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The Common Source of Option Return Anomalies

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September 14, 2026

Abstract

Dozens of firm characteristics predict the returns on delta-hedged equity options, with different explanations for different characteristics. I show that most of them are the same anomaly. Their long-short portfolios lose money because they hold options on volatile stocks, and options on volatile stocks are repriced every month when the standard contracts expire and positions roll into the next maturity. Implied volatility alone accounts for four fifths of the average long-short return, and for nearly all of it on the two rollover days; among stocks of similar volatility, the idiosyncratic-volatility and maximum-return anomalies point the other way. What the expiration weekend costs the holder of a contract that does not expire, beyond what any weekend costs, is not time decay or realized variance but a missing recovery in implied volatility, the rise that every other weekend shows and this one does not; it grows with volatility and with the open interest that rolls. The anomalies are not separate puzzles but different exposures to one recurring repricing, and each portfolio's exposure is known a month ahead, from which stocks are volatile and when the contracts expire.

JEL Codes: G12, G13, G14.

Keywords: option returns; option anomalies; implied volatility; expiration; cross-sectional asset pricing.

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The views expressed in this paper are those of the author and do not necessarily reflect the views of the Deutsche Bundesbank or the Eurosystem.

1 Introduction

A portfolio that buys delta-hedged calls on the most volatile tenth of U.S. stocks and sells them on the least volatile tenth loses about 1.7% a month. So, to a smaller degree, does a portfolio built the same way on idiosyncratic volatility, on the largest daily return of the past month, on the share price, on cash holdings, on equity issuance or on profitability. Dozens more do the same once the characteristic space is searched systematically (Bali, Beckmeyer, Mörke, and Weigert, 2023). These anomalies have been given different explanations: limits to arbitrage for idiosyncratic volatility (Cao and Han, 2013), mispricing for the accounting characteristics (Zhan, Han, Cao, and Tong, 2022), compensation for a few latent risks (Goyal and Saretto, 2025). Different as they are, these explanations all locate the anomaly in the firms themselves, in what makes their options hard to arbitrage, mispriced, or risky. This paper asks a prior question. Are these eighteen different facts, or one?

Mostly one. Most of the characteristics that predict option returns rank stocks, more or less well, by volatility. Options on volatile stocks lose money on two days a month: the third Friday, when the standard contracts expire, and the Monday after it, when positions are rolled into the next contract. The loss rises steeply with volatility, from about 0.2% of the position for the least volatile tenth of stocks to 1.1% for the most volatile tenth. A portfolio that holds volatile stocks' options at one end and stable stocks' options at the other inherits that difference, whether or not the characteristic that formed it predicts anything of its own. Which stocks are volatile and when the contracts expire are both known a month ahead, and so is what the anomalies share.

How much of each anomaly is inherited this way, and how much is the characteristic's own? I split each long-short return into two parts: what the portfolio earns because its stocks are volatile, and what it earns by predicting returns among stocks of similar volatility. Across eighteen characteristics, half of the average monthly long-short return is inherited from volatility and earned on the two rollover days, another third is inherited and earned on the other days, mostly as the top decile's loss outside the window, and the characteristic's own part is the remaining fifth. On the two rollover days alone the inherited part is nine tenths of the total: every characteristic's own part is within 0.15% of zero, and zero once its exposure to the volatility portfolio is controlled for. The distinction changes what some familiar predictors mean. The long-short return on idiosyncratic volatility is -0.69% a month, but -0.87% of it is inherited from volatility and the characteristic's own part is 0.18% , of the opposite sign; the maximum-return anomaly reverses the same way. These characteristics select the stocks with the lowest option returns while predicting, among stocks of similar volatility, the opposite sign. What they have

been predicting all along is which stocks are volatile, and that volatile stocks' options lose on the expiration.

Not every anomaly dissolves. Volatility deviation and distress keep most of their long-short returns among stocks of similar volatility, earned mostly outside the rollover window, and cash holdings, issuance and profit margins keep a part. The cross-section therefore has two pieces: a broad common component tied to volatility and the expiration calendar, and a smaller set of return patterns with different economic content. The common component is also the robust one. The rollover loss and its scaling with volatility survive every screen for price, short interest and quote quality, and every subperiod. The smaller loss that high-volatility options show on the other nineteen days of the month does not survive the strictest quote screen, and no claim about the expiration rests on it.

What are the portfolios exposed to? A repricing of the option itself, on a weekend when nothing about the contract changes. Over an ordinary weekend the implied volatility of a stock's options falls into the Friday close and recovers by the Monday close, by about three percent of its level in every decile, and the recovery compensates the holder for the weekend's decay. Over the expiration weekend the recovery falls short, by half for the least volatile stocks and by five sixths for the most volatile, and the holder's loss is that missing recovery, to hundredths of a percent. Whether the Friday close before an expiration is high or the Monday close after it is low, the weekend change alone does not say. Time decay and the stock's move are what they are on any weekend, to hundredths of a percent. I establish this by following a contract that does not expire through the month and attributing its daily gain to time decay, to the stock's move and to the change in its own implied volatility (Carr and Wu, 2020). The same recovery is missing on the standard contract a month further out: what is repriced is the stock's volatility surface, not the contract that has become the nearest maturity.

Why do options on volatile stocks lose so much more than others? Part of the answer is mechanical. A given percentage change in implied volatility is worth more dollars on an option whose volatility is high, so even if every stock's recovery fell short by the same fraction, the options on volatile stocks would lose more. That mechanical part accounts for half of the additional loss in the low-volatility deciles but only a fifth in the top decile, 0.15% of 0.66% of the initial investment. The rest is a larger repricing of the volatile stocks' options themselves. It rises with volatility, falls on the contracts still near the money, and is larger where more open interest was outstanding in the expiring maturity a month earlier; no such relation appears on the other weekends. These facts date the common component to the monthly renewal of option positions and are consistent with dealers moving prices to absorb the positions that roll. They

characterize the repricing rather than identify its cause: open interest counts positions, not the inventories dealers are left with.

The cross-section of option returns was first studied one predictor at a time, from the idiosyncratic-volatility anomaly of Cao and Han (2013) to the broad set of stock characteristics that Zhan et al. (2022) show predict delta-hedged returns, and more recently as a whole. Goyal and Saretto (2025) and Horenstein, Vasquez, and Xiao (2026) show that a few latent factors price the characteristic portfolios, and the anomalies therefore share a common component. Horenstein et al. (2026) price them about as well with four characteristic factors: the equal-weighted option portfolio and portfolios formed on volatility deviation, cash holdings and the volatility of volatility. This paper gives that common component an observable state and a date. Across the characteristic portfolios, the loading on the leading factor is the level of implied volatility, itself a variable with a strong factor structure (Christoffersen, Fournier, and Jacobs, 2018). The factor’s premium is earned on the two rollover days, which contribute a small share of its variance and all of its mean. Two of the anomalies that survive among stocks of similar volatility, volatility deviation and cash holdings, are the characteristics behind two of the four factors; the reversal of the volatility characteristics among such stocks is a distinction a factor model does not draw. Käfer (2025) shows that exposure to pharmaceutical options contributes to several of the same anomalies, the cash-holdings anomaly above all.

A second literature studies the expiration itself. Garcia-Ares and Muravyev (2025) show that option returns, and the long-short returns of the same eighteen anomalies, concentrate on the rollover day, and tie the concentration to customer order imbalances. Gao, He, and Hu (2026) trace the monthly cycle in the implied volatilities of non-expiring options to rollover demand meeting the limited capacity of market makers. This paper brings the anomaly portfolios to that event. It shows how much of each anomaly the event carries, and why the concentration differs so much across characteristics and across stocks: through the volatility of the stocks each portfolio holds. And it measures the event in the return of a contract that does not expire, as a repricing of the option larger than the mechanical effect of volatility and tied to the positions that roll.

Two design choices carry the measurement. The attribution is the framework of Carr and Wu (2020), applied as a sequence of Black–Scholes repricings between closes; Wu and Zhang (2025) and Wu and Xu (2026) use the same contract-level Greeks to estimate the prices of the underlying risks. And every comparison is between the expiration weekend and the other weekends of the same contract-month, because option returns are lower over any closed period, as Jones and Shemesh (2018) show for nontrading days and Muravyev and Ni (2020) for the overnight, and only the difference is specific to the expiration. The level of the premium is not the paper’s

object. The average hedged return is close to zero, and implied variance exceeds realized in the mean only in the top decile, in line with the small variance premium that Carr and Wu (2009) and Driessen, Maenhout, and Vilkov (2009) find in individual stocks.

The interpretation changes what an explanation of option returns has to explain. An account that gives each characteristic its own reason, limits to arbitrage for one, mispricing for another, a risk premium for a third, is explaining something that, for most of them, is not there once the volatility of the stocks they hold is taken out. What is there is one recurring repricing, its steep rise with volatility, and a smaller set of return differences, above all volatility deviation and distress, that remain beyond it. An explanation has to account for those three, and the first two come with a date on the calendar and a quantity, the positions that roll, attached to them.

The rest of the paper proceeds as follows. Section 2 describes the data. Section 3 presents the empirical strategy. Section 4 reports the main results. Section 5 examines the mechanism. Section 6 extends the results across maturities and contracts. Section 7 reports robustness checks, and Section 8 concludes.

2 Data

Option prices are from OptionMetrics and stock prices, returns and shares outstanding from CRSP. The equity sample is U.S. common stocks with a share price of at least five dollars at the end of the formation month; the index sample is S&P 500 options. Both run from January 1996 to August 2025, the end of the option data. Short interest is the Compustat short interest file, available from mid-2006, taken at the last settlement date before formation and scaled by shares outstanding, and earnings announcement dates are the report dates of quarterly earnings in Compustat.

Following Cao and Han (2013) and the literature after it, I exclude stocks that pay a dividend during the life of the option, because early exercise on an American option changes the position an investor holds without any change in prices. The exclusion uses the ex-dividend dates CRSP records, which are realized after formation; it removes stocks, about a quarter of those that carry an eligible contract, and not contracts by how they fare, and Appendix A reports the decile returns with the dividend payers retained. Every screen that selects contracts applies at the formation close. Two rules act on the daily records afterwards, and both are reported in the same appendix. A quoted midpoint that violates its arbitrage bound, or a closing price that disagrees with CRSP's, is replaced. A contract-month in which the stock's price basis changes during the holding period, a split or a reverse split, is dropped, because the contract's terms are

adjusted with the stock and the hedged gain across the event is not measured. The rule removes four tenths of a percent of contract-months. Duarte, Jones, Khorram, Mo, and Wang (2026) show that filters applied after formation on how a contract fares inflate reported option returns, and neither rule conditions on the return.

At the end of each month I select, for each stock and for the index, the standard monthly call and put closest to the money among those expiring in the month after next. The contract held is therefore not the one that expires during the holding month, though it has two to three weeks left when the position is closed. Moneyness is log strike over the forward price, and contracts more than twenty percent from the money are discarded. Contracts enter only if the bid is positive and below the ask, open interest is positive, the midpoint is at least 12.5 cents and the midpoint respects the arbitrage bounds. All of these screens apply at formation, and a contract that stops printing afterwards is carried at its last quote. The full sample runs from 1996 to 2025 and holds 449,901 contract-months on 7,992 stocks over 355 formation months, an average of 1,267 stocks a month. The index sample holds one call and one put per formation month over 355 months, selected the same way. Appendix A reports what each screen removes and gives the details of construction. Stocks are sorted on the eighteen characteristics of Zhan et al. (2022) and Duarte et al. (2026): five stock-level measures, four from the option surface, and nine from accounting data, each defined in the same appendix. The sorting variable for the main results is one of the four, the thirty-day at-the-money implied volatility from the OptionMetrics surface at the formation close.

The equity call’s full-month return has a mean of -0.05% against a median of -0.51% , and the gap is the tail (Table 1, which reports the moments the argument uses). The distribution is heavily skewed: the mean of the nineteen days outside the rollover window is 0.37% , and about a quarter of a percent when each month’s cross-section is winsorized at its fifth and ninety-fifth percentiles (Appendix Table 22). Every result in the paper is a time-series average of monthly cross-sectional means, and the ones that rest on a level rather than a difference are repeated on winsorized means and medians in Section 7.

Table 1: Returns and sorting variables

	Mean	SD	10th	Median	90th	Obs. (000s)
Full month	-0.05	8.92	-5.02	-0.51	5.15	450
Ex-rollover	0.37	9.06	-4.46	-0.22	5.65	450
Rollover	-0.43	3.57	-2.32	-0.35	1.29	450
Ln(PRICE)	3.32	0.90	2.16	3.29	4.43	449
Ln(ME)	21.38	1.54	19.53	21.22	23.48	449
Ln(AMIHUDD)	-6.77	1.91	-9.27	-6.74	-4.33	449
IVOL	0.39	0.30	0.15	0.32	0.71	448
MAX(1)	0.07	0.07	0.02	0.05	0.12	449
CALL IV ATM	0.50	0.25	0.24	0.44	0.82	449
IV TERM	-0.02	0.09	-0.08	-0.01	0.04	449
VOL DEVIATION	0.01	0.28	-0.29	0.01	0.32	447
MF SKEW	-0.40	0.60	-1.15	-0.39	0.27	449
CFV	0.19	5.79	0.00	0.00	0.04	377
CH	0.22	0.24	0.01	0.13	0.61	398
DISP	0.20	1.36	0.01	0.04	0.30	417
ISSUE1Y	0.09	1.60	-0.04	0.01	0.20	412
ISSUE5Y	1.06	33.95	-0.13	0.09	1.01	322
PM	-4.44	151.62	-0.25	0.09	0.29	424
PROFIT	-0.84	161.76	-0.37	0.09	0.30	429
TEF	0.06	0.64	-0.10	0.00	0.32	404
ZS	10.01	208.59	1.02	3.87	17.32	392

This table reports the pooled distribution of delta-hedged equity call returns and of the characteristics they are sorted on. Returns are in percent per month; the top block is the full-month return and its two pieces, and the lower block the characteristics, each in its own units, with moments taken over finite values; a minus sign before a characteristic's name in the sort tables marks one ranked in descending order. The rollover row covers the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover row the remainder of the holding period. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life.

3 Empirical Strategy

Three measurements carry the paper. The first is the return on a delta-hedged option held for a calendar month, split by the day on which each part of it is earned; it shows where in the month the anomalies live. The second is an exact split of each anomaly's long-short return into what the portfolio earns by holding options on volatile stocks and what it earns beyond that. The third follows a single contract through the month and attributes each day's gain to time decay, to the stock's move and to the repricing of the option's own implied volatility; it says what the expiration costs the holder and why. This section defines the three in turn.

Portfolios form at the close of the last trading day of month $m - 1$, at which characteristics and screens are evaluated. The position is struck one trading day later, at the close of the first trading day of month m , and held to the close of the last trading day of that month. Skipping a day separates the information used to sort from the prices at which positions are opened. A contract selected at formation whose quote at the initiation close is missing, or whose initial investment is zero, is not opened. Consider an option held on trading day d . Write C_d for the midpoint of its bid and ask quotes at the close and S_d for the closing price of the underlying. Write Δ_{d-1} for the option's delta at the previous close, r_{d-1} for the annualized risk-free rate, and a_d for the number of calendar days between the two closes. The daily delta-hedged gain is

$$\pi_d = C_d - C_{d-1} - \Delta_{d-1}(S_d - S_{d-1}) - \frac{a_d r_{d-1}}{365}(C_{d-1} - \Delta_{d-1}S_{d-1}). \quad (1)$$

The first two terms are the change in the option's price, the third removes the profit on the hedge, and the fourth charges the position for the capital it ties up. For the index, whose basket pays dividends, the hedge also carries the dividend yield at the previous close's delta. Rebalancing daily rather than once at initiation removes most of the directional exposure that accumulates when the underlying moves far from its starting price (Cao and Han, 2013).

The month is then split by day. Let H denote the trading days of the holding period and t_0 the day the position is struck. Scaling by the absolute value of the initial investment gives the monthly return, and restricting the sum to a set of days W gives the part of it earned on those days,

$$R = \frac{\sum_{d \in H} \pi_d}{|\Delta_{t_0} S_{t_0} - C_{t_0}|}, \quad R^{\text{roll}} = \frac{\sum_{d \in H \cap W} \pi_d}{|\Delta_{t_0} S_{t_0} - C_{t_0}|}, \quad R^{\text{ex}} = R - R^{\text{roll}}. \quad (2)$$

The two pieces add to the monthly return by construction and share a denominator; a comparison between them is a comparison of dollars earned on the same position. The window W is the last trading day of the standard monthly contract, event day zero, together with the trading day that follows it. For equity options day zero is the third Friday of the month, or the trading day before it when that Friday is a holiday; for the index it is the Thursday before. I refer to R^{roll} as the rollover return and to W as the rollover window. Because the contract held expires a month later, neither day of the window is an expiration or settlement date for it: whatever the holder loses on those days is a change in the price of a contract that is still alive.

Where does a day's gain come from? The contract's own price, repriced input by input, gives the account. Let $B(S, \sigma, \tau)$ be the Black-Scholes price of the contract at stock price S , implied volatility σ and calendar time to expiration τ , at the zero rate for its maturity. Let σ_d be the implied volatility OptionMetrics reports at the close of day d , which inverts the midpoint C_d . Moving the previous close's inputs to the current close's one at a time, in the order time, stock,

volatility, splits the gain into four parts,

$$\begin{aligned}
\pi_d^\theta &= B(S_{d-1}, \sigma_{d-1}, \tau_d) - B(S_{d-1}, \sigma_{d-1}, \tau_{d-1}) - \frac{a_d r_{d-1}}{365} (C_{d-1} - \Delta_{d-1} S_{d-1}), \\
\pi_d^\Gamma &= B(S_d, \sigma_{d-1}, \tau_d) - B(S_{d-1}, \sigma_{d-1}, \tau_d) - \Delta_{d-1} (S_d - S_{d-1}), \\
\pi_d^\nu &= B(S_d, \sigma_d, \tau_d) - B(S_d, \sigma_{d-1}, \tau_d), \\
\pi_d^\varepsilon &= \pi_d - \pi_d^\theta - \pi_d^\Gamma - \pi_d^\nu.
\end{aligned} \tag{3}$$

Each part has a plain meaning. The theta part is what the option loses to the passage of time, net of the financing charge: by the Black–Scholes equation, decay net of financing equals $-\frac{1}{2}\Gamma S^2\sigma^2$ per unit of calendar time, the variance the option charges the holder for the interval. The gamma part is what the stock’s move returns to the hedged holder, $\frac{1}{2}\Gamma S^2$ times the squared return to second order, the variance the stock delivers. Their sum is the contract’s realized variance carry, the variance delivered against the variance charged, measured on the calendar clock on which the option is priced; it is the realized-against-implied variance part of the delta-hedged gain that Bakshi and Kapadia (2003) derive. The vega part is the repricing of the contract’s own implied volatility at the new stock price and time: the change in what the market charges for the option’s remaining variance. The residual is the change in the gap between the quoted midpoint and the model price, and it is close to zero: within 0.005% of the initial investment over the rollover window on contract-months whose endpoint quotes are observed. Appendix C gives the rate convention that makes the identity exact, the audit of the residual by decile and window, and the treatment of contracts that stop printing. The four parts add to the daily gain identically and are scaled by the initial investment as the return is, so their sums over a window add to R^{roll} or R^{ex} .

This is the attribution of Carr and Wu (2020), implemented as a sequence of finite repricings between closes, with the contract’s own implied volatility as the volatility state. Two qualifications apply. The split is an ordering convention: the interaction between the stock’s move and the volatility change is assigned to the vega part, and the theta and gamma parts are finite revaluations whose Greek-times-variance readings are local approximations. And it is an accounting of the realized gain, not a test of what is expected. Compensation for variance risk is earned through the theta and gamma parts, and a predictable drift in the contract’s implied volatility through the vega part, so the mean of a part is consistent with a premium and does not identify one.

Two variables describe the same sources directly. The first is the variance the stock realized over a window against the variance the option implied, $RV^2 - IV^2$. Realized variance is the annualized mean squared daily log return of the stock over the window’s trading days, and

implied variance the square of the held contract’s implied volatility at initiation. The second is the change in the held contract’s own implied volatility over the window, ΔIV , read from OptionMetrics’ closing values on the days that bound it and carried from the last close on days the contract does not print, as the midpoint is. Appendix C reconciles the implied variance of the held contract with the surface implied variance of Table 2.

The portfolios are the literature’s. Stocks are sorted each formation month into deciles of the thirty-day at-the-money implied volatility, and a stock’s decile is its volatility state for that month; characteristic portfolios are formed on the full universe, into deciles. Each long-short return is a weighted sum of the returns of the stocks in its two end deciles, $\sum_i w_i R_i$, with w_i equal to plus or minus the reciprocal of the decile’s count. It is allocated across implied-volatility groups by summing the same terms over the stocks in each group with the weights held fixed, so that the parts add to the total. A second set of sorts is run within the lower eight deciles pooled, into deciles, and within the top decile, into quintiles. Portfolios are equal weighted, and reported returns are time-series averages of the monthly cross-sectional means. Standard errors are Newey–West with six lags, which allows for serial dependence in the monthly portfolio series.

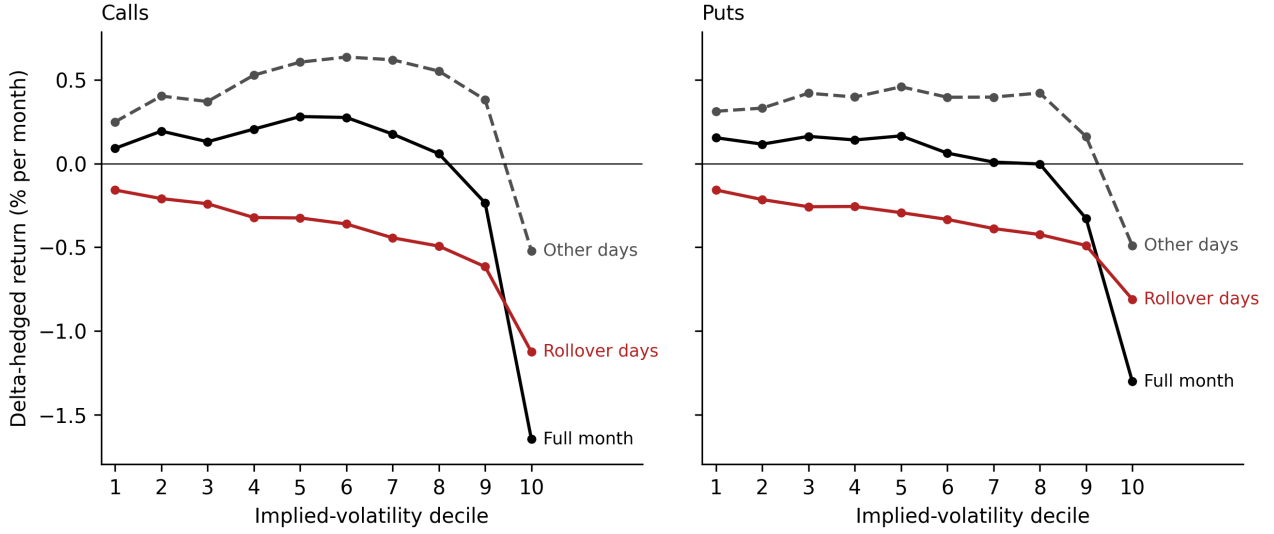
4 Common Component in Option Return Anomalies

4.1 Returns across volatility states

Where in the month do options on volatile stocks lose money? Figure 1 groups stocks into deciles of implied volatility and splits each decile’s monthly return into the two rollover days and the other nineteen. The answer is a calendar. The rollover return falls with volatility in every decile. The return on the other nineteen days rises with volatility through the sixth decile, stays positive through the ninth, and turns negative only in the tenth.

Over the whole month, eight of the ten deciles earn between nothing and three tenths of a percent and two lose (Table 2). A delta-hedged call earns 0.09% a month in the lowest decile and 0.28% in the fifth and sixth, with t -statistics of 2.6 and 2.4. The ninth decile loses 0.24%, with a t -statistic of -1.6 , and the tenth loses 1.65%, with a t -statistic of -8.6 . The put shows the same pattern: between nothing and two tenths of a percent in the eight lowest deciles, then losses of 0.33% and 1.30%. Split by day, the two pieces of the month move in opposite directions. The rollover return falls with implied volatility in every decile, from -0.16% in the lowest to -1.13% in the highest for the call and from -0.16% to -0.81% for the put, with a t -statistic beyond -6 everywhere. The return on the other nineteen days rises with implied volatility, from 0.25% in the lowest decile to 0.64% in the sixth for the call, stays positive through the ninth, and turns

Figure 1: Delta-hedged returns by implied-volatility decile



This figure plots the average monthly delta-hedged return on the standard monthly call (left) and put (right) closest to at the money against the decile of the stock's thirty-day at-the-money implied volatility at formation. The full month accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover days are the last trading day of the standard monthly contract and the trading day that follows; the other days hold the remainder, and the two add to the full month. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life.

to -0.52% in the tenth. The put runs between three and five tenths of a percent through the eighth decile, 0.16% in the ninth and -0.49% in the tenth. Most of the top decile's monthly loss, 1.13% of 1.65% on the call, falls on the two rollover days. Garcia-Ares and Muravyev (2025) report 0.36% for the lowest decile and -1.49% for the highest, with -1.01% of the latter on the rollover days, on a sample to 2023. The lower figure for the lowest decile here comes from excluding contract-months in which the stock splits and from validating quotes, which remove gains that are artifacts of adjusted contract terms. The long-short return on size in the tables that follow is large minus small, 0.42% ; Garcia-Ares and Muravyev (2025) report -0.37% for the same portfolio formed as small minus large, the same sign as here.

Is the top decile's loss the price of variance? Only there does implied variance exceed realized variance in the mean, and the variance columns of Table 2 show how the gap runs across states. The implied variance is the square of the at-the-money implied volatility rather than a variance-swap strike, and the comparison runs over the holding month rather than the option's life. The ordering is therefore consistent with variance compensation that depends on the state, without identifying the variance-swap premium Carr and Wu (2009) measure. In medians, implied volatility sits at or a point below the volatility realized over the year before formation in each of the nine lower deciles and eight points above it in the tenth. It exceeds the volatility realized

Table 2: Delta-hedged returns by implied-volatility decile

Decile	IV	Prior RV	Forward RV	IV ² –RV ²	Calls			Puts		
					Full month	Rollover	Ex-rollover	Full month	Rollover	Ex-rollover
1	0.24	0.25	0.22	-0.012 (-2.58)	0.09 (1.05)	-0.16 (-9.27)	0.25 (2.94)	0.15 (1.64)	-0.16 (-6.56)	0.31 (3.33)
2	0.30	0.31	0.28	-0.015 (-2.66)	0.19 (2.07)	-0.21 (-10.41)	0.40 (4.54)	0.12 (1.31)	-0.22 (-11.50)	0.33 (3.79)
3	0.34	0.36	0.32	-0.014 (-2.44)	0.13 (1.41)	-0.24 (-8.69)	0.37 (4.29)	0.16 (1.58)	-0.26 (-14.60)	0.42 (4.09)
4	0.39	0.40	0.36	-0.017 (-2.40)	0.21 (1.85)	-0.32 (-9.77)	0.53 (5.05)	0.14 (1.46)	-0.26 (-11.47)	0.40 (4.06)
5	0.44	0.45	0.40	-0.022 (-2.50)	0.28 (2.60)	-0.33 (-12.53)	0.61 (5.61)	0.17 (1.70)	-0.29 (-12.72)	0.46 (4.71)
6	0.49	0.50	0.44	-0.025 (-2.46)	0.28 (2.41)	-0.36 (-11.73)	0.64 (5.76)	0.06 (0.62)	-0.33 (-12.41)	0.40 (3.76)
7	0.54	0.55	0.49	-0.023 (-2.06)	0.18 (1.39)	-0.44 (-15.27)	0.62 (5.19)	0.01 (0.08)	-0.39 (-14.53)	0.40 (3.69)
8	0.61	0.61	0.54	-0.023 (-1.54)	0.06 (0.45)	-0.49 (-15.27)	0.55 (4.42)	-0.00 (-0.03)	-0.42 (-16.30)	0.42 (4.31)
9	0.70	0.69	0.60	-0.001 (-0.07)	-0.24 (-1.57)	-0.62 (-13.74)	0.38 (2.68)	-0.33 (-2.89)	-0.49 (-14.97)	0.16 (1.43)
10	0.88	0.80	0.71	0.179 (4.78)	-1.65 (-8.57)	-1.13 (-20.23)	-0.52 (-2.84)	-1.30 (-9.91)	-0.81 (-22.11)	-0.49 (-3.80)

This table reports average delta-hedged returns, in percent per month, on the standard monthly call and put closest to at the money, by decile of the stock's thirty-day at-the-money implied volatility at formation. IV is the time-series average of the decile's median implied volatility; Prior RV the same for realized volatility over the year before formation and Forward RV for realized volatility over the holding period, all annualized. IV²–RV² is the time-series average of the monthly cross-sectional mean of implied variance less realized variance over the holding period, annualized, with its Newey–West t -statistic beneath. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment, $|\Delta_{t_0} S_{t_0} - C_{t_0}|$, in which Δ_{t_0} is the option's delta, S_{t_0} the underlying price and C_{t_0} the midpoint of the option's quotes on the day the position is struck. The rollover column restricts the sum to the last trading day of the standard monthly contract and the trading day that follows; the ex-rollover column holds the remainder, and the two add to the full month. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

over the holding month in every decile. In means, which is what a variance position earns, the ordering reverses. Implied variance falls short of realized variance in each of the eight lowest deciles, by one to two and a half annualized variance points, with t -statistics beyond -2 in seven of them. It equals realized variance in the ninth and exceeds it in the tenth by eighteen points, a fifth of the level. The median month delivers less variance than the option implied, the tail months deliver much more, and in the mean the two balance or favor the holder everywhere but in the top decile. That is the pattern Carr and Wu (2009) and Driessen et al. (2009) report for individual stocks from variance swaps, and it fails in the top decile. How much of each anomaly this calendar accounts for is the next question.

4.2 Returns between states and within them

Do the characteristics predict option returns, or do they pick volatile stocks? The two are different economic objects: a source of expected return of the characteristic's own against exposure to a component that many other portfolios share. To first order the characteristics are proxies for volatility. The rank correlation between the signed characteristic and implied volatility is 0.71 for idiosyncratic volatility, 0.61 for the maximum daily return, 0.59 for the share price, and between 0.36 and 0.45 for the accounting measures; only the z-score is uncorrelated. Any of them therefore puts the most volatile stocks at one end of its portfolio and the rollover days inside every month, and the question is how much of each long-short return those two carry. Table 3 takes it up with the original portfolios, allocating each long-short return across implied-volatility groups with its decile weights held fixed, so that the parts add to the total.

The volatility anomalies live in the top decile and on the rollover days. The top decile is more than the whole of the idiosyncratic-volatility, maximum-return and size long-short returns over the month, with the lower eight deciles contributing the opposite sign, and four fifths to nine tenths of each over the two rollover days. Averaged across all eighteen characteristics, the long-short return is 0.61% a month, of which the top decile contributes 0.49%, and 0.31% of the 0.34% earned over the two days. Two anomalies are different: volatility deviation earns 0.57% of its 1.41% in the lower eight deciles and the z-score 0.29% of its 0.40%; those two are earned across the distribution.

The intuition is simple. If the stocks in an anomaly portfolio are mostly volatile, the portfolio inherits whatever volatile stocks' options earn that month, before the characteristic has predicted anything. The between-state part of a spread is that inheritance: what the portfolio would earn if every stock in it earned the average return of its volatility state that month. The within-state part is the rest, what the portfolio earns by picking stocks within each state. With the original decile weights w_i of each long-short portfolio and the ten implied-volatility deciles as states,

$$\sum_i w_i R_i = \sum_g W_g \bar{R}_g + \sum_i w_i (R_i - \bar{R}_{g(i)}), \quad W_g = \sum_{i \in g} w_i, \quad (4)$$

with $\bar{R}_g$ the mean over all stocks in state g . The allocation in Table 3 sums each stock's own return within a group and so mixes the two parts; Equation (4) separates them, and Table 4 reports both for every characteristic and window. Four fifths of the average spread is inherited from volatility. Across the eighteen characteristics the average long-short return of 0.61% a month is 0.50% between states and 0.11% within them, or 0.43% of 0.54% without the implied-volatility portfolio itself. On the two rollover days it is 0.30% between and 0.04% within, and over the other

Table 3: Each characteristic's long-short return by implied-volatility group and window

	Full month				Rollover			Ex-rollover		
	Spread	D1-8	D9	D10	D1-8	D9	D10	D1-8	D9	D10
AVERAGE	-0.61 (-8.94)	-0.07 (-2.14)	-0.04 (-2.56)	-0.49 (-9.13)	0.04 (5.10)	-0.07 (-11.19)	-0.31 (-17.09)	-0.11 (-3.63)	0.03 (1.54)	-0.18 (-3.55)
-Ln(PRICE)	-0.82 (-5.19)	-0.03 (-0.31)	-0.03 (-0.81)	-0.76 (-9.02)	0.03 (1.15)	-0.14 (-8.76)	-0.47 (-15.73)	-0.06 (-0.79)	0.11 (2.58)	-0.28 (-3.44)
Ln(ME)	0.42 (2.80)	-0.22 (-2.50)	-0.02 (-0.39)	0.65 (9.64)	-0.05 (-1.77)	0.12 (7.90)	0.39 (14.03)	-0.17 (-2.15)	-0.13 (-3.48)	0.26 (3.75)
Ln(AMIHU)	-0.09 (-0.60)	0.42 (4.18)	0.01 (0.33)	-0.53 (-9.30)	0.06 (1.97)	-0.10 (-5.78)	-0.32 (-11.93)	0.36 (3.85)	0.11 (2.74)	-0.21 (-3.32)
IVOL	-0.69 (-5.51)	0.10 (1.32)	-0.05 (-1.31)	-0.74 (-9.01)	0.05 (2.63)	-0.13 (-10.06)	-0.50 (-16.86)	0.05 (0.72)	0.09 (2.57)	-0.23 (-3.00)
MAX(1)	-0.49 (-4.41)	0.11 (1.57)	-0.02 (-0.47)	-0.59 (-8.02)	0.06 (3.11)	-0.11 (-9.92)	-0.39 (-15.39)	0.05 (0.83)	0.09 (2.86)	-0.19 (-3.01)
CALL IV ATM	-1.74 (-10.41)	-0.09 (-1.05)	0.00 —	-1.65 (-8.57)	0.16 (9.27)	0.00 —	-1.13 (-20.23)	-0.25 (-2.94)	0.00 —	-0.52 (-2.84)
-IV TERM	-0.53 (-5.19)	-0.20 (-3.23)	0.02 (0.68)	-0.36 (-4.00)	0.18 (8.42)	-0.02 (-1.70)	-0.30 (-7.90)	-0.38 (-5.69)	0.05 (1.39)	-0.06 (-0.59)
-VOL DEVIATION	-1.41 (-8.05)	-0.57 (-4.06)	-0.16 (-4.83)	-0.68 (-8.92)	0.04 (1.23)	-0.04 (-3.88)	-0.34 (-9.36)	-0.61 (-4.59)	-0.12 (-3.91)	-0.34 (-4.51)
MF SKEW	-0.08 (-0.68)	0.10 (1.38)	-0.00 (-0.22)	-0.18 (-2.94)	-0.04 (-2.51)	-0.05 (-3.85)	-0.12 (-6.20)	0.15 (1.89)	0.04 (1.94)	-0.06 (-1.05)
CFV	-0.62 (-5.08)	-0.17 (-2.12)	-0.06 (-1.79)	-0.40 (-6.35)	-0.01 (-0.42)	-0.10 (-7.41)	-0.24 (-10.26)	-0.16 (-2.20)	0.04 (1.07)	-0.16 (-2.87)
CH	-0.82 (-6.55)	-0.03 (-0.35)	-0.16 (-4.59)	-0.62 (-9.46)	0.03 (1.56)	-0.12 (-7.64)	-0.37 (-11.27)	-0.06 (-0.71)	-0.04 (-1.13)	-0.26 (-3.73)
DISP	-0.28 (-3.31)	-0.03 (-0.56)	-0.01 (-0.45)	-0.23 (-5.75)	-0.01 (-0.36)	-0.08 (-8.64)	-0.19 (-11.95)	-0.02 (-0.46)	0.07 (2.57)	-0.05 (-1.13)
ISSUE1Y	-0.56 (-5.69)	-0.01 (-0.24)	-0.07 (-2.84)	-0.47 (-7.44)	0.01 (0.91)	-0.10 (-9.22)	-0.28 (-10.69)	-0.03 (-0.47)	0.03 (1.22)	-0.19 (-3.40)
ISSUE5Y	-0.72 (-6.87)	-0.15 (-2.73)	-0.08 (-2.22)	-0.48 (-7.48)	-0.01 (-0.89)	-0.09 (-6.84)	-0.25 (-9.68)	-0.14 (-2.43)	0.01 (0.37)	-0.23 (-4.44)
-PM	-0.95 (-6.25)	-0.10 (-1.15)	-0.08 (-2.17)	-0.76 (-8.90)	0.09 (3.16)	-0.11 (-6.98)	-0.44 (-16.04)	-0.19 (-2.24)	0.03 (0.87)	-0.33 (-4.30)
-PROFIT	-0.54 (-6.30)	-0.06 (-1.16)	-0.03 (-0.93)	-0.45 (-7.72)	0.08 (5.15)	-0.09 (-7.93)	-0.28 (-11.76)	-0.14 (-2.82)	0.06 (1.82)	-0.17 (-3.11)
TEF	-0.60 (-5.07)	-0.00 (-0.01)	-0.08 (-2.39)	-0.52 (-6.73)	0.06 (2.44)	-0.11 (-7.25)	-0.38 (-11.15)	-0.06 (-1.09)	0.03 (0.89)	-0.14 (-1.87)
-ZS	-0.40 (-3.14)	-0.29 (-2.99)	0.01 (0.17)	-0.12 (-1.91)	0.02 (0.66)	0.00 (0.10)	-0.04 (-1.35)	-0.31 (-3.44)	0.00 (0.11)	-0.07 (-1.17)

This table reports, for each characteristic, the average long-short return on equal-weighted decile portfolios of delta-hedged equity calls formed on the full universe, in percent per month, and its allocation across stocks in the lower eight deciles, the ninth decile and the tenth decile of thirty-day at-the-money implied volatility at formation, with the portfolio weights held fixed so that the parts add to the total. Characteristics are signed so that decile ten is the end carrying the lower return; for market capitalization that end carries the higher return, and its long-short return is reported as such. A dash marks a group that holds no stock of either end decile, the implied-volatility portfolio's own ninth decile, whose part is zero by construction. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover columns restrict the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover columns hold the remainder. AVERAGE reports the equal-weighted average across characteristics of the monthly series. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

nineteen days 0.20% and 0.06%. For the volatility characteristics the inheritance is more than the whole long-short return. Idiosyncratic volatility’s 0.69% is 0.87% between states and 0.18% of the opposite sign within them, with a t -statistic of 2.1 on the within part, and the maximum return’s 0.49% is 0.72% between and 0.23% of the opposite sign within. The share price’s 0.82% is 0.79% between and 0.03% within, and size, illiquidity, the term slope, skewness and external financing have within-state parts of zero or the opposite sign. Within a volatility state, then, a stock whose returns were more volatile over the prior month earns a higher return on its hedged call over the nineteen days outside the rollover window, 0.21% for idiosyncratic volatility and 0.21% for the maximum daily return. With implied volatility held fixed, these characteristics rank stocks by realized volatility relative to implied, in the direction of the volatility-deviation signal of Goyal and Saretto (2009). Their rank correlations with volatility deviation are 0.27 and 0.27 within implied-volatility deciles against 0.07 and 0.11 across the universe, and within states they carry its sign.

Not everything is inherited. The volatility-deviation long-short return of Goyal and Saretto (2009), 1.41%, is 0.96% within states, and the z -score’s 0.40%, the default-risk anomaly of Vasquez and Xiao (2024), is 0.37% within. The five-year issuance, profit-margin and cash anomalies keep within-state parts of a quarter to four tenths of a percent, most of it earned outside the rollover window. On the two rollover days the within-state part of every spread is within 0.15% of zero, and the average of 0.04% is small but not zero, with a t -statistic of -4.6 . The volatility anomalies, then, are exposures to volatility and to the expiration calendar; the volatility-deviation and distress anomalies are a different cross-section. Sorts run within the lower eight deciles and within the top decile show the same (Internet Appendix Table IA.4). Within the lower eight, idiosyncratic volatility and the maximum return predict higher returns over the nineteen days, 0.57% and 0.45% from the first decile to the tenth, and lower returns over the two.

The decomposition is an accounting of each month’s cross-section. A different question is whether, month after month, an anomaly’s long-short return merely moves with the return on volatile stocks’ options or earns something of its own. A time-series regression of each long-short return on the volatility portfolio’s, long the most volatile decile and short the least volatile and the widest of the eighteen at 1.74% a month, separates the two,

$$R_t^c = \alpha^c + \beta^c R_t^{IV} + \varepsilon_t^c, \quad (5)$$

where R_t^c is the long-short return on characteristic c in month t over the window in question, R_t^{IV} the long-short return on the volatility portfolio over the same window, and α^c what the characteristic earns beyond its exposure β^c to volatile stocks’ options. The answer is the same (Table 5). Over the full month, fifteen of the seventeen other characteristics have a long-short

Table 4: Each characteristic's long-short return between and within volatility states

	Full month			Rollover			Ex-rollover		
	Spread	Between	Within	Spread	Between	Within	Spread	Between	Within
AVERAGE	-0.61 (-8.94)	-0.50 (-8.83)	-0.11 (-4.53)	-0.34 (-15.09)	-0.30 (-16.96)	-0.04 (-4.63)	-0.26 (-4.35)	-0.20 (-3.94)	-0.06 (-3.10)
AVERAGE EX IV	-0.54 (-8.57)	-0.43 (-8.42)	-0.11 (-4.53)	-0.31 (-14.27)	-0.26 (-16.37)	-0.04 (-4.63)	-0.23 (-4.17)	-0.16 (-3.68)	-0.07 (-3.10)
-Ln(PRICE)	-0.82 (-5.19)	-0.79 (-8.88)	-0.03 (-0.22)	-0.58 (-11.72)	-0.48 (-16.83)	-0.10 (-2.63)	-0.24 (-1.66)	-0.31 (-3.99)	0.07 (0.62)
Ln(ME)	0.42 (2.80)	0.67 (7.46)	-0.26 (-2.08)	0.46 (9.65)	0.46 (16.78)	-0.00 (-0.09)	-0.04 (-0.28)	0.21 (2.73)	-0.25 (-2.16)
Ln(AMIHU)	-0.09 (-0.60)	-0.52 (-7.38)	0.43 (3.27)	-0.35 (-7.10)	-0.39 (-16.49)	0.04 (0.93)	0.26 (1.68)	-0.14 (-2.12)	0.39 (3.07)
IVOL	-0.69 (-5.51)	-0.87 (-7.93)	0.18 (2.07)	-0.59 (-15.38)	-0.55 (-17.27)	-0.03 (-1.43)	-0.10 (-0.85)	-0.31 (-3.24)	0.21 (2.68)
MAX(1)	-0.49 (-4.41)	-0.72 (-7.59)	0.23 (2.91)	-0.44 (-13.40)	-0.46 (-16.70)	0.02 (1.01)	-0.05 (-0.50)	-0.26 (-3.11)	0.21 (2.84)
CALL IV ATM	-1.74 (-10.41)	-1.74 (-10.41)	0.00 (1.03)	-0.97 (-19.03)	-0.97 (-19.03)	0.00 (1.06)	-0.77 (-5.04)	-0.77 (-5.04)	0.00 (1.03)
-IV TERM	-0.53 (-5.19)	-0.54 (-9.17)	0.01 (0.10)	-0.14 (-3.74)	-0.29 (-14.07)	0.15 (3.95)	-0.39 (-3.45)	-0.26 (-4.87)	-0.14 (-1.47)
-VOL DEVIATION	-1.41 (-8.05)	-0.46 (-7.07)	-0.96 (-5.55)	-0.34 (-7.03)	-0.25 (-10.41)	-0.09 (-2.40)	-1.07 (-6.33)	-0.21 (-4.14)	-0.86 (-5.27)
MF SKEW	-0.08 (-0.68)	-0.24 (-4.16)	0.16 (2.01)	-0.21 (-6.80)	-0.13 (-6.55)	-0.08 (-3.24)	0.13 (1.27)	-0.10 (-2.47)	0.24 (2.87)
CFV	-0.62 (-5.08)	-0.45 (-6.49)	-0.17 (-1.66)	-0.34 (-9.23)	-0.29 (-11.67)	-0.05 (-1.88)	-0.28 (-2.53)	-0.16 (-2.94)	-0.12 (-1.31)
CH	-0.82 (-6.55)	-0.55 (-8.16)	-0.27 (-2.36)	-0.46 (-9.58)	-0.32 (-15.38)	-0.14 (-3.52)	-0.36 (-3.10)	-0.23 (-3.87)	-0.13 (-1.25)
DISP	-0.28 (-3.31)	-0.32 (-6.67)	0.05 (0.73)	-0.28 (-8.04)	-0.27 (-17.12)	-0.01 (-0.25)	0.00 (0.02)	-0.05 (-1.16)	0.05 (0.96)
ISSUE1Y	-0.56 (-5.69)	-0.40 (-6.87)	-0.16 (-2.14)	-0.37 (-11.54)	-0.26 (-14.76)	-0.11 (-4.62)	-0.19 (-2.26)	-0.14 (-2.62)	-0.05 (-0.74)
ISSUE5Y	-0.72 (-6.87)	-0.35 (-6.32)	-0.37 (-4.86)	-0.36 (-9.06)	-0.25 (-14.41)	-0.11 (-3.82)	-0.36 (-4.28)	-0.10 (-2.11)	-0.26 (-3.85)
-PM	-0.95 (-6.25)	-0.68 (-8.66)	-0.27 (-2.32)	-0.46 (-10.10)	-0.38 (-15.57)	-0.08 (-2.13)	-0.49 (-3.56)	-0.30 (-4.39)	-0.19 (-1.77)
-PROFIT	-0.54 (-6.30)	-0.45 (-8.99)	-0.08 (-1.27)	-0.29 (-8.88)	-0.26 (-16.10)	-0.03 (-1.28)	-0.25 (-3.20)	-0.20 (-4.47)	-0.05 (-0.82)
TEF	-0.60 (-5.07)	-0.57 (-8.44)	-0.03 (-0.30)	-0.43 (-8.80)	-0.33 (-15.65)	-0.09 (-2.35)	-0.17 (-1.70)	-0.24 (-3.95)	0.07 (0.81)
-ZS	-0.40 (-3.14)	-0.03 (-0.82)	-0.37 (-2.89)	-0.02 (-0.45)	-0.01 (-0.74)	-0.01 (-0.20)	-0.38 (-2.95)	-0.02 (-0.73)	-0.36 (-2.84)

This table splits, for each characteristic, the average long-short return on equal-weighted decile portfolios of delta-hedged equity calls formed on the full universe, in percent per month, into the part attributable to the portfolio's allocation across the ten deciles of thirty-day at-the-money implied volatility at formation, computed with each stock's return replaced by the mean return of its implied-volatility decile that month and the portfolio weights held fixed, and the within-state remainder; the two add to the total. Characteristics are signed so that decile ten is the end carrying the lower return; for market capitalization that end carries the higher return, and its long-short return is reported as such. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover columns restrict the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover columns hold the remainder. AVERAGE reports the equal-weighted average across characteristics of the monthly series, and AVERAGE EX IV the same average without the implied-volatility portfolio itself, whose within-state part is zero by construction. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

return distinguishable from zero; controlling for the volatility portfolio, three keep a same-signed alpha, volatility deviation, cash and five-year issuance, and one reverses, the maximum return. Over the two rollover days sixteen of the seventeen have a long-short return distinguishable from zero and not one keeps an alpha that is. On the days that carry most of the cross-section, no characteristic earns anything beyond what its exposure to volatility implies. Over the other nineteen days the volatility characteristics have alphas of the opposite sign to their long-short returns, 0.31% for idiosyncratic volatility, 0.29% for the maximum return and 0.45% for illiquidity, while volatility deviation, five-year issuance and the z-score keep theirs. The level of implied volatility is observed at formation and the expiration is a date on the calendar. What the fifteen characteristics have been predicting is therefore which stocks are volatile, and that volatile stocks' options lose on the expiration.

Why implied volatility, rather than one of the characteristics that proxy for it? Grouping stocks by idiosyncratic volatility instead would allocate most of the volatility portfolio's return to idiosyncratic-volatility groups in the same way, since the two are correlated, and the accounting alone cannot tell them apart. Three results can. The expiration loss is a repricing of implied volatility whose dollar size is the contract's vega times its level. Among stocks of similar implied volatility, idiosyncratic volatility and the maximum return carry the opposite sign. And on the rollover days, controlling for volatility, every anomaly has an alpha of zero. Implied volatility is the variable, and the other characteristics are its proxies. Whether the component is anything more than a factor is the last question of this section.

4.3 Factor structure by window

Is the common component simply the leading factor of an option factor model? In one sense it is exactly that, and the correspondence says what the factor is: its loadings are the volatility state, and its premium is earned on the two rollover days. Table 6 builds the ten decile portfolios of each of the eighteen characteristics three times, from the full-month return, from the return on the two rollover days and from the return on the other nineteen, and extracts the leading principal component of each panel. One component carries 83% of the variance of the full-month portfolios, 82% of the other-days portfolios and 73% of the rollover-day portfolios (Panel A). The loadings on it are implied volatility. Across the 180 portfolios, the correlation between a portfolio's loading on the leading component and its average implied volatility is at least 0.94 in every window (Panel B). The loadings estimated on the two rollover days and on the other nineteen are the same pattern, with a correlation of 0.94 between them. What differs across windows is whether the loadings are rewarded. On the two rollover days the cross-section of

Table 5: Each characteristic's long-short return regressed on the volatility portfolio's

	Full month				Rollover				Ex-rollover			
	Spread	α	β	R^2	Spread	α	β	R^2	Spread	α	β	R^2
-Ln(PRICE)	-0.82 (-5.19)	-0.22 (-1.08)	0.35 (5.28)	0.25	-0.58 (-11.72)	-0.04 (-0.75)	0.56 (10.04)	0.47	-0.24 (-1.66)	0.01 (0.09)	0.33 (3.80)	0.21
Ln(ME)	0.42 (2.80)	-0.14 (-0.84)	-0.32 (-5.61)	0.24	0.46 (9.65)	0.01 (0.20)	-0.46 (-5.67)	0.33	-0.04 (-0.28)	-0.27 (-1.86)	-0.30 (-4.46)	0.19
Ln(AMIHU)	-0.09 (-0.60)	0.32 (1.55)	0.24 (3.94)	0.12	-0.35 (-7.10)	0.05 (0.75)	0.42 (5.61)	0.25	0.26 (1.68)	0.45 (2.55)	0.25 (3.20)	0.12
IVOL	-0.69 (-5.51)	0.27 (1.53)	0.55 (6.88)	0.53	-0.59 (-15.38)	-0.06 (-1.16)	0.54 (10.69)	0.55	-0.10 (-0.85)	0.31 (2.63)	0.53 (6.75)	0.51
MAX(1)	-0.49 (-4.41)	0.35 (2.27)	0.48 (7.64)	0.49	-0.44 (-13.40)	0.01 (0.25)	0.47 (10.29)	0.50	-0.05 (-0.50)	0.29 (2.82)	0.45 (6.96)	0.44
-IV TERM	-0.53 (-5.19)	0.14 (1.12)	0.39 (5.91)	0.35	-0.14 (-3.74)	0.04 (0.67)	0.18 (3.21)	0.08	-0.39 (-3.45)	-0.05 (-0.53)	0.44 (6.47)	0.36
-VOL DEVIATION	-1.41 (-8.05)	-0.84 (-3.93)	0.33 (6.74)	0.19	-0.34 (-7.03)	-0.03 (-0.47)	0.32 (4.93)	0.16	-1.07 (-6.33)	-0.78 (-4.39)	0.38 (6.81)	0.23
MF SKEW	-0.08 (-0.68)	0.18 (1.13)	0.15 (1.75)	0.06	-0.21 (-6.80)	0.02 (0.53)	0.24 (5.36)	0.19	0.13 (1.27)	0.28 (2.27)	0.19 (1.98)	0.08
CFV	-0.62 (-5.08)	-0.28 (-1.62)	0.20 (3.25)	0.14	-0.34 (-9.23)	-0.05 (-1.17)	0.30 (7.12)	0.26	-0.28 (-2.53)	-0.14 (-1.21)	0.18 (3.62)	0.12
CH	-0.82 (-6.55)	-0.35 (-2.40)	0.27 (4.41)	0.16	-0.46 (-9.58)	-0.05 (-0.69)	0.43 (5.98)	0.26	-0.36 (-3.10)	-0.12 (-0.94)	0.30 (4.33)	0.18
DISP	-0.28 (-3.31)	0.21 (1.95)	0.28 (7.16)	0.28	-0.28 (-8.04)	-0.01 (-0.18)	0.28 (8.35)	0.19	0.00 (0.02)	0.20 (2.52)	0.25 (5.92)	0.25
ISSUE1Y	-0.56 (-5.69)	-0.08 (-0.83)	0.28 (6.04)	0.27	-0.37 (-11.54)	-0.04 (-1.37)	0.35 (10.55)	0.37	-0.19 (-2.26)	0.01 (0.09)	0.25 (5.92)	0.22
ISSUE5Y	-0.72 (-6.87)	-0.34 (-2.91)	0.22 (4.36)	0.16	-0.36 (-9.06)	-0.06 (-1.37)	0.31 (6.85)	0.23	-0.36 (-4.28)	-0.21 (-2.56)	0.19 (4.05)	0.12
-PM	-0.95 (-6.25)	-0.40 (-1.46)	0.32 (2.59)	0.17	-0.46 (-10.10)	-0.09 (-1.40)	0.38 (6.61)	0.26	-0.49 (-3.56)	-0.29 (-1.53)	0.26 (1.84)	0.12
-PROFIT	-0.54 (-6.30)	-0.04 (-0.41)	0.28 (7.44)	0.31	-0.29 (-8.88)	0.01 (0.18)	0.31 (7.94)	0.26	-0.25 (-3.20)	-0.04 (-0.60)	0.26 (6.94)	0.28
TEF	-0.60 (-5.07)	-0.01 (-0.04)	0.34 (6.32)	0.30	-0.43 (-8.80)	0.05 (0.70)	0.50 (7.40)	0.34	-0.17 (-1.70)	0.10 (0.96)	0.36 (6.78)	0.32
-ZS	-0.40 (-3.14)	-0.37 (-1.61)	0.02 (0.21)	0.00	-0.02 (-0.45)	-0.06 (-0.70)	-0.04 (-0.43)	0.00	-0.38 (-2.95)	-0.40 (-2.37)	-0.03 (-0.29)	0.00

This table regresses, for each characteristic, the monthly long-short return on equal-weighted decile portfolios of delta-hedged equity calls formed on the full universe, in percent per month, on the monthly long-short return of the portfolio formed on thirty-day at-the-money implied volatility at formation, built the same way, for the full month, the rollover window and the rest of the month. Spread is the characteristic's average long-short return, α and β the intercept and slope of the time-series regression, and R^2 its fit. Characteristics are signed so that decile ten is the end carrying the lower return; for market capitalization that end carries the higher return, and its long-short return is reported as such. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover window is the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover window holds the remainder. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

mean returns follows the loadings, with an R^2 of 0.89, and follows implied volatility itself more closely still, 0.94; on the other nineteen days neither explains the means, with R^2 of 0.06 and 0.16. The level factor itself, the equal-weighted portfolio of every contract, shows the same split. The two rollover days contribute 7% of the variance of its monthly return and all of its negative mean, -0.42% on those two days against 0.37% on the other nineteen. A factor estimated on monthly returns is therefore estimated from days that carry little of the mean it is asked to price.

The instrumented principal components of Kelly, Pruitt, and Su (2019), fitted to contract-month returns with the eighteen characteristics as instruments, show the same split from the side of the means (Internet Appendix Table IA.8). Three factors explain about 5% of the variation of returns on each window, but the part of returns that the characteristics predict, the predictive R^2 , is 1.9% on the rollover days against 0.3% over the month and on the other days. What a factor model reports as a loading is a stock's volatility, and what it reports as the factor's premium is the expiration repricing. What that repricing is, the next section takes up by following a single contract.

Table 6: Common variation in the anomaly portfolios, by window

Panel A: Share of variance carried by the leading components, in percent

	First	Second	Third	Fourth	Fifth	Components to 90%
Full month	83.1	2.1	1.6	1.1	1.1	7
Ex-rollover	82.2	1.9	1.7	1.2	1.1	8
Rollover	72.6	3.0	2.2	1.3	0.8	34

Panel B: Loadings on the leading component and mean returns, across the 180 portfolios

	Full month	Ex-rollover	Rollover
Correlation of loadings with implied volatility	0.95	0.94	0.96
R^2 of mean returns on loadings	0.42	0.06	0.89
R^2 of mean returns on implied volatility	0.58	0.16	0.94

This table reports the factor structure of the ten equal-weighted decile portfolios of delta-hedged equity calls formed on each of the eighteen characteristics, built three times from the same contract-months: from the full-month return, from the return on the other nineteen days (ex-rollover) and from the return on the last trading day of the standard monthly contract and the trading day that follows (rollover). Panel A reports the share of variance carried by the leading principal components of each panel, with every portfolio's monthly series demeaned and scaled to unit variance, and the number of components needed to reach ninety percent. Panel B reports, across the 180 portfolios of each panel, the correlation between a portfolio's loading on the leading component, the slope of its monthly return on the component's monthly score, and the time-series average of its stocks' thirty-day at-the-money implied volatility at formation; and the R^2 of the portfolios' mean monthly returns, in percent, on those loadings and on that implied volatility. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life.

5 Economic Content of the Common Component

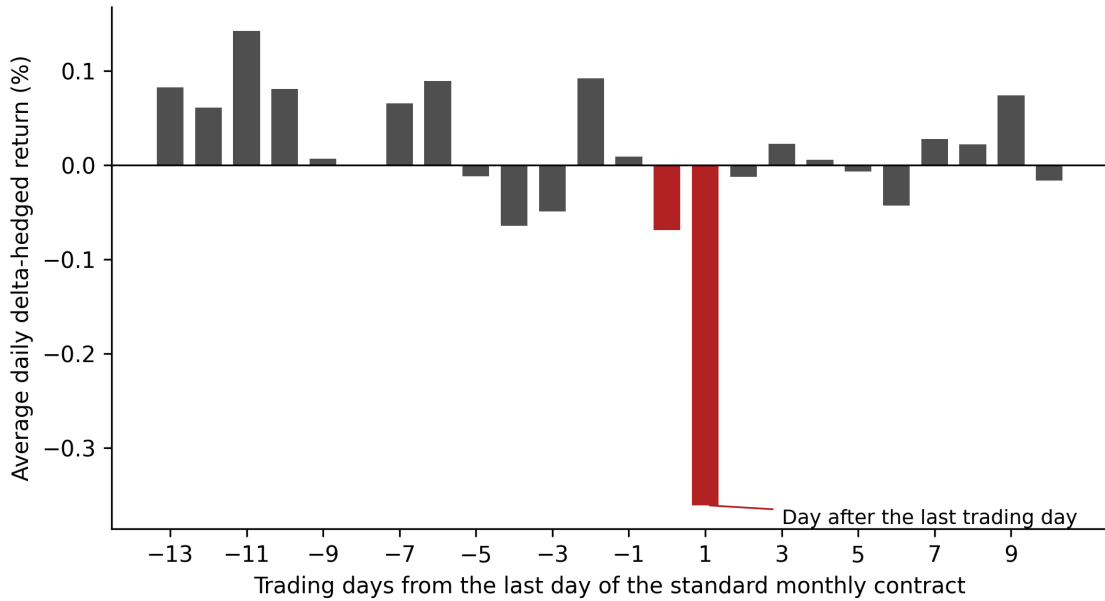
What is the component the characteristic portfolios share? This section follows a single contract through the month to find out. It first locates the loss within the rollover window, then shows

that the loss is a repricing of the contract’s own implied volatility over the expiration weekend, and then asks why the repricing differs so much across volatility states.

5.1 Day of the loss

On which of the two rollover days does the holder lose? On one. Figure 2 plots the equity call’s average daily return against the trading day, counted from the last day of the standard monthly contract. The expiration day itself earns -0.07% . The day after it earns -0.36% , with a t -statistic of -16.0 , and no other day of the twenty-four plotted loses more than 0.07% . The day after expiration is the first day on which the contract held is the nearest standard maturity in its stock, and the day on which the positions rolling out of the expired contract are absorbed. Garcia-Ares and Muravyev (2025) show the customer order imbalance on it, and Muravyev (2016) that such imbalances move option prices. Implied volatility itself moves on the same days. VIX falls by 0.80% on average over the two rollover days against 0.10% on other days, and the cross-sectional mean of individual stocks’ thirty-day at-the-money implied volatility falls by 0.27% against a rise of 0.02% , with t -statistics of -2.6 and -2.3 on the differences.

Figure 2: Average daily delta-hedged call returns around the standard monthly expiration



This figure plots the average daily delta-hedged gain on the equity call, scaled by the absolute value of the initial investment, against the trading day measured from the last trading day of the standard monthly contract. The daily gain is the change in the option’s midpoint less the profit on a hedge struck at the previous close and less the financing charge on the capital the position ties up. The contract held expires in the following month and so is not expiring on any day shown. Bars in dark red mark the rollover window. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life.

The loss is not a trading opportunity, and it is not a widening of spreads. A round trip at quoted spreads costs 4.3% of the initial investment on the long-short position, and even at the effective costs Muravyev and Pearson (2020) document, the cost exceeds the 0.34% long-short spread earned on the two days. Quoted spreads are no wider on the day than elsewhere, the median half-spread being 1.03% of the initial investment on the day after expiration against 1.10% at formation; it is the level of prices that moves, not the willingness to quote. And the loss grows with volatility over time as it does across stocks: the average rollover return runs from -0.35% in the calmest third of months by VIX to -0.58% in the most volatile, with a t -statistic of -3.1 on the VIX level. All of this is consistent with dealers absorbing the positions that roll out of an expiring contract, which Garcia-Ares and Muravyev (2025) show directly with order imbalances, though none of it separates a charge for intermediation from compensation for the inventory risk it carries. Because the loss falls on the Monday, the rest of this section studies the expiration weekend, the interval from the Friday close to the Monday close, against the other weekends of the same contract-month.

5.2 Missing recovery over the expiration weekend

What does the holder of a contract that does not expire pay over the expiration weekend? Much of it is what any weekend costs: time decay against a weekend’s worth of variance. Equation (3) gives the account day by day, and Appendix B reports it by decile and window. Over the two rollover days the theta part is -0.35% of the initial investment in the lowest decile and -1.38% in the highest, and the gamma part 0.23% to 0.73%. The window runs from the Thursday close to the Monday close, four calendar days of decay against two trading days of stock moves, and decay exceeds the variance delivered on any weekend the position holds. The vega part is within a tenth of a percent of zero in the eight lowest deciles, -0.15% in the ninth and -0.44% in the tenth, and the residual is within four hundredths of a percent of zero. Decay and the stock’s move are what every weekend brings. The vega part is what the expiration weekend changes, and its size shows only against the other weekends of the same contract-month.

On every weekend but one, the held contract’s implied volatility rises from the Friday close to the Monday close and the Monday’s return is close to zero. The rise is the ordinary weekend effect in option prices. The market prices a weekend at less than three days of variance, and an implied volatility computed on calendar time records that discount as a fall into the Friday close and a recovery by the Monday close, which compensates the holder for the weekend’s decay. On the expiration weekend the recovery is a fraction of the usual one, in the top decile a fall, and the Monday loses. Table 7 sets the expiration weekend beside the other weekends of the holding

month. On the other weekends implied volatility rises by three quarters of a point in the lowest decile and two and a third points in the highest, and the Monday earns between -0.02% and -0.18% of the initial investment. On the expiration weekend the rise is a quarter to half a point in the nine lower deciles and a fall of two thirds of a point in the tenth, and the Monday loses 0.13% in the lowest decile and 0.88% in the highest.

Table 7: The expiration weekend and the other weekends of the month

Decile	Change in implied volatility		Monday return	
	Other weekends	Expiration	Other weekends	Expiration
1	0.74 (15.57)	0.27 (4.08)	-0.02 (-1.77)	-0.13 (-9.89)
2	0.95 (15.62)	0.35 (4.85)	-0.03 (-2.03)	-0.18 (-11.55)
3	1.07 (15.92)	0.37 (4.28)	-0.05 (-3.34)	-0.21 (-9.34)
4	1.24 (15.71)	0.36 (4.02)	-0.04 (-2.09)	-0.28 (-9.98)
5	1.33 (15.56)	0.41 (4.37)	-0.05 (-2.42)	-0.28 (-11.89)
6	1.55 (16.59)	0.47 (4.42)	-0.05 (-2.09)	-0.32 (-10.83)
7	1.63 (16.70)	0.38 (3.40)	-0.06 (-2.94)	-0.38 (-14.40)
8	1.83 (15.99)	0.29 (2.24)	-0.07 (-2.78)	-0.43 (-14.13)
9	2.03 (16.68)	0.37 (2.50)	-0.10 (-3.44)	-0.52 (-13.83)
10	2.33 (17.17)	-0.64 (-3.59)	-0.18 (-4.83)	-0.88 (-18.02)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the change in the held call's own implied volatility from the Friday close to the following Monday close, in volatility points, and the delta-hedged return on that Monday, in percent of the initial investment. Other weekends are all weekends of the holding period other than the one beginning on the last trading day of the standard monthly contract, averaged within the contract-month first; Expiration is that weekend. Days after a market holiday are treated as Mondays. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

What the expiration Monday adds is almost entirely the vega part; decay and realized variance are what they are on any other Monday. Table 8 attributes the Monday return. On the other Mondays the theta part is -0.26% in the lowest decile and -1.01% in the highest, the gamma

part 0.12% to 0.43%, and the vega part 0.13% to 0.41%. The three add to a return within two tenths of a percent of zero. The stock delivers one trading day of variance against three calendar days of decay, and the recovery in the contract’s implied volatility pays the difference. On the expiration Monday the theta part is -0.27% to -1.04% and the gamma part 0.12% to 0.42%, and Panel B pairs the two Mondays within the contract-month. The theta part differs by one to three hundredths of a percent, more decay by the length of a holiday weekend, and the gamma part by two hundredths or less, with t -statistics below 1.6. The stock delivers the variance it delivers on any Monday, and the option decays as it decays over any weekend. The vega part, by contrast, is 0.01% to 0.04% in the seven lowest deciles and -0.25% in the tenth. Most of the recovery does not come. The paired difference in the return rises with volatility in every decile, from -0.12% in the lowest to -0.69% in the highest, with t -statistics beyond -6.7 . It matches the paired difference in the vega part, -0.11% and -0.66% , to within five hundredths of a percent in every decile, and the residual differs by at most a hundredth. This is the additional loss of the expiration weekend over an ordinary one, not the whole of the rollover loss. In the lower deciles the rollover loss itself is mostly decay against a weekend’s variance, which every weekend carries; what the expiration weekend adds is the repricing.

Measured against an ordinary weekend, then, the held contract’s implied volatility falls over the expiration weekend by half a point in the lowest decile and three points in the highest, and the hedged holder loses its vega times that fall. The weekend change alone does not reveal which close is out of line: the Friday close before an expiration may carry an implied volatility that is not depressed as it is before other weekends, or the Monday close after it may carry one that is. Gao et al. (2026) document that the implied volatilities of non-expiring options rise into the monthly expiration and fall after it, which points to the former. Either way, the effect has a familiar shape. Jones and Shemesh (2018) find option returns lower over nontrading periods than over trading days, and Muravyev and Ni (2020) find delta-hedged returns negative overnight and positive during the trading day; both attribute the pattern to how the variance of the closed period is treated in prices. The ordinary weekends here show a small version of that effect, and the expiration weekend shows it at five to ten times the size, rising with implied volatility. Why it rises so steeply is the next question.

5.3 Common proportional repricing and the excess beyond it

Why do options on volatile stocks lose so much more? Part of the answer is mechanical. A given percentage change in implied volatility is worth more dollars on an option whose volatility is high, because the dollar exposure to such a change is the option’s vega times the level of volatility. If

Table 8: Attribution of the Monday return, expiration weekend against the other weekends

<i>Panel A: The other Mondays and the expiration Monday</i>										
Decile	Other Mondays					Expiration Monday				
	Return	Theta	Gamma	Vega	Residual	Return	Theta	Gamma	Vega	Residual
1	-0.02 (-1.77)	-0.26 (-27.92)	0.12 (14.61)	0.13 (15.37)	-0.01 (-2.25)	-0.13 (-9.89)	-0.27 (-26.92)	0.12 (12.56)	0.02 (1.99)	-0.01 (-1.24)
2	-0.03 (-2.03)	-0.34 (-28.89)	0.15 (15.25)	0.16 (15.51)	-0.00 (-0.84)	-0.18 (-11.55)	-0.35 (-28.48)	0.14 (12.99)	0.03 (2.56)	-0.01 (-2.16)
3	-0.05 (-3.34)	-0.40 (-29.89)	0.18 (14.41)	0.19 (15.48)	-0.02 (-2.17)	-0.21 (-9.34)	-0.41 (-29.01)	0.16 (14.08)	0.04 (2.46)	0.00 (0.76)
4	-0.04 (-2.09)	-0.45 (-29.50)	0.20 (16.78)	0.22 (15.27)	-0.00 (-0.56)	-0.28 (-9.98)	-0.46 (-28.81)	0.20 (11.32)	0.03 (1.86)	-0.04 (-1.39)
5	-0.05 (-2.42)	-0.50 (-29.67)	0.21 (17.72)	0.24 (15.88)	0.00 (0.28)	-0.28 (-11.89)	-0.52 (-28.89)	0.21 (14.04)	0.03 (1.78)	0.00 (0.07)
6	-0.05 (-2.09)	-0.56 (-28.81)	0.25 (18.14)	0.27 (15.88)	-0.01 (-1.07)	-0.32 (-10.83)	-0.58 (-28.04)	0.23 (13.86)	0.03 (1.49)	-0.00 (-0.55)
7	-0.06 (-2.94)	-0.62 (-28.90)	0.27 (17.76)	0.29 (15.66)	-0.00 (-0.10)	-0.38 (-14.40)	-0.64 (-28.46)	0.25 (13.60)	0.01 (0.58)	0.00 (0.12)
8	-0.07 (-2.78)	-0.69 (-29.06)	0.30 (19.31)	0.32 (15.40)	-0.00 (-0.42)	-0.43 (-14.13)	-0.71 (-28.47)	0.30 (14.13)	-0.02 (-0.74)	-0.00 (-0.20)
9	-0.10 (-3.44)	-0.79 (-28.96)	0.34 (19.81)	0.36 (14.91)	-0.01 (-1.31)	-0.52 (-13.83)	-0.81 (-28.81)	0.33 (14.72)	-0.03 (-1.01)	-0.01 (-0.73)
10	-0.18 (-4.83)	-1.01 (-30.64)	0.43 (21.90)	0.41 (14.65)	-0.01 (-0.95)	-0.88 (-18.02)	-1.04 (-31.00)	0.42 (15.51)	-0.25 (-7.23)	-0.01 (-0.46)
<i>Panel B: Expiration Monday less the other Mondays, within the contract-month</i>										
Decile	Return	Theta	Gamma	Vega	Residual					
1	-0.12 (-7.53)	-0.01 (-4.97)	-0.00 (-0.35)	-0.11 (-7.74)	0.00 (0.31)					
2	-0.16 (-8.27)	-0.01 (-4.73)	-0.01 (-0.62)	-0.13 (-7.85)	-0.01 (-1.35)					
3	-0.16 (-6.71)	-0.01 (-4.88)	-0.02 (-1.57)	-0.15 (-8.04)	0.02 (2.06)					
4	-0.24 (-7.88)	-0.02 (-5.18)	0.00 (0.06)	-0.19 (-8.95)	-0.04 (-1.31)					
5	-0.23 (-8.79)	-0.02 (-4.72)	-0.01 (-0.74)	-0.21 (-9.72)	-0.00 (-0.09)					
6	-0.27 (-8.51)	-0.02 (-4.53)	-0.01 (-1.08)	-0.24 (-9.75)	0.00 (0.21)					
7	-0.32 (-11.53)	-0.02 (-4.76)	-0.02 (-1.39)	-0.28 (-11.81)	0.00 (0.15)					
8	-0.36 (-11.02)	-0.02 (-4.20)	-0.00 (-0.00)	-0.34 (-11.51)	0.00 (0.07)					
9	-0.41 (-10.88)	-0.02 (-3.83)	-0.01 (-0.59)	-0.39 (-13.56)	0.00 (0.09)					
10	-0.69 (-12.58)	-0.03 (-4.01)	-0.01 (-0.53)	-0.66 (-16.59)	0.01 (0.22)					

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the delta-hedged call return on the trading day after a weekend and its theta, gamma, vega and residual parts from the sequential Black–Scholes repricing of the contract between the two closes, in percent of the initial investment. Other Mondays are the trading days following a gap of at least three calendar days within the holding period, other than the day after the last trading day of the standard monthly contract, averaged within the contract-month first; the expiration Monday is that day. Panel B reports the difference between the expiration Monday and the average of the other Mondays within the contract-month. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life. Newey–West t -statistics with six lags appear below the estimates.

implied volatility fell short of its usual recovery by the same fraction of its level for every stock, a common proportional missing recovery, the options on volatile stocks would lose more for that reason alone. Table 9 measures how far that goes in the change in implied volatility itself, and Table 10 how far it goes once the common missing recovery is passed through each contract's own exposure.

On the other weekends the contract's implied volatility rises by three percent of its level in every decile (Table 9, which expresses the Friday-to-Monday change as a share of the Friday level), 3.1% to 3.2% in the nine lower deciles and 2.9% in the tenth. The weekend effect in implied volatility is proportional to the level, and the rise from three quarters of a point in the lowest decile to two and a quarter in the highest is nothing but that proportion. On the expiration weekend the rise is 1.8% of the level in the lowest decile, 1.7% in the sixth, 1.2% in the ninth and 0.5% in the tenth. The missing recovery is therefore 1.4% to 1.6% of the level in the seven lowest deciles, 1.9% in the eighth and ninth and 2.4% in the tenth, with t -statistics from -5 to -10 . In points the missing recovery rises sixfold across the deciles; as a share of the level it rises by two thirds, and all of that rise is in the top three deciles. Most of the scaling with volatility is proportionality. What is not proportional sits in the deciles in which the contract's implied volatility does not merely fail to recover but falls.

In return units the picture changes: the common proportional missing recovery accounts for only part of the vega loss, and the part it misses falls on the contracts still near the money. Table 10 makes the translation contract by contract. For each contract-month, a counterfactual expiration Monday reprices the contract from its Friday implied volatility to that level times one plus the ordinary-weekend proportional change of its decile that month plus the common missing recovery. The common missing recovery is the month's mean paired change in deciles one to seven, the seven deciles whose missing recovery as a share of the level is the same to within two tenths of a percentage point. The excess is the observed vega part less this counterfactual, both measured against the contract's own other Mondays. The contract's own ordinary-weekend change, used in place of its decile's, gives the same excess by decile and a noisier one by contract. To first order, the excess of contract i is

$$\text{excess}_i \approx \kappa_i (s_i - \bar{s}_m), \quad \kappa_i \equiv \frac{\nu_i \sigma_{i,F}}{|I_i|}, \quad (6)$$

where s_i is the paired change in the contract's implied volatility, expiration weekend less its ordinary weekends, as a share of its Friday level, negative when the recovery falls short, $\bar{s}_m$ the common missing recovery of month m on the same scale, ν_i the contract's vega at the Monday inputs, $\sigma_{i,F}$ its Friday implied volatility and $|I_i|$ its initial investment. The exposure κ_i is the

Table 9: The missing recovery as a share of the level of implied volatility

Decile	IV	ΔIV , points			ΔIV , percent of level			Vega part	Return
		Other	Expiration	Difference	Other	Expiration	Difference	Difference	Difference
1	24.5	0.73 (15.42)	0.25 (3.85)	-0.48 (-5.72)	3.18 (19.06)	1.75 (7.43)	-1.42 (-5.21)	-0.11 (-8.03)	-0.11 (-7.30)
2	30.9	0.95 (15.44)	0.32 (4.30)	-0.63 (-6.48)	3.17 (18.96)	1.68 (7.49)	-1.49 (-5.88)	-0.14 (-8.05)	-0.16 (-8.45)
3	35.8	1.04 (15.74)	0.34 (3.94)	-0.70 (-6.71)	3.07 (18.28)	1.65 (6.83)	-1.43 (-5.82)	-0.15 (-8.01)	-0.16 (-6.83)
4	40.4	1.21 (15.65)	0.35 (3.96)	-0.87 (-7.71)	3.16 (18.18)	1.60 (7.14)	-1.56 (-6.56)	-0.19 (-9.20)	-0.24 (-7.94)
5	45.2	1.30 (16.35)	0.37 (3.82)	-0.94 (-8.10)	3.06 (19.14)	1.59 (7.06)	-1.47 (-6.89)	-0.21 (-9.98)	-0.24 (-9.50)
6	50.1	1.53 (16.68)	0.44 (4.06)	-1.09 (-8.27)	3.23 (18.56)	1.72 (7.37)	-1.50 (-6.50)	-0.25 (-10.02)	-0.26 (-8.58)
7	55.4	1.59 (17.01)	0.35 (3.17)	-1.24 (-10.01)	3.09 (18.68)	1.51 (6.31)	-1.58 (-7.65)	-0.28 (-11.96)	-0.32 (-11.78)
8	61.7	1.80 (15.82)	0.26 (1.96)	-1.53 (-9.51)	3.15 (17.49)	1.30 (5.33)	-1.85 (-7.94)	-0.34 (-11.66)	-0.36 (-11.22)
9	70.2	2.00 (16.29)	0.26 (1.80)	-1.74 (-11.27)	3.07 (18.15)	1.21 (5.02)	-1.85 (-8.93)	-0.40 (-14.12)	-0.42 (-11.70)
10	85.8	2.24 (16.47)	-0.68 (-3.52)	-2.92 (-14.43)	2.88 (17.84)	0.49 (1.75)	-2.39 (-9.58)	-0.65 (-16.52)	-0.69 (-12.37)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the held call's implied volatility at the Friday close (IV, the time-series average of the monthly median, in points), the change in it from the Friday close to the Monday close in volatility points and as a percent of the Friday level, on the other weekends of the holding period averaged within the contract-month and on the expiration weekend, and the difference between the expiration weekend and the other weekends within the contract-month, for the change in implied volatility, for the vega part of the Monday return and for the Monday return, the last two in percent of the initial investment. The percent-of-level change is averaged contract by contract, so it need not equal the average change in points divided by the average level. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life, with positive open interest in the expiring maturity. Newey–West t -statistics with six lags appear below the estimates.

dollar loss per unit of proportional repricing per dollar invested, and it is largest for contracts still near the money. Averaged within decile g , the excess is $\bar{\kappa}_g(\bar{s}_g - \bar{s}_m)$ plus the covariance within the decile between κ_i and s_i . The first term is the missing recovery beyond the common one, which is zero on average in deciles one to seven by construction; the second is the concentration of the missing recovery on the high-exposure contracts.

The common missing recovery accounts for about half of the additional vega loss in the seven lowest deciles, 0.06% of 0.11% in the lowest, a third in the eighth and ninth, and a fifth in the tenth, 0.15% of 0.66%. The excess rises with volatility in every decile, from -0.05% in the lowest to -0.51% in the highest, with t -statistics from -9 to -15 . In the seven lowest deciles the excess is the covariance term: the observed vega loss is about twice the common one, which means that the missing recovery weighted by each contract's exposure is about twice the unweighted one of Table 9. Within every decile, the expiration-weekend repricing falls on the contracts with the most vega per dollar of initial investment, those still near the money, while the ordinary-

weekend rise is spread over contracts that have moved away from it. The concentration grows with volatility: the observed loss is nearly three times the common one in the eighth decile and more than four times in the tenth, in which the first term is nonzero as well. In return units, then, the volatility gradient of the expiration weekend survives the translation of a common proportional repricing through each contract, and most of it is the excess. The excess also has a cross-section of its own. Panel B relates it to the open interest in the expiring maturity recorded at the formation close, a month before the weekend, in monthly cross-sectional regressions,

$$y_{i,m} = a_{g(i),m} + b_m \text{OI}_{i,m} + c'_m X_{i,m} + u_{i,m}, \quad (7)$$

estimated month by month and averaged over months as in Fama and MacBeth (1973), where $y_{i,m}$ is the excess on contract i in month m , $a_{g,m}$ an intercept for each implied-volatility decile, $\text{OI}_{i,m}$ the within-month percentile rank of the open interest in the expiring maturity, and $X_{i,m}$ the level of implied volatility, log market capitalization and log price, included in some columns and not in others. From the bottom to the top of the open-interest distribution the excess is 0.13% larger, with a t -statistic of -4.7 , and 0.16% larger with implied volatility, size and price held fixed. With the contract's own ordinary-weekend change as the benchmark in place of its decile's, the coefficient is -0.01% within deciles alone and -0.09% , with a t -statistic of -2.6 , with the controls, and the observed vega part itself moves by 0.13% to 0.15%. The level of implied volatility keeps its own coefficient in every column: the excess is larger where more positions are outstanding and larger in the higher states, and the first does not account for the second. The larger losses of high-volatility options are therefore not one proportional repricing passed through larger exposures. Against that benchmark, most of the difference is a larger repricing, concentrated on the contracts that carry the most vega. The next subsection turns to the one question about its source that the data can address, which is how the missing recovery varies with the positions outstanding.

5.4 Positions outstanding and the cost

If the repricing comes from positions being rolled, it should be larger where more positions are outstanding in the expiring contract. Signed order flow is not available for the sample, but open interest in the expiring maturity is, and within a volatility state the recovery falls shorter where there is more of it. Table 11 groups stocks each month, within each implied-volatility decile, into terciles of the open interest in the expiring standard maturity, scaled by shares outstanding. The median is five hundredths of a percent of shares outstanding in the bottom tercile and 1.3% in the top in the lower eight deciles, and 3.5% in the top tercile of the top decile. The measure

Table 10: The expiration Monday against a common proportional repricing

<i>Panel A: The expiration Monday against a common proportional repricing, by decile</i>						
Decile	ΔIV , percent of level			Vega part, expiration less other Mondays		
	Other	Expiration	Difference	Observed	Common	Excess
1	3.19 (19.15)	1.85 (7.89)	-1.35 (-4.93)	-0.11 (-7.74)	-0.06 (-4.87)	-0.05 (-10.37)
2	3.18 (19.01)	1.77 (8.15)	-1.41 (-5.55)	-0.13 (-7.85)	-0.07 (-4.69)	-0.06 (-10.97)
3	3.11 (18.60)	1.73 (7.38)	-1.38 (-5.73)	-0.15 (-8.04)	-0.08 (-4.76)	-0.07 (-10.21)
4	3.19 (18.33)	1.65 (7.41)	-1.54 (-6.44)	-0.19 (-8.95)	-0.09 (-4.90)	-0.10 (-9.67)
5	3.11 (19.11)	1.71 (7.63)	-1.40 (-6.48)	-0.21 (-9.72)	-0.10 (-4.72)	-0.10 (-9.43)
6	3.27 (18.54)	1.81 (7.85)	-1.45 (-6.17)	-0.24 (-9.75)	-0.11 (-4.31)	-0.13 (-11.66)
7	3.14 (18.69)	1.60 (6.59)	-1.55 (-7.23)	-0.28 (-11.81)	-0.12 (-4.51)	-0.16 (-11.00)
8	3.19 (17.81)	1.39 (5.81)	-1.80 (-7.71)	-0.34 (-11.51)	-0.12 (-4.13)	-0.22 (-10.06)
9	3.11 (18.56)	1.43 (5.94)	-1.68 (-8.06)	-0.39 (-13.56)	-0.14 (-4.15)	-0.24 (-11.95)
10	2.98 (18.74)	0.71 (2.76)	-2.28 (-9.79)	-0.66 (-16.59)	-0.15 (-3.24)	-0.51 (-14.91)
All	3.15 (19.44)	1.56 (7.35)	-1.58 (-7.51)	-0.27 (-12.41)	-0.11 (-4.31)	-0.16 (-16.29)
<i>Panel B: Fama–MacBeth regressions with decile dummies</i>						
	OI at formation, rank	IV	Log size	Log price		
Excess, own benchmark	-0.01 (-0.21)					
Excess, own benchmark	-0.09 (-2.64)	-0.91 (-6.07)	-0.00 (-0.03)	0.10 (7.58)		
Excess, decile benchmark	-0.13 (-4.69)					
Excess, decile benchmark	-0.16 (-6.89)	-1.12 (-9.86)	-0.01 (-1.83)	0.06 (6.95)		
Observed vega part	-0.13 (-5.34)					
Observed vega part	-0.15 (-7.00)	-0.92 (-8.16)	-0.02 (-3.76)	0.06 (6.42)		

Panel A reports, by decile of thirty-day at-the-money implied volatility at formation, the held call's Friday-to-Monday change in implied volatility as a percent of its Friday level on the other weekends of the holding period (the ratio of the contract's summed changes to its summed Friday levels) and on the expiration weekend, and their difference; and the vega part of the Monday return on the expiration weekend less the average on the other Mondays, in percent of the initial investment, as observed and as it would be if the contract's implied volatility had moved by the mean ordinary-weekend proportional change of its decile that month plus the common missing recovery, the month's mean paired change in deciles one to seven, the deciles whose missing recovery as a share of the level is the same to within two tenths of a percentage point, with the excess the difference between the two. The counterfactual reprices each contract with Black–Scholes at its own strike, maturity, Monday stock price and Friday implied volatility. Panel B reports monthly cross-sectional regressions of the excess, under the decile benchmark and under the contract's own ordinary-weekend change, and of the observed vega part on the within-month percentile rank of the open interest in the expiring maturity recorded at the formation close, alone and with implied volatility, log market capitalization and log price, with a separate intercept for each implied-volatility decile, averaged over months in the manner of Fama and MacBeth. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life; Panel B requires positive open interest in the expiring maturity. Newey–West t -statistics with six lags appear below the estimates.

is OptionMetrics’ record at the close before expiration, which after November 2000 reflects the close two days before it. It precedes the expiration weekend but follows the other weekends of the holding month; the same measure is therefore also taken at the formation close a month earlier, before every weekend compared; its rank correlation with the later record is 0.98.

The object is again the difference between the expiration weekend and the others within the contract-month, which Panel A of Table 11 reports; Internet Appendix Table IA.6 reports the levels on each kind of weekend. Where more open interest expires, the recovery falls shorter. The incremental fall in the held contract’s implied volatility over the expiration weekend is 0.27 points larger in the top tercile of expiring open interest than in the bottom in the lower eight deciles. It is 0.83 points larger in the ninth decile and 0.94 in the tenth, with t -statistics beyond -3 . The incremental vega part is 0.03%, 0.13% and 0.24% lower. The incremental return is 0.13% lower in the ninth decile and 0.19% in the tenth, with t -statistics of -2.1 , and no different in the lower eight, in which the vega is small. In levels, the expiration-weekend change in implied volatility falls with expiring open interest by 0.32 to 1.10 points across the three groups, while the change on the other weekends moves by 0.17 points or less. Regressions of the paired contrast in the form of Equation (7) (Panel B) give the same result. Holding implied volatility, size and price fixed, a move from the bottom to the top of the distribution of expiring open interest lowers the incremental fall in implied volatility by 0.93 points, the incremental vega part by 0.17% and the incremental return by 0.18%. The t -statistics are -7.1 , -6.2 and -4.9 . The share of the stock’s open interest in the expiring maturity gives 0.52 points, 0.11% and 0.11%, and the measure taken at formation 0.82 points, 0.15% and 0.14%. The relation is strongest in the repricing and weaker in the total return, whose tercile spread is confined to the top two deciles. And the level of implied volatility keeps its own effect in the same regression, -3.7 points per unit: the scaling with volatility is not the count of positions that roll.

Gao et al. (2026) show that ex ante rollover demand predicts the fall in the implied volatilities of non-expiring options around the expiration across stocks, and Garcia-Ares and Muravyev (2025) observe the order imbalance on the day. What Table 11 adds is the paired design and the return. Within a volatility state and within the contract-month, the same open interest is associated with the missing recovery over the expiration weekend and not with the change over the other weekends. The association carries into the vega part and, in the top two deciles, the Monday return, and it leaves the scaling with volatility unaccounted for. Open interest counts positions, not the trades that close them or the inventory dealers are left with, and a stock with more open interest relative to its shares differs from one with less in ways the controls for size and price do not exhaust. The relation is an association, not an identification. What the comparison does establish is that the association is specific to the expiration weekend: the same open interest

Table 11: The expiration weekend and the open interest that rolls

<i>Panel A: Expiration weekend less the other weekends, terciles of expiring open interest within decile and month</i>							
Group	Monday return			ΔIV , Friday to Monday			Vega part
	Low	High	High–Low	Low	High	High–Low	High–Low
D1–8	-0.22 (-6.77)	-0.24 (-12.02)	-0.02 (-0.82)	-0.79 (-6.26)	-1.06 (-9.52)	-0.27 (-3.08)	-0.03 (-1.49)
D9	-0.36 (-5.74)	-0.49 (-12.83)	-0.13 (-2.15)	-1.19 (-5.81)	-2.01 (-11.49)	-0.83 (-4.22)	-0.13 (-3.06)
D10	-0.61 (-6.85)	-0.80 (-11.71)	-0.19 (-2.08)	-2.64 (-9.09)	-3.57 (-14.41)	-0.94 (-3.13)	-0.24 (-3.87)
All	-0.27 (-7.52)	-0.32 (-13.87)	-0.05 (-1.79)	-1.01 (-7.44)	-1.41 (-11.28)	-0.39 (-3.97)	-0.06 (-2.77)
<i>Panel B: Fama–MacBeth regressions with decile dummies</i>							
Dependent variable	Expiring OI, rank		Share of OI	OI at formation	IV	Log size	Log price
	Alone	Controls	Controls	Controls			
Return, expiration less other Mondays	-0.10 (-2.32)	-0.18 (-4.94)	-0.11 (-5.93)	-0.14 (-3.68)	-0.87 (-4.30)	0.01 (0.70)	0.09 (4.88)
ΔIV , expiration less other weekends	-0.69 (-4.55)	-0.93 (-7.11)	-0.52 (-8.13)	-0.82 (-6.57)	-3.74 (-6.63)	-0.06 (-2.15)	0.40 (6.49)
Vega part, expiration less other Mondays	-0.11 (-3.22)	-0.17 (-6.20)	-0.11 (-8.71)	-0.15 (-5.62)	-0.89 (-6.14)	-0.01 (-0.90)	0.09 (7.00)
Expiration-Monday return	-0.05 (-1.30)	-0.12 (-3.88)	-0.13 (-7.39)	-0.12 (-4.18)	-1.24 (-7.48)	0.00 (0.75)	0.08 (5.07)
ΔIV , Friday to Monday	-0.79 (-6.24)	-0.80 (-7.18)	-0.54 (-9.84)	-0.79 (-7.48)	-3.77 (-8.08)	-0.10 (-4.53)	0.20 (4.67)
Vega part, expiration Monday	-0.14 (-5.35)	-0.16 (-7.19)	-0.12 (-10.61)	-0.15 (-7.00)	-0.89 (-8.00)	-0.02 (-3.62)	0.06 (6.71)

This table groups stocks each month, within each decile of thirty-day at-the-money implied volatility at formation, into terciles of the open interest in the standard maturity expiring on the last trading day of the standard monthly contract, recorded by OptionMetrics at the close before that day and scaled by shares outstanding. Panel A reports, for stocks in the lower eight deciles, the ninth, the tenth and all ten, the difference between the expiration weekend and the average of the other weekends of the holding month, within the contract-month, in the delta-hedged call return on the Monday, in percent of the initial investment, and in the change in the held contract's implied volatility from the Friday close to the Monday close, in volatility points, in the bottom and top terciles and their difference, and the same difference in the vega part of the Monday return from the sequential Black–Scholes repricing of the contract. Panel B reports monthly cross-sectional regressions of the paired differences and of the expiration-weekend levels on the within-month percentile rank of expiring open interest, alone and with implied volatility, log market capitalization and log price; on the rank of the share of the stock's open interest in the expiring maturity with the same controls; and on the rank of expiring open interest recorded at the formation close with the same controls, all with a separate intercept for each implied-volatility decile, averaged over months in the manner of Fama and MacBeth. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life, with positive open interest in the expiring maturity. Newey–West t -statistics with six lags appear below the estimates.

goes with a repricing of the same contract over that weekend and not, beyond a tenth of a point, over the others.

The risk in the positions, rather than their count, does no better at explaining why the top decile is repriced so much more. Internet Appendix Table IA.7 measures the expiring open interest as the delta-equivalent dollars it represents and as the vega and dollar gamma it carries once re-established in the contract that becomes the nearest maturity. Each is scaled by the

stock's market capitalization and by its average daily trading volume. Relative to capitalization the position that rolls is four times larger in the top decile than in the lowest; relative to daily volume it is about six percent of a day's trading in every decile. Each measure predicts the missing recovery within decile and month about as strongly as the count of positions, and put together with the count, the count carries the relation. None accounts for the scaling with volatility. The missing recovery as a share of the level falls by 1.5 percentage points per unit of implied volatility without the measures and by 0.8 to 1.4 with them. The top decile's excess over the other nine is 0.7 of 0.8 percentage points with the position and the size and price controls added. The part of the expiration-weekend repricing that is more than proportional to the level of implied volatility is in the stocks whose implied volatility falls over the weekend, and the tested measures of what rolls do not account for it. Who those stocks are is the last question of this section.

5.5 Stocks that pay the most

Which stocks pay the most? Young, loss-making, cash-rich firms trading near ten dollars. Internet Appendix Table IA.2 reports the median stock in each slice of the volatility ranking. The median top-decile stock trades at \$10, is worth \$492 million, and was listed six years before; the median stock in the lower eight deciles trades at \$34, is worth \$2.3 billion and was listed thirteen years before. Half the top decile trades below ten dollars and more than half falls in the smallest size quintile of the optionable universe. Its firms lose money, with a median return on equity of -15% against 11% , and they hold 41% of assets in cash against 10% . They issued 6% of their shares in the prior year against 1% , and analyst forecast dispersion is more than three times as high. Their z-score is higher than the rest of the sample's, not lower, as a measure that rewards working capital and equity over liabilities is for cash-rich firms with little debt. These are young firms with uncertain prospects and little debt, not distressed firms with much of it.

Their options look as one would expect. The selected contract's quoted spread is 22% of its midpoint in the top decile against 15% in the lower eight, its open interest is higher, and fewer contracts go untraded on the formation day. Membership turns over: of the stocks in the top decile in a given month, 63% are there the next month, 36% a year later and 24% three years later, and 5,170 different stocks pass through it over the sample. The loss belongs to whichever stocks are currently the most volatile, not to a fixed set of firms.

Nor do scheduled earnings announcements account for the top decile's loss. An announcement falls inside the holding period for 28% of contract-months in the lowest decile and 34% in the highest, which rules out the composition of the deciles as the explanation, and Internet Appendix

Table IA.3 splits each slice by the presence of one. In the top decile the loss is 1.91% a month without an announcement and 0.97% with one, and the loss over the nineteen days outside the rollover window is 0.76% without and nothing with. The gap between implied and forward realized volatility is 0.23 without an announcement and 0.15 with one. Outside the top decile the pattern reverses: a delta-hedged call gains 0.94% over the nineteen days of an announcement month against 0.29% otherwise. An announcement after the position is closed but before the contract expires can still be priced at both ends; the comparison rules out the announcement’s variance, not its anticipation.

None of this is a trading strategy. A long-short portfolio formed on a characteristic within the top decile costs 1.96% a month to buy and sell at the lowest effective cost Muravyev and Pearson (2020) document, fifteen percent of the quoted half-spread, against an average long-short spread of 0.66% over the month. A position that holds the top decile outright and rolls it monthly pays a single round trip and is a different matter; the cross-section inside the decile is an average price, not a return an investor earns.

6 Maturities and Contracts

6.1 Two maturities

Is the loss specific to the contract that becomes the nearest maturity? It is not. Table 12 compares, within the same stock and the same weekend, the held contract with the standard contract expiring one month later, for the stocks that carry both quoted at the four closes, a third of the baseline universe. Both gains carry the financing charge of Equation (1) and both are scaled by the stock price at the Friday close; the two maturities are therefore in dollars per dollar of the same underlying, not per dollar of initial investment as elsewhere in the paper. Each is attributed with Equation (3). The restriction does not change the held contract’s result: on this sample its expiration-Monday return in the paper’s own normalization is -0.36% , against -0.36% on the full sample.

On the weekend before expiration neither contract loses much on the Monday, three hundredths of a percent of the stock price on the held contract and two on the further one. On the expiration weekend the held contract loses 0.15% of the stock price and the further contract 0.12%; the incremental expiration-weekend loss is therefore 0.12% on the nearer contract and 0.10% on the further one. The difference between the two increments is 0.01% of the stock price overall, with a t -statistic of -2.5 , and between 0.01% and -0.04% across deciles. The losses are comparable, not identical, and a dollar of the same underlying is not the same exposure on the

two contracts. The attribution shows why the two are close. The held contract decays faster, a theta part of -0.24% over the expiration weekend against -0.18% , and its stock's move returns more at its gamma, 0.10% against 0.08% ; the further contract carries more vega. On the weekend before expiration each contract's vega part refunds its decay, 0.08% and 0.07% , as the implied volatility of each rises from the Friday close to the Monday close, by a point on the nearer contract and half a point on the further one. On the expiration weekend the nearer contract's rises by a quarter of a point and the further one's does not move, and the vega parts are -0.01% and -0.02% . The expiration-weekend loss is common to the two standard maturities on the stock, comparable per dollar of the underlying. On both it is the recovery in the contract's implied volatility that does not come, as Gao et al. (2026) find for the implied volatilities of non-expiring options across maturities. The comparison covers the two standard maturities the stocks carry. Puts and the index are next.

6.2 Four contracts

Does the index share the calendar? It does not. The index carries a premium through the month; individual stocks carry a loss on two days and a gain on the rest. Table 13 splits the month for calls and puts on individual stocks and on the S&P 500 index, with the index hedge carrying the basket's dividend yield. The equity call loses 0.43% over the two rollover days and gains 0.38% over the other nineteen, for -0.05% over the month; the equity put loses 0.36% and gains 0.31% . The index call and the index put both lose 0.26% a month, and both lose most of it outside the rollover window: 0.14% and 0.20% over the other days against 0.12% and 0.05% over the two. The index's premium is the one Bakshi and Kapadia (2003) and Carr and Wu (2009) report. The index also differs from individual stocks in the calendar. Its contract settles on the Friday morning; its rollover window is the Thursday and the Friday and contains no weekend. The weekend repricing that carries the equity loss has no counterpart in it, and the comparison of the two rollover columns does not hold the nontrading period fixed.

For individual stocks, matched calls and puts on the same stock, strike and month earn the same hedged dollar gain. The difference is 0.03% of the stock price a month, with a t -statistic of 1.5, and within a tenth of a percent in every decile (Appendix Table 24). The cross-sectional results are stated on calls because the call's quotes are tighter; the put shows the same.

Table 12: Two maturities on the same stock over two weekends

Decile	Nearest maturity after the roll				Next maturity				Difference in differences
	Monday gain		Expiration weekend		Monday gain		Expiration weekend		
	Week before	Expiration	Theta	Vega	Week before	Expiration	Theta	Vega	
1	-0.01 (-1.56)	-0.06 (-9.61)	-0.11 (-29.41)	0.01 (2.07)	-0.01 (-0.83)	-0.05 (-8.40)	-0.09 (-30.32)	-0.00 (-0.26)	0.00 (0.56)
2	-0.02 (-2.40)	-0.08 (-10.52)	-0.15 (-31.01)	0.01 (2.27)	-0.01 (-1.23)	-0.06 (-8.59)	-0.11 (-32.21)	0.00 (0.17)	-0.00 (-0.49)
3	-0.01 (-1.32)	-0.09 (-10.33)	-0.17 (-31.34)	0.01 (1.79)	-0.01 (-1.07)	-0.09 (-9.23)	-0.13 (-32.67)	-0.01 (-1.04)	-0.00 (-0.67)
4	-0.02 (-1.84)	-0.10 (-9.78)	-0.19 (-29.88)	0.02 (2.13)	-0.01 (-0.81)	-0.09 (-10.45)	-0.15 (-31.76)	-0.01 (-0.63)	0.01 (0.92)
5	-0.03 (-2.49)	-0.12 (-11.25)	-0.21 (-29.73)	0.01 (1.47)	-0.02 (-1.48)	-0.10 (-9.81)	-0.16 (-31.59)	0.00 (0.07)	-0.01 (-1.16)
6	-0.04 (-2.75)	-0.12 (-11.42)	-0.24 (-29.27)	0.02 (1.91)	-0.01 (-1.11)	-0.11 (-9.27)	-0.18 (-30.34)	-0.01 (-0.52)	0.01 (1.07)
7	-0.03 (-1.89)	-0.16 (-13.94)	-0.26 (-28.70)	-0.00 (-0.03)	-0.02 (-1.21)	-0.12 (-10.73)	-0.20 (-30.51)	-0.01 (-0.77)	-0.02 (-2.26)
8	-0.02 (-1.29)	-0.18 (-13.70)	-0.29 (-29.57)	-0.01 (-1.04)	-0.02 (-1.30)	-0.14 (-10.93)	-0.22 (-30.84)	-0.01 (-1.02)	-0.04 (-2.66)
9	-0.04 (-2.10)	-0.22 (-13.23)	-0.34 (-30.31)	-0.02 (-1.50)	-0.02 (-1.53)	-0.17 (-10.92)	-0.25 (-32.17)	-0.03 (-1.92)	-0.03 (-1.65)
10	-0.10 (-4.78)	-0.40 (-18.99)	-0.43 (-34.06)	-0.13 (-6.99)	-0.07 (-3.13)	-0.32 (-17.25)	-0.33 (-37.41)	-0.13 (-7.17)	-0.04 (-1.88)
All	-0.03 (-2.71)	-0.15 (-16.22)	-0.24 (-31.38)	-0.01 (-0.86)	-0.02 (-1.75)	-0.12 (-13.38)	-0.18 (-33.12)	-0.02 (-2.20)	-0.01 (-2.46)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the Friday-close-to-Monday-close delta-hedged gain on the held call, which becomes the nearest standard maturity when the expiring contract leaves, and on the standard call closest to the money expiring one month later, selected at the same formation close, for stocks that carry both. Week before is the weekend five trading days before the last trading day of the standard monthly contract and Expiration the weekend that begins on that day. Each gain is the Monday delta-hedged gain, the change in the midpoint less the profit on the hedge and the financing charge, in percent of the stock price at the Friday close. Theta and Vega are the theta and vega parts of the expiration-weekend gain from the sequential Black–Scholes repricing of the contract, in the same units. Difference in differences is the held contract’s expiration Monday less its earlier Monday, less the same difference on the further contract. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life, restricted to stock-months with both contracts quoted at all four closes. Newey–West t -statistics with six lags appear below the estimates.

Table 13: Delta-hedged returns within the month, by contract

	Full month	Ex-rollover	Rollover
Single-name call	-0.05 (-0.49)	0.38 (3.64)	-0.43 (-16.39)
Single-name put	-0.06 (-0.62)	0.31 (3.21)	-0.36 (-17.97)
Index call	-0.26 (-4.03)	-0.14 (-2.48)	-0.12 (-5.72)
Index put	-0.26 (-4.54)	-0.20 (-4.04)	-0.05 (-3.11)

This table reports average delta-hedged returns, in percent per month, on the standard monthly call and put closest to at the money, for individual stocks and for the S&P 500 index. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; for the index the hedge also carries the index dividend yield at the previous close's delta. The rollover column restricts the sum to the last trading day of the standard monthly contract and the trading day that follows; the ex-rollover column holds the remainder, and the two add to the full month. Equity rows average across the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life; index rows are one contract a month. Newey–West t -statistics with six lags appear below the estimates.

7 Robustness

Most equity anomalies rest on microcaps (Hou, Xue, and Zhang, 2020), and the top implied-volatility decile plays that role for the volatility-related option anomalies. Is it volatility that the top decile captures, or something that travels with it? Appendix D reports the tables that address the alternatives. Price comes first: Boulatov, Eisdorfer, Goyal, and Zhdanov (2026) find that delta-hedged options on low-price stocks underperform, and half the top decile trades below ten dollars. Within terciles of the share price, the top decile loses 1.78% a month in the lowest tercile, 1.44% in the middle and 1.11% in the highest, and its rollover loss is 1.20%, 0.92% and 0.82%, each with a t -statistic beyond -6 . The two-day loss is present in every tercile. The loss over the other nineteen days is 0.58% in the lowest tercile and 0.29% in the highest, where its t -statistic is -0.9 . Short interest, the constraint behind Ramachandran and Tayal (2021), does not stand in for volatility either. Within terciles of short interest over the years the short-interest file covers, the top decile loses 1.42% to 1.53% a month on calls and 1.22% to 1.29% on puts in each tercile, and short interest itself predicts no lower call return in any slice.

Poor quotes, the concern of Duarte, Jones, and Wang (2024), do not produce the loss either. Restrict the top decile to contracts with volume on the formation day, to contracts with a relative spread below the monthly median, to both, or to contracts with open interest above the median. The rollover loss runs from 1.03% to 1.20% on every one of these, with t -statistics beyond -17 . What the screens change is the loss over the other days, which falls to 0.31% under the joint volume-and-spread screen and is no longer distinguishable from zero. The one-day loss in the top decile survives every quote-quality screen; the nineteen-day loss there does not survive the strictest one.

Nor is the concentration at the top a tail or a period. On within-month means winsorized at the fifth and ninety-fifth percentiles, the call gains 0.31% to 0.39% a month over the other days in each of the six lowest deciles and loses 0.53% in the tenth. On medians it earns within a tenth of a percent of nothing in the six lowest deciles and loses 1.36% in the tenth. The positive return outside the top decile is the right tail of a long-gamma position, and the concentration at the top does not depend on it. The boundary is not a sharp ten percent either, since the ninth decile loses on the put and on the median. Across time, the top decile loses 1.35% a month over 2010 to 2019 and 1.74% over 2020 to 2025, of which 0.97% and 1.38% fall on the two rollover days. The average anomaly outside the top decile is -0.07% before 2010 and within 0.05% of zero in the two later periods, with its two-day part -0.10% to -0.15% in each period and its nineteen-day part positive in the two later ones.

These checks qualify the claim in one respect. The top decile's loss over the two rollover days survives every screen, every price tercile and every subperiod; its loss over the other nineteen days is largest in the lowest price tercile and vanishes on the contracts that pass the joint volume-and-spread screen. The robust phenomenon is the rollover loss and its scaling with volatility, and the paper's statement of the top decile's monthly loss carries that qualification. The matched call-put comparison and the decile returns with dividend payers retained are in the same appendix; the full-sample decile table on all eighteen characteristics, the object the literature reports, and the characteristic portfolios formed within the two slices are in the Internet Appendix.

8 Conclusion

Most of the characteristics that predict delta-hedged option returns predict the same return. A portfolio formed on idiosyncratic volatility, on the largest daily return, on the share price, on cash holdings or on issuance loses money because it holds options on volatile stocks. Options on volatile stocks lose money on the two days each month when the standard contracts expire and positions roll. The characteristic portfolios earn most of their long-short returns by holding volatile stocks rather than by predicting returns among stocks of similar volatility, and around the expiration they earn almost nothing else. Among stocks of similar volatility, the idiosyncratic-volatility and maximum-return anomalies point the other way. What survives, above all volatility deviation and distress, is earned among stocks of similar volatility and away from the expiration, and is a different kind of predictability.

The common component is a repricing of the option itself. A contract that does not expire loses over the expiration weekend what it does not lose over an ordinary one. The loss is neither time decay nor the stock's move; it is the recovery in implied volatility that follows every other weekend and falls short after this one. Only part of the loss is mechanical, the larger dollar value of a given change in implied volatility on a volatile stock's option. The rest is a larger repricing of the volatile stocks' options themselves: it grows with volatility, falls on the contracts still near the money, and is larger where more positions are outstanding in the expiring contract. The repricing accompanies the monthly renewal of option positions, and the evidence is consistent with dealers moving prices to absorb what rolls.

The option-return anomalies do not disappear. Most of them are one anomaly under different names, and that anomaly has a name and a date. Its state is a stock's own implied volatility; its date is the expiration; and its return is a repricing on two days rather than a premium accrued over the month. A factor model's loadings on the anomaly portfolios are their implied volatility, and its premium is earned on the two days of the expiration. An explanation of the cross-section

of option returns has to account for a recurring repricing tied to the expiration calendar, for its steep rise with volatility, and for the smaller set of return differences that remain once it is taken out.

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A Sample Construction

Stock data are the CRSP daily file, common shares only (share codes 10 and 11) on the NYSE, AMEX and Nasdaq, linked to OptionMetrics through the WRDS link table; from January 2025 the daily file is CRSP's current-format file, with the same screens expressed in its share-type, security-type and exchange fields. Forward prices are the OptionMetrics forward-price file; the forward-price field in the contract file is empty throughout the sample. The risk-free rate is the OptionMetrics zero curve interpolated to the contract's remaining maturity, and the index dividend yield is OptionMetrics' index dividend file. Standard monthly contracts are identified by an expiration on the third Friday of the month, the Saturday after it, or the last trading day before it when the Friday is a holiday, which is how OptionMetrics records them before and after February 2015, with weekly and special-settlement series excluded. Index contracts settle on the morning of the third Friday, so their last trading day is the Thursday before and the event calendar shifts by one day. Short interest is the Compustat short interest file linked to CRSP through the Compustat-CRSP link, taken at the last settlement date within forty-five days before formation and divided by shares outstanding. Earnings announcement dates are the report dates of quarterly earnings in Compustat, linked the same way.

Two validations apply to OptionMetrics' daily records after formation. A call midpoint above the stock price, which cannot be a price, is treated as a day on which the contract did not print; and a closing stock price that differs from CRSP's for the same day by more than five percent is replaced by CRSP's. The first rule applies to 105 of the 12.5 million contract-days of the call sample and the second to 200. A third rule removes contract-months in which the stock's price basis changes during the holding period, a split, reverse split or other distribution on which CRSP's closing price relative to the previous close differs from one plus the return by more than ten percent: the contract's terms are adjusted with the stock, its quotes and the stock's price are no longer on the basis on which the position was struck, and the hedged gain across the event is not measured. This removes 1,841 contract-months, four tenths of a percent, spread evenly across the volatility deciles; before it was applied, the mean full-month return on those contract-months was a gain of 43% of the initial investment, and a single one of them could move a decile's average return by more than a tenth of a percent a month, so the rule lowers the reported returns rather than raising them. A contract that does not print on a day of the holding period is carried at its last midpoint and delta, which places a zero price change on that day and the whole move on the next. Such days are 0.5% of contract-days. The held contract's implied volatility on each day is OptionMetrics' value at the close, carried the same way on days it is missing, so every contract-month enters the variance and implied-volatility comparisons.

The five stock-level characteristics are log price, log market capitalization, log Amihud illiquidity over the prior month, idiosyncratic volatility from a three-factor regression over the prior month, and the maximum daily return over the prior month. The four option-based characteristics are the thirty-day at-the-money call implied volatility, the slope of implied volatility between thirty and ninety-one days, the log gap between realized volatility over the prior year and at-the-money implied volatility, and model-free skewness. Skewness follows Bakshi, Kapadia, and Madan (2003); the standardized surface carries about nine nodes a side, so the smile is interpolated in log-moneyness onto a dense grid to three standard deviations and repriced before integrating. The nine accounting characteristics are cash-flow variance, cash holdings, analyst dispersion, one- and five-year share issuance, profit margin, profitability, total external financing and the z-score, defined as in Zhan et al. (2022); all but profit margin and the z-score are taken from the Chen and Zimmermann (2022) cross-section, and those two are built from Compustat annual items with a six-month reporting lag.

Table 14 reports the average number of stocks surviving each screen in a formation month. The binding constraint is open interest: three fifths of optionable stocks carry a standard contract at the target expiration with a two-sided quote above the minimum midpoint, and requiring positive open interest in that contract removes a sixth of them. Table 15 reports the decile returns on the universe that retains the dividend payers, who are half of the lowest decile and four percent of the highest: the top decile loses 1.33% a month, 1.02% of it on the two rollover days, and the rollover loss rises with the state as it does on the baseline.

Table 14: Stocks surviving each screen

	Stocks per month	Share of common stocks
Common stocks	4,691	1.000
Share price of at least five dollars	3,567	0.760
Matched to an options record	3,551	0.757
Standard contract at the target expiration	2,095	0.447
Two-sided quote	2,073	0.442
Midpoint of at least 12.5 cents	2,073	0.442
Positive open interest	1,719	0.366
Inside the arbitrage bounds	1,719	0.366
Inside the moneyness band	1,687	0.360
Selected contract	1,687	0.360
Of which pay a dividend during the option's life	401	0.085

This table reports the average number of stocks in a formation month surviving each screen, and that number as a share of common stocks. Screens apply at the formation close only. The moneyness band is $\ln(0.8) \leq \ln(K/F) \leq \ln(1.2)$, in which K is the strike and F the forward price at the contract's maturity. The final row counts stocks whose ex-dividend date falls during the contract's remaining life, which the baseline sample excludes.

Table 15: Delta-hedged call returns by implied-volatility decile with dividend payers retained

Decile	Dividend payers (%)	Full month	Rollover	Ex-rollover
1	48	0.32 (3.87)	-0.15 (-8.54)	0.47 (5.96)
2	42	0.28 (3.21)	-0.19 (-10.12)	0.47 (5.51)
3	37	0.28 (3.05)	-0.21 (-9.53)	0.49 (5.78)
4	31	0.21 (2.22)	-0.26 (-9.89)	0.47 (5.14)
5	25	0.25 (2.32)	-0.33 (-10.95)	0.58 (5.63)
6	19	0.31 (2.72)	-0.33 (-12.45)	0.63 (5.70)
7	15	0.28 (2.36)	-0.37 (-12.41)	0.65 (5.89)
8	10	0.15 (1.20)	-0.48 (-16.20)	0.63 (5.19)
9	6	-0.04 (-0.30)	-0.54 (-13.85)	0.50 (3.65)
10	4	-1.33 (-7.21)	-1.02 (-19.87)	-0.31 (-1.76)

This table reports average delta-hedged call returns, in percent per month, by decile of thirty-day at-the-money implied volatility at formation, on the universe that retains stocks with an ex-dividend date during the contract's life, which the baseline excludes; the second column is the share of such stocks in the decile. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover column restricts the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover column holds the remainder. Newey–West t -statistics with six lags appear below the estimates.

B Attribution of the Return by Decile and Window

Two variables move a delta-hedged option's value between two closes: the stock moves and time passes, against the variance the option implied; and the option's own implied volatility is repriced. Table 16 reports the two by decile and window. Over the nineteen days outside the rollover window realized variance exceeds the variance the held contract implied in each of the eight lowest deciles, by one to two and a half annualized variance points with t -statistics of about two, matches it in the ninth, and falls short of it by six points in the tenth, with a t -statistic of -2.7 . The held contract's implied volatility rises in every decile over those days, by three and a half points in the lowest and nine in the top two. Over the two rollover days realized variance is

within a point of implied in the eight lowest deciles, three points short of it in the ninth and ten in the tenth, and the contract's implied volatility rises by two to four tenths of a point in the nine lower deciles and falls by one and a fifth points in the tenth.

Table 16: Realized against implied variance, and the contract's implied volatility, by decile and window

Decile	Ex-rollover		Rollover	
	RV^2-IV^2	ΔIV	RV^2-IV^2	ΔIV
1	0.008 (1.72)	3.50 (14.45)	0.006 (1.23)	0.17 (1.87)
2	0.011 (2.01)	4.31 (15.09)	0.003 (0.56)	0.30 (2.85)
3	0.011 (1.90)	4.93 (15.06)	-0.004 (-0.58)	0.28 (2.49)
4	0.014 (1.96)	5.79 (15.37)	-0.007 (-0.85)	0.27 (2.33)
5	0.018 (2.11)	6.45 (14.68)	-0.006 (-0.62)	0.32 (2.66)
6	0.021 (2.16)	7.17 (14.48)	-0.004 (-0.37)	0.36 (2.62)
7	0.023 (2.11)	7.84 (14.83)	-0.021 (-1.59)	0.29 (2.04)
8	0.024 (1.76)	8.48 (14.88)	-0.009 (-0.39)	0.17 (1.01)
9	0.011 (0.68)	9.14 (15.24)	-0.034 (-1.64)	0.08 (0.39)
10	-0.061 (-2.66)	8.87 (13.39)	-0.104 (-3.22)	-1.16 (-5.05)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the time-series average of the monthly cross-sectional mean of two variables over each window. RV^2-IV^2 is the annualized realized variance of the stock's daily returns, from CRSP, over the window's trading days less the square of the held contract's implied volatility at initiation. ΔIV is the change in the held contract's implied volatility over the window, in volatility points, read at the closes that bound it; for the rollover window these are the close before the last trading day of the standard monthly contract and the close of the trading day after it. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

Table 17 attributes the return by decile and window with Equation (3). Over the nineteen days outside the rollover window the theta part runs from -2.05% of the initial investment in the lowest decile to -7.95% in the highest, and the gamma part from 2.16% to 7.06% : a more volatile option decays faster and its stock moves more, and each is an order of magnitude larger than the return. Their sum, the realized variance carry, is within 0.11% of zero in the eight

lowest deciles, with no t -statistic beyond 1.6, -0.30% in the ninth with a t -statistic of -2.8 , and -0.90% in the tenth with a t -statistic of -7.0 . That is the ordering of the mean variance gap of Table 16 earned at the contract's changing gamma: outside the top two deciles the stocks deliver the variance their options charge, and the top decile's stocks deliver seven percent less than the held contract implied, a fifth less than the thirty-day surface implied, and the holder pays. Appendix C reconciles the two implied variances. The vega part is positive in every decile, 0.38% in the lowest, 0.80% in the eighth and 0.44% in the tenth: a contract that starts at the money ages and moves away from its strike as the month passes, and its own implied volatility is repriced upward, by three and a half to nine points over the nineteen days; the holder earns that repricing at the contract's vega. The return outside the rollover window is therefore the vega part in the lower deciles, and in the top decile the vega part less a realized-variance deficit twice its size. The residual is between -0.16% and -0.06% in nine deciles and -0.24% in the lowest. It is the change in the gap between the quoted midpoint and the model price across the closes that bound the window, and on the nine tenths of contract-months whose endpoint inputs are observed it is between -0.01% and -0.03% in every decile (Table 18); the rest is contracts whose implied volatility or quote is carried at exit, most of them far from the money.

The top decile's loss over the nineteen days, 0.52% , is a deficit of realized against implied variance worth 0.90% at its gamma, less a rise in its own implied volatility worth 0.44% at its vega. The vega part is smaller in the tenth decile than in the ninth, 0.44% against 0.78% , because the top decile's stocks are the ones whose volatility falls over the month. Internet Appendix Table IA.1 sets the change in the held contract's implied volatility from initiation to exit beside the change in its stock's thirty-day at-the-money surface over the same month, and beside the gap between the two at each end, on the contracts with an implied volatility at both ends and a surface reading at both dates; the restriction drops the contracts that have moved furthest from the money, three tenths of the top decile. The surface rises by less than two points over the month in the lowest decile, is flat in the eighth, and falls by seven points in the tenth, the mean reversion one expects of a decile selected on high implied volatility. The held contract's implied volatility rises regardless, by three to seven points in the nine lower deciles: at initiation the contract is within two thirds of a point of its stock's surface, and at exit it is two points above the surface in the lowest decile and seven above it in the ninth. The gap at exit is what separates a contract that has aged and moved from its strike from the thirty-day at-the-money point; it mixes moneyness, maturity and the shape of the surface, and the table describes it without separating them. In the top decile the contract's implied volatility rises by three and a half points on this sample, and by seven and three quarters against the ninth decile's nine on

Table 17: Attribution of the delta-hedged call return, by decile and window

Decile	Ex-rollover						Rollover					
	Return	Theta	Gamma	$\Theta + \Gamma$	Vega	Residual	Return	Theta	Gamma	$\Theta + \Gamma$	Vega	Residual
1	0.25 (2.94)	-2.05 (-27.98)	2.16 (17.42)	0.11 (1.53)	0.38 (10.73)	-0.24 (-2.64)	-0.16 (-9.27)	-0.35 (-27.00)	0.23 (14.80)	-0.13 (-13.31)	-0.02 (-1.31)	-0.01 (-1.57)
2	0.40 (4.54)	-2.68 (-29.14)	2.74 (19.89)	0.06 (1.00)	0.47 (11.76)	-0.13 (-2.49)	-0.21 (-10.41)	-0.46 (-28.55)	0.28 (16.77)	-0.19 (-20.36)	-0.01 (-0.31)	-0.02 (-2.33)
3	0.37 (4.29)	-3.13 (-30.17)	3.13 (20.95)	0.01 (0.11)	0.52 (10.71)	-0.16 (-2.96)	-0.24 (-8.69)	-0.54 (-29.14)	0.30 (17.74)	-0.24 (-21.87)	-0.01 (-0.58)	0.01 (1.08)
4	0.53 (5.05)	-3.55 (-29.92)	3.54 (21.55)	-0.00 (-0.02)	0.62 (10.98)	-0.09 (-1.92)	-0.32 (-9.77)	-0.61 (-28.99)	0.35 (15.69)	-0.26 (-16.03)	-0.02 (-1.12)	-0.04 (-1.26)
5	0.61 (5.61)	-3.97 (-30.18)	3.97 (21.53)	0.00 (0.05)	0.68 (10.97)	-0.08 (-1.58)	-0.33 (-12.53)	-0.69 (-29.06)	0.39 (17.58)	-0.30 (-24.03)	-0.02 (-0.90)	-0.01 (-0.93)
6	0.64 (5.76)	-4.41 (-29.40)	4.37 (22.39)	-0.04 (-0.57)	0.75 (10.26)	-0.07 (-3.17)	-0.36 (-11.73)	-0.76 (-28.20)	0.44 (17.50)	-0.33 (-21.75)	-0.03 (-1.32)	-0.00 (-0.28)
7	0.62 (5.17)	-4.89 (-29.62)	4.82 (22.44)	-0.07 (-0.84)	0.77 (9.78)	-0.08 (-2.80)	-0.44 (-15.27)	-0.85 (-28.63)	0.46 (16.76)	-0.38 (-24.67)	-0.05 (-1.89)	-0.01 (-0.87)
8	0.55 (4.43)	-5.45 (-29.81)	5.33 (23.50)	-0.11 (-1.29)	0.80 (9.11)	-0.13 (-3.44)	-0.49 (-15.28)	-0.94 (-28.68)	0.54 (17.14)	-0.40 (-20.26)	-0.09 (-2.90)	-0.00 (-0.32)
9	0.38 (2.68)	-6.20 (-29.75)	5.90 (23.03)	-0.30 (-2.78)	0.78 (7.94)	-0.10 (-2.89)	-0.62 (-13.74)	-1.07 (-28.94)	0.60 (17.95)	-0.47 (-23.02)	-0.15 (-4.12)	-0.00 (-0.23)
10	-0.52 (-2.84)	-7.95 (-31.34)	7.05 (24.56)	-0.90 (-7.01)	0.44 (3.71)	-0.06 (-0.78)	-1.13 (-20.23)	-1.38 (-31.09)	0.73 (20.15)	-0.64 (-24.59)	-0.44 (-9.47)	-0.04 (-1.73)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the delta-hedged call return over each window and its four parts from the sequential Black–Scholes repricing of the contract, in percent of the initial investment per month. Each daily gain is attributed by repricing the contract with Black–Scholes at the implied volatility OptionMetrics reports, moving the previous close’s inputs to the current close’s in the order time, stock, volatility. Theta is the change from the passage of calendar time net of the financing charge; Gamma the change from the stock’s move net of the delta hedge; $\Theta + \Gamma$ their sum, the realized variance carry; Vega the change from the move in the contract’s own implied volatility; and Residual the change in the gap between the quoted midpoint and the model price. The four parts add to the return. The rollover window is the last trading day of the standard monthly contract and the trading day that follows; the ex-rollover window holds the remainder. Quotes and implied volatilities are carried from the last close on days the contract does not print. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life. Newey–West t -statistics with six lags appear below the estimates.

the full sample with carried values (Table 16), because its stock’s surface fell by seven while the contract moved eleven points above it.

Over the two rollover days the attribution is different in kind. The theta part is -0.35% in the lowest decile and -1.38% in the highest, and the gamma part 0.23% to 0.73% : the window runs from the Thursday close to the Monday close, four calendar days of decay against two trading days of stock moves, and the theta part exceeds the gamma part as it does over any weekend the position holds. The vega part is within a tenth of a percent of zero in the eight lowest deciles, -0.15% in the ninth and -0.44% in the tenth, and the residual is within four hundredths of a percent of zero in every decile, and within 0.005% of zero on contract-months whose endpoint inputs are observed. What distinguishes the rollover window from the other weekends of the month is therefore not what the stock or the clock does; it is what the contract’s implied volatility does, which Section 5 shows.

C Audit of the Attribution

Write $e_d = C_d - B(S_d, \sigma_d, \tau_d; r_{d-1})$ for the gap between the quoted midpoint and the model price at the close of day d , the model price evaluated at the zero rate of the previous close, the rate at which the position is financed over the interval that ends at d ; at the initiation close the rate is that close's own. In Equation (3) the model price of the previous close is evaluated at the same rate as e_{d-1} and the three model prices of the current close at the same rate as e_d , so the first step moves time and the rate together, the hedge and financing terms are common to the gain and to the sum of the three parts, and $\pi_d^\varepsilon = e_d - e_{d-1}$ exactly. Over the rollover window, whose closes are a and b , the residual is $e_b - e_a$; over the ex-rollover days, which lie on both sides of it, the residual is $(e_T - e_{t_0}) - (e_b - e_a)$, with t_0 the initiation close and T the exit. The sums in the tables reproduce these identities to 0.01%; a close at which the return construction records no gain, a day without a CRSP price, is skipped by the attribution as it is by the return, so each day's parts span the interval its gain spans. A nonzero residual over a window therefore requires a gap at one of its bounding closes, and a gap at a close on which both the quote and the implied volatility are OptionMetrics' own is the difference between the tree OptionMetrics inverts and the Black–Scholes price at the same inputs. OptionMetrics inverts the midpoint with a binomial tree, and for a call on a stock that pays no dividend during the contract's life the American price is the European one, so the gap is a numerical level rather than an early-exercise premium. The rate term inside the theta part, the contract's revaluation from one close's zero rate to the next's, averages -0.008% of the initial investment a month in every decile. Table 18 reports the residual by decile on all contract-months and on those whose bounding quotes and implied volatilities are observed, the share of the latter, and the mean gap at initiation and at exit. The tree-versus-model level is never more than two tenths of a percent of the initial investment in a decile's mean, and on the observed-endpoint contract-months the residual is between -0.01% and -0.03% over the ex-rollover window and within 0.005% of zero over the rollover window in every decile. These are decile averages of the change in the gap between two closes, and they bound the average change, not each contract's; the hundredths that remain are the tree-versus-model level varying with moneyness and maturity as the contract ages. The gap at exit is what the residual on the remaining tenth of contract-months is made of: these are contracts whose implied volatility OptionMetrics does not compute at exit, most of them far from the money, on which the carried implied volatility prices the contract above its quote. A quote that is noisy but inverted exactly produces no residual; its noise sits in the vega part, and the quote-quality screens of Section 7 address it.

The paper compares implied with realized variance in two places, and the two objects differ. Table 2 squares the thirty-day at-the-money surface implied volatility at formation and sets

Table 18: The attribution residual and the quote-model gap at the endpoints

Decile	Ex-rollover residual			Rollover residual			Quote less model price		
	All	Observed	Share (%)	All	Observed	Share (%)	Initiation	Exit	Exit, ·
1	-0.24 (-2.64)	-0.01 (-4.31)	90	-0.01 (-1.57)	-0.00 (-2.28)	95	-0.06	-0.32	0.06
2	-0.13 (-2.49)	-0.02 (-4.76)	91	-0.02 (-2.33)	-0.00 (-3.57)	95	-0.07	-0.22	0.08
3	-0.16 (-2.96)	-0.02 (-5.87)	91	0.01 (1.08)	-0.00 (-3.29)	96	-0.08	-0.24	0.10
4	-0.09 (-1.92)	-0.02 (-5.49)	91	-0.04 (-1.26)	-0.00 (-2.32)	96	-0.09	-0.23	0.10
5	-0.08 (-1.58)	-0.02 (-4.30)	92	-0.01 (-0.93)	-0.00 (-2.40)	96	-0.10	-0.19	0.11
6	-0.07 (-3.17)	-0.02 (-4.68)	92	-0.00 (-0.28)	-0.00 (-1.69)	96	-0.12	-0.19	0.12
7	-0.08 (-2.80)	-0.02 (-5.52)	92	-0.01 (-0.87)	-0.00 (-1.80)	96	-0.13	-0.22	0.14
8	-0.13 (-3.44)	-0.02 (-4.52)	91	-0.00 (-0.32)	-0.00 (-1.00)	96	-0.14	-0.28	0.15
9	-0.10 (-2.89)	-0.03 (-3.58)	91	-0.00 (-0.23)	-0.00 (-1.03)	95	-0.16	-0.26	0.17
10	-0.06 (-0.78)	-0.03 (-2.05)	89	-0.04 (-1.73)	0.00 (3.29)	94	-0.20	-0.31	0.21

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the residual of the sequential Black–Scholes repricing, the daily gain less its theta, gamma and vega parts, summed over the ex-rollover and rollover windows, in percent of the initial investment per month, on all contract-months and on the contract-months whose quote and implied volatility are OptionMetrics’ own at the window’s endpoints, the initiation and exit closes and the closes before and after the last trading day of the standard monthly contract, together with the share of such contract-months; and the mean gap between the quoted midpoint and the Black–Scholes price at OptionMetrics’ implied volatility at initiation and at exit, with the median absolute gap at exit, in the same units. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life. Newey–West t -statistics with six lags appear below the estimates.

it against the variance realized from the formation close to the exit close; the attribution and Table 16 square the held contract’s own implied volatility at initiation and set it against the variance realized over each window from the initiation close. Both use CRSP returns. Table 19 reports each object and the intermediate ones on the same contract-months. The window barely matters: the variance realized from formation and from initiation differ by a thousandth, and the ex-rollover window by less than five thousandths. The implied variance does. In the nine lower deciles the surface and the held contract agree within seven thousandths, but in the top decile the surface’s implied variance is 1.00 against the held contract’s 0.88, a two-month contract priced below the thirty-day point of a downward-sloping term structure. The top decile’s stocks therefore deliver a fifth less variance than the surface implies and seven percent less than the contract they hold implies, and it is the second gap, at the contract’s gamma, that the attribution earns.

Table 19: Implied and realized variance in the decile table and in the attribution

Decile	Implied variance		Realized variance from			Implied less realized			
	Surface	Held	Formation	Initiation	Ex-roll.	S, form.	S, init.	H, init.	H, ex-roll.
1	0.057	0.061	0.069	0.068	0.069	-0.012 (-2.58)	-0.012 (-2.50)	-0.008 (-1.70)	-0.008 (-1.72)
2	0.093	0.097	0.108	0.108	0.109	-0.015 (-2.66)	-0.014 (-2.57)	-0.010 (-1.89)	-0.011 (-2.01)
3	0.126	0.130	0.140	0.140	0.141	-0.014 (-2.44)	-0.014 (-2.33)	-0.010 (-1.68)	-0.011 (-1.90)
4	0.161	0.166	0.178	0.178	0.180	-0.017 (-2.40)	-0.016 (-2.28)	-0.012 (-1.70)	-0.014 (-1.96)
5	0.202	0.208	0.224	0.223	0.226	-0.022 (-2.50)	-0.021 (-2.41)	-0.016 (-1.87)	-0.018 (-2.11)
6	0.251	0.256	0.275	0.274	0.276	-0.025 (-2.46)	-0.023 (-2.35)	-0.018 (-1.91)	-0.021 (-2.13)
7	0.310	0.314	0.333	0.332	0.336	-0.023 (-2.06)	-0.022 (-1.96)	-0.018 (-1.68)	-0.022 (-2.05)
8	0.391	0.391	0.413	0.412	0.415	-0.023 (-1.54)	-0.022 (-1.48)	-0.021 (-1.48)	-0.024 (-1.75)
9	0.519	0.512	0.520	0.518	0.523	-0.001 (-0.07)	0.000 (0.01)	-0.007 (-0.41)	-0.011 (-0.67)
10	1.001	0.885	0.821	0.819	0.823	0.179 (4.78)	0.181 (4.84)	0.065 (2.89)	0.061 (2.67)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the time-series average of the monthly cross-sectional mean of: the square of the surface implied volatility at formation; the square of the held contract's implied volatility at initiation; the annualized variance of the stock's daily CRSP returns from the formation close to the exit close, from the initiation close to the exit close, and over the ex-rollover window; and the four implied-less-realized gaps that pair them, the first of which is the object of Table 2 and the last of Table 16. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life, on the contract-months with every object available. Newey–West t -statistics with six lags appear below the gaps.

D Additional Tables

Table 20: The top decile within terciles of price and of short interest

Tercile	Median	Deciles 1–8			Decile 10		
		Full month	Rollover	Ex-rollover	Full month	Rollover	Ex-rollover
<i>Panel A: Share price, calls</i>							
Low	\$13	0.22 (1.75)	-0.44 (-13.40)	0.66 (5.41)	-1.78 (-8.77)	-1.20 (-18.64)	-0.58 (-2.96)
Mid	\$28	0.21 (2.02)	-0.32 (-12.44)	0.52 (5.28)	-1.44 (-5.42)	-0.92 (-13.68)	-0.52 (-2.10)
High	\$67	0.14 (1.35)	-0.25 (-11.35)	0.38 (4.10)	-1.11 (-3.07)	-0.82 (-6.10)	-0.29 (-0.88)
<i>Panel B: Short interest, calls</i>							
Low	0.8%	0.13 (1.05)	-0.29 (-8.10)	0.42 (3.58)	-1.53 (-4.85)	-0.92 (-6.67)	-0.61 (-1.77)
Mid	3.4%	0.24 (1.83)	-0.32 (-9.79)	0.56 (4.28)	-1.50 (-5.31)	-1.21 (-11.29)	-0.29 (-1.10)
High	10.1%	0.31 (2.28)	-0.34 (-9.55)	0.65 (4.93)	-1.42 (-5.21)	-1.15 (-14.40)	-0.27 (-1.04)
<i>Panel C: Short interest, puts</i>							
Low	0.8%	0.15 (1.13)	-0.25 (-8.76)	0.40 (2.96)	-1.29 (-6.10)	-0.70 (-6.72)	-0.59 (-2.54)
Mid	3.5%	0.06 (0.44)	-0.29 (-10.97)	0.34 (2.65)	-1.22 (-5.61)	-0.84 (-10.14)	-0.38 (-1.73)
High	10.6%	0.05 (0.40)	-0.30 (-10.59)	0.35 (2.89)	-1.29 (-7.19)	-0.84 (-14.52)	-0.45 (-2.46)

This table reports average delta-hedged returns, in percent per month, for stocks in the lower eight deciles and in the top decile of thirty-day at-the-money implied volatility at formation, within terciles of the share price for calls (Panel A) and of short interest scaled by shares outstanding for calls (Panel B) and for puts (Panel C). Median is the time-series average of the tercile's median price or short interest. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover column restricts the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover column holds the remainder. Panel A uses the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life; Panels B and C use the part of it for which short interest is available. Newey–West t -statistics with six lags appear below the estimates.

Table 21: Quote-quality screens

	Deciles 1–8			Decile 10		
	Full month	Rollover	Ex-rollover	Full month	Rollover	Ex-rollover
All contracts	0.18 (1.77)	-0.32 (-13.75)	0.50 (5.19)	-1.65 (-8.57)	-1.13 (-20.23)	-0.52 (-2.84)
Volume at formation	0.08 (0.87)	-0.34 (-14.15)	0.42 (4.52)	-1.72 (-7.61)	-1.20 (-22.74)	-0.52 (-2.38)
Spread below median	0.05 (0.50)	-0.29 (-12.91)	0.33 (3.72)	-1.38 (-6.73)	-1.03 (-17.72)	-0.35 (-1.82)
Volume and spread	0.03 (0.29)	-0.31 (-13.18)	0.33 (3.63)	-1.42 (-6.41)	-1.12 (-18.29)	-0.31 (-1.45)
Open interest above median	0.03 (0.35)	-0.34 (-14.78)	0.38 (4.15)	-2.01 (-9.30)	-1.20 (-20.91)	-0.81 (-3.95)

This table reports average delta-hedged call returns, in percent per month, for stocks in the lower eight deciles and in the top decile of thirty-day at-the-money implied volatility at formation, restricting each slice to contracts that pass the screen named in the row. Volume, the relative spread and open interest are measured on the selected contract at the formation close, and the medians are taken within the formation month. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover column restricts the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover column holds the remainder. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life. Newey–West t -statistics with six lags appear below the estimates.

Table 22: Means, winsorized means and medians by implied-volatility decile

Decile	Full month			Rollover			Ex-rollover		
	Mean	Winsorized	Median	Mean	Winsorized	Median	Mean	Winsorized	Median
1	0.09	0.13	-0.08	-0.16	-0.18	-0.19	0.25	0.31	0.08
2	0.19	0.14	-0.18	-0.21	-0.23	-0.25	0.40	0.36	0.02
3	0.13	0.06	-0.28	-0.24	-0.28	-0.30	0.37	0.33	-0.03
4	0.21	0.05	-0.30	-0.32	-0.34	-0.35	0.53	0.38	-0.01
5	0.28	0.04	-0.35	-0.33	-0.37	-0.38	0.61	0.39	-0.02
6	0.28	-0.03	-0.44	-0.36	-0.42	-0.43	0.64	0.37	-0.06
7	0.18	-0.15	-0.56	-0.44	-0.48	-0.48	0.62	0.32	-0.14
8	0.06	-0.31	-0.78	-0.49	-0.55	-0.56	0.55	0.22	-0.26
9	-0.24	-0.58	-1.09	-0.62	-0.66	-0.68	0.38	0.06	-0.47
10	-1.65	-1.43	-2.37	-1.13	-0.94	-1.03	-0.52	-0.53	-1.36

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the time-series average of the monthly cross-sectional mean, of the mean after winsorizing the month's cross-section at its fifth and ninety-fifth percentiles, and of the median, for the delta-hedged call return over the full month, over the rollover window and over the other days, in percent per month. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life.

Table 23: The top decile by subperiod

Period	IV–RV	Return			Average anomaly		
		Full month	Rollover	Ex-rollover	Full month	Rollover	Ex-rollover
<i>Deciles 1–8</i>							
1996-2009	-0.02	0.08 (0.54)	-0.35 (-13.50)	0.43 (2.90)	-0.07 (-1.09)	-0.12 (-9.35)	0.05 (0.90)
2010-2019	0.00	0.10 (0.95)	-0.26 (-5.87)	0.37 (4.10)	0.02 (0.43)	-0.10 (-4.62)	0.12 (3.62)
2020-2025	0.01	0.55 (1.80)	-0.34 (-5.90)	0.89 (2.97)	0.04 (0.38)	-0.15 (-5.30)	0.19 (1.72)
<i>Decile 10</i>							
1996-2009	0.02	-1.82 (-7.04)	-1.14 (-21.43)	-0.68 (-2.70)	-0.50 (-6.27)	-0.16 (-4.61)	-0.35 (-5.34)
2010-2019	0.09	-1.35 (-7.39)	-0.97 (-10.10)	-0.39 (-2.02)	-0.75 (-7.68)	-0.24 (-5.70)	-0.51 (-5.27)
2020-2025	0.25	-1.74 (-2.51)	-1.38 (-7.87)	-0.36 (-0.56)	-0.91 (-3.61)	-0.46 (-3.82)	-0.44 (-1.72)

This table reports, by subperiod, average delta-hedged call returns and the average long-short return across characteristics, in percent per month, for stocks in the lower eight deciles and in the top decile of thirty-day at-the-money implied volatility at formation. IV–RV is the time-series average of the gap between the slice’s median implied volatility and its median realized volatility over the prior year, annualized. Within the lower eight deciles each characteristic portfolio is formed into deciles and within the top decile into quintiles, and the average anomaly is the equal-weighted average across characteristics of the monthly long-short series. The full-month return accumulates the daily delta-hedged gain over the holding period and scales it by the absolute value of the initial investment; the rollover columns restrict the sum to the last trading day of the standard monthly contract and the trading day that follows, and the ex-rollover columns hold the remainder. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract’s life. Newey–West t -statistics with six lags appear below the estimates.

Table 24: Matched calls and puts on the same stock, strike and month

Decile	Full month	Ex-rollover	Rollover
1	0.01 (0.25)	0.01 (0.12)	0.01 (0.48)
2	-0.01 (-0.37)	-0.02 (-0.68)	0.01 (1.36)
3	-0.05 (-0.90)	-0.05 (-1.06)	0.01 (1.22)
4	-0.01 (-0.19)	-0.00 (-0.06)	-0.00 (-0.18)
5	0.04 (1.83)	0.03 (1.06)	0.01 (1.25)
6	0.07 (4.27)	0.05 (2.78)	0.01 (0.96)
7	0.05 (2.27)	0.05 (1.96)	0.00 (0.10)
8	0.02 (0.92)	0.02 (0.77)	0.00 (0.16)
9	0.08 (3.05)	0.08 (2.47)	0.01 (0.39)
10	0.05 (1.03)	0.08 (1.71)	-0.03 (-1.72)
All	0.03 (1.48)	0.02 (1.25)	0.00 (0.17)

This table reports, by decile of thirty-day at-the-money implied volatility at formation, the average difference between the delta-hedged dollar gain on the selected call and on the selected put where the two share a stock, a strike and a formation month, as a percentage of the stock price at formation. The gain on each contract is its return times its own initial investment, over the full month, over the days outside the rollover window and over the rollover window. The sample is the baseline universe of optionable common stocks excluding those paying a dividend during the contract's life, restricted to stock-months in which the selected call and put share a strike. Newey–West t -statistics with six lags appear below the estimates.