The Third Friday Price Spike

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Abstract

Most U.S. equity index derivatives settle at the market open on the 3^{rd} Friday of each month. We document that equity prices open 10 basis points higher on 3^{rd} Fridays, on average, and fully reverse by midday. Call payoffs are inflated and put payoffs deflated, transferring at least $1.5 billion annually. We link this spike to option dealers' hedging activity: their aggregate inventory delta predictably drifts down into expiry, requiring equity purchases to remain hedged. Measuring dealers' delta drift from positions, we show it predicts the Third Friday Price Spike and we find no comparable predictability on non-expiry days.

Keywords: Equity; Derivatives; Futures; Market Microstructure; Hedging.

JEL Classifications: G10, G12, G13, G14.

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S&P 500 index options constitute the largest equity index derivatives market globally. A significant fraction of these contracts are "a.m.-settled," meaning they expire on the morning of the 3^{rd} Friday of each month, with payoffs determined by the opening trade prices of index component stocks. These payoffs, and with them the distribution of wealth across market participants, are set at the 3^{rd} Friday open. At the same time, the period immediately preceding 3^{rd} Friday option expiry is a natural setting for temporary price pressure. Near expiration, option deltas change rapidly with the passage of time, requiring dealers to adjust their delta hedges to maintain neutral exposure. Because expiring a.m.-settled options stop trading at the Thursday close but settle at the Friday open, these hedge adjustments are concentrated in an illiquid overnight window before settlement.

Motivated by these facts, we examine how 3^{rd} Friday settlement shapes both equity prices and derivative payoffs. We document a systematic pattern in equity index prices around 3^{rd} Friday option expirations, which we dub the third Friday price spike (3FPS): the S&P 500 drifts upward from the close on the preceding Thursday to the 3^{rd} Friday open, when the SOQ is fixed, then fully reverses by midday 3^{rd} Friday.[1] This tent-shaped price pattern is economically large (an average spike of 10 basis points per event), statistically significant, specific to 3^{rd} Friday option expiry days, and highly persistent over our sample (1992 to 2023).

The economic consequences of the 3FPS are substantial. Option payoffs are calculated from a temporarily elevated SOQ: in-the-money calls receive a higher payoff, in-the-money puts a lower payoff, and some options close to the money cross into or out of the money. Since index options are cash-settled and option payoffs are a zero-sum game, there is a systematic wealth transfer between option writers and buyers.

We quantify the wealth transfer by comparing actual option payoffs at expiry to counterfactual payoffs computed under stated settlement benchmarks. In our preferred benchmark, the average expiration-night drift of 10 basis points is removed from the realized settlement value. The payoff differences are most pronounced for options close to the money, where call payoffs are systematically higher and put payoffs systematically lower. Aggregating across all expiring S&P 500 options yields an estimated wealth transfer of \$1.5 to \$2.2 billion per year across benchmarks, even before accounting for other affected contracts such as futures, futures options, and options on related

[1] The Special Opening Quotation (SOQ) determines the payoffs of a.m.-settled 3^{rd} Friday derivatives. It is calculated from the opening sales prices of index component stocks on their primary listing exchange and is available only once all component stocks have traded during the regular market session after 9:30:00 a.m. Eastern Time.

indices.[2]

These transfers are realized at settlement, not collected in advance in option prices. Using put-call parity, we show that 3^{rd} Thursday option quotes do not embed the expected spike. The forward implied by expiring option pairs sits within a fraction of a basis point of fair carry, a deviation far smaller than the cost of trading on it.

What explains the 3FPS in U.S. equities and its consequences for derivative payoffs? We propose a novel channel based on predictable changes in option dealers' hedging demand. Due to persistent demand imbalances, dealers are typically short out-of-the-money (OTM) put options. Being short a put with negative delta gives dealers positive equity exposure, which vanishes as the put's delta drifts toward zero near expiry. Thus, dealers must buy equity exposure before option expiry in order to remain delta-hedged, typically via index futures, ETFs, or basket trades. Index arbitrage can transmit the pressure to the constituent stocks, whose opening trades determine the SOQ. We construct a measure of this predictable hedging demand, the dealer delta drift (DDD), and show it predicts overnight returns into 3^{rd} Friday settlements.

Central to this mechanism is the acute sensitivity of delta to the passage of time near expiration. As the 3^{rd} Friday settlement approaches, delta converges toward its terminal values of -1, 0, or 1 with increasing intensity, even in the complete absence of shocks to the underlying. This acceleration is sharpest overnight, when dealers' hedging instruments are least liquid. We design a set of tests evaluating whether this expected delta drift, and the hedge-adjustment trades it induces, can plausibly generate systematic overnight price pressures consistent with the 3FPS.

First, we establish the existence of price pressures by studying order imbalances in the E-mini S&P 500 futures contract, the primary hedging instrument for S&P 500 options. If the 3FPS is the result of option dealers' hedge-adjustment trades, then we expect to see order imbalances in dealers' major hedge instruments. Around 3^{rd} Friday, order imbalances display the same pattern as the 3FPS: positive and significant overnight, then significantly more negative intraday.

Second, we show that the delta of dealers' put book drifts downward into expiration, creating incentives to buy equities. Using CBOE Open-Close Volume files, we estimate daily dealer positions across all S&P 500 options. Consistent with prior evidence (e.g., Garleanu, Pedersen, and Poteshman, 2009), dealers are predominantly short out-of-the-money puts. These puts typically

[2]The major U.S. equity index options, including the Nasdaq 100, the Dow Jones, and the Russell 2000, are likewise a.m.-settled on the 3^{rd} Friday via their own opening quotations. We study S&P 500 options, the largest such market and the only one for which we observe dealer positions, so our estimates are a lower bound on the total wealth transfer across index-option markets.

expire worthless, so the puts' delta drifts from negative values toward zero, but because dealers are short, their aggregate delta drifts downward.

Third, we establish a direct link between the DDD and subsequently realized market-wide price movements. Estimating a series of overnight predictability regressions of S&P 500 returns on the DDD, we show that more negative values of the drift predict larger positive overnight returns into the SOQ. The effect is both statistically and economically significant, despite the well-known difficulty of predicting index returns in the time series. Importantly, we find no comparable predictability on non-expiry days or over weekends, and no comparable pattern around p.m. settlements.

Our fourth test further exploits variation in dealer positioning. We sort expiry days by the sign of the DDD to assess whether its direction predicts the sign of the 3FPS. When the DDD is negative, implying net equity purchases, the overnight S&P 500 return averages a positive 17 basis points on the non-quarterly expiration dates. In contrast, when the DDD is positive, implying net equity sales, the overnight return is close to zero. The difference is a significant 19 basis points (t-statistic = 2.16).

Throughout these tests, we distinguish quarterly from non-quarterly expirations. We observe detailed dealer positions in S&P 500 index options alone. On quarterly 3^{rd} Fridays, several settlement-related forces coincide, as S&P 500 futures and options on the futures also settle into the same SOQ. Non-quarterly 3^{rd} Fridays, instead, isolate S&P 500 index option expiry. Thus, the dealer delta drift is measured most precisely on non-quarterly expirations. Consistent with this, our predictive regressions yield the strongest results on non-quarterly expiry dates, even though the unconditional spike is smaller there: it averages 7.0 basis points on non-quarterly expirations against 15.5 basis points on quarterly ones. This is as expected, since on non-quarterly dates fewer instruments expire, while we observe a larger fraction of the expiring instruments.

Summarizing, we document a robust relationship between dealers' inventory risk arising from option positions and predictable changes in overnight equity returns on 3^{rd} Fridays. The underlying mechanism is consistent with price pressure arising from hedge-adjustment trades executed during the illiquid overnight trading period preceding a.m. option settlement. Since option payoffs are a zero-sum game, cash-settled a.m. payoffs inherit a predictable wealth transfer.[3]

[3]The Online Appendix (OA) further investigates a set of potential alternative explanations drawn from the extant literature: fundamental shocks (overnight news, earnings, and macro announcements) and "pinning" - the phenomenon whereby underlying prices tend to cluster around their nearest strikes on expiration days. A battery of empirical tests fails to find support for these explanations.

We conclude by discussing the broader implications of the 3FPS, including the possibility of predatory trading or market manipulation, and its lessons for regulation and settlement design.

Related Literature: Our paper contributes to several strands of the literature. First, we add to the early work on option-expiration effects. Studies such as Stoll and Whaley (1991) and Hancock (1993) document limited price distortions from moving option settlement to market open, but they draw on only a few early years of data, when the options market was still relatively small. More recent research emphasizes the role of derivative-market frictions in shaping underlying prices. Ni, Pearson, Poteshman, and White (2021) show that option market-maker rebalancing accounts for a sizable portion of return volatility and jump probability in individual stocks. We extend this literature by documenting a new and persistent price pattern at the index level and quantifying the wealth transfer it implies.

Second, we contribute to research on intermediary hedging and inventory risk arising from option markets. Baltussen, Da, Lammers, and Martens (2021) show that gamma-hedging practices of option market makers drive intraday momentum around market-close times. In addition, Adams, Dim, Eraker, Fontaine, Ornthanalai, and Vilkov (2025) and Vasquez, Amaya, Pearson, and Garcia-Ares (2025) find relatively balanced intermediary positions in p.m.-settled 0DTE S&P 500 options. We study intermediary positions in a.m.-settled 3^{rd} Friday S&P 500 options, which are imbalanced, and show that predictable delta-hedging is associated with price pressures into expiry. Such charm-induced hedging flows appear most prominently in the literature on expiration-day "pinning" (Avellaneda and Lipkin, 2003; Ni, Pearson, and Poteshman, 2005; Golez and Jackwerth, 2012). In contrast, the delta drift we study is directional, due to the persistent dealer short position in puts that expire out-of-the-money.

Third, we speak to the literature on intraday price pressures and predictable return patterns. Boyarchenko, Larsen, and Whelan (2023) show that U.S. equity returns are large and positive overnight around the opening of European markets, driven by the inventory management of exchange-based market makers. Furthermore, Gao, Han, Li, and Zhou (2018) show that price pressures, including those from option market makers, drive intraday momentum in equity markets. Lou, Polk, and Skouras (2019) document strong overnight and intraday return continuation and an offsetting cross-period reversal at the individual-stock level and in equity return factors (see also Bogousslavsky, 2021 and Hendershott, Livdan, and Rösch, 2020). We show that even in the most liquid equity-index derivative market, predictable market-wide return patterns arise in the window when settlement values are fixed, raising questions about settlement design.

I. Data and Market Background

A. Option Markets and Settlement Practices

Options on the S&P 500 index started trading on the Chicago Board Options Exchange (CBOE) on July 1^{st}, 1983. Today, S&P 500 options are the world's most traded index options, with robust liquidity and trading volume across expiration dates and strikes. Below, we highlight key settlement practices of the S&P 500 derivatives market, while the OA offers a more extensive description of S&P 500 option markets, as well as S&P 500 futures and Exchange Traded Funds (ETFs).

Standard S&P 500 (SPX) options expire on the 3^{rd} Friday of each month, with payoffs originally calculated from official closing prices. Driven by concerns regarding dealer inventory management, on June 18^{th}, 1987, the Securities and Exchange Commission (SEC), the Commodity Futures Trading Commission (CFTC), the Chicago Mercantile Exchange (CME), and the Chicago Board Options Exchange (CBOE) changed their reference point for S&P 500 settlement prices from p.m. (i.e., market close) to a.m. settlement (i.e., market open).

Since June 1987, the settlement price of quarterly S&P 500 index options has been calculated on 3^{rd} Friday mornings via the Special Opening Quotation (SOQ), and settlement is delivered in cash instead of stocks. As of November 20^{th}, 1992, all monthly S&P 500 options also settle into the SOQ, motivating the use of November 1992 as the primary starting date in our study. Furthermore, trading in expiring options ceases at the market close on Thursday before expiration, 17 hours and 15 minutes before settlement values are determined. This 17:15-hour window corresponds to the period from the 4:15 p.m. Thursday option close to the 9:30 a.m. Friday market open. In 2025, the SEC approved a CBOE rule change to extend trading in expiring a.m.-settled index options from Thursday close to five minutes before the market open on the 3^{rd} Friday (CBOE Regulatory Notice #56357). The change aims to reduce overnight exposure around settlement.

The SOQ is calculated as the market-value-weighted sum of the S&P 500 constituent stocks' first reported trade prices on their primary listing exchange. The SOQ is typically published 30–45 minutes after the market open, as it can only be calculated once all constituent stocks have opened for trading. After the opening bell, many stocks in the index may not yet have opened due to a lack of buy and sell orders or an imbalance between them. Highly liquid, large-cap stocks usually trade close to the market opening time on their primary exchange, while less liquid stocks may take several minutes to open. Therefore, the SOQ is composed of single-stock trade prices at different points in time (OA Table A.1 illustrates the calculation).

Besides the monthly a.m.-settled S&P 500 options, the CBOE has introduced additional S&P 500 option classes with different settlement conventions over time. Notably, p.m.-settled options were reintroduced in 2007 under the SEC's PM Option Expiration Pilot Program. These include (i) options expiring on the last business day of a calendar month, (ii) weekly options introduced in 2010, and (iii) monthly options expiring on the 3^{rd} Friday, introduced in 2011, as well as the more recent zero-day (0DTE) options expiring daily.

S&P 500 index options are not the only a.m.-settled contracts: on quarterly 3^{rd} Fridays, S&P 500 futures and options on those futures settle into the same SOQ, and standard options on related indices, such as the Nasdaq 100, the DJIA, and the Russell 2000, are likewise a.m.-settled on 3^{rd} Fridays via their own opening quotations (OA Table A.2 summarizes the key contract specifications).[4] We nevertheless focus on S&P 500 index options because they are by far the largest a.m.-settled book (OA Figure A.1) and the only one with position data that allow us to estimate dealer inventories (described below). Non-quarterly 3^{rd} Fridays, on which no futures-related contract settles, therefore serve as our cleanest laboratory, and several of our tests focus on them.

B. Data

Our analysis combines data from multiple sources. From Bloomberg, we obtain daily S&P 500 index official closing prices and SOQ values over the sample from November 1992 to December 2023.[5] From Refinitiv, we collect tick-level data on the S&P 500 (SPX) and E-mini S&P 500 futures traded on the CME. We obtain tick-level best bid and offer prices, trade prices, and volumes. The sampling of tick-level data follows standard practices. From the SPX tick data, we also derive a 4:15 p.m. index value, which several exhibits use as the closing price.

From the CBOE, we use the Open-Close Volume Summary dataset starting in January 1996,

[4]Relatedly, options on front-contract S&P 500 futures trade on the quarterly expiry calendar and expire into the SOQ, while non-quarterly (serial) options on S&P 500 futures are p.m.-settled at the close value of the underlying futures contract. In addition, in 2005, the CBOE introduced option contracts on the SPDR ETF. As ETFs are traded like common stocks, SPDR options have the same features as individual U.S. stock options; that is, they settle on the 3^{rd} Friday of the month at the closing price of that day.

[5]Bloomberg ticker SPXM until January 2003 and ticker SPXSET afterward.

which provides daily buy and sell volumes in S&P 500 options by participant type. We focus on positions in standard monthly contracts that expire on 3^{rd} Fridays and therefore exclude weekly (SPXW) and 0DTE S&P 500 index options. From January 1996 to December 2010, volumes are separated into "firms" and "customers," leaving "market makers" as the residual. From January 2011 to December 2023, the residual to "firms" and "customers" is further disaggregated by the CBOE into "professional customers," "broker dealers," and "market makers." For consistency, we define "market maker" trades as the residual to "firms" and "customers" across the entire sample, following Pan and Poteshman (2006) and Ni, Pearson, Poteshman, and White (2021). In what follows, we use the terms "market makers" and "dealers" interchangeably.

OptionMetrics provides end-of-day S&P 500 option data, which we use to calculate exposures to Greeks such as delta (Δ), gamma (Γ), and charm ($\mathcal{C}$). Throughout, we scale open interest by the contract multiplier of 100 to express exposures in index units. We exclude the expiration days of September 2001, September 2008, and October 2008 from all datasets used in the main analysis.[6]

II. The Third Friday Price Spike in Equities

In this section, we study equity returns around 3^{rd} Friday option expirations. We find that the S&P 500 drifts up on average by about 10 basis points from Thursday close to 3^{rd} Friday open, and subsequently fully reverts, with overnight returns showing strong predictive power for the subsequent intraday reversal.

A. Third Friday Returns

We begin our analyses by computing overnight equity returns, as

$$\text{Return}_t^{\text{SOQ}} = \log(\text{SOQ}_t) - \log(\text{SPX}_{t-1}^{\text{close}}), \tag{1}$$

where SOQ is the S&P 500 Special Opening Quotation and $\text{SPX}^{\text{close}}$ is the closing value of the S&P 500 index. The SOQ is published on every trading day, so equation (1) applies the same opening

[6]Excluding crash-affected expirations is standard practice in empirical derivatives research. Golez and Jackwerth (2012), for example, exclude the October 1987 and October 2008 crash months from their study of expiration-day effects in S&P 500 futures (see also Stoll and Whaley, 1991). The September 2001 expiration fell at the end of the week in which markets reopened after the September 11 attacks, and the September and October 2008 expirations coincided with the height of the financial crisis. OA Table A.4 shows that our findings are robust to including these dates.

construction on expiration and control days alike; only on 3^{rd} Fridays does the SOQ additionally determine settlement (OA Section A.1). We compute intraday returns as $\log(\text{SPX}_t^{\text{close}}) - \log(\text{SOQ}_t)$.

Table I reports average returns in basis points and corresponding t-statistics over the period November 1992 to December 2023. We show results for trading periods around monthly 3^{rd} Friday settlement dates, the control group of other trading days, and the differences between 3^{rd} Friday returns and the control group.[7] Panel (a) uses returns on all other trading days as the control group, while Panel (b) uses only Fridays that are not 3^{rd} Fridays as the control group, thereby isolating the expiration effect from any general Friday seasonal pattern.

On expiry days, 3^{rd} Thursday overnight returns are abnormally large and positive, equal to 9.80 bps with a t-statistic of 3.04. This compares to near-zero and insignificant average overnight returns on other days. The difference between overnight returns on 3^{rd} Thursdays and other days is statistically significant (t-statistic = 2.41): equity prices drift upward overnight before 3^{rd} Friday expirations. Panel (b) shows no comparable effect on non-expiry Fridays, underscoring that the spike is tied to option settlement rather than a weekly seasonal pattern.

Intraday returns on 3^{rd} Fridays are also abnormally large but negative, equal to -15.10 bps (t-statistic = -3.57). On other days, average intraday returns are positive but small. The difference averages -17.58 bps (t-statistic = -3.50). Again, using non-expiry Fridays as the control group yields similar results. OA Table A.3 shows that these estimates are robust to the measurement of the closing price and to the estimation sample.

[INSERT TABLE I HERE]

Next, we study returns in the S&P 500 futures market to further examine the behavior of returns overnight and intraday. Futures intraday returns are computed from 5-minute volume-weighted average (VWAP) prices on E-mini futures.[8] Our futures sample spans January 2003 to December 2023, as liquid overnight trading in the E-mini began around 2003 (see the OA for more details on overnight trading).

[7]In cases where the 3^{rd} Friday is not a trading day, expiration occurs on the immediately preceding business day, most commonly a Thursday. Throughout the paper we will refer to the option expiry date as the 3^{rd} Friday, even though on six occasions in our sample the option expiry occurred on the preceding Thursday due to market holidays. Similarly, we regularly refer to the Thursday immediately preceding option expiry as the 3^{rd} Thursday, even though it need not be the calendar month's third Thursday.

[8]We use the front-month futures contract and roll into the next-to-maturity contract when it becomes more liquid, typically a few days before quarterly expiry. This reflects typical rolling behavior but does not capture the SOQ on quarterly futures settlement dates. However, results are very similar when using the expiring futures contract until its expiry.

Figure 1 shows the results. The solid black line displays cumulative 5-minute returns between 4:00 p.m. on 3^{rd} Thursdays (left-hand side of the x-axis) and 4:00 p.m. on 3^{rd} Fridays (right-hand side of the x-axis), showing that prices drift up overnight, accelerating in early morning trade until the 9:30 interval, at which point returns sharply revert. The average overnight cumulative return in the active futures contract is equal to 12 bps, which completely reverses by noon. The modest difference from Table I reflects the shorter futures sample (OA Table A.3) and the VWAP price basis. Thus, S&P 500 futures prices display a tent-shaped reversal pattern from the close of regular trading on 3^{rd} Thursdays, which peaks when the SOQ is calculated on 3^{rd} Fridays and fully reverts by about noon on the 3^{rd} Friday.

[INSERT FIGURE 1 HERE]

B. Third Friday Overnight-Intraday Reversal

The 24-hour price path around 3^{rd} Fridays displays a classic reversal pattern that typically arises in models of demand for immediacy and inventory risk management. To demonstrate a formal statistical link between overnight returns in advance of 3^{rd} Friday a.m. settlements and subsequent intraday returns, we estimate a reversal regression of intraday futures returns on preceding overnight returns. We consider cumulative intraday intervals (9:30–9:35, 9:40, . . . , 4:00 p.m.), and measure overnight returns from prior close to open.

Figure 2 plots the estimated slope coefficients, with Panel (a) for 3^{rd} Fridays and Panel (b) for all other days. Error bars represent 95% confidence intervals based on Newey-West standard errors with 3 lags. The predictive slope coefficient is strongly negative and significant on 3^{rd} Fridays into the early afternoon, as is evident from the gray bars in Panel (a). Coefficients are sizable (about -0.4), with (unreported) R^2 values of roughly 10% to 25%, which are large given the high-frequency nature of the regressions. Toward the close, the reversal effect weakens and becomes insignificant, consistent with Figure 1. In contrast, on other days reversal coefficients are close to zero (Panel (b)). These findings imply that large overnight returns are systematically reversed intraday, but only on 3^{rd} Friday expirations. In sum, S&P 500 prices exhibit a tent-shaped reversal pattern unique to 3^{rd} Fridays.

[INSERT FIGURE 2 HERE]

C. Persistence of the 3FPS

We next examine the persistence of overnight drift and intraday reversal around 3^{rd} Fridays. We consider two trading strategies and evaluate cumulative returns over time. The first buys the S&P 500 at the 3^{rd} Thursday close and sells at the SOQ on the 3^{rd} Friday, capturing the overnight return. The second shorts the S&P 500 at the 3^{rd} Friday open via the SOQ and closes at the 3^{rd} Friday close, capturing the intraday reversal. A single strategy could trade both legs, buying at the Thursday close and reversing into a short at the open, and we track the legs separately to show each component's persistence.

Figure 3 shows the resulting cumulative returns since November 1992. The gray solid line shows that overnight returns on 3^{rd} Thursdays have accumulated over most of our sample, except for a contraction over the 2000 to 2002 period. The gray dotted line shows 3^{rd} Friday intraday returns accumulated similarly, with a more pronounced increase recently. The black line shows the combined strategy, which averages approximately 25 basis points per expiration and turns one dollar in November 1992 into $2.52 by December 2023. Overall, we conclude that the 3FPS pattern is generally present throughout our sample period and not driven by particular subperiods. OA Figure A.2 displays the overnight 3^{rd} Friday returns separately for quarterly and non-quarterly expirations, by year and cumulatively: the spike is present in both groups, averaging 15.5 basis points on quarterly and 7.0 basis points on non-quarterly expirations.

[INSERT FIGURE 3 HERE]

D. P.M.-Settled Options

Next, we evaluate whether the price spike is specific to a.m. settlement. As outlined in the previous section, the CBOE has introduced S&P 500 options with other settlement practices over time. In particular, p.m.-settled monthly options have expired on 3^{rd} Fridays since September 2011.[9] Is a similar pattern of pre-settlement drift and subsequent reversal present around p.m. settlement?

Table II repeats the earlier analysis for the subsample in which p.m.-settled options traded (September 2011 onward) and adds weekend returns (3^{rd} Friday close to Monday open), which span the post-p.m.-settlement window. The a.m. pattern persists in this subsample: an overnight

[9] See `https://www.sec.gov/files/rules/sro/c2/2012/34-66140.pdf`.

drift of 10.07 bps (t-statistic = 2.20) followed by an intraday reversal of -15.51 bps (t-statistic = -2.34). For p.m. expiries the pre-settlement window is the Friday trading session itself, which coincides with the a.m. contracts' post-SOQ reversal window (column 2). The weekend is the only window free of this overlap, so we benchmark its return against the a.m. contracts' intraday reversal. The weekend return following p.m. settlement shows an insignificant decline of -13.14 bps, which we do not read as a precise zero: a formal test finds it statistically indistinguishable from the intraday reversal (difference of -5.13 bps, t-statistic = -0.59, column 4). Overall, we find no evidence of a pre-settlement spike around p.m. settlement and weak evidence of a post-settlement decline. An institutional reason why p.m. settlement may be less susceptible is that it occurs at the close of a liquid trading session, lacking the illiquid last-trade-to-settlement window in which the a.m. effect arises.

[INSERT TABLE II HERE]

SOQ prices on expiry Fridays are systematically elevated relative to prior closing prices. This regularity forms the basis for our subsequent analysis of derivative payoffs and wealth transfers.

III. The Third Friday Price Spike in Equity Options

The 3FPS alters the payoffs of all U.S. equity derivatives with monthly 3^{rd} Friday a.m. expiry.[10] Because option payoffs are determined from a systematically elevated SOQ, call payoffs are skewed upward, while put payoffs are skewed downward. This section quantifies the transfer by revaluing every expiring option under a counterfactual settlement value. The estimate is approximately $1.5 billion per year. Moreover, via a put-call parity test at the 3^{rd} Thursday close we show the 3FPS is not priced into options ex ante.

A. Quantifying the Wealth Transfer: Option Payoffs

We quantify the wealth transfer by comparing actual option payoffs at expiry to counterfactual payoffs. We consider a.m.-settled S&P 500 index options only and, as a result, our estimates should be interpreted as a lower bound on the total wealth transfer.[11]

[10] We thank Neil Pearson for helpful comments and suggestions on this section of the paper.

[11] Among others, we ignore futures options, options on other U.S. indices like the Nasdaq 100 and Russell 2000, and OTC options. Dealers in these index-option markets are likewise typically short out-of-the-money puts, so an analogous effect, if present, would carry the same sign.

Actual payoffs are calculated from the 3^{rd} Friday SOQ. Counterfactual payoffs are calculated from a counterfactual settlement value equal to the realized SOQ scaled down by 10 basis points, the average 3FPS documented in Section II. Thus, the counterfactual settlement value is the value the SOQ would have taken had the realized overnight return been 10 basis points lower.

Per expiry, let S_0 denote the 3^{rd} Thursday close, from which the settlement window runs, and S_T the settlement value, the SOQ. Let f denote the (convex) option payoff, $f(S) = \max(S - K, 0)$ for a call with strike K. The wealth transfer is a difference of two expectations over the same expiration mornings, an actual leg A and a counterfactual leg B

$$\text{Transfer} = \underbrace{E\big[f(S_T^{\text{actual}})\big]}_{\text{leg A}} - \underbrace{E\big[f(S_T^{\text{cf}})\big]}_{\text{leg B}}, \qquad S_T^{\text{cf}} = \frac{S_T}{1+\delta}, \tag{2}$$

with $\delta = 0.0010$. The implied downward shift in the settlement level is $h \equiv S_T - S_T^{\text{cf}} = \delta S_T^{\text{cf}}$, ten basis points of the counterfactual settlement value. The two legs are columns 1 and 2 of Table III. Note that as leg B reuses each morning's realized settlement, every feature of the settlement distribution other than its mean (e.g., each expiration morning's overnight news, its volatility shock, its sign) enters both legs identically, a preservation property embedded in equation (2).

The form of leg B is dictated by the convexity of f. Let $V(S,t)$ denote the value function of an expiring option, smooth at every instant before settlement. Over the settlement window, a move dS changes the option's value in expectation by

$$E[dV] = V_S\, E[dS] + \tfrac{1}{2}\, V_{SS}\, E[(dS)^2] + V_t\, dt. \tag{3}$$

For an expiring at- or near-the-money option the quadratic term is essentially the option's entire remaining value, typically not a small correction. In Black-Scholes terms, an expiring at-the-money option is worth approximately $0.4\,\sigma$ of notional, where σ is the volatility of the remaining overnight return. At the measured expiration-night volatility of roughly 65 basis points this is approximately 26 basis points. The drift term is the 10 basis point shift times the option's Δ of 0.56, approximately 6 basis points. An expiring option's Δ is essentially its probability of finishing in the money and exceeds one half because it is evaluated under the 3FPS.

Consequently, by basing the benchmark counterfactual on the actual realized SOQ, lowered by the average 3FPS, we preserve the quadratic term.[12] In contrast, a counterfactual that settles options at an average overnight return relative to the previous day's close sets leg B's $E[(dS)^2]$ to zero, and thereby assigns the option's convexity value as wealth transfer. Given the stated benchmark, the computation is model-free. The exercise revalues the same option book under a stated alternative settlement value, and no delta, gamma, or implied volatility enters the calculation. The benchmark only moves the mean of the settlement distribution, a pure location shift that removes the documented average drift and nothing else, and we do not claim it identifies a fair settlement value. A detailed treatment of the counterfactual construction and its properties is provided in OA Section A.3.

The empirical calculation is an accounting exercise. For every expiring option we compute the actual payoff at the SOQ and the counterfactual payoff at the scaled-down SOQ, multiply both by the option's open interest (including the 100× contract multiplier), sum across strikes, average across expirations, and difference. The only inputs are each option's strike, its open interest, the realized SOQ, and the average 3FPS in the S&P 500. The sample runs from January 1996 (the start date of the open interest series) to December 2023, covering all expiring S&P 500 options with positive open interest.

Table III shows the results. S&P 500 call options paid off \$8.565 billion on the average 3^{rd} Friday morning. Had their settlement been determined from the counterfactual settlement value, they would have paid off \$8.476 billion. The difference of \$89 million per month represents the average wealth transfer from call option writers to call option buyers. Similarly, S&P 500 put options paid off \$3.211 billion on the average 3^{rd} Friday morning, versus a counterfactual of \$3.251 billion, yielding an average wealth transfer from put option buyers to put option writers of \$40 million per month. The sum of the wealth transfers in call and put options, multiplied by 12 (expiries per year), yields a wealth transfer of approximately \$1.5 billion annually.

To make the benchmark dependence transparent, OA Table A.5 repeats the exercise under three alternative counterfactuals: (i) settlement at the prior Thursday close (a zero overnight return), (ii) the prior close grown at the average overnight return on non-expiry Fridays (0.70

[12] When we write both legs of equation (2) with equation (3) from the same Thursday state (S_0, t_0) over the same settlement window, with leg B's move being each morning's realized move lowered by the shift h, the level and time-decay terms are identical across the two legs and drop out of the difference:

$$\text{Transfer} = V_S\, h + \tfrac{1}{2}\, V_{SS}\,\big(E\big[(dS)^2\big] - E\big[(dS-h)^2\big]\big) = h\big[V_S + V_{SS}\big(E[dS] - \tfrac{1}{2}\, h\big)\big] \;\approx\; h\, V_S.$$

Note that the cancellation itself does not rely on the expansion or on any smoothness assumption (as both legs settle on the same realized morning, it holds exactly by construction) and each option's transfer is bounded by h.

basis points), and (iii) the prior close grown at the average overnight return on all other trading days (1.30 basis points), with both averages measured over the sample period for which we have OptionMetrics data. These alternatives assume a single overnight return for all option expiries and therefore embed the convexity distortion described above. The OA accordingly reports their implied transfers, of \$2.2 billion, \$2.1 billion, and \$2.0 billion annually, as upper bounds. Across benchmarks, the implied annual wealth transfer from a.m.-settled S&P 500 index options ranges from \$1.5 billion to \$2.2 billion.

If expiration-day price movements reflect equilibrium responses to hedging demand and liquidity constraints, the payoff differences can be read as compensation for bearing those risks. The risk in question is borne by whoever carries expiring claims through an overnight window in which hedging demand is large and the underlying market is illiquid. The accounting is the same under both readings (the wealth transfer as compensation for risk, or as a deviation from a benchmark), and quantifies the magnitude of the 3FPS in option payoffs.

[INSERT TABLE III HERE]

B. *Is the 3FPS Priced into Options?*

Put-call parity ties the prices of a call and a put with common strike K to the contemporaneous forward price of the index at a point in time. At the 3rd Thursday close, parity reads

$$C - P = Se^{-q\tau} - Ke^{-r\tau}, \tag{4}$$

where S is the index level at the close, $\tau = 17{:}15$ hours is the remaining time to settlement, and r and q are the overnight interest rate and dividend yield. Equation (4) implies a call is the portfolio long the put, long $e^{-q\tau}$ units of the index, and short $Ke^{-r\tau}$ of riskless lending.

Returns on the strike-matched pair mirror the overnight index return into settlement mechanically, and this is why call payoffs gain and put payoffs lose relative to their counterfactual values in Table III: parity fixes the signs and the call-put split of the transfer.[13] Beyond matched option pairs, parity implies no restrictions: it restricts neither each option leg's own return into settle-

[13] Following Coval and Shumway (2001), applying equation (4) at the Thursday close and again at settlement, and dividing by the call price, expresses the call's net return as the price-weighted net return of the replicating portfolio. Evaluating at settlement, where the pair pays $(S_T - K)^+ - (K - S_T)^+ = S_T - K$, this collapses to the single restriction, $C\,R_C - P\,R_P = (S_T - K) - (C - P) \approx S_T - S$, where S_T is the SOQ, and R_C and R_P are the matched overnight call and put returns.

ment nor the aggregate book, since call and put open interest are not matched strike for strike. OA Section A.4 provides a detailed treatment of parity and option returns.

Rearranging equation (4), the quoted pair implies a forward, $K + (C - P)e^{r\tau}$: the settlement mean embedded in the quotes. If quotes incorporate the expected overnight drift, implied forwards would sit above the fair-carry forward, $Se^{(r-q)\tau}$. If instead quotes are set at fair carry, the predictable drift is left in the settlement window rather than in end-of-day option prices. Whether Thursday quotes embed the expected spike is a natural empirical question that parity can address.

We answer this question by measuring quoted put-call parity deviations at the 3^{rd} Thursday close. For each matched at-the-money call-put pair of expiring options, we compare the parity-implied forward to the fair-carry forward. Because a forward is one number per date, matched at-the-money pairs identify the priced-in drift for the entire expiring book. Because a call and a put with a common strike and expiry have identical sensitivities to implied volatility, changes in the volatility level move C and P one for one and cancel in $C - P$: the level of option premia can neither produce nor mask a deviation. If Thursday quotes embedded the average 10 basis point spike, the parity-implied forward would sit approximately 10 basis points above fair carry at every strike.

Table IV shows that Thursday quotes do not embed the spike. Matched pairs on the expiring book imply a forward within a fraction of a basis point of the fair-carry forward (-0.33 basis points, $t = -0.47$), and the data reject the priced-in level (column 3, $t = -14.57$).

The average deviation is also far smaller than the cost of trading on it. Exploiting a deviation requires buying one option at its ask price and selling the other at its bid price, which costs 8.2 basis points on average (column 4). On 60% of expirations the deviation is smaller than this cost (column 5). Within the trading-cost band, quotes could have shaded toward the known drift without creating an executable arbitrage, and they did not. The average deviation is indistinguishable from zero in both subperiods. In the 2010 to 2023 subsample it is $+0.06$ basis points, and on 74% of dates it is smaller than the trading cost.

Expiring options are therefore quoted at fair carry into the settlement night. The 3FPS is a feature of the settlement window, not of the option prices set the evening before, and the wealth transfer documented in the subsection above is realized at settlement, not collected in advance in Thursday quotes. OA Section A.4 repeats the payoff accounting of the subsection above in returns, from each option's 3^{rd} Thursday closing quote to its settlement payoff, and finds equivalent results:

a return-based wealth transfer of approximately $1.5 billion per year.[14]

[INSERT TABLE IV HERE]

IV. Option Dealers' Inventory Hedging into Option Expiry

This section investigates whether predictable dealer hedging demand can account for the Third Friday Price Spike (3FPS). Dealers delta-hedge their option inventories by taking an offsetting position in the underlying index, or in close substitutes such as S&P 500 futures. Because trading in the expiring contracts ceases at the 3^{rd} Thursday close, dealers hold these positions through the settlement window while the options' Δs drift toward their terminal values from the passage of time alone. To remain hedged, dealers must therefore trade in the overnight period, when liquidity is relatively thin. We quantify this hedging demand with our main measure, the projected dealer delta drift, and find that it predicts the 3FPS.

A. Equity Price Pressures around Option Expiry

First, we establish the existence of equity price pressure by studying order imbalances. From the perspective of inventory-risk models, the ideal empirical measure of order imbalance would be the net-inventory held by equity market makers. As this is not observable, we use E-mini S&P 500 futures, the primary hedging instrument for SPX options, and follow Boyarchenko, Larsen, and Whelan (2023) to measure order imbalance by signed volume, i.e., the number of buyer-initiated minus seller-initiated contracts traded. Table V contains summary statistics for all days and 3^{rd} Fridays over the sample where we have liquid overnight futures contracts (January 2003 to December 2023), split by the overnight window (Panel (a)) and the intraday window (Panel (b)).

On non-expiry days, signed volume is close to zero overnight (-0.16, t-statistic $= -1.17$) but negative intraday (-1.79, t-statistic $= -3.67$), consistent with the view that futures are primarily used for hedging. By contrast, on 3^{rd} Fridays order imbalances are materially different. Overnight they are significant and positive (2.63, t-statistic $= 3.59$), whereas intraday they turn roughly six times more negative than on non-expiry days (-11.26, t-statistic $= -5.38$). This corresponds to an overnight order imbalance of about $274 million, which is sizable relative to typical overnight trading imbalances.

[14] The equivalence is arithmetic rather than an implication of parity: each option's return comparison divides its payoff comparison by the same Thursday quote, so the quote cancels from the dollar aggregate whatever its level.

Because quarterly "Triple Witching" dates (March, June, September, December) are known to feature unusually large futures and index-arbitrage activity (Barclay, Hendershott, and Jones, 2008), one might worry that the overnight imbalance is driven by those dates alone. To address this, we estimate signed volumes separately for quarterly and non-quarterly 3^{rd} Fridays. We find the same qualitative pattern on both groups of dates: positive overnight order imbalances followed by large negative intraday imbalances, significant in each group taken separately. The overnight imbalance is larger on quarterly dates (4.23 versus 1.83 thousand contracts), in line with the somewhat weaker unconditional spike off-quarter. Hence, the price-pressure pattern is not a by-product of unusual Triple Witching day activity but a general feature of a.m.-settled 3^{rd} Fridays. These results are consistent with a price-pressure-based explanation.

$$\Big[\text{ INSERT TABLE V HERE }\Big]$$

B. Options' Charm: The Sensitivity of Delta to the Passage of Time

Consider the Black-Scholes diffusion setting where the index follows $dS/S = \mu dt + \sigma dW^{\mathbb{P}} = rdt + \sigma dW^{\mathbb{Q}}$. An application of Itô's lemma reveals the expected change of options' delta:

$$\frac{1}{dt}E_t^{\mathbb{P}}[d\Delta_t] = \mu S_t \Gamma_t + \frac{1}{2}\sigma^2 S_t^2 \mathcal{S}_t + \mathcal{C}_t, \tag{5}$$

where gamma $= \Gamma = \frac{\partial^2 V}{\partial S^2} = \frac{\partial \Delta}{\partial S}$, speed $= \mathcal{S} = \frac{\partial^3 V}{\partial S^3} = \frac{\partial \Gamma}{\partial S}$, and charm $= \mathcal{C} = \frac{\partial \Delta}{\partial t}$. Equation (5) describes the continuous evolution of the expiring book's Δ up to settlement, of which charm is the component that accrues from the passage of time alone. Gamma is the rate of change of Δ with respect to the price of the underlying. "Speed" ($\mathcal{S}$) is the rate of change of Γ with respect to the price of the underlying.

Cash settlement adds one further, discrete term, the "Δ cliff." At the SOQ the expiring book's Δ jumps from its terminal value to zero. The two objects, charm and delta cliff, are distinct, with distinct timing within the same framework. The charm term accrues inside the settlement window, when the expiring options no longer trade, whereas the discrete term lands at the SOQ, after the settlement value is fixed. Sections D and E measure both in dealers' books.

"Charm" ($\mathcal{C}$), the focus of this section, is the rate of change of Δ with respect to the passage of time. Ignoring the index dividend yield, for a European option, the Black-Scholes $\mathcal{C}$ is given by

$$\mathcal{C}_t = \frac{\partial \Delta}{\partial t} = -\frac{\partial \Delta}{\partial \tau} = -\frac{\partial^2 V}{\partial S \partial \tau} = \frac{\partial \Theta}{\partial S} \tag{6}$$

$$= \phi(d_1)\left(\frac{d_1}{2\tau} - \frac{r + \sigma^2/2}{\sigma\sqrt{\tau}}\right) \tag{7}$$

which is identical for puts and calls. $\mathcal{C}$ is commonly used to monitor and adjust delta hedges over (a) weekends or holidays due to the extended non-trading period; or (b) when options are near expiration since the magnitude of $\mathcal{C}$ increases quickly as time-to-maturity (τ) goes to zero. Unlike Γ and $\mathcal{S}$, exposures to $\mathcal{C}$ imply that, to maintain their delta hedge, dealers need to adjust their hedge with the passage of time, even if there is no movement in the underlying. Importantly, the effect of $\mathcal{C}$ spikes into expiration, as demonstrated below. This point is well understood among practitioners, who often refer to this phenomenon as "delta bleed." In the academic literature, charm-induced hedging flows appear most prominently in models of expiration-day "pinning": Avellaneda and Lipkin (2003) show that such flows can switch sign around a strike with large open interest and pull the underlying toward it, and Ni, Pearson, and Poteshman (2005) document the resulting clustering of optionable stock prices on expiration dates. The delta drift we study differs in kind: aggregated across dealers' S&P 500 inventory, its average is driven by dealers' short position in out-of-the-money puts, whose Δs decay toward zero into expiry (Section E), so the implied hedging flow is directional rather than strike-stabilizing and, unlike the strike-local flows behind pinning, does not reverse direction around a particular strike. Consistent with this distinction, we find no pinning of the S&P 500 around option strikes at the 3^{rd} Friday open (OA Section A.2). Outside the pinning setting, the time drift in options' Δ has received little attention in the academic literature.

Figure 4 illustrates charm for two hypothetical options. Panel (a) plots the Δ of a hypothetical call option over the 48 hours before expiry, as time $\tau \to 0$. Panel (b) contains a hypothetical put. The dotted line represents an in-the-money (ITM) option and the solid line an out-of-the-money (OTM) option. Upon expiry, the Δ of a call (put) option will be either 1 (-1) (i.e., the option expires in-the-money) or 0 (i.e., the option expires out-of-the-money). The slope of these lines is $\mathcal{C}$, measuring the rate at which Δ changes due to the passage of time, and thus the rate at which option dealers must trade in stocks to adjust their hedges. As the figure illustrates, $\mathcal{C}$ is negligible for options with many days to expiry, but $\mathcal{C}$ spikes as options near expiry. The Δ of an option drifts due to the passage of time, and especially so immediately before option expiry.

$\left[\text{INSERT FIGURE 4 HERE} \right]$

Panel (c) displays the properties of $\mathcal{C}$ for options with $\tau = 48$ and $\tau = 17{:}15$ hours until expiry. The horizontal axis is plotted in terms of moneyness ($\log \frac{S_t}{K}$). For different levels of moneyness, the effect of $\mathcal{C}$ for deep ITM and OTM options is effectively zero, since their Δ is already at its terminal value, leaving little room for further drift. However, for options that are close to the money, the effect of $\mathcal{C}$ can be large. The Δ of just OTM calls is dragged rapidly toward 0 (negative $\mathcal{C}$), while the Δ of just ITM calls is dragged rapidly toward 1 (positive $\mathcal{C}$). The intuition for puts is symmetric: The Δ of OTM puts drifts from negative values (say, -0.4) toward 0, while the Δ of ITM puts drifts from intermediate values (say, -0.6) toward -1.

To summarize this subsection, options' delta drifts to 0 or 1 (for calls) and 0 or -1 (for puts) as the option approaches expiration, even if the price of the underlying does not change. This effect is especially strong for options that are close to the money, since their Δs are approximately 0.5 (-0.5) and so have a long way to drift. As a consequence of options' delta drift, option dealers' inventory delta drifts into option expiry, too. This drift occurs even if dealers are initially fully delta-hedged and even if the options have ceased trading. We turn to option dealers' inventory positions next.

C. Dealers' Option Position Before Option Expiry

We examine the positions of option market makers in S&P 500 index options, with a focus on 3^{rd} Thursday close positions and the expected drift in their net-Δ position. We exploit CBOE Open-Close Volume files to estimate option dealers' inventory. Section I describes the data. For every S&P 500 option on every day since 1996, the CBOE Open-Close Volume files show the number of options bought and sold by the market maker sector. Cumulating these trades yields an estimate of dealers' net-position, i.e., an estimate of the number of options that dealers are long minus the number of options that dealers are short, for every S&P 500 option on every day. Since we do not observe dealers' starting inventory in January 1996, we use a six-month burn-in period that allows most initial option positions to expire. Hence, our sample of dealer positions is July 1996 to December 2023. Our results are robust to the choice of initialization period.

While our data on S&P 500 options are comprehensive, we do not observe dealers' position in other derivatives. For example, equity futures options also settle into the SOQ on Triple Witching days. To address the additional noise introduced by these days, we report the results of our predictive regressions both for the full set of expiration days and for the cleaner subsample of non-quarterly dates.

Table VI documents the dealer position in a.m.-settled S&P 500 options. Panel (a) column 1 shows that, on an average day, dealers' net-position in calls is -0.16 million. Column 2 shows that on an average 3^{rd} Thursday, immediately before option expiry, dealers' net-position in calls is -0.86 million. In contrast, dealers' average position in puts is -16.82 million generally, and -18.98 million into expiry. This shows that dealers' long and short positions in calls are of about equal magnitude, yielding a net-position close to zero, while dealers' short position in puts exceeds their long position, resulting in a large negative net-position. These positions reveal systematic demand imbalances, consistent with evidence in Garleanu, Pedersen, and Poteshman (2009) and Golez and Jackwerth (2012).

The aggregate number of options in dealers' portfolio does not reveal their risk exposures without accounting for options' moneyness, time to expiry, the expected equity return volatility, and many more aspects. The subsequent columns address this via dealers' net Greek exposures: net-Δ, net-Γ, and net-$\mathcal{C}$.

$\Big[$ INSERT TABLE VI HERE $\Big]$

Column 4 shows that, at the 3^{rd} Thursday close, dealers' net-position in calls carries an aggregate Δ of 2.37 million, and the dealer put position carries a Δ of 2.15 million. Call options have positive Δ. Therefore, one would expect a short call position to carry an aggregate negative Δ. Here, however, long and short positions differ along the dimensions of moneyness and time to expiry in such a way that an aggregate short call position carries an aggregate positive Δ. Both these exposures are calculated as the sum-product of the dealer position across options and the respective options' Δ (Figure A.3 in the OA displays time series plots of dealer net-Δ and net-Γ). To offset this Δ-exposure from options, dealers would short 4.52 million units of the S&P 500. As options expire, the expiring contracts' Δ disappears from dealers' inventory and dealers can be expected to trade out of the corresponding stock position. However, we show below that dealers manage the expiring book's Δ down to near zero over the final trading days before expiry, and that the expiring delta level does not predict the 3FPS. This is consistent with the level unwind being anticipated and spread over liquid regular trading hours, where ample liquidity absorbs the trades with minimal price impact. In contrast, the delta drift generates an exposure change over the 17:15-hour overnight window, when expiring options have already ceased trading and equity liquidity is thin, creating scope for price pressure.

Column 6 shows that dealers carry a negative inventory Γ into option expiry. As a result, positive equity price changes would make dealers' Δ more negative (via their negative Γ exposure), incentivizing them to buy stocks to remain hedged. However, similar to the amount of expiring Δ, we find that option dealer inventory Γ does not explain the 3FPS. Also note that dealers' inventory Γ does not differ substantially between all days (column 5) and expiry days (column 6), which is difficult to reconcile with Γ driving a spike that occurs only into expiry days.

Column 8 shows that dealers carry substantial negative net-$\mathcal{C}$ from their options inventory immediately before option expiry. A $\mathcal{C}$ of -23.20 million implies that dealers' inventory delta drifts down with the passage of time, when measured at the 3^{rd} Thursday close. To offset this drift, dealers have an incentive to buy stocks into option expiry, which can explain the 3FPS. In Section E, we construct a direct measure of the projected dealer delta drift, which averages $-38{,}000$ index units over the 17:15-hour overnight window - equivalent to approximately $-2{,}200$ index units per hour. Another attractive property of $\mathcal{C}$ becomes clear when comparing column 8 with column 7, which displays dealer option $\mathcal{C}$ on an average day of the sample. $\mathcal{C}$ is much more pronounced ahead of option expiry, explaining why the 3FPS is specific to option expiry days.

D. Level and Drift in Option Dealers' Inventory Delta

Level and drift in option dealers' inventory delta are distinct objects and behave differently. Figure 5 plots the average level of dealers' net-Δ in the five trading days before 3^{rd} Friday expiration. The expiring-book Δ is positive several days before expiration, but declines sharply as settlement approaches: from 0.76 million index units five trading days before expiry to 0.21 million on the last trading day before the SOQ, where it is statistically indistinguishable from zero. By contrast, dealers' net-Δ in other 3^{rd} Friday options remains positive throughout this window. Thus, the decline is specific to the expiring book and is suggestive evidence that dealers anticipate the cliff and wind the position down in advance.

[INSERT FIGURE 5 HERE]

While there is little sign of a systematic cliff in option dealers' inventory delta at option expiry, the dealer delta drift is typically negative. We separate the level of dealer delta and the dealer delta drift through the positions data and through timing, since the level is observable daily while the drift accrues only over the settlement window. The level unwind corresponds to the anticipated disappearance of the expiring book's Δ at settlement. Winding the level down early reduces dealer risk, creating an incentive for dealers to spread that trade over liquid regular trading hours (Figure 5). Thus, there is no statistically significant expiring delta left for dealers to unwind at settlement. If anything, the remaining expiring-book Δ is slightly positive on the last pre-expiry day, and dealers would therefore be short stocks against that residual delta. Hedging the overnight drift early would instead create exposure, because the drift has not yet accrued when the expiring options stop trading at the Thursday close. As the options approach their expiry overnight, the remaining positive option delta drifts toward zero, giving dealers an incentive to buy back their short hedge.

The reason why dealers' option inventory experiences a typically negative drift, but no systematic cliff, lies in the details of dealers' option positions. Dealers' dominant option position is short out-of-the-money puts. In our setting, dealers enter option expirations on average net short 18.98 million puts (Table VI, Panel (a)). To hedge this short put position, dealers are short stocks. As the out-of-the-money puts expire out-of-the-money, dealers' delta drifts to zero and they buy back their stocks, creating positive price pressure in the underlying stocks, but creating no delta cliff, since the puts expire at zero delta.

E. The Projected Dealer Delta Drift (DDD)

Next, we introduce a new measure, the projected Dealer Delta Drift (DDD). Delta drift captures the predictable change in options' Δs over the settlement window that arises from the passage of time. It therefore serves as a proxy for the integrated charm exposure, primarily of expiring options, between the 3^{rd} Thursday close and the 3^{rd} Friday open (a 17:15-hour window). We construct DDD by projecting each contract's Δ from the 3^{rd} Thursday close toward its terminal value at expiry (-1, 0, or 1), using the options' moneyness at the 3^{rd} Thursday close, adjusted for the positive expected overnight equity index return. This approach avoids committing to a specific option-pricing model and is less sensitive to the extreme curvature of higher-order Greeks as time-to-expiry approaches zero.

We compute DDD as the change in dealers' net-Δ across their a.m.-settled option book between the 3^{rd} Thursday close and the 3^{rd} Friday open. Let $q_{i,t}$ denote dealers' net-position in option i

at the 3^{rd} Thursday close, and let $\Delta_{i,t}^{\text{Thu}}$ denote the option's delta at that time. Dealers' net-Δ exposure at the 3^{rd} Thursday close is $\Delta_t^{\text{Thu}} = \sum_i q_{i,t}\, \Delta_{i,t}^{\text{Thu}}$. We then form projected deltas at the 3^{rd} Friday open, $\widetilde{\Delta}_{i,t}^{\text{Fri}}$, and the corresponding projected net-Δ exposure $\widetilde{\Delta}_t^{\text{Fri}} = \sum_i q_{i,t}\, \widetilde{\Delta}_{i,t}^{\text{Fri}}$. Our projected dealer delta drift is defined as

$$\text{DDD}_t = \widetilde{\Delta}_t^{\text{Fri}} - \Delta_t^{\text{Thu}}. \tag{8}$$

We hold positions fixed at their Thursday-close values over the settlement window; for expiring options, which cease trading at the 3^{rd} Thursday close, this holds by construction. The only object that requires estimation is $\widetilde{\Delta}_{i,t}^{\text{Fri}}$.

To estimate $\widetilde{\Delta}_{i,t}^{\text{Fri}}$, we adopt a simple classification rule based on terminal deltas. At expiry, a call has $\Delta = 1$ if it finishes in-the-money (ITM) and $\Delta = 0$ otherwise; a put has $\Delta = -1$ if it finishes ITM and $\Delta = 0$ otherwise. We assume that moneyness at the 3^{rd} Thursday close determines moneyness at expiration, with a small adjustment for the expected overnight drift in the index. Let S_t^{Thu} denote the S&P 500 level at the 3^{rd} Thursday close and let $\bar{r}^{ON}$ denote the expected overnight log return (an annualized μ of 8%, approximately 1.6 bps over the window). We classify a call with strike K as expiring ITM if $K < S_t^{\text{Thu}} \exp(\bar{r}^{ON})$ and as expiring OTM otherwise. Analogously, we classify a put as expiring ITM if $K > S_t^{\text{Thu}} \exp(\bar{r}^{ON})$ and as expiring OTM otherwise. We then set $\widetilde{\Delta}_{i,t}^{\text{Fri}} = 1$ (0) for ITM (OTM) calls and $\widetilde{\Delta}_{i,t}^{\text{Fri}} = -1$ (0) for ITM (OTM) puts. For contracts expiring on later dates, the same projection applies over each contract's remaining life, with Δ gliding linearly toward its terminal value, so that only the overnight fraction of each contract's Δ-glide accrues within the settlement window. The DDD defined in equation (8) measures the total projected Δ-change over the 17:15-hour overnight window before a.m. expiry. This is the quantity used in the predictive regressions (Table VII). For non-expiry days and weekends, the same construction applies with the appropriate time-to-expiry horizon.

The 3^{rd} Thursday close is the economically motivated starting point for the drift window: it is when the expiring options stop trading, so from that moment the expiring book is frozen and its delta drift can no longer be managed in the option market and must instead be hedged in the underlying market. Measuring the drift from a later reference point, such as early 3^{rd} Friday morning, would omit drift that has already accrued and still requires hedging. When dealers execute the resulting trades within the window is a matter of execution timing: the price pattern in Figure 1 accelerates around 3:00 a.m., when European markets open and overnight liquidity improves, consistent with dealers concentrating their hedge adjustments where trading is cheapest.

Panel (b) of Table VI shows our calculation of the DDD quantitatively. Column 1 shows the current inventory-Δ at the 3^{rd} Thursday close, with calculation and results equivalent to column 4 in Panel (a). Dealers carry a Δ-position of 4.52 million in their a.m.-settled option book before option expiry. Column 2 shows that the expected dealer inventory Δ 17:15 hours later is 4.48 million. The difference, approximately −38,000 index units, is the DDD. Its unconditional mean is negative but imprecisely estimated (t-statistic $= -1.57$). The drift originates in the put book (row 2: −0.08 million, t-statistic $= -2.10$), while the call book drifts slightly upward. Our predictive tests exploit the time-series variation in the DDD rather than its unconditional mean, and the sign sorts of Figure 7 below link the typically negative drift to the positive average spike.

The negative average DDD shows that dealers' net-Δ positions tend to decline overnight before option expiry. In economic terms, this exposure implies the need to purchase approximately \$41 million of S&P 500 exposure overnight.[15] This quantity amounts to roughly 15% of the typical signed order imbalance of about \$274 million observed ahead of 3^{rd} Friday settlements. Whether hedging flows of this magnitude can move prices by the observed 10 basis points depends on overnight price elasticity. Overnight equity markets are substantially less liquid than regular-hours trading, with larger price impacts per unit of order flow (Boyarchenko, Larsen, and Whelan, 2023; Barclay and Hendershott, 2003). The predictability regressions in Table VII link the projected flows to prices in the direction the mechanism requires: a one standard deviation change in the DDD predicts overnight index returns with an R^2 of approximately 1.3%.

Figure 6 shows DDD over all days in our sample. In this figure, we express DDD as a rate (index units per hour) by dividing the total projected delta change by hours to expiry, to make the magnitude of the delta drift comparable for options with different times to expiry. The red dots highlight expiry dates and reveal that the dealer delta drift is both more extreme and more negative on 3^{rd} Thursdays than on other days, with the most extreme observations well below zero. Moreover, there is substantial variability that we exploit in our next tests. Option dealers' inventories predictably drift overnight prior to a.m. settlement, requiring offsetting purchases of S&P 500 equities, or related products, to restore delta-neutrality of dealers' inventory.

[INSERT FIGURE 6 HERE]

As a check on the construction, we regress DDD on contemporaneous Greek exposures, for

[15] Computed as the average across expiries of the projected drift multiplied by the contemporaneous S&P 500 level.

all 3^{rd} Friday expiries, non-quarterly expiries (unaffected by Triple Witching activity), weekends, and non-expiry days (OA Table A.7). The estimates confirm that projected Δ changes are tightly linked to net-$\mathcal{C}$: across the expiry-day specifications, a one standard deviation increase in dealer $\mathcal{C}$ is associated with an approximately 0.6 standard deviation increase in the projected dealer delta drift (0.3–0.5 on the weekend and non-expiry samples). This link is expected by construction, since the DDD aggregates the time-decay of option deltas, which $\mathcal{C}$ measures. Thus, the regression validates the proxy rather than providing independent evidence on the hedging mechanism.

F. Predictability Regressions

To directly test the delta-hedging explanation for the 3FPS, we examine whether time-series variation in the DDD predicts overnight S&P 500 returns on 3^{rd} Fridays. Table VII reports the results of a predictability regression of overnight returns on the lagged DDD, measured at the previous day's close. Panel (a) uses index returns from close to the SOQ, while Panel (b) uses S&P 500 futures returns (standard contract through September 1997, E-mini thereafter). The return window begins at the 4:15 p.m. close, the same point at which dealer positions and the projected drift are measured, so the predictors use only information available at the start of the return window. Because the DDD is constructed from the 3^{rd} Thursday index level, Panel (a)'s dependent variable and the regressor share that price; Panel (b)'s futures-based returns do not, so the result there cannot arise from a common price input. The sample is July 1996 to December 2023. Standard errors are calculated using a block bootstrap where the optimal block length is chosen in a data-driven way following Patton, Politis, and White (2009), and we also report Newey-West t-statistics with 3 lags.

$\left[\text{INSERT TABLE VII HERE}\right]$

In Panel (a), the coefficient on the DDD is economically large and statistically significant. A more negative drift is associated with higher overnight returns into the 3^{rd} Friday expiry. A one standard deviation increase in the projected drift predicts a 0.13-standard-deviation reduction in the 3FPS, with an R^2 of 1.29%, which is sizable given the short 17:15-hour horizon. The drift enters alone in the odd-numbered specifications. The even-numbered specifications control for the dealers' net-Γ, and the drift coefficient is essentially unchanged. Net-Γ itself is statistically significant only in column 2 of Panel (a). A growing literature documents the price effects of dealers' Γ-hedging (Baltussen, Da, Lammers, and Martens, 2021; Barbon and Buraschi, 2020). Those effects, however, amplify or dampen the preceding price move (momentum or reversal, depending on the sign of dealers' positions) and make no unconditional directional prediction, so net-Γ alone cannot explain the 3FPS. The OA (Table A.8) reports versions that additionally include the expiring dealer delta level. The drift coefficient is unchanged there, and the level itself does not predict the overnight return (univariate $t = 0.65$). Unreported controls for short-term price-pressure proxies (VIX index, TED spread) also leave the effect unchanged. The estimate is likewise insensitive to the assumed expected return used in constructing the projected drift: re-estimating the regression for every annualized μ between 0% and 16%, including $\mu = 0$, leaves the coefficient essentially unchanged (OA Figure A.4).

To verify that the result is not driven by the unusually high activity on Triple Witching days, we repeat the analysis for the subset of non-quarterly expiries (columns 3 and 4). The coefficients remain significant and of greater magnitude, confirming that predictability is not specific to quarterly expirations. Columns 5 and 6 show the results for S&P 500 returns over weekends, as predicted by dealer positions at Friday close.[16] Over weekends, the passage of time is largest (more than 2.5 days elapse), but DDD is relatively small due to its maturity dependence. Accordingly, we find little predictability over weekends, consistent with our finding that equity price pressures occur around option expiry, not over weekends.

Non-expiry days provide a second placebo. On those days the mechanism is doubly absent: the drift can be hedged smoothly during liquid trading hours rather than in a forced overnight window, and DDD varies roughly a quarter as much as on expiry days (visible in Figure 6), so a predictability regression is uninformative there. The OA reports it for completeness (Table A.8, column 6), with point estimates and R^2 close to zero. The predictive content of DDD is thus concentrated in periods close to a.m. option expiry, where we observe the 3FPS and the associated shifts in derivative payoffs. Panel (b) shows that the results carry over to futures returns, with somewhat attenuated all-expiry estimates and nearly identical non-quarterly ones.[17] Overall, the evidence shows that dealers' expected net-Δ change measured at the 3^{rd} Thursday close reliably forecasts S&P 500 overnight returns into the SOQ, consistent with the recurring 3FPS pattern

[16]Note that projecting the dealer delta drift over weekends requires expanding the time window from 17:15 hours to 2 days and 17:15 hours.

[17]In addition, unreported robustness tests using the post-2010 CBOE "market maker" classification (2011 to 2023) produce very similar results, confirming that our findings do not depend on how dealer positions are identified. In our main specification we identify market makers as the counterparty to "customers" and "firms."

arising from dealers' hedge adjustments.

Finally, we examine the conditional impact of the DDD on the 3FPS via sorting. We divide expiry days into two groups, based on the sign of DDD, as measured at the 3^{rd} Thursday close. Panel (a) of Figure 7 presents the results for all 3^{rd} Friday expiries, while Panel (b) focuses on non-quarterly expiries. Consistent with the regression evidence, we find a negative relation between the projected dealer delta drift and subsequent overnight equity returns. When DDD is negative, indicating a dealer incentive to buy stocks into option expiry, the average overnight S&P 500 return is 16 bps, compared with only 4 bps when DDD is positive (Panel (a)). Restricting the sample to non-quarterly expiries, where market activity is less dominated by futures and related contract settlements, strengthens the pattern. Overnight returns average 17 bps when DDD is negative, but turn negative at -2 bps when DDD is positive (Panel (b)). In the non-quarterly sample, 113 expirations have a negative projected drift and 105 a positive drift. The difference between the two groups is 19 bps (t-statistic = 2.16). Put differently, the 3FPS is positive on average because dealers' net-Δ change is typically negative, but the spike can flip sign when their net-Δ change turns positive.

We conclude that dealers' delta-hedging is a plausible mechanism driving the 3FPS and its consequences for derivative payoffs. Option market makers' hedging requirements are associated with systematic equity price pressures around option expiry: a mechanical downward time drift in dealers' inventory delta gives dealers an incentive to buy in the relatively illiquid overnight window before a.m. expiry, in line with the upward drift in equity prices we document. These gains subsequently reverse intraday, producing recurring price spikes in equities and systematic shifts in cash-settled index derivative payoffs.

G. Discussion and the Potential for Market Manipulation

Underlying price pressures that impact derivatives prices give rise to the possibility of market manipulation, as manipulators could push the underlying index price up in the period immediately preceding settlement, such that settlement prices move in the direction that benefits their positions. Ni, Pearson, and Poteshman (2005) and Griffin and Shams (2018) present evidence suggesting that manipulators are active around option expiration dates for individual stocks and the VIX index.

We acknowledge that manipulative buying and hedging-induced buying are difficult to distinguish empirically, as both imply purchases into the settlement window by traders who benefit from a higher SOQ. Our evidence ties the overnight pressure to dealers' ex-ante, inventory-implied hedging need, which we view as the primary driver of the 3FPS. However, additional flows associated with manipulation may also be at play. One further observation locates the price pressure, but cannot confirm or reject the presence of market manipulation. On expiry mornings, the settlement-window return measured at the SOQ exceeds the same-window return measured from index futures by about 4 basis points more than the ordinary-day cash-futures gap (unreported). Pressure concentrated in the opening trades of the index constituents, from which the SOQ is computed, is to be expected whether the buying reflects hedging in stock baskets or opportunistic positioning. We therefore present this comparison as locating the pressure rather than as identifying intent.

Similarly, the predictability of equity returns around the a.m. option settlement opens possibilities for predatory trading, that is, trading that exploits the needs of others to change their positions. Investors who are informed about dealers' delta drift before the 3^{rd} Friday settlement could anticipate the hedging trades and benefit from the resulting price pressures.[18]

Lastly, we contribute to the growing literature documenting predictable price patterns that persist in large and liquid markets. Hartzmark and Solomon (2025) provide a recent example: predictable uninformed cash flows from dividend reinvestment forecast aggregate market returns. Like the dividend-day effect, the 3FPS persists over our 31-year sample in equities, equity futures, and equity options, raising fundamental questions about why sophisticated investors do not arbitrage these patterns away. Limits to arbitrage remain a puzzling yet fruitful frontier for the asset pricing literature. Several frictions may help explain this persistence. Trading against the 3FPS requires taking overnight index exposure into the settlement window, where liquidity is thin and price impact is large. Doing so at scale demands sophisticated trading infrastructure and substantial balance-sheet capacity, particularly around quarterly Triple Witching days when volumes spike.

V. Conclusions

Each month, when U.S. equity index derivatives settle into the S&P 500 Special Opening Quotation (SOQ), the index opens on average 10 basis points above its prior close and fully reverses by

[18] Brunnermeier and Pedersen (2005) give numerous real-world examples of predatory trading. Henderson, Pearson, and Wang (2020) find evidence of predatory trading around the pricing dates of structured equity products, impacting the prices of even the largest and most liquid U.S. stocks.

midday. This predictable Third Friday Price Spike (3FPS) is specific to expiry days with a.m. settlement and extends to futures markets. Because derivative payoffs are determined from these temporarily elevated opening prices, call option payoffs are inflated, put option payoffs deflated, and we estimate that \$1.5 to \$2.2 billion in wealth is redistributed among investors in S&P 500 index options alone each year. Further, these transfers are realized at settlement and are not priced into options in advance: a put-call parity test shows that expiring options are quoted at fair carry on the 3^{rd} Thursday.

We trace this price spike to the predictable hedging demand implied by option dealers' inventories. As expiration approaches, the passage of time moves dealers' inventory delta downward on average, an effect driven by their short put positions and requiring overnight equity purchases to maintain delta-neutral portfolios. We measure this incentive with a projected dealer delta drift, constructed from option market makers' positions data measurable at the 3^{rd} Thursday close: a series of predictability tests demonstrates a robust link between mechanical hedging needs over an illiquid overnight window and market-wide effects on equity returns, option returns, and option payoffs. Our findings suggest that the alignment of derivative expirations with thin trading windows warrants scrutiny from exchanges and regulators.

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VI. Tables

	Option Expiry Days		Control Group			
	I. Th_{close} to 3^{rd} Fr_{open}	II. 3^{rd} Fr_{open} to 3^{rd} Fr_{close}	III. Close to Open	IV. Open to Close	I. - III.	II. - IV.
	Panel (a) Control Group: Non-Expiry Days					
mean	9.80	-15.10	1.30	2.47	8.50	-17.58
t-stat	(3.04)	(-3.57)	(1.66)	(2.25)	(2.41)	(-3.50)
	Panel (b) Control Group: Non-Expiry Fridays					
mean	9.80	-15.10	0.58	4.10	9.21	-19.20
t-stat	(3.04)	(-3.57)	(0.29)	(1.57)	(2.29)	(-3.66)

Table I. S&P 500 Returns around 3^{rd} Fridays

This table reports average S&P 500 returns, with associated t-statistics in parentheses. The t-statistics in columns 1 to 4 test the mean return against the null of zero; those in columns 5 and 6 test the difference in mean returns, allowing for unequal variances. Columns 1 and 2 show returns around 3^{rd} Fridays, columns 3 and 4 show returns for the control group. Columns 5 and 6 show the difference of means between 3^{rd} Friday returns and control group returns. In Panel (a), the control group consists of all days that are not 3^{rd} Fridays; in Panel (b), the control group consists of all Fridays that are not 3^{rd} Fridays. Returns are computed from official S&P 500 closing prices and the Special Opening Quotation, which is published on every trading day; the sample contains 371 3^{rd} Friday expirations. Returns are in basis points. The sample period is November 1992 to December 2023.

	Th_{close} to 3^{rd} Fr_{open}	3^{rd} Fr_{open} to 3^{rd} Fr_{close}	3^{rd} Fr_{close} to Mo_{open}	Difference $(2) - (3)$
mean	10.07	-15.51	-13.14	-5.13
t-stat	(2.20)	(-2.34)	(-1.66)	(-0.59)

Table II. S&P 500 Returns around 3^{rd} Fridays, Post-2011

This table reports average S&P 500 returns, with associated t-statistics in parentheses. The t-statistics test the mean return against the null of zero. Column 1 shows returns from Thursday close to the 3^{rd} Friday open, column 2 shows returns from the 3^{rd} Friday open to the 3^{rd} Friday close, and column 3 shows returns from the 3^{rd} Friday close to Monday open. Column 4 reports the mean difference between the column 2 and column 3 returns, computed as a paired difference, with its t-statistic, across the 129 expiries for which both windows are available. Columns 2 and 3 average over all available expiries, so column 4 can differ from the difference of the displayed means. Returns are computed from official S&P 500 closing prices and the Special Opening Quotation, which is published on every trading day. Returns are in basis points. The sample period runs from September 2011, when p.m.-settled 3^{rd} Friday options were reintroduced, to December 2023.

	Payoffs		
	I. Actual	II. Counterfactual	I. - II.
Sum Calls ($ mn., rounded)	8,565	8,476	89
Sum Puts	3,211	3,251	-40
Sum abs(I. - II.)			129

Table III. S&P 500 Option Payoffs on 3^{rd} Fridays

This table shows actual and counterfactual S&P 500 option payoffs. Row 1 contains calls, row 2 contains puts. Column 1 shows the mean monthly payoff from expiring SPX options. The monthly payoff is calculated as the sum-product of each option's payoff and the respective option's open interest, including the 100× contract multiplier. Option payoffs are determined on 3^{rd} Fridays via the Special Opening Quotation (SOQ). Column 2 shows the mean counterfactual option payoff, where each option's counterfactual payoff is calculated from a counterfactual settlement value equal to the realized SOQ lowered by 10 basis points, the average 3FPS over the full 1992 to 2023 sample; the counterfactual thus preserves each expiration morning's realized volatility and news. The average 3FPS over this table's sample is approximately 11 basis points, so the estimated transfer is conservative. Column 3 displays the difference between actual and counterfactual payoffs, and row 3 displays the sum of the absolute differences. Entries are computed before rounding, so displayed differences can deviate from the difference of the displayed values in the last digit. All numbers are in millions of dollars. The sample period is January 1996 to December 2023.

	Deviation	t vs 0	t vs +10	Trading Cost	Inside Bid-Ask (%)
1996 to 2023	−0.33	(−0.47)	(−14.57)	8.2	60
1996 to 2009	−0.73	(−0.55)	(−8.06)	8.4	46
2010 to 2023	0.06	(0.12)	(−19.10)	8.0	74

Table IV. Put-Call Parity Deviations at the 3^{rd} Thursday Close

This table reports put-call parity deviations in S&P 500 option quotes at the Thursday 4:15 p.m. close. For each matched at-the-money call-put pair of standard monthly options ($|K/S-1| \leq 1\%$), the parity-implied forward, $K+(C-P)e^{r\tau}$, is compared to the fair-carry forward, $Se^{(r-q)\tau}$. Quotes are OptionMetrics closing quotes, the underlying is the 4:15 p.m. index value matching the quote time, and the interest rate and dividend yield are from OptionMetrics. Deviations are in basis points of the index and are averaged within each Thursday, so each date is one observation. The options are the expiring, a.m.-settled book, quoted on the 3^{rd} Thursday before settlement. Row 1 reports the full sample. Rows 2 and 3 split it into subperiods. The t-statistics, reported in parentheses, test the mean deviation against the null of zero (column 2) and against the +10 basis points a fully priced-in spike would imply (column 3). Column 4 reports the average trading cost in basis points, since trading on a put-call parity deviation requires buying one option at its ask price and selling the other at its bid price, which costs half the sum of the call and put bid-ask spreads. Column 5 reports the share of dates on which the deviation is smaller than this cost. The three disclosed crisis expirations are excluded. Six expirations whose 3^{rd} Friday is an exchange holiday settle on Thursday morning, leaving no 3^{rd} Thursday close before settlement. The sample period is January 1996 to December 2023.

Days:	Non-Expiry	Expiry	Qtr Expiry	Non-Qtr Expiry
		Panel (a): Overnight		
mean	-0.16	2.63	4.23	1.83
t-stat	(-1.17)	(3.59)	(3.26)	(2.08)
		Panel (b): Intraday		
mean	-1.79	-11.26	-14.04	-9.88
t-stat	(-3.67)	(-5.38)	(-4.16)	(-3.74)

Table V. Order Imbalances in S&P 500 Futures

This table reports summary statistics for the signed volume of the most liquid S&P 500 E-mini futures contract, which is usually the front-month contract. Panel (a) contains the average signed volume overnight (i.e., between 4:15 p.m. and 9:30 a.m.). Panel (b) contains the average signed volume intraday (i.e., between 9:30 a.m. and 4:00 p.m.). The columns show signed volume over non-expiry days, expiry days (i.e., 3^{rd} Fridays), quarterly expiry days, and non-quarterly expiry days, respectively. Signed volume is the number of buyer-initiated minus seller-initiated contracts traded, in 1000s of contracts. The t-statistics, reported in parentheses, test the mean signed volume against the null of zero. The sample period is January 2003 to December 2023.

Panel (a)

	Net No. (mn.)		Net-Δ (mn.)		Net-Γ (k.)		Net Charm (mn.)	
Days:	1. All	2. Exp	3. All	4. Exp	5. All	6. Exp	7. All	8. Exp
Calls	-0.16	-0.86	2.50	2.37	13.98	21.22	7.80	27.64
Puts	-16.82	-18.98	2.36	2.15	-35.36	-48.69	-15.60	-50.83
Sum	-16.98	-19.84	4.86	4.52	-21.39	-27.47	-7.80	-23.20

Panel (b)

	1. Net-Δ at Th_{close}	2. Projected Net-Δ at Fr_{open}	2. - 1. Projected Dealer Delta Drift (DDD)	t-stat
Calls	2.37	2.40	0.04	(0.97)
Puts	2.15	2.08	-0.08	(-2.10)
Sum	4.52	4.48	-0.04	(-1.57)

Table VI. Dealers' Positions in S&P 500 Options

This table reports dealer positions in a.m.-settled 3^{rd} Friday options. Row 1 shows the average dealer position in calls, row 2 shows the average dealer position in puts, row 3 shows the sum. In Panel (a), Net Number is in millions of option contracts. Net-Δ, Net-Γ, and Net Charm are in index units (i.e., scaled by the 100$\times$ option multiplier), expressed in millions (mn.) or thousands (k). Net Charm is an annual rate (index units per year). Net Greeks are calculated as the sum-product of dealers' net-number across options and the respective options' Greek risk measure. The "All" columns show the average position across all a.m.-settled S&P 500 options on all days. "Expiry" columns show the average position across all a.m.-settled S&P 500 options on the day (Thursday) before a monthly expiry. In Panel (b), column 1 shows the dealer net-Δ across all a.m.-settled S&P 500 options at the close of the day (Thursday) before a monthly expiry. Column 2 reports the dealer net-Δ expected at the 3^{rd} Friday open, assuming no changes other than the passage of time. Column 3 shows the difference, the dealer delta drift, and column 4 shows the associated t-statistic, reported in parentheses, which tests the mean drift against the null of zero. The sample period is July 1996 to December 2023.

	1. Expiry All	2. Expiry All	3. Expiry Non-Qtr.	4. Expiry Non-Qtr.	5. Weekend	6. Weekend
Panel (a): Predicting index returns						
Dealer Delta Drift	-0.13	-0.13	-0.17	-0.19	-0.05	-0.05
	[0.06]	[0.06]	[0.07]	[0.07]	[0.04]	[0.04]
	(-2.31)	(-2.40)	(-3.06)	(-3.25)	(-1.26)	(-1.22)
Dealer Gamma		-0.09		-0.11		-0.01
		[0.04]		[0.06]		[0.02]
		(-2.18)		(-1.62)		(-0.84)
$R^2(\%)$	1.29	1.85	2.56	3.24	0.21	0.15
N	325	325	218	218	1201	1201
Panel (b): Predicting index futures returns						
Dealer Delta Drift	-0.09	-0.09	-0.15	-0.16	-0.07	-0.06
	[0.05]	[0.05]	[0.06]	[0.06]	[0.04]	[0.05]
	(-1.95)	(-2.01)	(-2.94)	(-3.05)	(-1.39)	(-1.36)
Dealer Gamma		-0.06		-0.06		-0.01
		[0.04]		[0.06]		[0.02]
		(-1.52)		(-1.01)		(-0.32)
$R^2(\%)$	0.48	0.57	1.79	1.70	0.34	0.27
N	327	327	219	219	1248	1248

Table VII. Regressing S&P 500 Returns on the Dealer Delta Drift

This table displays estimates from regressing the overnight return of the S&P 500 on the lagged dealer delta drift. In Panel (a), returns are computed from the high-frequency 4:15 p.m. index value to the Special Opening Quotation. The high-frequency value is unavailable on the Thursday before two expirations (March 2000 and January 2002), which drop from Panel (a). In Panel (b), returns are computed from the futures mid-quote at close to the mid-quote at open. Columns 1 and 2 contain returns from Thursday close to 3^{rd} Friday open, columns 3 and 4 include only non-quarterly 3^{rd} Fridays, and columns 5 and 6 contain returns from Friday close to Monday open. Even-numbered columns control for the dealers' net-Γ, measured at the same close as the dealer delta drift. All variables are standardized to zero mean and unit variance. Block bootstrapped standard errors, with the optimal block length chosen in a data-driven way following Patton, Politis, and White (2009), are in square brackets. Newey-West t-statistics with 3 lags are in parentheses. The adjusted R^2 is multiplied by 100. The sample period for Panels (a) and (b) is July 1996 to December 2023.

VII. Figures

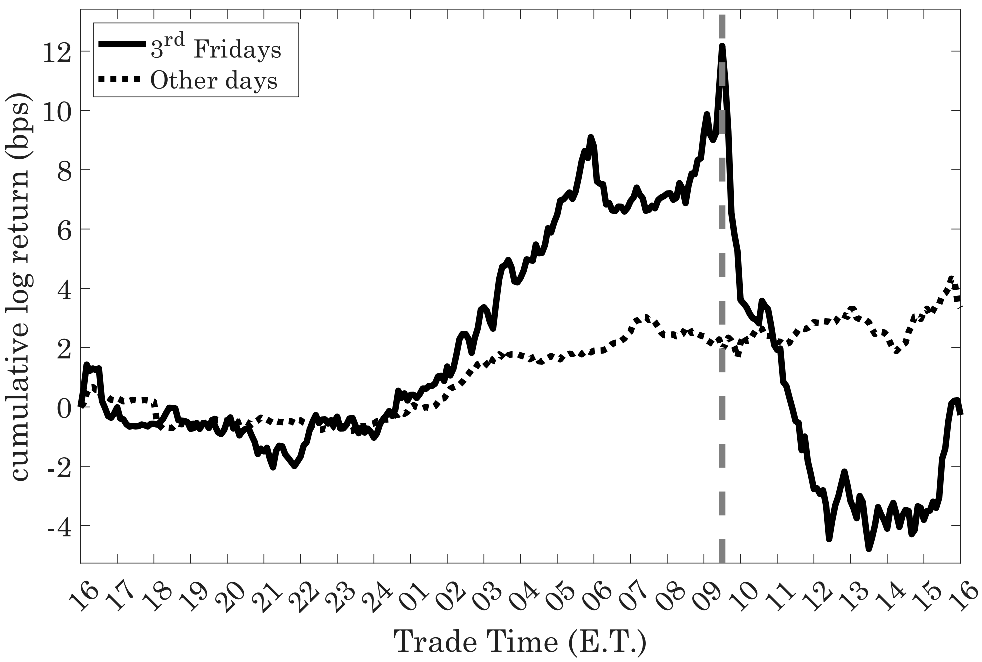
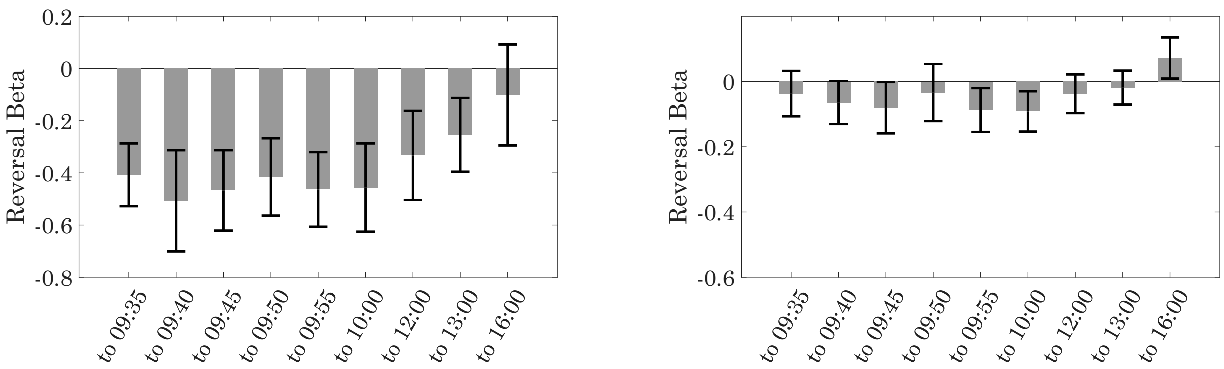


Figure 1. The Third Friday Price Spike in S&P 500 E-mini Futures
The solid black line plots average cumulative 5-minute log returns of S&P 500 E-mini futures around 3^{rd} Friday market open (9:30 a.m., dashed vertical line). The dotted line plots cumulative returns on all other days. The vertical axis is in basis points and the horizontal axis is time of day in Eastern Time. The expiry-day average is computed over 250 3^{rd} Friday expirations and the all-other-days average over 4,785 days. The sample period is January 2003 to December 2023.



(a) Expiry Days **(b)** Other Days

Figure 2. Regressing Intraday S&P 500 Returns on Preceding Night Returns
This figure displays the standardized betas and associated confidence intervals from regressing intraday S&P 500 returns on preceding overnight S&P 500 returns. Returns are measured from S&P 500 futures mid-quotes. The LHS returns are measured from 9:30 to 9:35, 9:40, 9:45, etc. The figure bars represent this expanding window of LHS returns from left to right. The RHS return is measured from the preceding equity close to open. Panel (a) displays results around 9:30 a.m. on 3^{rd} Fridays, and Panel (b) displays results for all other days. The regression includes an intercept. Both return series are standardized to zero mean and unit variance. The error bars show the 95% confidence intervals, based on Newey-West standard errors with 3 lags. The sample period is January 2003 to December 2023.

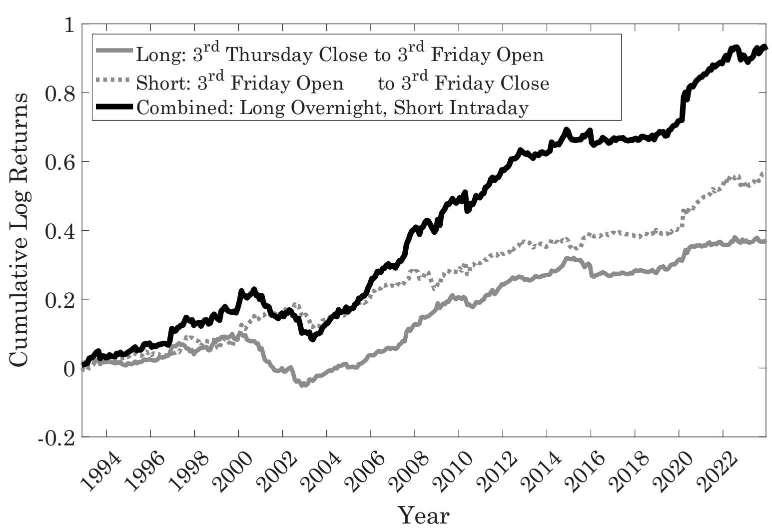
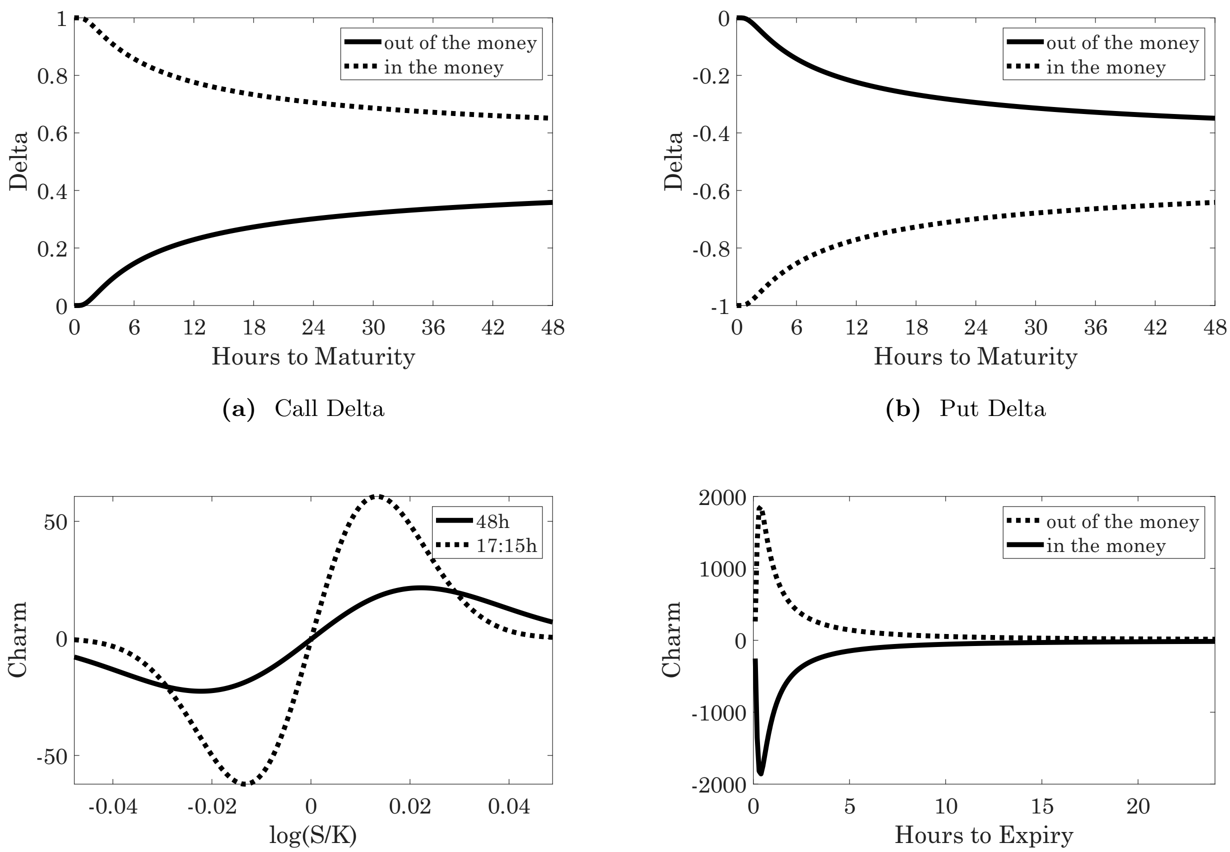


Figure 3. The Third Friday Price Spike, Cumulative
The gray solid line shows cumulative log returns from a long position from 3^{rd} Thursday close to 3^{rd} Friday open. The gray dotted line shows cumulative log returns from a short position from 3^{rd} Friday open to 3^{rd} Friday close. The black line shows the combined strategy that trades both legs, buying at the 3^{rd} Thursday close and reversing into a short position at the 3^{rd} Friday open. To compute returns, we use the SPX closing price at close and the Special Opening Quotation at open. The sample period is November 1992 to December 2023.



(a) Call Delta

(b) Put Delta

(c) Charm by Moneyness

(d) Charm by Time to Expiry

Figure 4. Illustration: Option Charm

This figure displays the behavior of option "Charm," i.e., the change in delta from changes in time to expiry. Panels (a) and (b) show the Black-Scholes delta for European options with an underlying price of 3000, an interest rate of 0, a dividend yield of 0, and an underlying volatility of 30%. For calls (puts), "in-the-money" denotes a strike of 2975 (3025) and "out-of-the-money" denotes a strike of 3025 (2975). Panel (c) shows Black-Scholes charm for options with 48 hours and with 17 hours and 15 minutes until expiry. Panel (d) shows Black-Scholes charm for puts with underlying prices of 2990 and 3010 and a strike of 3000.

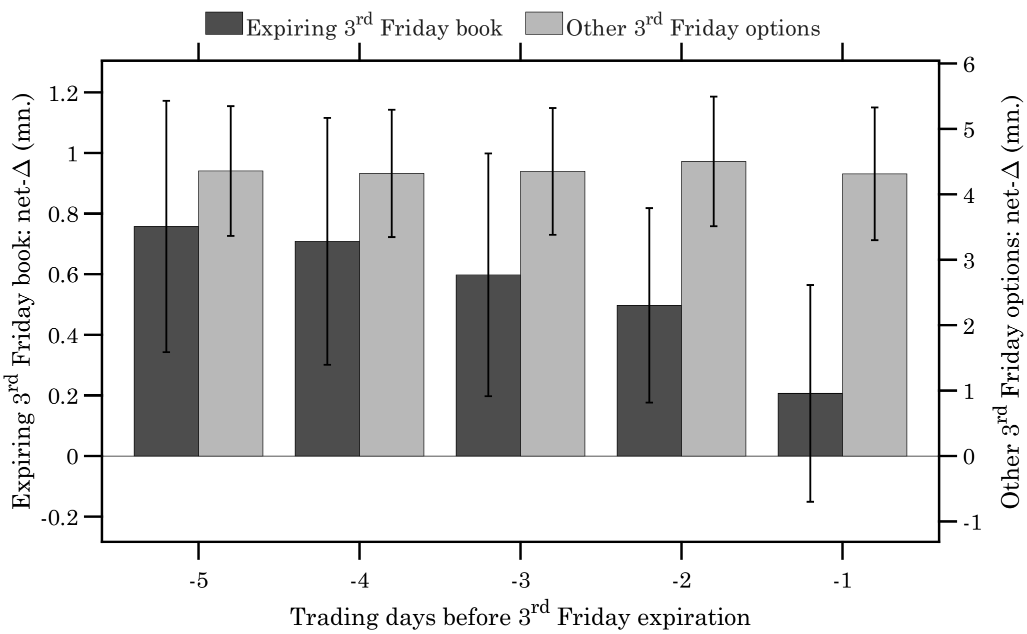


Figure 5. Dealer Net-Δ Before 3^{rd} Friday Expiration

This figure plots the average aggregate dealer net-Δ in a.m.-settled 3^{rd} Friday S&P 500 options over the five trading days before 3^{rd} Friday expiration. Dark gray bars use the left axis and show options expiring into the SOQ. Light gray bars use the right axis and show all other options. Net-Δ equals call plus put dealer net-Δ and is reported in millions of index units. Error bars show 95% confidence intervals based on Newey-West standard errors. The sample period is July 1996 to December 2023.

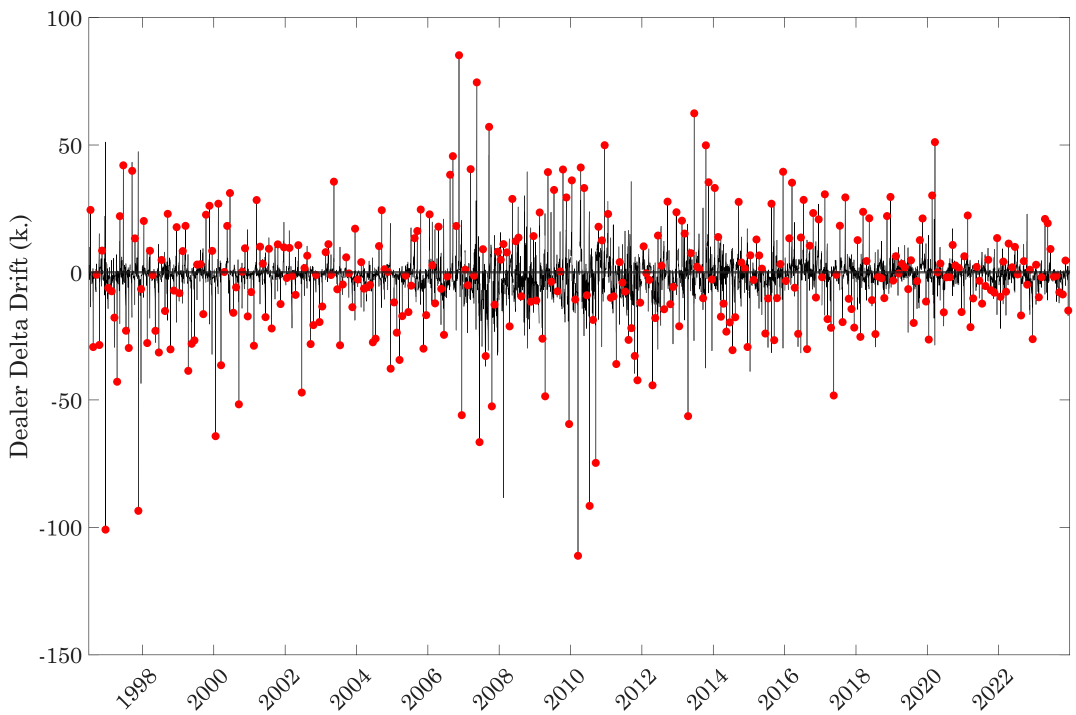
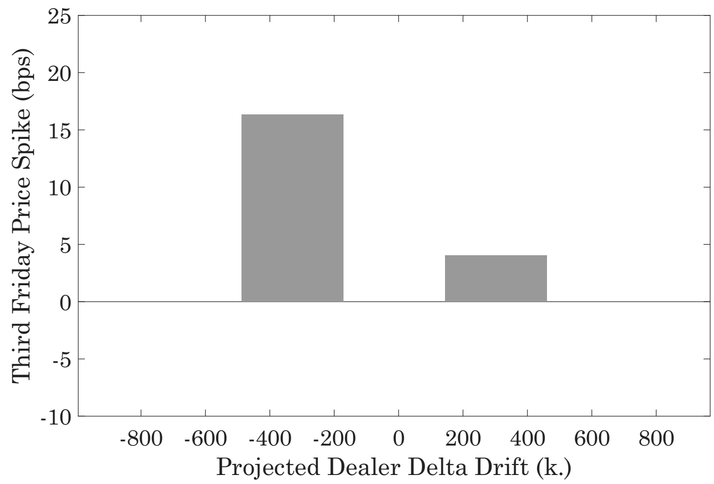
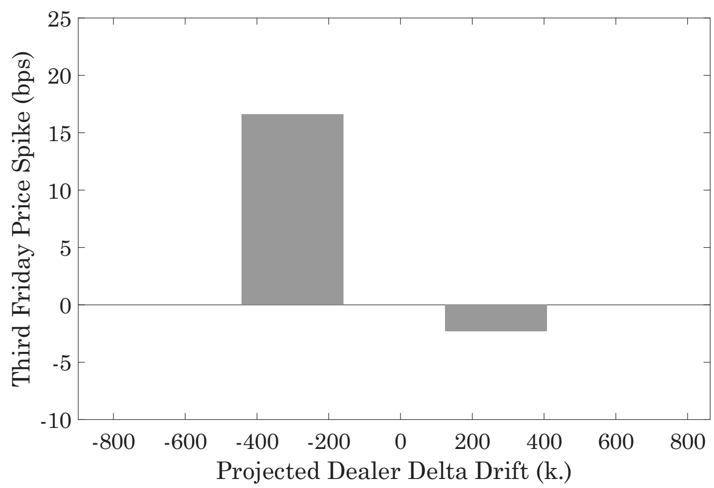


Figure 6. The Projected Dealer Delta Drift (Hourly Rate)

This figure plots the projected dealer delta drift (DDD) over our sample. We estimate the DDD as the sum-product of dealer net positions across options at option market close and the respective options' projected Δ change until expiry, as described in Section IV. We express the DDD as index units per hour (by dividing the total projected change in dealers' net-Δ by hours to expiry) to make the magnitude comparable across options with different times to expiry. The sample includes all a.m.-settled 3^{rd} Friday S&P 500 options that are first to expire. The red dots mark every month's 3^{rd} Thursday, highlighting the hourly rate of projected dealer hedging demand into the 3^{rd} Friday option expiry. The sample period is July 1996 to December 2023.



(a) Expiry Days



(b) Non-Qtr Expiry Days

Figure 7. Sorting Expiry Days by the Projected Dealer Delta Drift

This figure displays the third Friday price spike in the S&P 500 by the projected dealer delta drift in option dealers' inventory. S&P 500 returns are measured from the 3^{rd} Thursday high-frequency 4:15 p.m. index value to the SOQ at 3^{rd} Friday open. The dealer delta drift is measured at 3^{rd} Thursday close. We sort expiry days by the sign of the dealer delta drift and report averages of the dealer delta drift (x-axis) and subsequent S&P 500 returns (y-axis). Panel (a) contains all 3^{rd} Fridays, while Panel (b) contains the non-quarterly 3^{rd} Fridays. The sample period is July 1996 to December 2023.

The Third Friday Price Spike
Online Appendix

This Online Appendix (OA) contains further details on U.S. equity derivatives markets and additional analyses on the third Friday price spike (3FPS). Section A.1 contains a more extensive discussion of relevant U.S. equity index market details. Section A.2 contains details of alternative potential explanations of the 3FPS, for which we find no support in the data. Section A.3 formalizes the counterfactual construction behind the wealth-transfer estimates, derives the per-option transfer exactly, and reports the transfer under alternative benchmarks, which are upper bounds. Section A.4 repeats the payoff accounting in return space and develops the put-call parity algebra behind Section III.B of the main text. Sections A.5 and A.6 contain supplementary tables and figures.

A.1. Further Market Details

A. Equity Futures and Indices

The S&P 500 index (SPX) is the most widely tracked index in the world. Futures on the SPX (hereafter, SP futures) were introduced on the Chicago Mercantile Exchange (CME) on April 21^{st}, 1982, with one futures contract initially offering an exposure of 500 times the index. As the index level rose over time, the contract became expensive to trade at this multiplier and the contract multiplier was cut to 250 times the index on November 3^{rd}, 1997. Contracts since follow a quarterly expiry schedule, expiring on the 3^{rd} Friday of the March-June-September-December cycle. By far the most activity (volume and open interest) is in the front contract (the contract closest to expiry) up to about one week before expiry, after which most market participants roll their positions forward to the next closest contract. Settlement is in cash, meaning that at expiration the futures holder receives or pays a cash payment equal to the difference between the index price and the settlement price of the futures contract. Between inception and June 1984, settlement prices were determined based on the closing price of the 3^{rd} Thursday, after which settlement prices were determined based on the closing price of the 3^{rd} Friday. Driven by concerns about settlement effects, settlement was changed to a Special Opening Quotation (SOQ, explained in detail later) as of June 18^{th}, 1987, computed at the 3^{rd} Friday market open time.[19]

Trading took place both by open outcry and electronically during U.S. regular trading hours concurrently with the cash market plus a 15-minute settlement window after the close of the cash market (i.e., 9:30 a.m. to 4:15 p.m. E.T.). In September 1993, the S&P 500 futures contract began trading electronically outside regular hours via the CME Globex electronic trading platform. Trading in the contract ceases on the 3^{rd} Thursday of the expiry month and all futures contracts that have not been traded out by the end of the last trading day must be settled. As the futures expire into the SOQ, this means futures holders run overnight settlement risk relative to their last traded Thursday price.

Further, as of September 9^{th}, 1997, E-mini futures on the SPX commenced trading, offering the same characteristics as the regular contract with two main exceptions. First, the contract offers

[19] Stoll and Whaley (1991) show that this change in settlement procedure resulted in more trading volume in the open, as well as a slight increase in price reversals around the open. Their sample is, however, limited to only a few years before and after the change (January 1985 through June 1989). Further, futures and options on the S&P 100 and the Value Line index continued to settle at the closing price of the underlying index.

an exposure equal to 50 times the index. Second, trading takes place only on the CME Globex platform which facilitates global trade for most hours of the day, five days a week. Exact trading times on the CME Globex platform have changed over time: until July 2003, trading started at 1:00 a.m., but afterward the trading day was extended to almost 24 hours a day to allow for greater access and flexibility for market participants around the world. Hence, the mini contracts facilitated easier trading and offered greater flexibility to trade around the clock. After the minis' introduction, the standard contracts were quickly surpassed in traded volume, and on September 17^{th}, 2021, the standard-size SPX futures were delisted.

Since the S&P 500 Index is the most widely accepted stock index benchmark of institutional investors, and because the CME's market had the most volume and liquidity, the S&P 500 stock index futures immediately became the dominant stock index futures contract. Other U.S. equity futures share similar characteristics, with futures on the NYSE, DJIA, Nasdaq, Russell 2000, and S&P 400 introduced in 1982, 1997, 1996, 1993, and 1992, respectively. These contracts also had E-mini contracts introduced and shared similar trading hours and settlement procedures (i.e., 3^{rd} Friday expiries based on a Special Opening Quotation and settlement in cash).[20]

Further, Exchange Traded Funds (ETFs) commenced trading as of January 29^{th}, 1993, on the S&P 500 index, with the Standard & Poor's Depositary Receipts (ticker: SPY) ETF being one of the largest ETFs in the world today. Soon ETFs on many other indices followed suit. ETFs trade on stock exchanges and hence typically follow stock exchange trading hours. Equity index futures and ETFs allow investors to accomplish two basic objectives: they can buy or sell the market, and they can more effectively and efficiently hedge against market risk, making them important instruments for option market makers.

B. Option Markets

SPX options have traded on the CBOE since 1983. Following the futures practice, standard SPX options expire on the 3^{rd} Friday of each month, with settlement prices originally based on the official closing price on the expiration day. On June 18^{th}, 1987, the reference point was changed for S&P 500 settlement prices from p.m. (i.e., market close) to a.m. settlement (i.e., market open) for the quarterly index options. Settlement also changed from delivery in stocks to delivery in cash. As of November 20^{th}, 1992, all monthly S&P 500 options also settle into the SOQ, motivating the use of November 1992 as the primary starting date in our study. Trading in expiring options ceases at the market close on Thursday before expiration, 17 hours and 15 minutes before settlement values are determined.

Besides SPX index options, options on SP futures have traded actively since January 28^{th}, 1983, on the CME. These options are American style (i.e., they can be exercised early), refer to one underlying futures contract, trade with strike prices $5 apart, and are effectively cash-settled.[21] As of June 1987, SP futures options that expire on the quarterly cycle follow the same 3^{rd} Friday settlement calendar as the futures themselves and expire into the SOQ. Further, starting in June 1987 SP futures options are also available with expiry dates in months outside the quarterly futures expiry calendar. Importantly, whereas the quarterly SP options are a.m.-settled, the serial monthly options are p.m.-settled based on the close value of the underlying futures contract. As of 1997, S&P 500 futures options are also offered on the E-mini contract sharing the same characteristics as

[20] The exception was the S&P 100 futures contract, which continued to settle at the close of the 3^{rd} Friday. However, this contract comes with relatively little trading activity.

[21] At settlement, in-the-money futures options deliver the underlying futures contract; because the futures expire at the same time and are cash-settled, the ultimate payoff of the option is effectively settled in cash.

options on the regular SP contract. Only trading mechanisms differ, following the regular versus E-mini futures trading mechanisms.

In 2005, the CBOE introduced option contracts on the SPDR ETF. As ETFs are generally traded like common stock, SPY options have the same features as individual U.S. stock options; they are American style, refer to 100 units of the underlying ETF (which is denominated at 10% of the value of the S&P 500 index itself), and are not cash-settled but instead settle via physical delivery of ETFs. ETF options expire on the 3^{rd} Friday of the month at the closing price of that day. ETF options trade about the same hours as the underlying ETF; in the case of the SPDR, this is 9:30 a.m. to 4:15 p.m. E.T.

Johnson, Liang, and Liu (2018) show that SPX options have the most option activity, followed by SP options and SPDR ETF options, with OTM put options being the most prominent position type. In addition, options on the SPX and other U.S. indices also trade over-the-counter (OTC). Johnson, Liang, and Liu (2018) show their size to be about half that of the listed market, while sharing a similar trend in option activity.

The CBOE has introduced a diverse array of SPX option products over time. Standard a.m.-settled SPX index options with monthly 3^{rd} Friday expiry have been the dominant contract for most of our sample and are central to our analysis. P.m.-settled options were reintroduced in 2007 under the SEC's PM Option Expiration Pilot Program, initially with expirations on the last business day of the calendar month, followed by weekly options in 2010, monthly options expiring on the 3^{rd} Friday in 2011, and, more recently, contracts expiring on a daily basis. For most of the period we study, however, open interest and trading activity remain concentrated in the a.m.-settled 3^{rd} Friday contracts, with p.m.-settled and zero-day (0DTE) contracts only becoming sizable toward the end of the sample. Table A.2 summarizes the key contract specifications.

Figure A.1 displays the monthly average dollar open interest (in billions) in S&P 500 options with 3^{rd} Friday expiry and a.m. settlement versus p.m.-settled options between January 1996 (the start date of our option open interest data) and December 2023. The a.m.-settled market rises from about \$5 billion in 1996 to more than \$200 billion toward the end of our sample. Since around 2015, p.m.-settled options have gained prominence, but their size remains a fraction of the a.m.-settled SPX contracts.

C. Overnight Trading

Because SPX derivatives settle into the SOQ, while trading halts the prior evening, market participants face overnight risk. Instruments to manage this exposure expanded meaningfully in the early 2000s, with E-mini S&P 500 futures quickly becoming the primary vehicle for overnight index hedging. Introduced in 1997 on CME Globex, E-mini futures enabled electronic trading nearly 24 hours a day, and by the mid-2000s dominated overnight SPX risk management. Boyarchenko, Larsen, and Whelan (2023) document that the share of overnight futures volume rose from about 2% in the late 1990s to roughly 15% by 2010 and around 20% by 2020.

Pre-market equity trading also deepened over this period. Platforms such as Instinet and, later, Nasdaq and NYSE pre-market sessions facilitated stock and ETF trading before 9:30 a.m., with the SPY ETF, launched in 1993, emerging as the key instrument for accessing SPX exposure outside regular hours. Despite these developments, overnight equity markets remain substantially less liquid than daytime trading, with overnight volume comprising a relatively small fraction of total daily volume.

It is important to note that overnight futures trading is not a necessary condition for the 3FPS. The SOQ-based price spike is present across our full sample from November 1992 (Table I,

Figure 3), well before liquid overnight E-mini trading emerged. Dealers can transmit hedging demand to the SOQ through multiple channels, including market-on-open orders in constituent stocks, pre-market equity trading, and orders routed through designated market makers at the opening auction. E-mini futures provide a convenient instrument for measuring overnight order imbalances from 2003 onward, but the underlying hedging incentive from delta drift exists whenever a.m.-settled options are outstanding, regardless of whether overnight futures liquidity is available.

D. The SOQ

As outlined above, in 1987 the Securities and Exchange Commission (SEC), the Commodity Futures Trading Commission (CFTC), the Chicago Mercantile Exchange (CME), and the Chicago Board Options Exchange (CBOE) agreed to shift their reference point for S&P 500 (SPX) settlement prices from p.m. to a.m. settlement. The primary motive for this change was concern over the "Triple Witching" events, where the simultaneous expiry of futures, futures options, index options, and single-stock options occurs. This happens only four times per year on the 3^{rd} Friday of March, June, September, and December. Liquidity providers and designated market makers complained to regulators that they were often unable to manage imbalances on their books due to the extreme volatility and volumes on these days.

The SOQ is calculated by applying index weights to the first reported trade price (the opening price) of each constituent stock on its primary listing exchange. Hence, the SOQ can only be calculated once all constituent stocks have opened for trading. The SOQ is typically published 30–45 minutes after market open. It is possible, but increasingly rare, that stocks in the index do not trade immediately at market open, due to a lack of buy and sell orders or an imbalance between them. At the opening bell, when Standard & Poor's publishes the "current" opening SPX value, it includes the previous day's closing prices for each stock that has not yet opened.

The SOQ is calculated and disseminated in this way on every trading day, not only on expirations. It acquires settlement significance only on 3^{rd} Fridays, when it determines the payoff of a.m.-settled index options and, on the four quarterly expirations, the settlement of S&P 500 futures and options on futures. On all other days it is simply the index's first-trade-based opening value. We therefore use the SOQ as the opening price on control days as well as expiration days, so that both legs of our comparisons rest on one price construction. Note that this is distinct from the "current" opening SPX value described above, which we do not use.

The opening trade price and time of single stocks are determined by their Designated Market Maker (DMM) and the procedure differs by primary listing exchange. On the NYSE, for example, orders can be entered and canceled from 6:30 a.m. until 9:30 a.m. Between 8:00 a.m. and 9:30 a.m. imbalances are reported every second if there is a change in imbalance from the previous second. At 9:30 a.m. DMMs automatically open a security for trading if the security's auction price is within 10% of its closing price from the previous session. Securities outside this range have to be manually opened and so will trade after 9:30 a.m.

Highly liquid, large-cap stocks usually trade on their primary exchange very close to the market opening time. In the case of the SPX, the exchange reports this opening trade price to S&P and the price enters the SOQ calculation according to each stock's weight in the SPX. Less liquid stocks might not have opened for trading on their primary listing exchange, in which case the exchange does not immediately report an opening price. The exchange will report the opening price only after the first stock trade post market open has occurred. This rarely takes more than a few minutes but theoretically can take longer for very illiquid stocks. Therefore, the SOQ is composed of single-stock trade prices from different points in time.

Table A.1 illustrates the SOQ calculation for a hypothetical three-stock equally-weighted index. In Panel (a), at open (9:30:00) only stock 1 trades on the exchange. Thus, the index value is based on stock 1's opening price and stocks 2 and 3's previous closing prices. The SOQ only becomes available once all component stocks have traded (on their primary listing exchange) which is recorded at 9:33:29. Thus, the SOQ is based on each stock's opening sales price, which is observed at different points in time. In Panel (a), the overnight index return is positive, all individual stock opening returns are positive, and the SOQ minus opening quote (or trade) wedge is positive. In Panel (b), the index opens with a negative overnight return, all stocks' opening trades are negative, and the SOQ minus opening quote (trade) wedge is negative. These examples highlight the difference between the closing traded price of an index, the opening quoted price of an index, which includes closing prices for stocks that did not trade overnight, and the SOQ.

[INSERT TABLE A.1 HERE]

A.2. Alternative Explanations of the 3FPS

In this section, we present results on potential explanations of the 3FPS for which we find no support in the data: shocks from the arrival of fundamental information (overnight news from firm-specific or macro announcements), and "pinning" - the phenomenon whereby underlying prices tend to cluster around their nearest strikes on expiration days.

A. The Arrival of Fundamental Information

A potential explanation is that news arrives overnight Thursday, driving up prices through an information channel. For a persistent positive overnight return to arise from this channel, news revelation to investors would need to arrive systematically between the U.S. market close on the 3^{rd} Thursday and open on the 3^{rd} Friday. We consider two primary sources of news that arrives over this period: firm-specific news releases and macroeconomic releases.

Hypothesis H_{01}: Overnight Firm-Specific News. A large fraction of U.S. corporate earnings announcements are released outside of regular trading hours with the common release day being Friday (Boyarchenko, Larsen, and Whelan, 2023).[22]

Previous literature (see, e.g., Bernard and Thomas, 1989; Sadka, 2006, and the subsequent literature) has documented a positive (negative) drift in stock prices of individual firms following a positive (negative) earnings announcement surprise. Consequently, a significant positive arrival of earnings news 3^{rd} Thursday overnight might be driving the upward return drift observed over the same interval.

To examine whether firm-specific announcements drive the 3FPS, we collect earnings data of all S&P 500 index constituents from I/B/E/S and Compustat. Following Hirshleifer, Lim, and Teoh (2009), for each firm i and on day t we define the earnings surprise as

$$ES_{i,t} = \frac{A_{i,t} - F_{i,t^-}}{P_{i,q-1}}, \tag{A.1}$$

[22]Approximately 95 percent of firms announce earnings outside regular trading hours, roughly equally split between firms announcing in the pre-open (between midnight and the opening bell) and post-close (between the closing bell and midnight). Pre-open, most earnings announcements are concentrated in the four hours before open. Post-close, the vast majority of earnings announcements are concentrated in the first hour after market close.

where A is the actual earnings per share (EPS) as reported by the firm, F is the most recent median forecast of the EPS, and $P_{i,q-1}$ is the stock price of the firm at the end of the preceding quarter. Since I/B/E/S updates the professional forecasters' expectations on a monthly basis, the shock is the difference between the actual earnings and forecasters' expected earnings approximately one month prior to the announcement date. We define the daily earnings surprise of the S&P 500 index, ES_t, as:

$$ES_t = \sum_{i \in \text{announcing}} w_{i,t-1} \times ES_{i,t} \tag{A.2}$$

where $w_{i,t-1}$ is firm i's lagged equity market capitalization as a share of the index at the close of day $t-1$, and the sum is over all firms announcing earnings on day t. Because the sum runs over announcing firms only, the weights do not sum to one: ES_t is the index-weighted aggregate surprise contributed by that day's announcers, and its scale falls with the number of firms announcing.

Figure A.5 plots the time series of ES_t. Earnings shocks follow a quarterly cycle and are generally positive (roughly three-quarters of all shocks are positive). Notably, we see large negative earnings shocks especially during the financial crisis and mostly positive shocks following the financial crisis.

To examine a 3FPS explanation based on firm-specific news, we sort announcements into those published in the evening (after the 4:00 p.m. E.T. close) and those published pre-open (between midnight and the 9:30 a.m. opening bell), and examine the aggregate earnings surprise over both intervals. Both windows fall outside trading hours, and the pre-open window is the one that overlaps the settlement window in which the 3FPS occurs: prices rise on average between the 3^{rd} Thursday close and the 3^{rd} Friday open and revert from 9:30 a.m. until about noon. The first two columns of Table A.9 report the average ES_t across all evening and all pre-open windows. On average earnings surprises tend to be positive in both subperiods. The last two columns report the ES_t around 3^{rd} Fridays. Both are insignificant, and both are smaller than their all-days counterparts: 1.74 against 4.14 in the evening window and 4.06 against 4.57 pre-open. Earnings news around 3^{rd} Fridays is therefore, if anything, weaker than on other days, and it is not concentrated in the window that carries the spike.

[INSERT FIGURE A.5 AND TABLE A.9 HERE]

If an information-based channel drives the 3FPS, we expect higher returns when more news is observed. To further examine an information-based channel we regress the overnight return before 3^{rd} Fridays on the aggregate earnings surprise observed on the most recent announcement day preceding the expiration. Table A.10 reports the results. On average 3FPS overnight returns are highly positive but unrelated to earnings news, with an insignificant coefficient of -4.57 (t-statistic = -1.40).

[INSERT TABLE A.10 HERE]

Hypothesis H_{02}: Overnight Macroeconomic News. We next examine whether overnight macro news released before the 3^{rd} Friday open might be responsible for the 3FPS. Equity risk premia are consistently larger on days when important macroeconomic news is released (e.g., Savor and Wilson, 2014; Wachter and Zhu, 2022; Lucca and Moench, 2015). The 3FPS might be a reflection of such significant news arriving in the overnight window that causes a strong upward drift pre-open on 3^{rd} Fridays.

To examine a 3FPS explanation based on macroeconomic news, we collect dates and times from Bloomberg's Economic Calendar on the major U.S. macroeconomic announcements based on investor attention according to Bloomberg users. From these series we filter the series that are released in the overnight window preceding 3^{rd} Fridays and have a Bloomberg attention score above 60. Subsequently, we separate these series into inflation announcements and all other announcements, as market responses to inflation news and to other macroeconomic news tend to differ.[23] These series are released on 45 (inflation) or 131 (all other) of the 3^{rd} Fridays.

We test the effect of macroeconomic announcements on the 3FPS by regressing the 3FPS return separately on an inflation-announcement dummy (column 1) and on a dummy for all other announcements (column 2), each equal to 1 when such a series is released at or before the market open on the 3^{rd} Friday. Table A.11 reports the results. The intercept confirms that the unconditional 3FPS is highly positive on average. The coefficients on the announcement dummies are insignificant, indicating that 3FPS returns are not significantly different on macroeconomic announcement days compared to non-announcement days.

In sum, the 3FPS pattern differs from the pattern in earnings or macroeconomic news and the size of the 3FPS does not vary with measures of news content, and we thus find no support for an information-based channel for the 3FPS.

[INSERT TABLE A.11 HERE]

B. Pinning

An alternative explanation is based on pinning, or anti-pinning, of index prices around option strike prices on option expiry dates. Stock pinning is the well-documented phenomenon whereby stock prices that are close to at-the-money option strike prices display price dynamics that are very different from a random walk. These stocks tend to move toward their strike and become "pinned", i.e., closing prices at expiration will be unusually close to options' strike price. Stock prices may cluster near option strike prices when large at-the-money open interest and rapidly changing Δs cause market makers' hedging trades to pull prices toward (or push them away from) the strike as expiration approaches (Avellaneda and Lipkin, 2003). Krishnan and Nelken (2001) show that Microsoft closes near integer multiples of \$5 on a much larger percentage of expiration Fridays compared to other days. Ni, Pearson, and Poteshman (2005) show that on the 3^{rd} Friday expiry days optionable stocks are more likely to experience returns that are small in absolute value and argue that expiration date clustering is due to stock prices that are close to at-the-money option strike prices remaining in the neighborhood of these strikes.

At the index level, Golez and Jackwerth (2012) show that S&P 500 futures prices are pulled toward the at-the-money strike price of futures options (pinning) around their 3^{rd} Friday p.m. settlement on non-quarterly expiration days, but are pushed away (anti-pinning) from the cost-of-carry adjusted at-the-money strike price of index options before the expiration of index options. The magnitude of this effect in the futures market is at least \$115 million per expiration, calculated using open interest in futures. Moreover, Golez and Jackwerth (2012) show that S&P 500 futures are more likely to be pinned from below, meaning closing prices of SPX futures on the non-quarterly 3^{rd} Friday expiration days tend to be higher. Although Golez and Jackwerth (2012) do not find significant evidence of pinning in the SPX SOQ on 3^{rd} Friday expiration days, pinning

[23]Common high-attention series in the Bloomberg calendar include GDP QoQ, CPI Ex Food and Energy, Industrial Production, Housing Starts, Retail Sales, and Empire Manufacturing. Only releases with Bloomberg timestamps before the 9:30 a.m. open enter our announcement dummies.

might push the 3^{rd} Friday a.m. settlement prices upward and thereby explain the 3FPS effect we document. We examine the role of pinning in the 3FPS by testing whether equity prices cluster around nearby strike prices at expiration over our sample.

Hypothesis H_{03}: Expiry Price Distribution. To test for pinning, we compute the distance between equity index or futures prices at the 3^{rd} Friday open, relative to the nearest at-the-money strike price from below. Figure A.6 shows the resulting distribution over our sample period when dividing the distance in bins of \$0.50 increments. We separately show the distribution for (i) the E-mini futures prices on quarterly expiration dates when both the index and futures options expire in the a.m. window (Panel (a)), (ii) the E-mini futures price on non-quarterly expiration dates when only index options expire in the a.m. window (Panel (b)), (iii) the SPX SOQ on quarterly expiration dates (Panel (c)), and (iv) the SPX SOQ on non-quarterly expiration dates (Panel (d)). Since options come in strike price increments of \$5, this distance lies in the interval $[0, 5)$ and we divide it into ten bins of \$0.50 each. If equity prices followed a random walk, we would expect a uniform distribution with each bin containing approximately 10% of observations.

$\Big[$ INSERT FIGURE A.6 HERE $\Big]$

We fail to find evidence of pinning behavior in either the E-mini futures open price or the SPX SOQ on 3^{rd} Fridays. The empirical percentages generally differ little from 10%, with bars not systematically clustering at the ends (pinning) or middle (anti-pinning) of the distribution.

A.3. Counterfactual Benchmarks and the Convexity Adjustment

This appendix section formalizes the counterfactual construction of Section III, establishes its properties, and reports the wealth transfer under the alternative benchmarks. The Itô derivation in the main text (equation (3) and the expansion in footnote 12) and the exact calculation below prove the same result in two ways. The exact route requires no expansion and no smoothness.

Let f denote an expiring option's payoff function and S_T the realized settlement value (the SOQ). The counterfactual scales each realized settlement down by the average 3FPS, $S_T^{\text{cf}} = S_T/(1+\delta)$ with $\delta = 0.0010$, a downward shift of $h \equiv S_T - S_T^{\text{cf}} = \delta S_T/(1+\delta)$, so the per-option wealth transfer is

$$\begin{aligned} T &= E\big[f(S_T)\big] - E\big[f(S_T^{\text{cf}})\big] \\ &= E\big[f(S_T) - f(S_T - h)\big] \\ &= E\left[\int_{S_T-h}^{S_T} f'(u)\,du\right] \\ &= E\big[\min\big((S_T-K)^+,\, h\big)\big] \\ &\approx E\big[h\big]\,\Pr(S_T > K) \;\approx\; E\big[h\big]\,V_S, \end{aligned} \tag{A.3}$$

with the last two lines written for a call with strike K; puts are symmetric with the opposite sign. The first equality is the definition of the transfer: the expected payout the option books at the realized settlement minus the expected payout it would have booked at the counterfactual settlement. The second substitutes $S_T^{\text{cf}} = S_T - h$ and uses the linearity of the expectation: both terms average over the same realized settlements, so the difference of the two expectations is the expectation of the settlement-by-settlement payoff difference. The third writes each payoff difference as the integral of the payoff slope between the two settlement values (the fundamental theorem of calculus, applied realization by realization). The fourth evaluates that integral realization by realization: a call's slope is the indicator $\mathbf{1}\{u > K\}$, so the integral collects the part of the shift that lies above the strike, which is the shift itself when the settlement clears the strike by more than h and the in-the-money amount otherwise. The final line takes expectations, exact to first order in the shift: settlements landing inside the shift band are a set of probability of order h, and the remaining probability is read as the Thursday Δ of an expiring option. This arrives at the right-hand side of the expansion in main-text footnote 12: the exact route and the Itô route end at the same place. Two properties follow.

First, existence and a bound. Call and put payoffs are Lipschitz with constant one: for any two settlement values, the payoff difference is at most the settlement difference, $|f(S_1) - f(S_2)| \leq |S_1 - S_2|$. This is the familiar fact that a vanilla option never gains or loses more than dollar for dollar with the underlying - wherever the payoff has a slope, that slope is the option's delta, and it never exceeds one in absolute value. Applied to the two legs, which sit h apart on every expiration, the pathwise difference inside the expectation lies in $[0, h]$ for calls and in $[-h, 0]$ for puts: no single option can transfer more than the shift. A bounded random variable always has a finite expectation, so the transfer exists under no moment or distributional assumption: the identity is applied realization by realization, and jumps, stochastic volatility, and heavy tails are all admissible. The bound is a property of vanilla payoffs rather than of contingent claims in general: a payoff levered L-fold is Lipschitz with constant L and transfers at most $L\,h$, while a digital option, whose payoff jumps at the strike, admits no per-option bound at all. The expiring S&P 500 book consists of vanilla calls and puts, so the bound applies to every option in Tables III and A.6. Reporting the two legs separately, as in Table III, additionally requires each leg to be finite, which holds whenever call prices are finite and (trivially in the data) where both legs are finite sums. Because payoffs are piecewise linear, f' exists everywhere except at the strike, a single point that does not affect the integral.

Second, the construction moves only the mean. Differencing the call and put transfers at the same strike yields

$$T^{\text{call}} - T^{\text{put}} \;=\; E\big[h\big]. \tag{A.4}$$

A linear payoff, the synthetic forward, therefore transfers exactly the removed drift and nothing else. Every feature of the settlement distribution other than its mean appears in both legs of equation (A.3) and cancels, and hence the counterfactual preserves each expiration morning's realized volatility and news.

Next, we empirically analyze the wealth transfer under the three alternatives referenced in Section III. Table A.5 reports the results. Every row settles the actual leg at the SOQ. The rows differ only in the counterfactual settlement. The alternatives replace the realized settlement distribution with a single number (the prior Thursday close, that is, a zero overnight return; the prior close grown at the average overnight return on non-expiry Fridays, 0.70 basis points; and the prior close grown at the average overnight return on all other trading days, 1.30 basis points, with both averages measured over the sample period for which we have OptionMetrics data) and therefore remove options' convexity value together with the drift. In the expansion of equation (3), they set the counterfactual leg's $E[(dS)^2]$ to zero, and because their two legs no longer share the realized path, the pathwise bound established above does not apply to them. The implied annual transfers under these alternative benchmarks are \$2.2 billion, \$2.1 billion, and \$2.0 billion compared to the benchmark's \$1.5 billion. Because these alternatives replace the settlement distribution with a single number, they assign the options' convexity value to the transfer, so their totals are upper bounds: they exceed the benchmark by 30, 27, and 23 percent of their own totals, respectively. Most of the excess is convexity value. The remainder, positive for the first two rows and slightly negative for the third, reflects that settling at a fixed number strips each expiration's full realized overnight move, which averages 10.8 basis points on this sample rather than the benchmark's flat 10. The convexity effect runs through both legs, lowering each alternative's counterfactual call and put values alike, so it inflates the call transfer and shrinks the put transfer in magnitude; it is the annualized total that is bounded above.

A.4. The 3FPS in Option Returns

A. Actual and Counterfactual Option Returns

The payoff comparison of Section III.A of the main text revalues settled claims at index prices. This section repeats that comparison in return space.[24] Each expiring option's actual return runs from its 3^{rd} Thursday closing mid-quote to its settlement payoff, and its counterfactual return from the same mid-quote to the counterfactual payoff. Both legs divide by the same observed price, the final pre-settlement quote midpoint $P > 0$, so

$$R^{\text{actual}} - R^{\text{cf}} = \frac{f(S_T) - f(S_T^{\text{cf}})}{P} = \frac{1}{P}\int_{S_T^{\text{cf}}}^{S_T} f'(u)\,du, \tag{A.5}$$

and every step of equation (A.3) passes through after division by P: the computation remains model-free, because the price leg is an observed quote held fixed across the two scenarios. Following this through the aggregation makes precise the equivalence stated in the footnote closing Section III.B of the main text. Write $\Delta f_i = f_i(S_T) - f_i(S_T^{\text{cf}})$ for option i's payoff gap.

At the portfolio level the dollar aggregation does not need the price at all. With the premium-based dollar open interest of Table A.6, $c_i = OI_i\, P_i \times 100$, per option and exactly,

$$c_i\left(R_i^{\text{actual}} - R_i^{\text{cf}}\right) = OI_i \times 100 \times \Delta f_i, \tag{A.6}$$

so the price cancels before any aggregation, and sums of per-option dollar objects are invariant to how options are grouped: strike-bucketing cannot break the identity. The dollar panel of Table A.6 is therefore the payoff accounting of Table III, recomputed over this exhibit's 0.50 to 1.50 moneyness window, whose deep tails carry a few percent of each transfer; it holds to the cent on every expiration. Thursday quotes never enter the payoff comparison and cancel from the dollar return comparison whatever their level, which is why the size of the wealth transfer cannot depend on whether quotes embed the spike.

Two things follow for how the return exhibit should be read. Its dollar panel is not independent evidence, by the identity above. Its sign pattern is likewise a theorem of the construction rather than a finding: because $S_T^{\text{cf}} < S_T$ on every date, $\Delta f_i \geq 0$ for every call and ≤ 0 for every put pathwise, so calls must lie above their counterfactual and puts below in every bucket. What the exhibit adds is the distribution of the transfer across moneyness in percentage terms, and those percentages are not fixed in advance: put-call parity pins the price-weighted difference of a matched pair's returns, and the pair's realized dollar profit across the settlement window, but it leaves each leg's own return free (the parity subsection below).

Table A.6 shows the results. In percentage terms the gap is largest at the money, where realized call and put returns of -1.5 and -43.4 percent compare with counterfactual returns of

[24] Option returns into the 3^{rd} Friday expiry are usually missing from option pricing studies, since the standard OptionMetrics dataset contains option prices only at the close.

−21.3 and −30.8 percent. In dollar terms, expiring calls earned \$107 million per month against a counterfactual of \$22 million, while expiring puts lost \$77 million against a counterfactual loss of \$37 million, an annualized transfer of approximately \$1.5 billion. A formal test of whether Thursday quotes anticipate the spike would require a fair-return benchmark for individual expiring option legs, which we do not impose; Section III.B of the main text tests the parity-implied forward against fair carry directly.

B. Put-Call Parity and Option Returns

Put-call parity restricts option returns in exactly one way, stated formally by Coval and Shumway (2001). Parity at the pricing date reads (they carry the strike and dividends as a discounted riskless leg; our notation absorbs dividends into the yield q):

$$C - P = Se^{-q\tau} - Ke^{-r\tau}, \tag{A.7}$$

main-text equation (4). Their net-return and beta results follow from it in a few elementary steps, which we summarize before restating their content in this appendix's own objects.

Reading parity as a price tag on a portfolio, rearrange equation (A.7) to isolate the call:

$$C \;=\; P \;+\; Se^{-q\tau} \;-\; Ke^{-r\tau}, \tag{A.8}$$

so the call costs exactly what the three-leg portfolio costs. Applying equation (A.7) again one period later and writing each leg as its date-t price times its gross return gives parity in gross-return form,

$$1 + R_C = \frac{P}{C}\,(1 + R_P) + \frac{Se^{-q\tau}}{C}\,(1 + R_S) - \frac{Ke^{-r\tau}}{C}\,(1 + R_f), \tag{A.9}$$

where R_S is the dividend-adjusted return on the underlying and R_f the riskless return over the period. Nothing but parity at two dates and the definition of a return has been used, so the relation is exact and model-free. Its three weights sum to exactly one, because dividing equation (A.8) by C gives

$$1 \;=\; \frac{P}{C} + \frac{Se^{-q\tau}}{C} - \frac{Ke^{-r\tau}}{C}, \tag{A.10}$$

which is the same three weights: parity prices the call as the portfolio, and no other input is involved. Subtracting equation (A.10) from equation (A.9) therefore cancels the ones and leaves their relation in net returns,

$$R_C = \frac{P}{C}\,R_P + \frac{Se^{-q\tau}}{C}\,R_S - \frac{Ke^{-r\tau}}{C}\,R_f. \tag{A.11}$$

Because beta is linear and the riskless leg has beta zero, applying it to equation (A.11) drops the bond term and gives their beta relation:

$$\beta_C \;=\; \frac{P}{C}\,\beta_P \;+\; \frac{Se^{-q\tau}}{C}\,\beta_S \tag{A.12}$$

(with $q = 0$ this is their printed form), so that as long as put-call parity holds, the beta of a call determines the beta of the put with the same strike and maturity. That is parity's entire return content: one price-weighted linear restriction per strike pair, linking the call, the put, and the underlying, and nothing more. What pins the level of an individual option's return is not parity but the pricing kernel and the option's embedded leverage: any call on an asset whose price is negatively correlated with the pricing kernel earns a positive expected return, increasing in the strike, and any put earns an expected return below the riskless rate, likewise increasing in the strike.

Summarizing, parity is satisfied under any physical drift and restricts no expected return by itself. SPX options are European and cash-settled (parity holds with equality), and the expiring book stops trading at the Thursday close, so that snapshot is the last instant at which pricing-in could occur.

Hold the pair from the Thursday close into settlement, where parity degenerates to the payoff identity $(S_T - K)^+ - (K - S_T)^+ = S_T - K$. Financing the premium at r, the realized dollar P&L is, exactly and on every path,

$$\text{P\&L}_{\text{pair}} = (S_T - K) - (C - P)\, e^{r\tau} = S_T - S e^{(r-q)\tau}, \tag{A.13}$$

the underlying's move against fair carry, dollar for dollar, model free; carry over the 17:15-hour window is below 1.5 basis points against the 10 basis point spike. If the SOQ prints 10 basis points above the no-spike path, every strike's pair books exactly those 10 basis points.

Parity restricts neither leg's own return. To see it step by step, write each leg's realized net return over the settlement window,

$$R_C = \frac{(S_T - K)^+ - C}{C}, \qquad R_P = \frac{(K - S_T)^+ - P}{P}. \tag{A.14}$$

Multiply each by its own price and difference the two; the terminal identity above collapses the two payoffs into $S_T - K$, leaving

$$C\, R_C - P\, R_P = (S_T - K) - (C - P), \tag{A.15}$$

an accounting identity that holds under any quotes, fair or not. Parity's only contribution is to pin the value of the right-hand side: substituting equation (A.7) for $C - P$,

$$C\, R_C - P\, R_P = \big(S_T - S e^{-q\tau}\big) - K\big(1 - e^{-r\tau}\big) \;\approx\; S_T - S, \tag{A.16}$$

the underlying's overnight move (both carry terms are a small fraction of the spike over the 17:15-hour window). This is one equation in the two unknowns (R_C, R_P).

The same pair logic applies to the wealth transfer itself, and there it needs no prices at all. The actual and counterfactual settlements differ by that expiration's shift, $h = S_T - S_T^{\text{cf}}$. Apply the terminal identity at both settlement values,

$$\begin{aligned} (S_T - K)^+ - (K - S_T)^+ &= S_T - K, \\ (S_T^{\text{cf}} - K)^+ - (K - S_T^{\text{cf}})^+ &= S_T^{\text{cf}} - K, \end{aligned} \tag{A.17}$$

and subtract the second line from the first, grouping the call terms together and the put terms together:

$$\underbrace{\big[(S_T - K)^+ - (S_T^{\text{cf}} - K)^+\big]}_{\Delta f^{\text{call}} \in [0, h]} \;-\; \underbrace{\big[(K - S_T)^+ - (K - S_T^{\text{cf}})^+\big]}_{\Delta f^{\text{put}} \in [-h, 0]} \;=\; S_T - S_T^{\text{cf}} \;=\; h. \tag{A.18}$$

At every strike, on every expiration, the call's transfer minus the put's transfer equals exactly the removed drift: the synthetic forward inherits the shift one for one, by arithmetic (equation (A.4) in its pathwise form). The bracket bounds hold because a vanilla payoff never moves by more than the settlement does, so the identity also says how h splits at each strike: the call collects the part corresponding to settling in the money, the put gives up the rest, and the split is set by where the settlement lands relative to the strike. Parity therefore explains the signs of the wealth exhibits (every call strike gains, every put strike loses) and the call-put split of h, and none of the magnitudes. The magnitudes come from two empirical objects, the settlement distribution and the open interest.

A.5. OA Tables

	Previous Close	9:30:00	9:30:31	9:33:29
		Panel (a) SOQ > Index Open		
Stock 1	50	55	55	56
Stock 2	20	No Trade	22	23
Stock 3	10	No Trade	No Trade	11
Index	26.7	28.3	29	30
SOQ		Not Available	Not Available	29.3
		Panel (b) SOQ < Index Open		
Stock 1	50	45	45	44
Stock 2	20	No Trade	18	17
Stock 3	10	No Trade	No Trade	9
Index	26.7	25	24.3	23.3
SOQ		Not Available	Not Available	24

Table A.1. Illustration: The Special Opening Quotation (SOQ)
This table illustrates the calculation of the S&P 500 Special Opening Quotation (SOQ) and why the SOQ can differ from the S&P 500 opening value. Panel (a) shows an example where the SOQ ($29.3) is higher than the index opening quote ($28.3). At market open (9:30:00) only stock 1 trades on exchange. Thus, the opening index value is the (here equal-weighted) average of the opening trade price of stock 1 ($55) and the previous closing prices of stocks 2 ($20) and 3 ($10). In contrast, the SOQ only becomes available once all index component stocks have traded and is then calculated as the average of trade prices $55, $22, and $11. Panel (b) shows an example where the SOQ ($24) is lower than the index opening quote ($25). Shaded cells mark each stock's first reported trade, the previous-close index value, and the index and SOQ values the comparison turns on.

Security	S&P 500 Index Options	S&P 500 Futures Options	S&P 500 Futures
Underlying	100 x S&P 500 Index (SPX)	E-mini S&P 500 Futures (ES)	50 x S&P 500 Index
End of Trading	Th. pre 3^{rd} Fr. p.m.	3^{rd} Friday a.m.	3^{rd} Friday a.m.
Settlement	3^{rd} Friday a.m.	3^{rd} Friday a.m.	3^{rd} Friday a.m.
Settlement Method	Cash (via SOQ)	Futures	Cash (via SOQ)
Expiration months	12 months + LEAPS	9 quarters + 3 Dec	9 quarters + 3 Dec
Exercise Style	European	American	/
Strikes	5 idx points	5 idx points	/
Exchange	CBOE	CME	CME

Table A.2. Contract Specifications

This table summarizes key contract specifications for S&P 500 index options, S&P 500 futures options, and S&P 500 E-mini futures. Columns report the three securities; rows report the underlying, end-of-trading time, settlement time and method, expiration months, exercise style, strike increments, and listing exchange. A "/" marks a specification that does not apply to that security.

	Overnight	Intraday	N
Official close, full sample	9.80	-15.10	371
	(3.04)	(-3.57)	
Official close, positions sample	10.64	-16.40	325
	(2.97)	(-3.46)	
Spliced high-frequency close, full sample	9.79	-15.14	371
	(3.03)	(-3.58)	

Table A.3. Robustness: Closing-Price Measurement and the Sample Split

This table reports the mean overnight return into the settlement (Thursday close to the 3^{rd} Friday Special Opening Quotation, SOQ) and the mean intraday return after the settlement (SOQ to Friday close) on expiration days, with t-statistics in parentheses. Row 1 uses the official S&P 500 closing price over the full sample and corresponds to Table I, columns 1 and 2. Row 2 restricts row 1 to the estimation sample of the dealer delta drift regressions (Table VII, column 1; July 1996 to December 2023). Row 3 measures the close with the high-frequency 4:15 p.m. index value where available (from January 1996) and the official closing price otherwise. The official closing price is determined in the closing auction, which can reflect price pressure from indexing and exchange-traded fund trading (Bogousslavsky and Muravyev, 2023). All rows exclude the three crisis expirations listed in Section I. Returns are in basis points. The sample period is November 1992 to December 2023.

Panel (a): The Third Friday Price Spike (Table I)

	Overnight	Intraday	N
Excluding the three crisis expirations	9.80	-15.10	371
	(3.04)	(-3.57)	
Including the three crisis expirations	9.36	-14.24	374
	(2.44)	(-3.29)	

Panel (b): The Dealer Delta Drift Regressions (Table VII, Panel (a))

	1. Expiry All	2. Expiry All	3. Expiry Non-Qtr.	4. Expiry Non-Qtr.	5. Weekend	6. Weekend
Excluding the three dates	-0.13	-0.13	-0.17	-0.19	-0.05	-0.05
	(-2.31)	(-2.40)	(-3.06)	(-3.25)	(-1.26)	(-1.22)
N	325	325	218	218	1201	1201
Including the three dates	-0.13	-0.13	-0.15	-0.17	-0.04	-0.04
	(-2.64)	(-2.74)	(-2.77)	(-2.96)	(-0.87)	(-0.82)
N	328	328	219	219	1201	1201

Table A.4. Robustness to Including the Three Excluded Crisis Expirations
This table repeats the paper's two headline exhibits including the three crisis expirations excluded throughout the paper (September 2001, September 2008, and October 2008; Section I). Panel (a) reports the expiration-day columns of Table I, Panel (a): the mean overnight return into the settlement (Thursday close to the 3^{rd} Friday Special Opening Quotation, SOQ) and the mean intraday return after the settlement (SOQ to Friday close), in basis points, with t-statistics in parentheses. Row 1 excludes the three crisis expirations and corresponds to Table I; row 2 includes them. Panel (b) reports the dealer delta drift coefficient in the six specifications of Table VII, Panel (a), under the same two samples; the excluding rows correspond to the published table. In Panel (b), all variables are standardized to zero mean and unit variance, and Newey-West t-statistics with 3 lags are in parentheses, as in Table VII. Columns 2, 4, and 6 include the dealer net-Γ control, and columns 5 and 6 contain weekend returns (Friday close to Monday open). The sample period is November 1992 to December 2023 in Panel (a) and July 1996 to December 2023 in Panel (b).

	Calls			Puts			
	Actual	Cf	Diff	Actual	Cf	Diff	Annual
Prior close (zero overnight return)	8,565	8,419	146	3,211	3,249	-38	2,217
Prior close + 0.70 bps (non-expiry Fridays)	8,565	8,425	140	3,211	3,246	-35	2,109
Prior close + 1.30 bps (all other days)	8,565	8,430	135	3,211	3,244	-33	2,017
Realized settlement (SOQ) − 10 bps	8,565	8,476	89	3,211	3,251	-40	1,547

Table A.5. Wealth Transfers under Alternative Benchmarks

This table shows the wealth transfer between S&P 500 option writers and buyers under alternative counterfactual benchmarks. Each row corresponds to one counterfactual settlement value: row 1 settles options at the prior 3^{rd} Thursday close (a zero overnight return), rows 2 and 3 at the prior close grown at the average overnight return on non-expiry Fridays (0.70 basis points) and on all other trading days (1.30 basis points), with both averages measured over this table's January 1996 to December 2023 sample, and row 4 at the realized SOQ lowered by 10 basis points, the average 3FPS over the full 1992 to 2023 sample and the paper's benchmark. Rows 1 to 3 replace the realized settlement distribution with a single number and are reported as upper bounds. The table reports mean monthly actual and counterfactual (Cf) payoffs of expiring calls (columns 1 and 2) and puts (columns 4 and 5) in millions of dollars, their differences (columns 3 and 6), and the annualized sum of the absolute call and put differences (column 7). Payoffs are calculated as in Table III. Entries are computed before rounding, so displayed differences can deviate from the difference of the displayed values in the last digit. The sample period is January 1996 to December 2023.

	Actual		Counterfactual	
	Calls	Puts	Calls	Puts
	Panel (a) Returns (%)			
In the money	1.2	-3.0	-0.1	-0.8
At the money	-1.5	-43.4	-21.3	-30.8
Out of the money	-75.8	-99.1	-80.9	-98.8
	Panel (b) Returns ($ mil.)			
In the money	109.5	-49.3	36.6	-17.4
At the money	1.9	-14.1	-10.1	-6.6
Out of the money	-4.1	-13.7	-4.2	-13.5
Sum	107.3	-77.1	22.4	-37.5

Table A.6. S&P 500 Option Returns into 3^{rd} Fridays

This table shows summary statistics for S&P 500 option returns into expiry. Columns 1 and 2 of Panel (a) report average (net) returns of expiring S&P 500 options from Thursday close to their final settlement payoff at the 3^{rd} Friday Special Opening Quotation (SOQ). Columns 3 and 4 report counterfactual returns, calculated via a counterfactual settlement value in which the realized SOQ is lowered by 10 basis points, the average 3FPS. Panel (b) reports average returns in millions of dollars, calculated option by option as each option's return times its dollar open interest and summed within each moneyness bucket. Dollar open interest is premium-based: open contracts are valued at their 3^{rd} Thursday closing mid-quotes, including the 100× contract multiplier. We measure moneyness (mnes) as the ratio of option strike to underlying price. Calls are itm if $0.5 < \text{mnes} \leq 0.99$, atm if $0.99 < \text{mnes} \leq 1.01$, and otm if $1.01 < \text{mnes} \leq 1.5$. Puts are classified oppositely. Options are sorted into a moneyness bucket at Thursday close and equally weighted within each bucket. The Sum row adds the three moneyness buckets. Entries are computed before rounding, so displayed sums can deviate from the sum of the displayed values in the last digit. The sample period is January 1996 to December 2023.

	1. Expiry All	2. Expiry All	3. Expiry Non-Qtr.	4. Expiry Non-Qtr.	5. Weekend	6. Non-Expiry
Dealer Charm	0.57	0.58	0.58	0.58	0.34	0.49
	[0.06]	[0.06]	[0.07]	[0.07]	[0.15]	[0.04]
	(11.24)	(11.30)	(9.83)	(9.94)	(2.70)	(14.80)
Dealer Gamma	-0.04	-0.05	-0.09	-0.10	0.10	0.07
	[0.07]	[0.07]	[0.08]	[0.08]	[0.04]	[0.03]
	(-0.60)	(-0.84)	(-1.15)	(-1.19)	(2.73)	(3.02)
Expiring Dealer Delta		-0.09		-0.02		
		[0.06]		[0.06]		
		(-1.44)		(-0.48)		
$R^2(\%)$	32.52	33.13	34.19	33.94	12.31	24.32

Table A.7. Regressing the Projected Dealer Delta Drift on Greeks

This table presents estimates from regressing the projected dealer delta drift (DDD) on contemporaneous dealer Greek risk measures. The regression serves as a validity check of the DDD construction: the DDD aggregates the time decay of option deltas, which is what net-$\mathcal{C}$ measures, so a tight link is expected by construction. Each column regresses the DDD on dealer charm and dealer gamma; columns 2 and 4 add the level of the expiring dealer delta, which is left blank elsewhere. Columns 1 and 2 contain dealer positions at 3^{rd} Thursday close, columns 3 and 4 include only non-quarterly 3^{rd} Thursdays, column 5 contains positions on any Friday close, and column 6 includes only Thursdays that do not precede an option expiry. All variables are standardized to zero mean and unit variance. Block bootstrapped standard errors, with the optimal block length chosen in a data-driven way following Patton, Politis, and White (2009), are in square brackets. Newey-West t-statistics with 3 lags are in parentheses. The adjusted R^2 is multiplied by 100. The sample period is July 1996 to December 2023.

	1. Expiry All	2. Expiry All	3. Expiry Non-Qtr.	4. Expiry Non-Qtr.	5. Weekend	6. Non-Expiry	7. Expiry All	8. Expiry Non-Qtr.
Panel (a): Predicting index returns								
Dealer Delta Drift	-0.13	-0.12	-0.17	-0.18	-0.05	0.01		
	[0.06]	[0.06]	[0.07]	[0.06]	[0.04]	[0.02]		
	(-2.31)	(-2.30)	(-3.06)	(-3.25)	(-1.26)	(0.90)		
Expiring Dealer Delta		0.03		0.06			0.04	0.05
		[0.06]		[0.09]			[0.06]	[0.09]
		(0.51)		(0.85)			(0.65)	(0.61)
$R^2(\%)$	1.29	1.07	2.56	2.51	0.21	0.00	-0.18	-0.24
Panel (b): Predicting index futures returns								
Dealer Delta Drift	-0.09	-0.09	-0.15	-0.16	-0.06	0.01		
	[0.05]	[0.05]	[0.06]	[0.06]	[0.04]	[0.02]		
	(-1.95)	(-1.93)	(-2.94)	(-3.13)	(-1.39)	(0.46)		
Expiring Dealer Delta		0.02		0.09			0.03	0.07
		[0.06]		[0.08]			[0.06]	[0.08]
		(0.43)		(1.11)			(0.53)	(0.89)
$R^2(\%)$	0.48	0.23	1.79	2.11	0.34	-0.01	-0.22	0.09

Table A.8. Joint Regressions: Dealer Delta Drift and Expiring Dealer Delta

This table presents the results from regressing the overnight return of the S&P 500 on lagged dealer positions: the dealer delta drift in columns 1 to 6, joined by the expiring dealer delta level in columns 2 and 4, and the expiring dealer delta level alone in columns 7 and 8. Panel (a) presents results for index returns, computed from the high-frequency 4:15 p.m. index value to the Special Opening Quotation. Panel (b) presents results for futures returns, computed from the futures mid-quote at close to the mid-quote at open. Columns 1 and 2 contain returns from Thursday close to 3^{rd} Friday open, columns 3 and 4 include only non-quarterly 3^{rd} Fridays, column 5 contains returns from Friday close to Monday open, and column 6 includes only returns that are not into a 3^{rd} Friday. Columns 7 and 8 use the same samples as columns 1 and 3, respectively. All variables are standardized to zero mean and unit variance. Block bootstrapped standard errors, with the optimal block length chosen in a data-driven way following Patton, Politis, and White (2009), are in square brackets. Newey-West t-statistics with 3 lags are in parentheses. The adjusted R^2 is multiplied by 100. The sample period for Panels (a) and (b) is July 1996 to December 2023.

	All Days		Around 3^{rd} Fridays	
	Evening	Day	Evening	Day
mean	4.14	4.57	1.74	4.06
median	1.08	1.27	1.52	1.13
t-stat	(9.10)	(6.56)	(1.03)	(1.36)
Std	25.30	43.25	26.89	40.13

Table A.9. Earnings Announcement Surprises

This table reports average dollar-weighted earnings announcement surprises during the evening (4:00 p.m. to midnight E.T.) and during the pre-open window (midnight to the 9:30 a.m. opening bell, E.T.). We calculate the earnings surprise as the sum-product of firms' earnings announcement surprises from I/B/E/S and the respective firms' lagged equity market capitalization. Columns 1 and 2 consider all days. Columns 3 and 4 consider only the evening and pre-open windows surrounding the market open of the monthly 3^{rd} Friday. The table reports the mean, the median, a t-statistic testing the mean against the null of zero, and the standard deviation of the aggregate surprise. All numbers are in hundredths of basis points, a scale that follows from aggregating index-weighted surprises across announcing firms rather than averaging them. Due to the availability of our earnings surprise data sample, the sample period is September 1997 to December 2020.

	S&P 500 Third Friday Price Spike	
intercept	10.27	10.31
	(2.35)	(2.37)
earnings surprise		-4.57
		(-1.40)
$R^2(\%)$	0.00	0.07

Table A.10. Regression: Expiry Return on Earnings Surprises

This table shows estimates from regressing the third Friday price spike on earnings surprises. The 3FPS is calculated from the 3^{rd} Thursday high-frequency 4:15 p.m. index value to the 3^{rd} Friday Special Opening Quotation. We measure earnings news as the aggregate winsorized earnings announcement surprise of S&P 500 firms from I/B/E/S, combining evening and morning announcements, on the most recent announcement day preceding the expiration. Column 1 reports the unconditional mean (an intercept-only regression); column 2 adds the earnings-surprise regressor. Every second row contains Newey-West t-statistics with 1 lag. Returns are in basis points. Earnings news is normalized to zero mean and unit variance. The adjusted R^2 is multiplied by 100. Due to the availability of our earnings surprise data sample, the sample period is September 1997 to December 2020.

	S&P 500 Third Friday Price Spike	
Intercept	12.63	12.78
	(3.36)	(2.81)
Dummy (CPI, PPI, GDP)	-14.61	
	(-1.13)	
Dummy (others)		-5.43
		(-0.77)
N	331	331
Dummy N	45	131

Table A.11. Regression: Expiry Return on Macro Announcement Dummies
This table reports estimates from regressing the third Friday price spike on macro announcement dummies. The 3FPS is calculated from the 3^{rd} Thursday high-frequency 4:15 p.m. index value to the 3^{rd} Friday Special Opening Quotation. We consider macro announcements listed on Bloomberg that occurred on a 3^{rd} Friday before (and including) market open. We only consider announcements with a Bloomberg attention score above 60. Column 1 contains inflation ("cpi", "ppi", and "gdp price index") announcement dummies. Column 2 contains dummies for all other announcements. N is the number of expirations in the regression; Dummy N is the number of those on which the announcement dummy equals one. Two expirations without a valid 3^{rd} Thursday high-frequency index value (March 2000 and January 2002) drop out of the sample. Returns are in basis points. Every second row contains Newey-West t-statistics with 3 lags. The sample period is January 1996 to December 2023; our Bloomberg macro announcement data end in August 2023, so the final four expiries carry no announcement dummies.

A.6. OA Figures

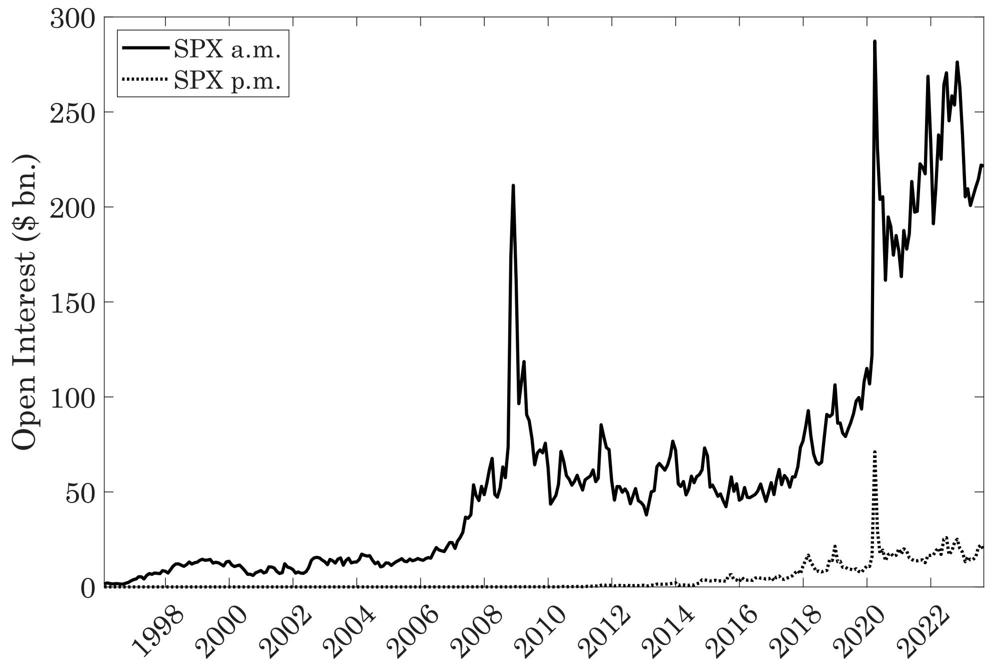
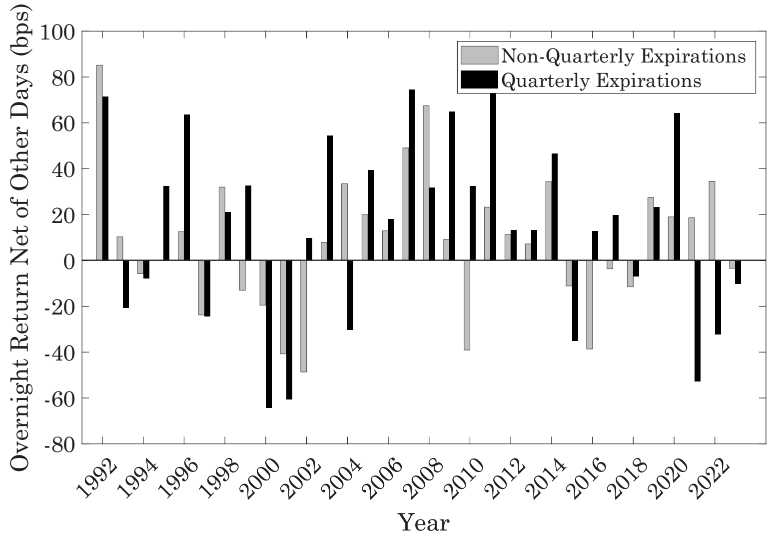
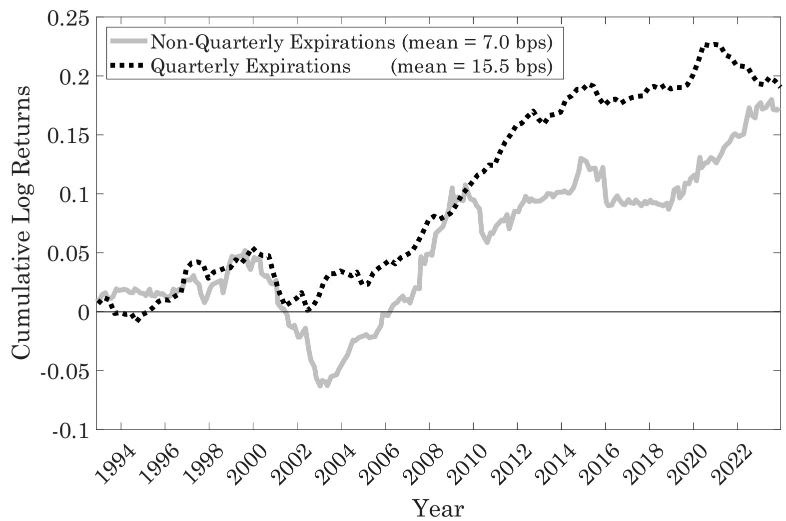


Figure A.1. S&P 500 Option Market Size

This figure displays the monthly average open interest (in billions of dollars) of S&P 500 options with a.m. (solid line) and p.m. (dotted line) settlement. The sample period is January 1996 to December 2023.



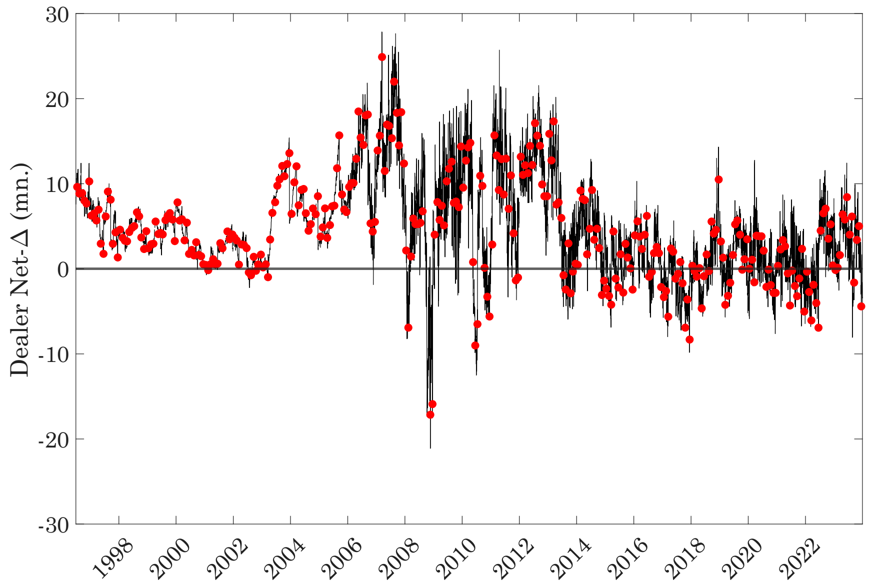
(a) Average Overnight Returns by Year



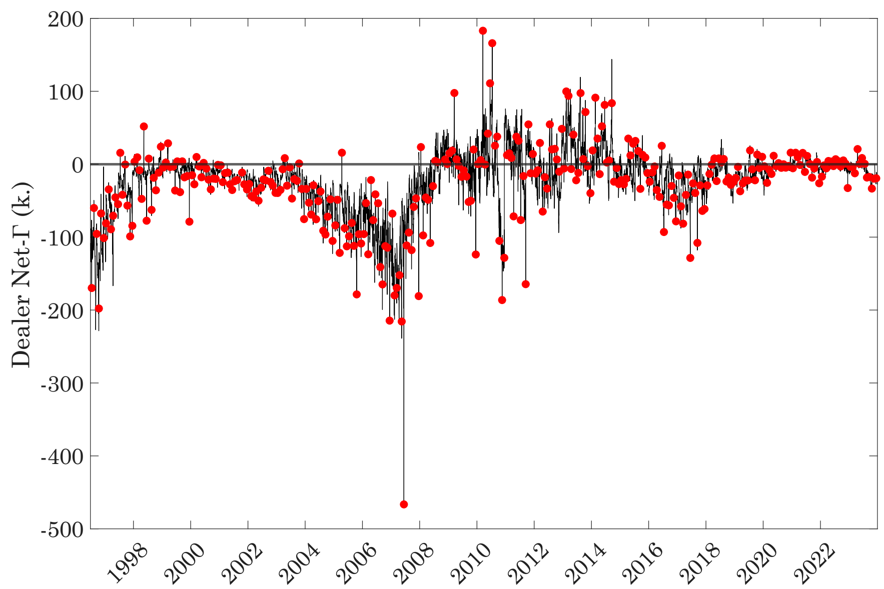
(b) Cumulative Overnight Returns

Figure A.2. The Third Friday Price Spike by Expiration Type

This figure plots the overnight S&P 500 return from 3^{rd} Thursday close to 3^{rd} Friday open, separately for quarterly and non-quarterly 3^{rd} Friday expirations. Panel (a) shows, for each calendar year, the average overnight expiry return in each group net of that year's average overnight return on all other trading days, in basis points (gray bars: non-quarterly; black bars: quarterly). The 1992 bars average the November and December expirations only. Panel (b) shows cumulative log returns by group (gray solid line: non-quarterly; dotted black line: quarterly); the legend reports each group's average overnight return, 15.5 basis points on quarterly and 7.0 basis points on non-quarterly expirations. The sample period is November 1992 to December 2023.



(a) Dealer Net-Δ



(b) Dealer Net-Γ

Figure A.3. Dealer Net-Δ and Net-Γ

This figure plots the time series of dealers' aggregate net-Δ and net-Γ in a.m.-settled S&P 500 options. Panel (a) shows dealer net-Δ in millions of index units, and Panel (b) shows dealer net-Γ in thousands of index units. Net Greeks are calculated as the sum-product of dealers' net-number across options and the respective options' Greek risk measure. Black lines show values on all trading days; red dots highlight 3^{rd} Thursday values (the day before option expiry). The sample period is July 1996 to December 2023.

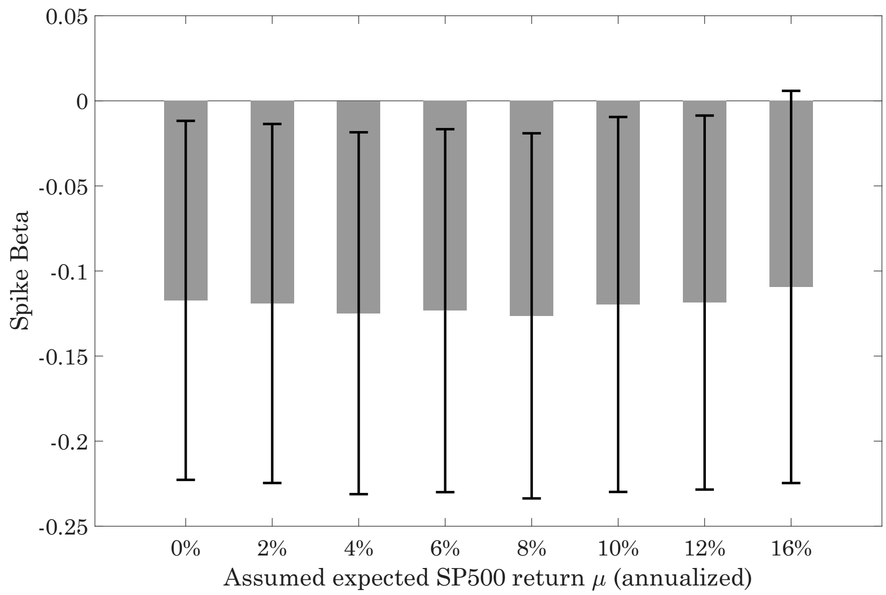


Figure A.4. Robustness: The Assumed Expected Equity Return (μ)

This figure reports the coefficient from the predictability regression of the overnight S&P 500 return into the SOQ on the dealer delta drift (column 1 of Table VII), re-estimated for each annualized expected return μ between 0% and 16% used in the construction of the projected Friday open. At $\mu = 0$ the projected open equals the 3^{rd} Thursday close and the regressor embeds no expected price movement. The paper's benchmark construction uses $\mu = 8\%$ per year. Both variables are standardized to zero mean and unit variance. Error bars are 95% confidence intervals based on Newey-West standard errors with 3 lags. The sample period is July 1996 to December 2023.

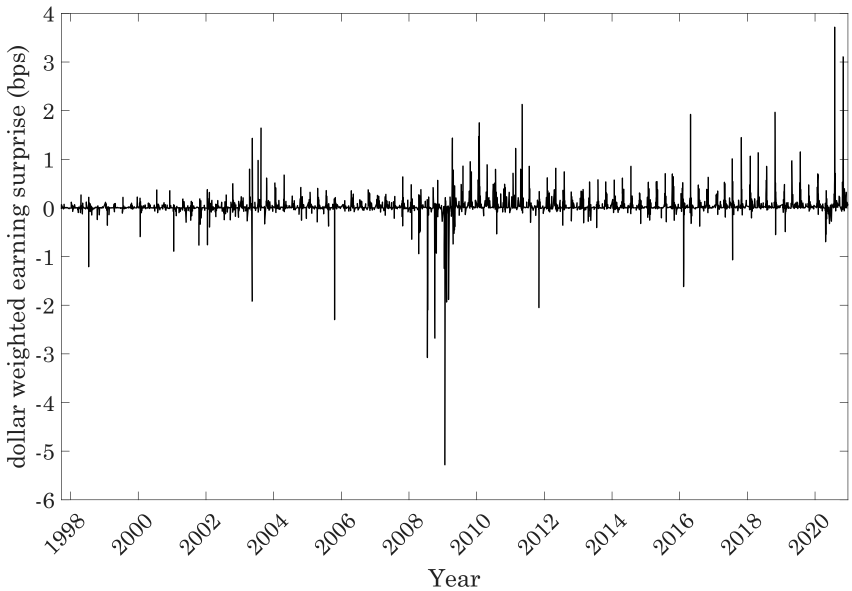
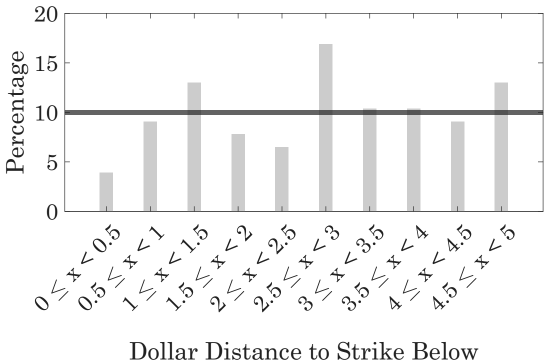
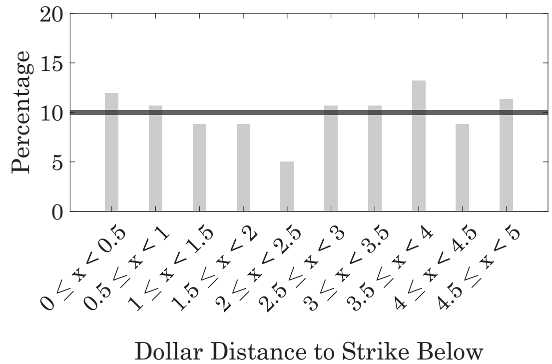


Figure A.5. Earnings Announcement Surprises

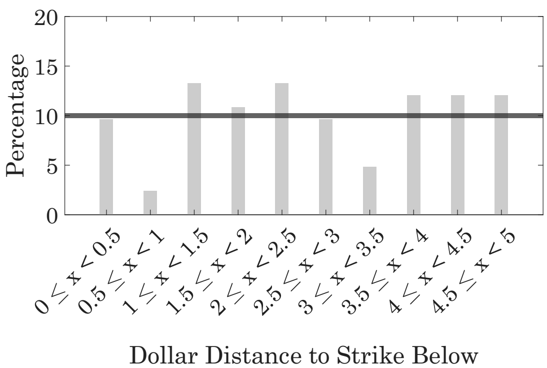
This figure displays the aggregate daily earnings announcement surprise of U.S. public companies. We calculate the earnings surprise as the sum-product of firms' earnings announcement surprises from I/B/E/S and the respective firms' lagged equity market capitalization. We consider announcements between 4:00 p.m. and midnight (E.T.). The sample period is September 1997 to December 2020.



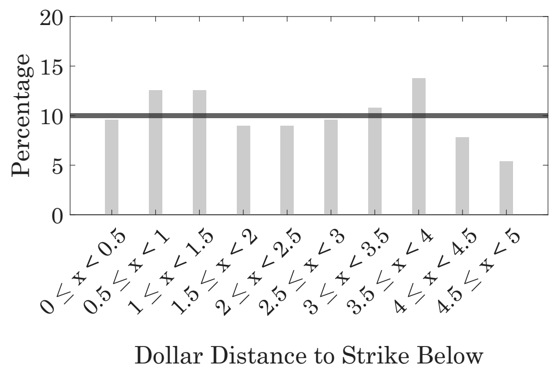
(a) Futures, Quarterly



(b) Futures, Non-Quarterly



(c) Stocks, Quarterly



(d) Stocks, Non-Quarterly

Figure A.6. Test for Pinning in S&P 500 Stocks and E-mini Futures

This figure shows the frequency with which equity prices lie within a certain distance to the closest lower S&P 500 option strike at the 3^{rd} Friday open. Thus, the figure tests for the presence of "pinning", which is the tendency of asset prices to be abnormally close to options' strike prices at option expiry. S&P 500 option strike prices occur every \$5. Panel (a) displays second-to-maturity S&P 500 E-mini futures on quarterly 3^{rd} Fridays (when first-to-maturity futures expire and become exceedingly illiquid). Panel (b) displays first-to-maturity S&P 500 E-mini futures on non-quarterly 3^{rd} Fridays (when S&P 500 E-mini futures do not expire). Panels (c) and (d) display the S&P 500 SOQ on quarterly and non-quarterly 3^{rd} Fridays, respectively. Due to the availability of liquid futures open prices, the sample period is January 2003 to December 2023, with the futures panels ending in December 2022 where our tick data end.