Decoding Options Pricing and Risk around Earnings Announcements

Zach Wang, Charlie Morris, Henry Morris

March 8th, 2024

Abstract

This paper delves into options trading during earnings events, examining the relationship between market sentiment, implied volatility, and actual stock moves. It uncovers a link between negative implied volatility skew and increased earnings dispersion. The analysis emphasizes the reliability of implied volatilities in reflecting market expectations, especially during heightened volatility. Finally, we discuss the parameters of that would inform an effective straddle selling strategy around EAD (Earnings Events Days).

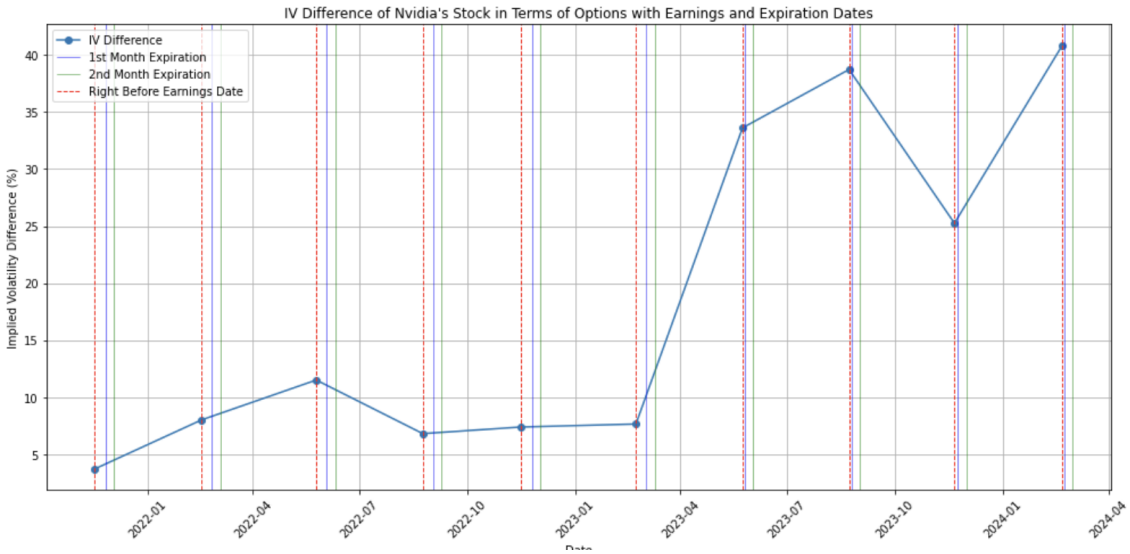


Figure 1: 'NVDA' week after EAD expiry vs month after IV deferential

1 Introduction

Nvidia and its massive run-up since the AI boom has captured the headlines as well as the eye of investors hoping to get in on 'the next big thing'. The company's meteoric rise and its seemingly unfaltering ability to impress Wall Street analysts and industry experts have made it into a rising tide that has risen with the 'Magnificent 7' and brought an otherwise flat S&P 500 up 24% in the last 5 months and 7% YTD. As a result of general market exuberance, this group of 7 high-flying tech companies, or the 'Magnificent 7' now accounts for a massive 31% of the market capitalization of the S&P 500 (it is a separate question whether this means the index is overly influenced by a small number of stocks). In November 2023 the firms in the S&P 493 firms were up 6% while the Magnificent 7 had rallied 71% and together lifted the S&P 500 performance to 19%.

Figure 1 shows the week-after-earnings announcement date (EAD) expiry versus the month-after implied volatility (IV) differential for NVDA (Nvidia). This increase in IV differential is attributed to the growing anticipation surrounding higher earnings expectations for NVDA and the heightened significance investors place on the insights gleaned from these earnings events.

Leading into the run-up to Nvidia Q4 2023 earnings report on Feb 21 options traders piled in on over $20 Billion in Options Premia paid. This combined sum represented a greater volume of premium than among the next 9 top volume single names, a list made up of 5 of the Mag-7 names. Moreover, in the post-pandemic landscape, there has been a notable surge in post-earnings data. While SPY and other index options are studied and highlighted as the most liquid and high-volume options markets, we aim to analyze the single-level options level results and trends.

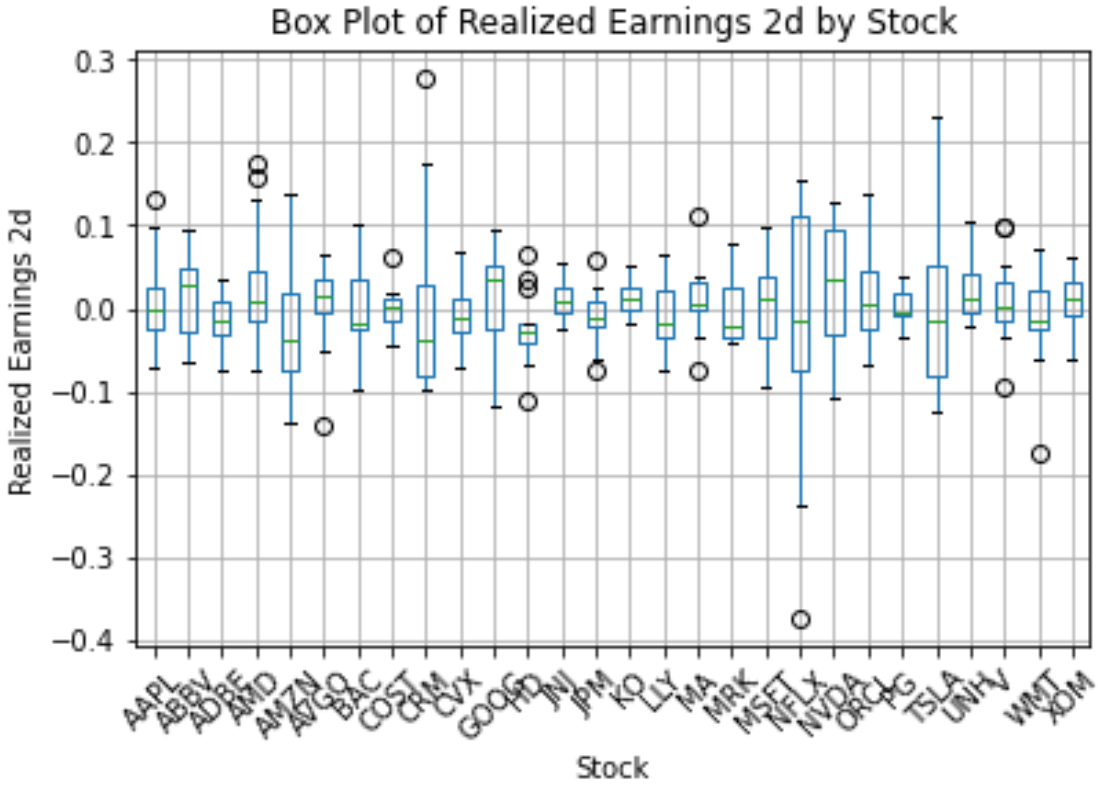


Figure 2: Wide dispersion in earnings results over the past 3 years

Our group was interested in the impacts of broader market sentiment and specifically 'tech exuberance' over the last 3 years. We initially set out trying to answer the question of how, in a highly uncertain, but still exuberant regime, market participants went about pricing in implied moves near earnings day events. We also considered how earnings and revenue expectation vs actual results might be predictive of the realized moves in volatility. Finally, we consider the term structure of IV before Earnings Day Announcements (EAD) to better understand how accurately the implied move reflects the realized volatility over the next day and week.

2 Data

In our project, we use WRDS 'Options Metrics' data to calculate the implied moves and the volatility surfaces for single-name equity options suggested by near-term options pricing. Because of the microstructures to options 3 days from expiry, we exclude options expiring within 3 trading days from our analysis and use the options chain for the next maturity. For our universe of stocks which we include in our sample, we use 28 of the largest 30 public US equities by market cap, excluding Facebook due to the ticker change and Berkshire Hathaway due to its organization as a highly diversified conglomerate. We rely on 'EarningsWshiperer.com' to determine whether or not a firm reported earnings before the market open or after market close.

We calculate the opening stock price surprise based on the WRDS Compustat equity data and pull daily open prices for the securities in our analysis. For earnings and earnings surprise data, we rely on the Ibes Thomson Reuters surprise history data set. We organize the data output to a standardized table and we use raw estimates and realized results to calculate surprise as a % of upside of downside to the estimate.

Our team specifically noted that the levels of IV that markets are pricing into EAD have steadily increased, suggesting that it has gotten quicker at incorporating earnings price information. With the quantitative data, we try and explore how this effect might be dispersed by company and industry (e.g. Technology companies, especially those at the forefront of innovation, often experience heightened volatility during earnings seasons. Investors eagerly await financial results and forward-looking guidance, leading to increased IV in the front-end pricing of options. This reflects the market's uncertainty about how technological developments will impact the company's financial performance.)

Call/put volume skew refers to the imbalance in trading activity between call options (which give the right to buy a security) and put options (which give the right to sell a security) within a given time frame. Here we show the massive volume imbalance that developed between quarterly earnings data between 2020 and 2023, and we note the substantial increase in call volume buying over this period. We attributed the levels of skew that developed over this period to the general level of liquidity in the system, generally bubbly market

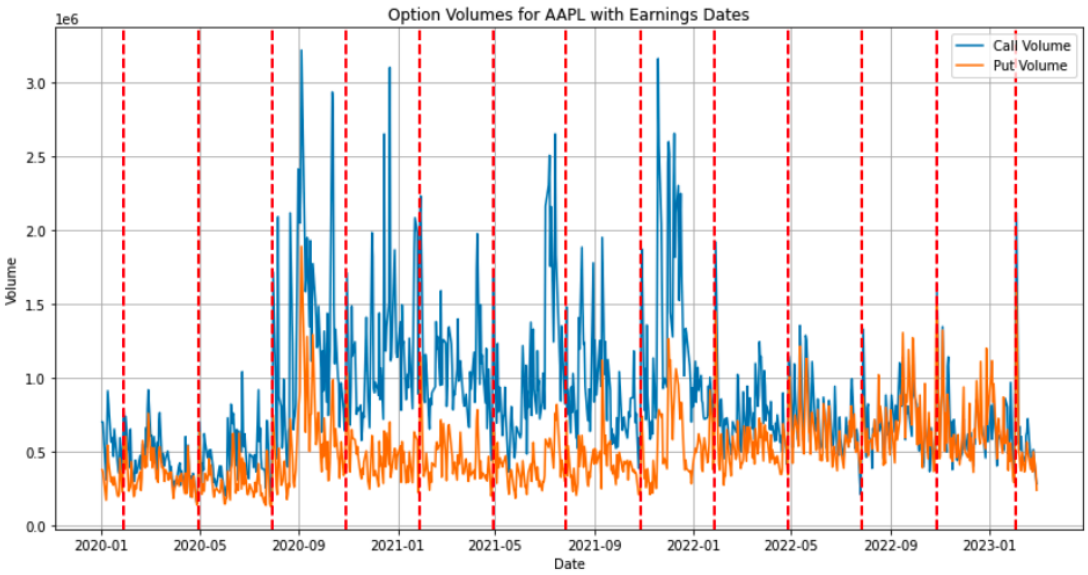


Figure 3: Massive spike and volume skew we observe across apple earnings

sentiment, and to macroeconomic factors like changes in interest rates, overall market conditions, and global economic indicators which have encouraged a bullish outlook.

3 Literature Review

The academic literature on options and earnings events has been extensive, and recent works, such as Li and Ruan's (2022) study, have contributed significantly to understanding the dynamics of implied volatility (IV) and Variance Risk Premium (VRP) surfaces in the context of planned events like earnings releases. Building on the foundation laid by Bollerslev et al. (2009), Li and Ruan extended this research, particularly examining the impact of COVID-19-induced uncertainty on the options market. The concept of VRP, as calculated by the compensation investors require for bearing volatility risk, is a valuable metric in assessing risk perceptions in the options market. Li and Ruan's methodology, rooted in event studies, provides a structured approach to understanding how VRP dynamics unfold around earnings events. They isolate the event level, and local effects of an announcement using the following formula:

$$XD = X - \overline{X}$$

Here, X represents a measure of IV or VRP, $\overline{X}$ is the mean of the variable X in the days leading up to the announcement, and XD represents the adjusted value of the option market variable after the event. A positive XD variable indicates that options after the announcement are more expensive than those further

from the announcement date, offering insights into how the market prices in information and risk.
Previous studies in the field of options and earnings events have explored various aspects of this relationship:

1. Volatility Smile or Skew: The volatility smile or skew, first highlighted by Figlewski (1989) and later discussed by Rubinstein (1994), refers to the observation that implied volatility tends to vary across different strike prices and maturities. This phenomenon challenges the assumption of constant volatility in the Black-Scholes model. The presence of a volatility smile indicates that market participants are willing to pay different premiums for options with different strike prices, suggesting varying degrees of perceived risk. Understanding the volatility smile is crucial for traders and investors as it provides insights into market expectations and risk perceptions. For instance, a steeper smile may indicate heightened uncertainty or anticipation of significant market events.

2. Market Reactions to Earnings Announcements: Ball and Brown (1968) conducted foundational research exploring how markets react to earnings announcements. This work set the stage for understanding the link between corporate information releases and subsequent stock price movements. Jensen and Johnson (1995) expanded on this by highlighting the significant impact of earnings surprises on stock prices. Positive or negative surprises relative to market expectations can lead to pronounced reactions in equity markets, influencing investor sentiment and trading behavior.

4 Results

4.1 Jump Volatility for EAD

Jump volatility, a component of overall volatility, captures the impact of sudden and significant price movements, often associated with events like earnings releases. We use a model of Jump Volatility, as outlined in the literature which enables us to represent the IV specifically priced into the EAD event and exclude exogenous factors. For an option expiring at time T, we get *(Dubinsky et al., 2019)*:

$$\sigma = \sqrt{\sigma^2 + (\sigma_j^{\mathbb{Q}})^2/(j-t)} \tag{1}$$

We describe σ as our historical diffusive volatility and $\sigma_j^{\mathbb{Q}}$ as the price jump volatility for time j. This simplifies to:

$$(\sigma_j^{\mathbb{Q}})^2 = (j-t)(\sigma_t^2 - \sigma^2) \tag{2}$$

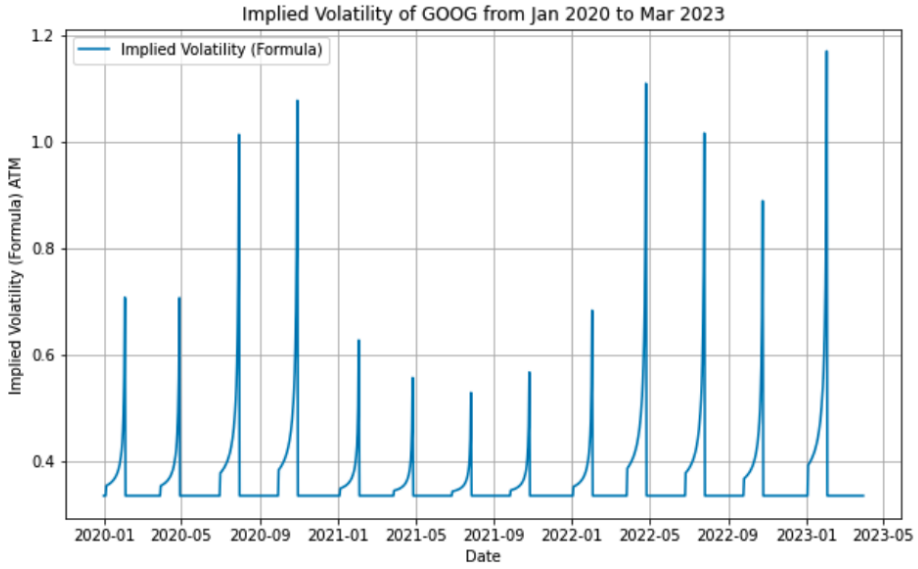


Figure 4: Google Jump Volatility Calculation

This simple model delivers three general implications of earnings announcements *(Dubinsky et al., 2019)*:

- IVs increase continuously and nonlinearly before an EAD (T decreases)
- IV discontinuously falls after the announcement, where Jump Vol IV remains quite flat in the 1 mo after EAD
- The term structure of IV is downward-sloping before the announcement.

The massive fall-offs in IV represent the market is quickly assimilating and adjusting to the information provided by the earnings report. The jump upwards pre-earnings and then the noncontinuous drop downwards reflects the efficient assimilation of new information and the market's adjustment to the company's revealed fundamentals. Our group noted that IV for EAD begins to be priced in roughly 1.5-2mo before quarter EAD and it initially jumps up over 1-2 trading days. Using the smile and the jump volatility equation results in a model that only assumes EAD-induced vol rather than the multitude of other factors responsible assuming historical vol is the same as 'diffusive'. While the model is a good place to start and to see the spike and the fall-offs specifically related to earnings day events, it fails to account for any of the other macroeconomic and micro-structure effects of options vol.

Using WRDS vol surface data, we plot the IV levels using the ATM level for Google over the same period.

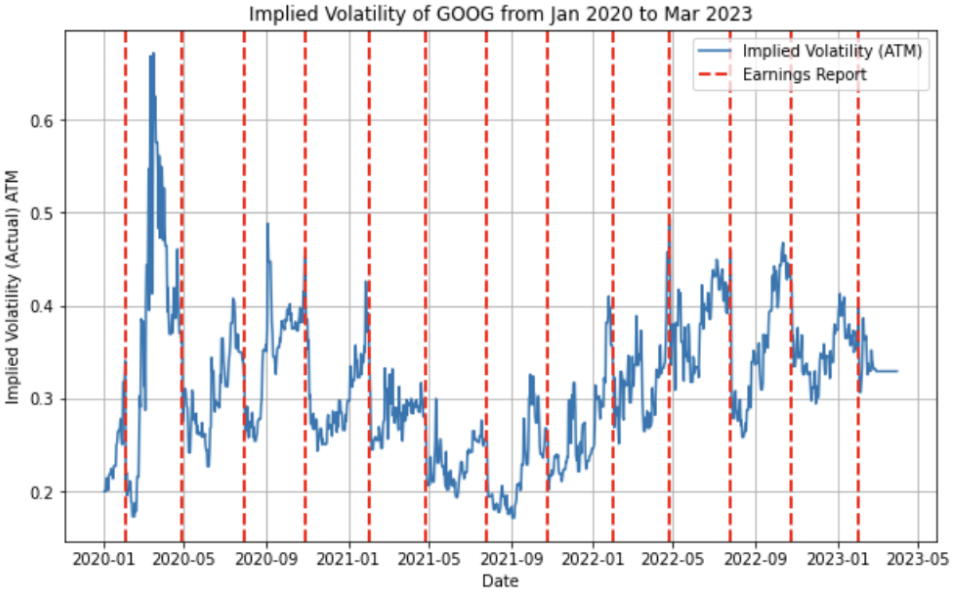


Figure 5: Google IV Surface Volatility Calculation

As information from the earnings report is absorbed by the market, uncertainty decreases. However, we also observe that there are also a large number of broader market structures at play which result in assessing the impact of macroeconomic events or understanding shifts in investor sentiment that may not be exclusively tied to earnings releases. We would have had to do much more feature engineering to try and get a more realistic ATM IV model.

4.2 Negative IV Skew and Earnings:

Our analysis of IV Put Skew aimed to represent the relationship between the negative skew in implied volatility (IV) and the dispersion in option prices, focusing on the difference between at-the-money (ATM) implied volatility and out-of-the-money (OTM) puts.

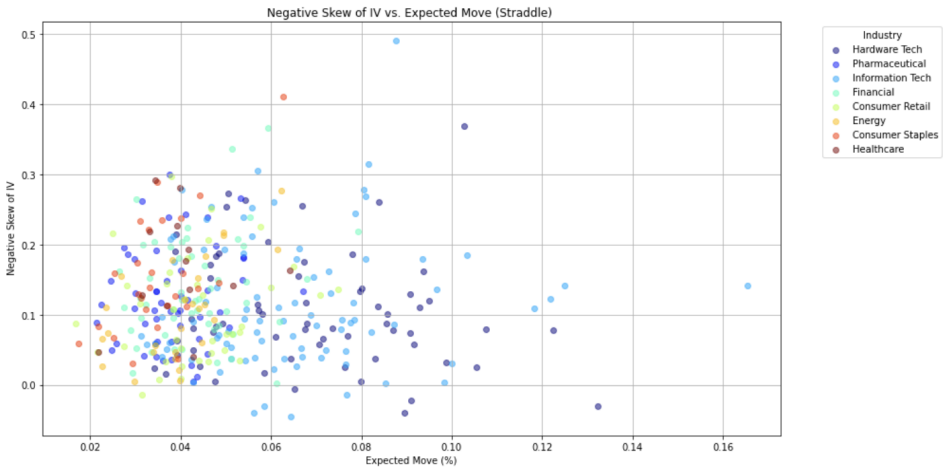


Figure 6: Realized move plotted on the level of IV Put Skew

The scatterplot shows that the greater the negative skew, generally the greater the level of expected moves in either direction (although this relationship is not the strongest). This suggests a higher demand and premium for protective puts (OTM puts) compared to ATM options. This phenomenon is indicative of heightened investor concerns about potential downside risks, resulting in an asymmetry in option pricing.

4.3 Realized Earnings vs Expected Move

To understand the realized 2-day price change and implied volatility for our universe of companies. Here we analyzed the realized move versus both of the IV surfaces as well as using the ATM straddle implied expected move. Below are the 2 equations that do this for us:

$$IV_{Surface} = ATMIV * \sqrt{(\text{time frame})}$$

$$IV_{Straddle} = \frac{(C_{ATM\_price} + P_{ATM\_Price})}{Spot\_Price}$$

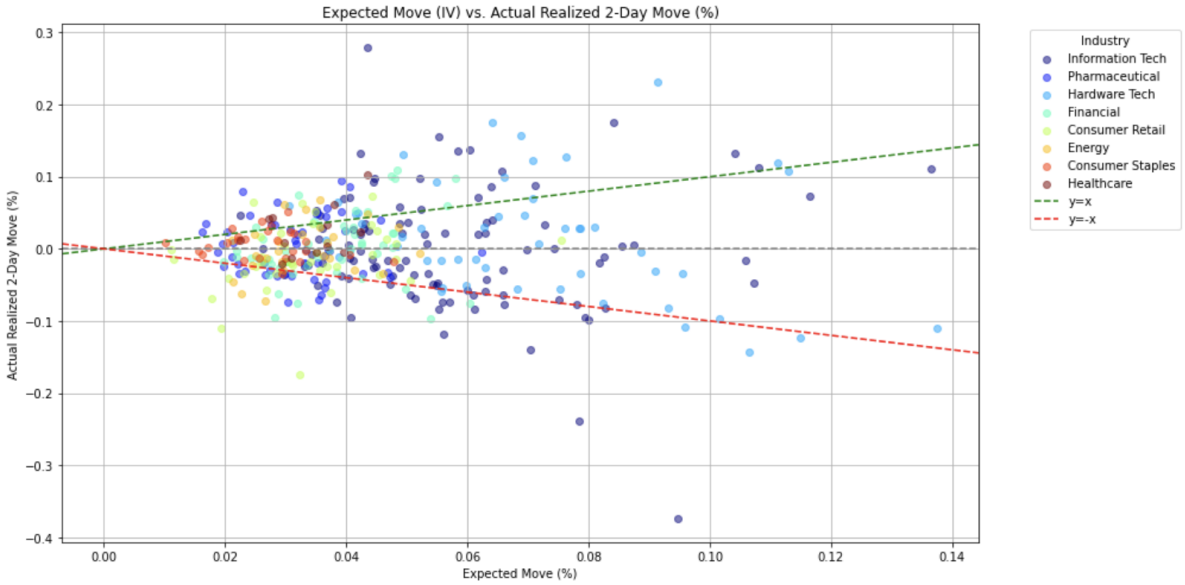


Figure 7: Realized Move plotted on the Expected Move (IV calculation)

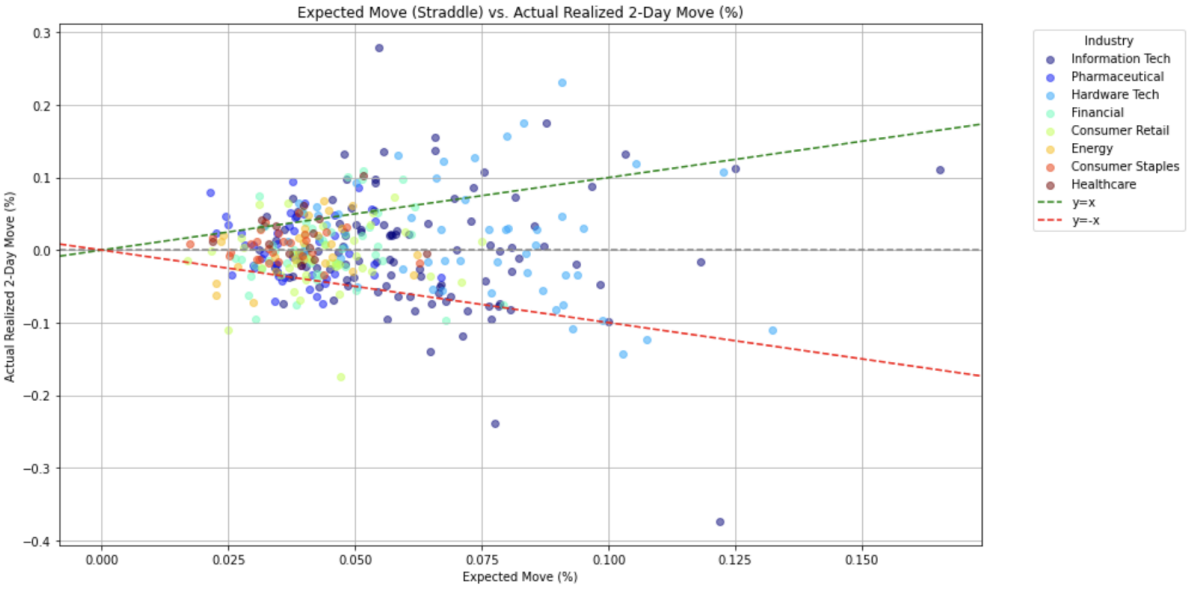
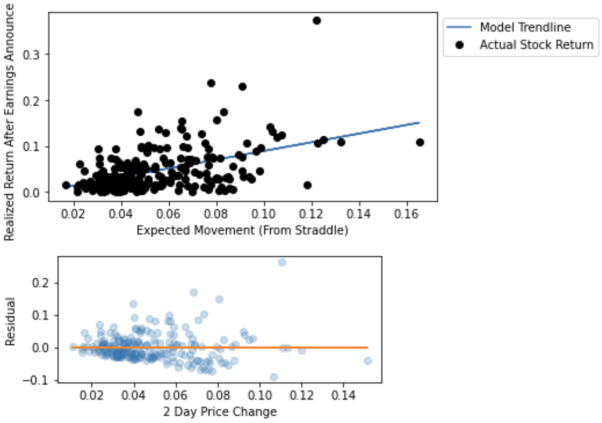


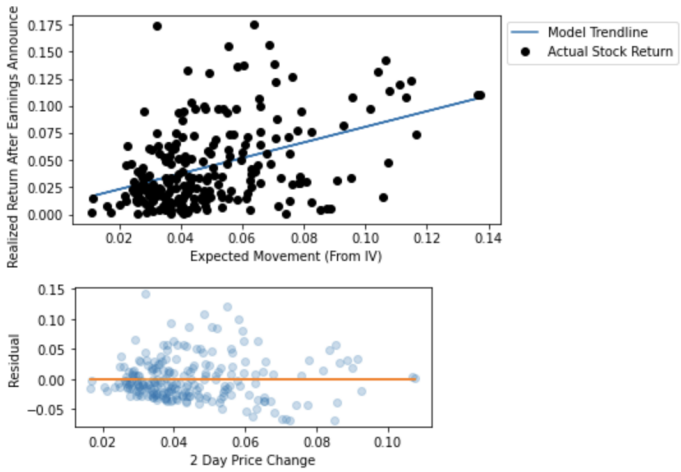
Figure 8: Realized Move plotted on the Expected Move (Straddle IV

The dotted lines represent the implied move plotted on the y-axis. The data shows us that approximately 69% of the actual realized 2-day stock earnings fall within the implied move before the earnings announcement date for both of the IV representations. This suggests that despite extreme market sentiment and dispersion in realized results, the implied volatilities used were consistently explaining $\pm 1\sigma$ of the realized moves. In particular, we notice high levels of dispersion in information tech and hardware tech post-earnings realized results with a skew towards outperforming expected move (With a few outliers to the downside). On the other hand, stocks within the other categories generally tend to price lower in expected move, but they also exhibit much less dispersion ($\pm\sigma$ moves).

If we run a regression on actual 2 day returns vs. expected moves, we get a weak linear relation with $R^2 = 2.13$ and MSE 0.042. The residuals have not significant pattern, which should imply there is not a hidden relationship at play.



If we remove some outliers our MSE drops to 0.34, but R^2 also goes down to 0.186



This would imply that there's not a great linear relationship here, but that the variables are likely positively correlated. The apparent randomness also makes higher ordered regressions not do much better without extreme overfitting (look in code for more graphs).

Figure 9: 2-day realizes earnings (pts) vs %Revenue Surprise

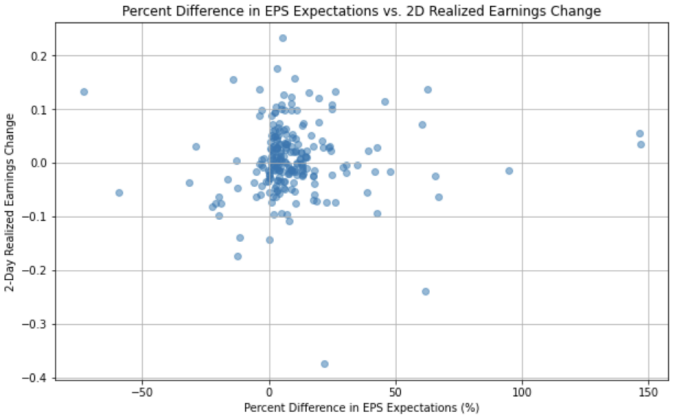


Figure 10: 2-day realizes earnings (pts) vs %EPS Surprise

Let's now explore how revenue/EPS expectations compared to their actual results might impact price changes.

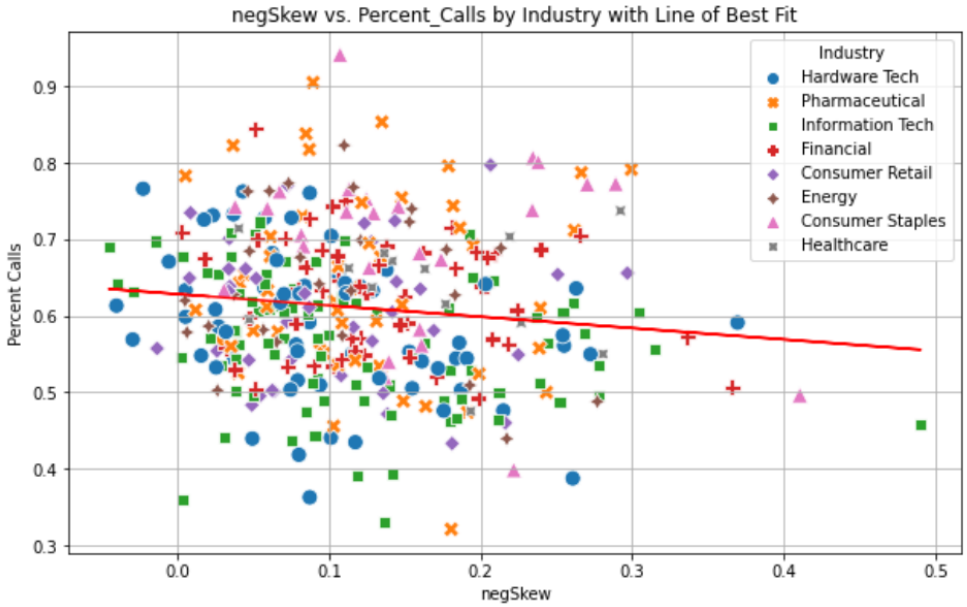
- Positive Skew: When analyzing our set of earnings per share (EPS) and revenue expectations, the positive skew and clustering in terms of the general outperformance indicates a higher concentration of optimistic forecasts. Analysts are likely systematically underestimating earnings and revenue results, resulting in greater 'surprises'.
- Overreacting to Underperforming Results: When faced with underperforming results compared to EPS expectations, individuals, including investors and analysts, tend to make greater moves on the downside than when there is outsized overperformance. This could manifest in rapid adjustments to portfolios or immediate market responses. We also connect this to the idea of loss aversion, where investors and analysts are more sensitive to potential downside risk than the upside potential of positive surprises.

While there is some level of positive directionality to our OLS regression coefficients, the explanatory value

of revenue and earnings surprise was not statistically significant. To improve this test, it would have been preferable to use Wall Street's 'whisper' pre-earnings numbers (closer to actual investor consensus and expectation) as well as having a way to systematically track announced adjustments to year forward earnings expectations (forward expectations generally drive market reaction much more than present results)

4.4 Volume skew vs IV Results

We observed a massive spike in call volume vs put volume over the highest implied and realized IV cycles. Our group was curious about the relationship and whether there was any statistical significance between the shape of the IV smile and the magnitude of negative skew. We plotted each earnings day event on a graph of % calls over negative skew.



Our OLS line of best fit had a coefficient of -0.14813299433978097, suggesting that as the percentage of call volume increases, there is an estimated decrease in negative skew. For a 0.1% increase in the negative skew, this suggests a 0.015% decrease to percentage of options as calls. This corresponds with the idea that a higher proportion of call trading might be associated with a tendency for the market to exhibit less negative skew in implied volatility. However, this value is analyisis not super relaible given the low ($R^2 = 0.0147$).

5 Backtesting

For our backtest, we considered a simple strategy of selling straddles around earnings date results, we use a European-style Black-Scholes model for options pricing in our simulation. The simulation runs multiple scenarios by randomly selecting realized earnings moves and implied volatilities in each iteration. Utilizing the Black-Scholes option pricing model, our model calculates call and put option values based on the simulated parameters. Each day in our simulation cycle represents an earnings event and for each day the strategy sells a straddle – a call and a put option with matching strike prices and expiration dates. Daily profit or loss results from the difference between the total option premium received and the realized stock price move. Cumulative profit and loss (PNL) for each simulation is obtained by summing daily PNL values. The outcomes are shown with the x-axis representing trading days, the y-axis representing cumulative PNL, and each line representing a different simulation run. This backtest offers a detailed analysis of the straddle-selling strategy's performance under varied conditions.

This histogram represents the distribution of final profit and loss (PNL) values obtained after running the simulation 100 times with varied outcomes.

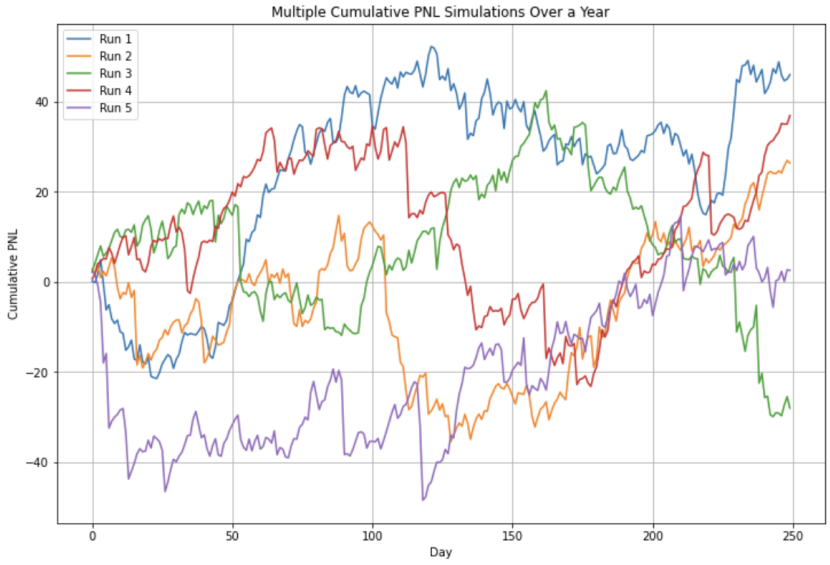


Figure 11: 5 simulations of our Montecarlo simulation

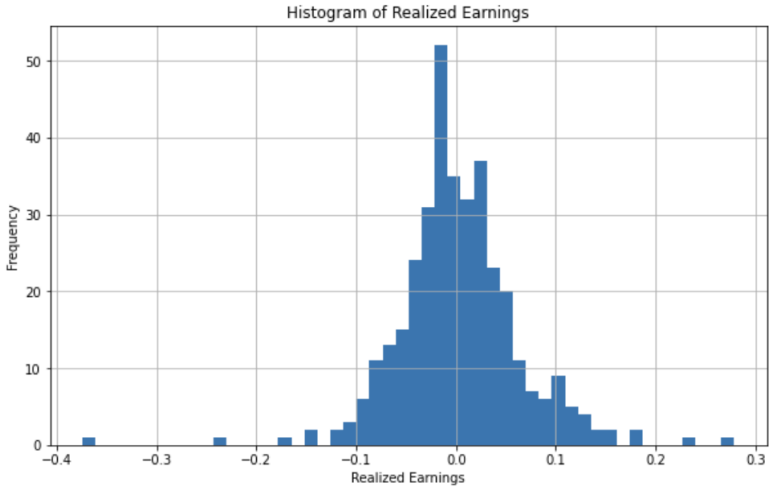


Figure 12: Distribution and the shape of our P&L Results

While the mean profits average to a negative number, the presence of a positive median and exposure to the right tail suggests that the strategy could be consistently profitable so long as the strategy demonstrates a strong understanding of downside risks and can successfully reduce the odds it ends up shorting the straddle in severe earnings that realize the 'tail' results. significantly contribute to overall performance.
The Montecarlo simulation shows us that while the strategy might have strong upward trends in performance, a few bad trades can 'blow up' the profitability of such trades. It's also important to consider the broader market context that our test was based on when evaluating the performance of the straddle-selling strategy. Over the last three years, the market has experienced outsized realized volatility around earnings event days (EAD). This heightened volatility might explain the strategy's seemingly erratic performance.

To better understand the relationship between the premium priced into implied move calculations, we relied on the VRP, or Volatility Risk Premium. This is a financial metric that represents the compensation investors demand for taking on volatility risk. It is derived from the difference between implied volatility (market expectations of future volatility, often derived from options prices) and realized volatility (actual price fluctuations observed in the market).

$$VRP = IV^2 - RV^2$$

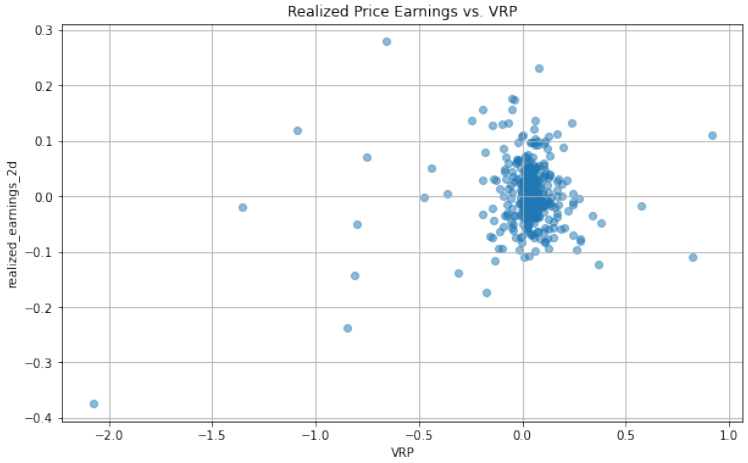


Figure 13: Realized Earnings level over VRP

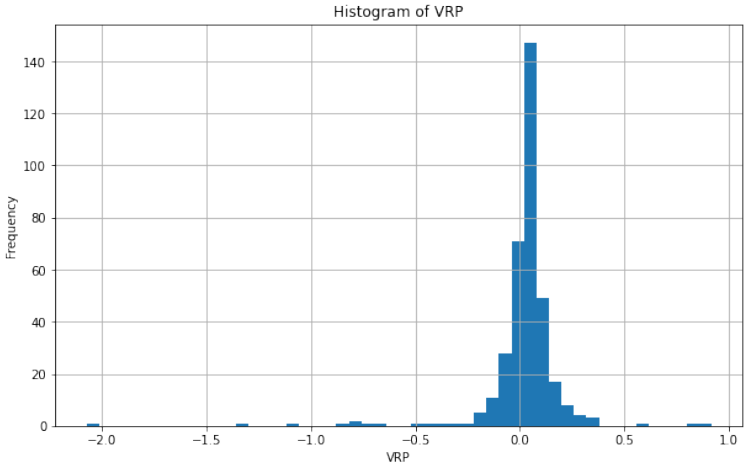


Figure 14: Distribution of VRP level

First note that we calculate RV from the 30 days after the earnings report. Next, when plotting for VRP we notice that there is generally relatively high clustered around the axis. Now showing a clear relationship between the level of VRP and realized earnings result. This suggests that there is generally not a very predictive case of paying more for VRP. Our histogram representation backs up this analysis as it shows a slight positive mean and concentration around the 0.1 VRP level. Our group also noted that the distribution of VRP levels seems to suggest that there is a nature of lognormality to it. The left seems to be slightly fatter closer to the median, while there is a tailing-off effect on the right tail till around 0.4.

6 Discussion

Broadly speaking, we find that negative IV skew correlates with increased earnings dispersion, while realized earnings versus expected moves show implied volatilities consistently explaining significant parts of actual moves. Volume skew analysis reveals a spike in call volume, highlighting the impact of market sentiment and macroeconomic factors on options trading. Our results seem to point towards there being a stronger market reaction to underperforming results than overperformance within revenue and EPS results. The general positive skew in skew seems to be a quite consistent factor within the system.

Applying the backtest underscores the need for effective risk management in volatile market conditions. Any straddle selling signal or strategy should foremost consider the correlation and sensitives between negative IV skew and increased earnings dispersion contributes to risk assessment. The optimal strategy should consider adjusting position sizes or avoiding straddle positions during periods of heightened negative IV skew based on fund-risk tolerance and LP requirements. Our data shows that there is a general reflection of close to 69% of realized moves within the pre-EAD implied volatilities, suggesting that generating substantial alpha will benefit from 'whisper' information and actionable EAD-related analysis/reports prior. To apply this, we would need to assess the accuracy of implied volatilities. The spike in call volume, which is a strong measure of market sentiment, can be combined with general investor and institutional sentiment analysis to understand how the market flows and the nature of sellers/buyers within the market. We also find that in general while premiums can be substantially more enticing in periods of extreme optimism or pessimism, our backtests suggest that a higher share strategy should reduce exposure across these periods.

Perceptions of analyst reports and earnings can also play a strong factor where the market's heightened response to underperformance (leading to negative realized results) suggests that any particular straddle we sell should have an emphasis on the downside risks. This might mean the trade is developed and passed through equity analysts and checked for various 'fundamentals' due diligence processes. In times of positive IV skew, our data suggests that there can be increased opportunities to capitalize on potential underlying

overperformance. The consideration of VRP models reveals the lack of clear predictability in paying more for VRP; our thresholds for buying into high VRP or selling low VRP straddles should thus be even higher. Integrating VRP trends into risk models enables dynamic adjustments to position sizes based on changing risk perceptions, preventing excessive exposure during uncertain periods and avoiding significant drops.

7 Conclusion

In conclusion, our analysis begins to shed light on the dynamics as well as the options pricing, market sentiment, and IV skews that go into pre-earnings event trading. Our study reveals correlations between negative implied volatility (IV) skew and heightened earnings dispersion. We further further strong evidence showing how implied volatilities consistently explain significant portions of realized moves, suggesting their reliability in gauging market expectations.

In our analysis, we recognized that there is a significant challenge of predicting directional price movements around earnings dates. Despite efforts to gauge the expected move, our study reveals that there is not a straightforward linear relationship, emphasizing the inherent unpredictability in the market during these critical periods. While our backtest doesn't rely on a signal or any particular market factors for its decision-making, we take a few major takeaways from the exercise into our discussion of ideal scenarios and risk management when selling volatility around earnings dates. The mean profitability remains negative, while the positive median suggests that there are instances of profitable trades, but outliers negatively impact the overall performance. This underscores the need for continuous refinement and adaptation, acknowledging the dynamic nature of market conditions.

Finally, we would like to leave the reader with a word of caution that engaging in options selling and buying around earnings days is akin to navigating a realm of considerable randomness. Without market trade flow information or material non-public information, it resembles more of a gamble than a calculated investment. As the renowned Warren Buffett once opined, selling naked options is like "picking up pennies in front of a steamroller", derivatives being akin to "financial weapons of mass destruction."

References

[1] Ball, Ray, and Philip Brown. *An Empirical Evaluation of Accounting Income Numbers. Journal of Accounting Research*, 6(2), 159–78, 1968. https://doi.org/10.2307/2490232

[2] Bollerslev, Tim, et al. *Expected Stock Returns and Variance Risk Premia. The Review of Financial Studies*, 22(11), 4463–92, November 2009. https://doi.org/10.1093/rfs/hhp008

[3] Dubinsky, Andrew, et al. *Option Pricing of Earnings Announcement Risks. The Review of Financial Studies*, 32(2), 646–87, 2019. https://www.jstor.org/stable/48616972

[4] Implied Binomial Trees - RUBINSTEIN - 1994. *The Journal of Finance*, 1994. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-⊆6261.1994.tb00079.x

[5] Jensen, Gerald R., and Robert R. Johnson. *Discount Rate Changes and Security Returns in the U.S., 1962–1991. Journal of Banking & Finance*, 19(1), 79–95, April 1995. https://doi.org/10.1016/0378-⊆4266(94)00048-⊆8

[6] Li, Jianhui, et al. *The Price of COVID-19-Induced Uncertainty in the Options Market. Economics Letters*, 211, February 2022. https://doi.org/10.1016/j.econlet.2021.110265

[7] Options Arbitrage in Imperfect Markets - FIGLEWSKI - 1989. *The Journal of Finance*, 1989. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-⊆6261.1989.tb02654.x