		(0.74)				
$r_{14:00-14:30,t}$			-0.269***			
			(-46.30)			
$r_{14:30-15:00,t-1}$			0.002			
			(0.53)			
$r_{14:30-15:00,t}$				-0.291***		
				(-45.63)		
$r_{15:00-15:30,t-1}$				0.004		
				(0.54)		
$r_{15:00-15:30,t}$					-0.357***	
					(-22.94)	
$r_{15:30-16:00,t-1}$					0.163***	
					(12.55)	
$r_{15:30-16:00,t}$						-0.382***
						(-32.96)
$r_{16:00-(N)10:00,t-1:t}$						0.058***
						(6.59)
constant	0.010***	0.004***	0.003***	0.004***	0.018***	0.051***
	(8.55)	(6.93)	(6.43)	(6.32)	(10.29)	(11.12)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.124	0.151	0.123	0.130	0.105	0.084

Table 6: **Average Dollar Returns of Call Delta-Hedging Portfolios Sorted by Previous Half-Hour Call Delta-Hedging Returns**

This table presents the average returns of portfolios sorted by call delta-hedging performance. These 30-minute portfolios are constructed according to the call delta-hedging returns from the preceding half-hour at the start of the holding period. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the overnight performance from the last market close until 10:00 of the current day. For the portfolio maintained from 16:00 to (N)10:00, we base the construction on performance recorded between 15:30 and 16:00. The return is measured in dollars per contract. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Low	2	3	4	High	HML	t-stat
10:00-10:30	3.22	0.07	-0.29	-0.98	-5.71	-8.93***	(-10.75)
10:30-11:00	5.50	0.58	-0.03	-0.84	-7.51	-13.02***	(-10.82)
11:00-11:30	4.65	0.58	-0.01	-0.62	-5.69	-10.34***	(-10.71)
11:30-12:00	4.53	0.44	-0.08	-0.65	-5.73	-10.26***	(-10.73)
12:00-12:30	5.02	0.55	0.02	-0.52	-5.42	-10.44***	(-10.78)
12:30-13:00	4.67	0.49	0.00	-0.49	-5.28	-9.95***	(-10.91)
13:00-13:30	5.16	0.60	0.03	-0.40	-4.71	-9.87***	(-10.73)
13:30-14:00	5.73	0.81	0.24	-0.17	-4.82	-10.56***	(-10.71)
14:00-14:30	5.66	0.60	0.00	-0.62	-6.90	-12.56***	(-10.84)
14:30-15:00	4.62	0.50	-0.02	-0.52	-4.94	-9.57***	(-10.33)
15:00-15:30	4.78	0.37	0.00	-0.44	-4.92	-9.71***	(-10.47)
15:30-16:00	6.92	1.48	0.63	0.38	-3.22	-10.14***	(-10.63)
16:00-(N)10:00	13.78	2.67	1.06	-0.01	-13.61	-27.39***	(-10.35)

Table 7: **Average Dollar Return of Put Delta-Hedging Portfolios Sorted by Previous Half-Hour Put Delta-Hedging Return**

This table presents the average returns of portfolios sorted by put delta-hedging performance. These 30-minute portfolios are constructed according to the put delta-hedging returns from the preceding half-hour at the start of the holding period. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the overnight performance from the last market close until 10:00 of the current day. For the portfolio maintained from 16:00 to (N)10:00, we base the construction on performance recorded between 15:30 and 16:00. The return is measured in dollars per contract. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Low	2	3	4	High	HML	t-stat
10:00-10:30	1.87	-0.19	-0.51	-1.41	-7.22	-9.10***	(-10.65)
10:30-11:00	5.50	0.64	-0.03	-0.70	-7.13	-12.63***	(-10.82)
11:00-11:30	4.68	0.58	0.03	-0.48	-5.43	-10.11***	(-10.74)
11:30-12:00	4.51	0.49	-0.04	-0.57	-5.90	-10.41***	(-10.83)
12:00-12:30	4.83	0.58	-0.02	-0.52	-5.67	-10.50***	(-10.71)
12:30-13:00	4.81	0.62	0.03	-0.45	-5.13	-9.94***	(-10.87)
13:00-13:30	4.20	0.49	-0.03	-0.64	-5.39	-9.59***	(-10.63)
13:30-14:00	5.94	0.87	0.30	-0.17	-4.85	-10.79***	(-10.22)
14:00-14:30	5.84	0.65	0.03	-0.60	-6.95	-12.79***	(-10.76)
14:30-15:00	4.44	0.56	0.02	-0.45	-5.50	-9.93***	(-10.48)
15:00-15:30	4.47	0.42	-0.03	-0.47	-5.36	-9.82***	(-10.74)
15:30-16:00	7.08	1.70	0.87	0.58	-3.13	-10.21***	(-10.49)
16:00-(N)10:00	16.95	3.28	1.53	1.05	-12.29	-29.24***	(-10.09)

Table 8: **Average Return of Zero Delta Straddle Independent Double-Sorted Portfolios**

This table presents the average returns of 3×3 independent double-sorted portfolios. These 30-minute portfolios are constructed independently sorted by the change of call ATM implied volatility and put ATM implied volatility from the preceding half-hour at the start of the holding period. The average return is expressed as a percentage and calculated across all 30-minute portfolios in the sample. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Zero-Delta Straddle Average Returns (Unit:%)

	Put Small	Put Medium	Put Large
Call Small	2.65***	1.22***	0.49***
	(22.67)	(18.56)	(8.23)
Call Medium	1.30***	0.33***	-0.36***
	(18.72)	(9.33)	(-8.88)
Call Large	0.73***	-0.18***	-1.57***
	(9.67)	(-4.16)	(-24.37)

Panel B: Average Number of Firms in Portfolios

	Put Small	Put Medium	Put Large
Call Small	89	52	74
Call Medium	52	103	58
Call Large	74	57	87

Table 9: **Average Return of Independent Double-sorted Zero-Delta Straddle Portfolios**

This table presents the average returns of the diagonal portfolios among 3×3 independent double-sorted portfolios. These 30-minute portfolios are constructed independently sorted by the change of call ATM implied volatility and put ATM implied volatility from the preceding half-hour at the start of the holding period. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the overnight performance from the last market close until 10:00 of the current day. For the portfolio maintained from 16:00 to (N)10:00, we base the construction on performance recorded between 15:30 and 16:00. 'Small', 'Medium' and 'Large' represent the portfolios corresponding to small, medium and large changes of volatility for both call and put options, respectively. The return is measured in percentage. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Small	Medium	Large	LMS	t-stat
10:00-10:30	1.54	-0.38	-1.43	-2.97***	(-10.02)
10:30-11:00	2.17	0.09	-2.27	-4.44***	(-11.04)
11:00-11:30	1.70	0.08	-1.70	-3.40***	(-11.46)
11:30-12:00	1.78	-0.03	-1.69	-3.47***	(-11.41)
12:00-12:30	1.85	0.16	-1.64	-3.47***	(-11.38)
12:30-13:00	2.14	0.20	-1.32	-3.46***	(-10.39)
13:00-13:30	1.84	0.05	-1.54	-3.42***	(-11.55)
13:30-14:00	2.52	0.43	-1.01	-3.53***	(-11.23)
14:00-14:30	2.31	0.07	-2.33	-4.65***	(-11.06)
14:30-15:00	1.74	0.04	-1.55	-3.30***	(-11.31)
15:00-15:30	1.85	0.10	-1.65	-3.50***	(-11.34)
15:30-16:00	4.23	1.24	0.24	-3.99***	(-10.65)
16:00-(N)10:00	8.85	2.25	-2.55	-11.41***	(-10.38)

Table 10: **Independent Double-sorting on Option Dollar Quoted Spread**

This table presents the average returns of the diagonal portfolios among 3×3 independent double-sorted portfolios. These 30-minute portfolios are constructed independently sorted by the change of call ATM dollar quoted spread and put ATM dollar quoted spread from the preceding half-hour at the start of the holding period. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the overnight performance from the last market close until 10:00 of the current day. For the portfolio maintained from 16:00 to (N)10:00, we base the construction on performance recorded between 15:30 and 16:00. 'Small', 'Medium' and 'Large' represent the portfolios corresponding to small, medium and large changes of volatility for both call and put options, respectively. The return is measured in percentage. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Small	Medium	Large	LMS	t-stat
10:00-10:30	0.45	0.18	-1.09	-1.54***	(-9.10)
10:30-11:00	0.12	0.12	-0.35	-0.47***	(-4.91)
11:00-11:30	0.34	0.10	-0.28	-0.62***	(-8.67)
11:30-12:00	0.42	0.17	-0.34	-0.76***	(-9.24)
12:00-12:30	0.46	0.13	-0.22	-0.68***	(-8.28)
12:30-13:00	0.58	0.54	-0.17	-0.75***	(-8.75)
13:00-13:30	0.46	0.16	-0.29	-0.75***	(-7.71)
13:30-14:00	0.88	1.10	0.32	-0.56***	(-6.07)
14:00-14:30	0.52	0.08	-0.55	-1.07***	(-8.86)
14:30-15:00	0.41	0.15	-0.27	-0.68***	(-8.70)
15:00-15:30	0.43	0.15	-0.25	-0.68***	(-8.49)
15:30-16:00	2.28	1.66	1.53	-0.74***	(-6.16)
16:00-(N)10:00	4.73	3.45	0.74	-3.98***	(-7.95)

Table 11: **Average Underlying Return of Independent Double-Sorted Portfolios**

This table presents the average returns of 3×3 independent double-sorted portfolios. These 30-minute portfolios are constructed independently sorted by the change of call ATM implied volatility and put ATM implied volatility from the preceding half-hour at the start of the holding period. The average underlying return is of unit of basis points. percentage and calculated across all 30-minute portfolios in the sample. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

	Put Small	Put Medium	Put Large
Call Small	-0.34	-0.41	-0.82
	(-0.60)	(-0.82)	(-1.39)
Call Medium	0.23	0.20	-0.24
	(0.48)	(0.47)	(-0.50)
Call Large	0.85	0.70	0.06
	(1.47)	(1.41)	(0.11)

Table 12: **Cross-sectional Regressions: Intraday Option Reversals excluding FOMC Meetings**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. We have eliminated all FOMC meetings. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in percentages. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.016**						
	(2.51)						
$r_{10:00-10:30,t}$		-0.194***					
		(-31.61)					
$r_{10:30-11:00,t}$			-0.205***				
			(-38.73)				
$r_{11:00-11:30,t}$				-0.257***			
				(-37.89)			
$r_{11:30-12:00,t}$					-0.271***		
					(-42.15)		
$r_{12:00-12:30,t}$						-0.276***	
						(-30.16)	
$r_{12:30-13:00,t}$							-0.282***
							(-45.34)
constant	0.014***	0.003**	0.005***	0.004***	0.004***	0.004***	0.004***
	(11.74)	(2.17)	(6.27)	(6.31)	(7.56)	(7.18)	(8.76)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.060	0.101	0.096	0.109	0.112	0.111	0.113

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.287***					
	(-33.17)					
$r_{13:30-14:00,t}$		-0.296***				
		(-42.61)				
$r_{14:00-14:30,t}$			-0.274***			
			(-45.66)			
$r_{14:30-15:00,t}$				-0.299***		
				(-35.09)		
$r_{15:00-15:30,t}$					-0.350***	
					(-20.64)	
$r_{15:30-16:00,t}$						-0.380***
						(-29.92)
constant	0.006***	0.004***	0.003***	0.003***	0.018***	0.050***
	(8.21)	(6.90)	(5.78)	(5.54)	(9.76)	(9.74)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.115	0.137	0.115	0.122	0.059	0.064

Table 13: **Average Return of Spread Portfolios Sorted Zero-Delta Straddle Portfolios**

This table presents the average returns of spread portfolios sorted by zero-delta straddle performance. These 30-minute portfolios are constructed according to the zero-delta straddle returns from previous half-hour zero-delta straddle returns. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the performance from the previous trading day's 15:30 to market close. The spread portfolio returns are calculated as the difference between the high and low zero-delta straddle portfolios, expressed as a percentage. These returns are computed from the mid-point price (MidP) and from the effective bid–ask spread (ESPR), estimated to be equal to 25%, 50%, 75%, and 100% of the quoted spread (QSPR). The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

			ESPR/QSPR							
Holding Period	MidP		25%		50%		75%		100%	
10:00-10:30	2.49***	(8.44)	1.21***	(6.93)	0.18	(1.44)	-0.68***	(-4.63)	-1.42***	(-7.02)
10:30-11:00	-4.44***	(-11.11)	-2.96***	(-10.83)	-1.84***	(-9.43)	-0.96***	(-6.05)	-0.24	(-1.56)
11:00-11:30	-3.56***	(-11.54)	-2.39***	(-11.13)	-1.51***	(-9.28)	-0.82***	(-5.63)	-0.25*	(-1.67)
11:30-12:00	-3.67***	(-11.51)	-2.72***	(-11.40)	-1.99***	(-10.49)	-1.42***	(-8.56)	-0.95***	(-5.96)
12:00-12:30	-3.70***	(-11.44)	-2.87***	(-11.35)	-2.23***	(-10.92)	-1.72***	(-10.00)	-1.29***	(-8.48)
12:30-13:00	-3.59***	(-10.90)	-2.76***	(-11.17)	-2.12***	(-10.69)	-1.62***	(-9.37)	-1.20***	(-7.42)
13:00-13:30	-3.67***	(-11.09)	-2.76***	(-11.14)	-2.05***	(-10.69)	-1.47***	(-9.37)	-0.98***	(-7.03)
13:30-14:00	-3.84***	(-11.28)	-2.99***	(-11.37)	-2.32***	(-11.12)	-1.78***	(-10.28)	-1.32***	(-8.68)
14:00-14:30	-4.96***	(-11.02)	-4.18***	(-10.72)	-3.54***	(-10.23)	-3.00***	(-9.59)	-2.53***	(-8.79)
14:30-15:00	-3.53***	(-11.40)	-2.70***	(-11.34)	-2.04***	(-10.83)	-1.51***	(-9.65)	-1.06***	(-7.66)
15:00-15:30	-3.70***	(-11.37)	-2.91***	(-11.31)	-2.29***	(-10.91)	-1.78***	(-10.03)	-1.36***	(-8.57)
15:30-16:00	-4.50***	(-10.94)	-3.48***	(-11.09)	-2.66***	(-10.96)	-1.99***	(-10.24)	-1.42***	(-8.60)

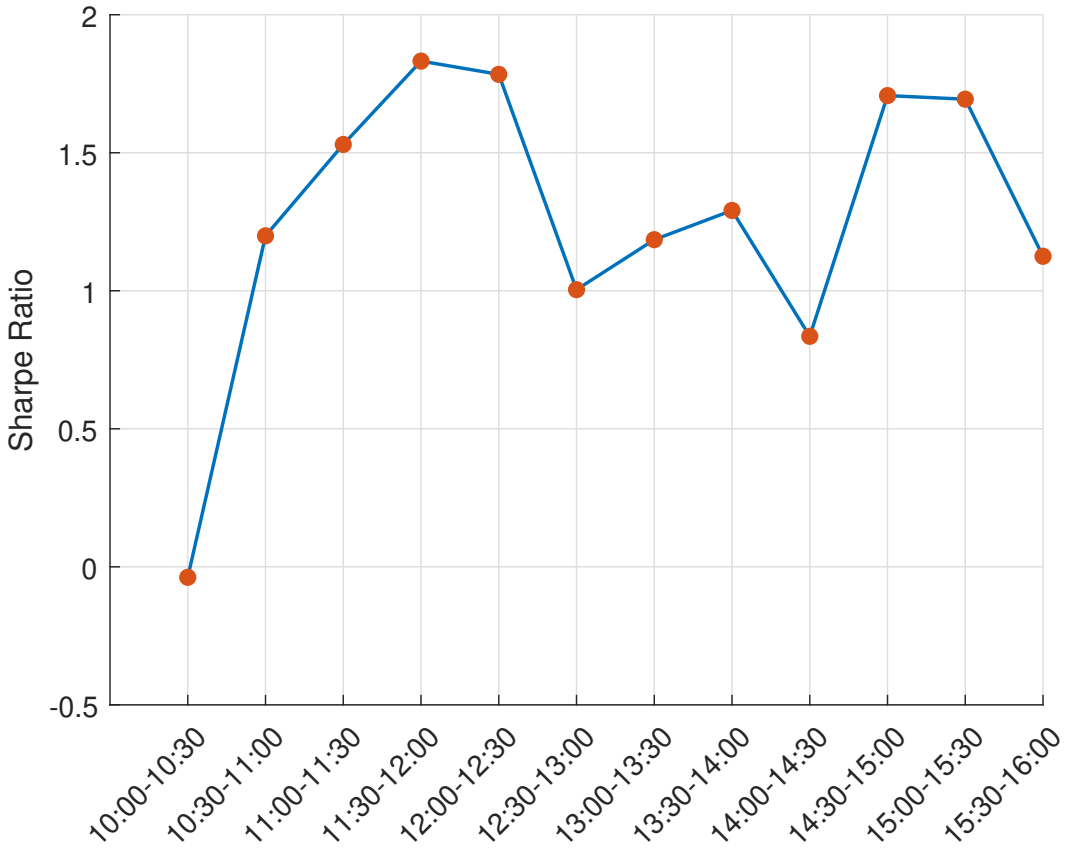


Fig. 1. Sharpe Ratios

The figure presents Sharpe ratios (with an opposite sign) of portfolios sorted by zero-delta straddle performance. These 30-minute portfolios are constructed according to the zero-delta straddle returns from previous half-hour zero-delta straddle returns. For the portfolio held between 10:00 and 10:30, we construct these portfolios considering the performance from the previous trading day's 15:30 to market close.The data spans from January 2020 to December 2023.

Internet Appendix for

"Intraday Option Reversals: Return Predictability and Market Efficiency"

Not for Publication

Appendix A. Excluding High-Volatility and Event-Driven Days

In this section, we show results for cross-sectional regressions that exclude days with high volatility. Specifically, we exclude March 2020 which is the start date of COVID. We also eliminate earnings announcement dates. We also present results that exclude expiration days.

Table A1: **Cross-sectional Regressions: Intraday Option Reversals excluding COVID Period**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. We have eliminated March 2020 which corresponds to the start of the Covid period. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in percentages. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.015**						
	(2.37)						
$r_{10:00-10:30,t}$		-0.196***					
		(-33.00)					
$r_{10:30-11:00,t}$			-0.207***				
			(-38.84)				
$r_{11:00-11:30,t}$				-0.257***			
				(-39.81)			
$r_{11:30-12:00,t}$					-0.271***		
					(-43.61)		
$r_{12:00-12:30,t}$						-0.276***	
						(-31.29)	
$r_{12:30-13:00,t}$							-0.284***
							(-47.03)
constant	0.014***	0.004**	0.004***	0.003***	0.004***	0.004***	0.004***
	(12.07)	(2.43)	(7.44)	(8.06)	(8.09)	(8.25)	(9.44)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.058	0.102	0.097	0.110	0.112	0.111	0.113

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.297***					
	(-28.63)					
$r_{13:30-14:00,t}$		-0.293***				
		(-42.84)				
$r_{14:00-14:30,t}$			-0.268***			
			(-45.87)			
$r_{14:30-15:00,t}$				-0.295***		
				(-35.87)		
$r_{15:00-15:30,t}$					-0.353***	
					(-21.59)	
$r_{15:30-16:00,t}$						-0.382***
						(-29.86)
constant	0.010***	0.004***	0.003***	0.003***	0.016***	0.047***
	(8.34)	(6.82)	(6.11)	(5.59)	(11.14)	(12.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.113	0.143	0.115	0.121	0.059	0.062

Table A2: **Cross-sectional Regressions: Intraday Option Reversals excluding Expiration Dates**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. We have eliminated all the expiration dates of the options. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in percentages. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.021**						
	(2.01)						
$r_{10:00-10:30,t}$		-0.181***					
		(-27.83)					
$r_{10:30-11:00,t}$			-0.202***				
			(-23.48)				
$r_{11:00-11:30,t}$				-0.243***			
				(-20.55)			
$r_{11:30-12:00,t}$					-0.257***		
					(-30.73)		
$r_{12:00-12:30,t}$						-0.264***	
						(-16.60)	
$r_{12:30-13:00,t}$							-0.268***
							(-34.82)
constant	0.019***	0.009***	0.009***	0.007***	0.006***	0.014*	0.006***
	(7.80)	(5.73)	(5.71)	(5.16)	(5.95)	(1.72)	(6.45)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.061	0.100	0.089	0.102	0.107	0.099	0.109

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.286***					
	(-19.53)					
$r_{13:30-14:00,t}$		-0.289***				
		(-33.58)				
$r_{14:00-14:30,t}$			-0.261***			
			(-24.23)			
$r_{14:30-15:00,t}$				-0.286***		
				(-26.98)		
$r_{15:00-15:30,t}$					-0.351***	
					(-12.36)	
$r_{15:30-16:00,t}$						-0.401***
						(-26.09)
constant	0.012***	0.007***	0.006***	0.008***	0.032***	0.063***
	(4.80)	(5.66)	(6.76)	(5.99)	(8.91)	(8.18)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.102	0.129	0.108	0.115	0.049	0.064

Table A3: **Cross-sectional Regressions: Intraday Option Reversals excluding Earnings Announcements**

This table presents cross-sectional regressions of delta neutral straddles returns on the previous half-hour return and a number of controls. We have eliminated all the earnings announcement dates. The model takes the form:

$$r_{hh,i,t} = \alpha_t + \beta_1 r_{hh-1,i,t} + \beta_2 Controls_{hh-1,i,t} + \epsilon_{hh,i,t},$$

where $r_{hh,i,t}$ is the straddle return for stock i during the current half-hour period (denoted by hh) on day t. The control variables, denoted as $\text{Controls}_{hh-1,i,t}$, include factors such as implied volatility and the bid-ask spreads of call and put options for stock i during the previous half-hour period on day t. For the prediction of the first half-hour return ($r_{10:00-10:30,t}$) we consider the last half-hour return of the previous day ($r_{15:30-16:00,t-1}$). The return is measured in percentages. The adjusted t-statistics, as proposed by Newey and West (1987), are reported in parentheses. Statistical significance is denoted by ***, **, and * for the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Panel A: Early Hours

Interval	$r_{10:00-10:30,t}$	$r_{10:30-11:00,t}$	$r_{11:00-11:30,t}$	$r_{11:30-12:00,t}$	$r_{12:00-12:30,t}$	$r_{12:30-13:00,t}$	$r_{13:00-13:30,t}$
$r_{15:30-16:00,t-1}$	0.002						
	(0.17)						
$r_{10:00-10:30,t}$		-0.210***					
		(-6.68)					
$r_{10:30-11:00,t}$			-0.204***				
			(-14.12)				
$r_{11:00-11:30,t}$				-0.248***			
				(-11.25)			
$r_{11:30-12:00,t}$					-0.319***		
					(-7.57)		
$r_{12:00-12:30,t}$						-0.279***	
						(-16.76)	
$r_{12:30-13:00,t}$							-0.277***
							(-16.39)
constant	0.011	-0.003	-0.002	-0.001	-0.000	-0.001	0.003**
	(1.65)	(-1.38)	(-1.58)	(-0.44)	(-0.07)	(-0.64)	(2.36)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.049	0.092	0.100	0.112	0.128	0.120	0.118

Panel B: Late Hours

Interval	$r_{13:30-14:00,t}$	$r_{14:00-14:30,t}$	$r_{14:30-15:00,t}$	$r_{15:00-15:30,t}$	$r_{15:30-16:00,t}$	$r_{16:00-(N)10:00,t:t+1}$
$r_{13:00-13:30,t}$	-0.328***					
	(-10.31)					
$r_{13:30-14:00,t}$		-0.265***				
		(-10.27)				
$r_{14:00-14:30,t}$			-0.301***			
			(-16.35)			
$r_{14:30-15:00,t}$				-0.302***		
				(-17.40)		
$r_{15:00-15:30,t}$					-0.287***	
					(-6.70)	
$r_{15:30-16:00,t}$						-0.371***
						(-9.75)
constant	0.001	0.002	-0.000	-0.002	0.008*	0.017
	(1.11)	(1.62)	(-0.17)	(-1.31)	(1.73)	(1.39)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.125	0.119	0.122	0.131	0.051	0.090

Appendix B. Trading Volume

In this section, we show results for portfolios sorted based on option volume.

Table B4: **Average Return of Zero-Delta Straddle Portfolios Sorted by Previous Half-Hour Option Volume**

This table presents the average returns of portfolios sorted by option volume. These 30-minute portfolios are constructed according to the stock options volume from the preceding half-hour at the start of the holding period. The returns are expressed in percentages. The adjusted t-statistics, as described by Newey and West (1987), are reported in parentheses. Statistical significance is indicated by ***, **, and * at the 1%, 5%, and 10% levels, respectively. The data spans from January 2020 to December 2023.

Holding Period	Low	2	3	4	High	HML	t-stat
10:00-10:30	-0.06	-0.20	-0.16	-0.13	-0.18	-0.12	(-1.22)
10:30-11:00	0.13	-0.03	-0.04	0.02	-0.06	-0.18*	(-1.73)
11:00-11:30	0.23	0.06	0.07	0.03	0.00	-0.23***	(-3.70)
11:30-12:00	0.24	0.07	0.05	-0.01	-0.04	-0.28***	(-5.65)
12:00-12:30	0.36	0.09	0.09	0.05	0.02	-0.34***	(-3.75)
12:30-13:00	0.59	0.37	0.25	0.23	0.16	-0.43**	(-2.22)
13:00-13:30	0.26	0.15	0.06	0.03	0.04	-0.21***	(-4.14)
13:30-14:00	1.49	0.89	0.61	0.34	0.18	-1.31***	(-6.87)
14:00-14:30	0.06	-0.04	0.04	0.01	-0.01	-0.07	(-1.27)
14:30-15:00	0.27	0.08	0.08	0.04	-0.01	-0.27***	(-4.98)
15:00-15:30	0.29	0.18	0.14	0.05	-0.04	-0.33***	(-5.51)
15:30-16:00	3.65	2.37	1.90	1.26	0.62	-3.04***	(-9.74)
16:00-(N)10:00	6.23	3.93	3.25	2.10	0.78	-5.44***	(-9.38)