# No Max Pain, No Max Gain: Stock Return Predictability at Options Expiration

ILIAS FILIPPOU PEDRO A. GARCIA-ARES FERNANDO ZAPATERO

August 10, 2023

**Abstract**

*Max Pain price* is the strike price at which the total payoff of all options (calls and puts) written on a particular stock, and with the same expiration date, is the lowest. We construct a measure of (potential) Max Pain gain/loss, sort stocks according to this measure, and find that a spread portfolio that buys high Max Pain stocks and sells low Max Pain stocks generates large, positive and statistically significant returns and alphas. Our results provide strong evidence of stock return predictability at the expiration of the options. Finally, we find that these returns reverse after the options expiration week. This is all consistent with stock manipulation on the part of market participants with short option positions. Specifically, the Max Pain strategy is more profitable when traders have large written positions of Max Pain options around expiration. Our results are especially strong for relatively small and illiquid stocks.

We would like to thank Julio Crego, Benjamin Golez, Chris Jones, Dmitriy Muravyev, Neil D. Pearson (discussant), Miguel de Jesus (discussant), Francisco Perez, Aurelio Vasquez and seminar participants at 30th Finance Forum, ITAM finance conference, Boston University and ITAM for useful comments. The paper was a recipient of the best paper award at the 30th Finance Forum. Filippou: John M. Olin Business School, Washington University in St. Louis, iliasfilippou@wustl.edu; Garcia-Ares: Instituto Tecnológico Autónomo de México (ITAM), pedro.garcia@itam.mx; Zapatero: Questrom School of Business, Boston University, fzapa@bu.edu.

*Keywords*: Max Pain, stock price pressure, manipulation, option expiration.

*JEL Classification*: G12, G13, G14, G23.

# 1 Introduction

We test the *Max Pain theory* and show that it is possible to design long-short strategies based on an intuitive measure of Max Pain that generate large and statistically significant returns and alphas. The Max Pain theory states that as the expiration of the options approaches, stock prices converge to the *maximum pain price*, the strike price at which the total payoff of the options written on that stock and with that expiration will be the lowest. The Max Pain hypothesis is based on the investors' assumption that the majority of the options contracts expire worthlessly, and there must be a single point at which, if the contracts expire, would hurt the options buyers the most and least to the options writers.

The empirical validity of the Max Pain theory is consistent with possible stock price manipulation on the part of some market participants with exposure to the options payoffs. For example, institutional investors generate profits by writing call and put options and collecting the premiums from option buyers. Thus, they have an incentive to manipulate the stock price before the expiration of the options to cause most of the options to expire at-the-money or out-of-the money.

First we need to identify the Max Pain strike price corresponding to a particular stock for a particular expiration date. Suppose all the short positions in both calls and puts written on that stock and with that expiration were held by a single market participant. We take one of the strike prices and compute what would be the cost for the seller if the stock price finished at that strike price at maturity. Some options (puts and/or calls) would be out of the money, some would be in the money and their total cost would depend on the open interest of that option. We repeat this exercise for all strike prices, and the one that yields the lowest cost for the option seller is the Max Pain strike price.

Next we introduce our measure of Max Pain gain/loss. We define it as the difference between the Max Pain strike price on a particular day and the stock price on the same day, divided by the same stock price.

Last, we design a Max Pain strategy in the equities market. In particular, on the second Friday of each month -typically one week before the options expiration- we allocate stocks into deciles based on our Max Pain gain/loss measure. We hold our portfolio until the expiration of the attached options, in general, the third Friday of the month. We construct a zero-cost portfolio that buys high Max Pain stocks as according to the max pain theory their prices are supposed to go up to minimize option sellers losses and sells low Max Pain stocks as they are supposed to go down in price to reduce costs for the sellers. We find a positive and statistically significant return of the spread for both equally-weighted and value-weighted portfolios. The corresponding CAPM and Fama and French (1993) (FF3) alphas are also positive and significant. The source of profits to our Max Pain strategy is mainly coming from the positive returns generated by the high Max Pain stocks.

Our paper is related to Ni, Pearson, and Poteshman (2005) who show that changes in options trading can affect the price of the stocks. In addition, the prices of stocks with attached options tend to cluster at strike prices as the expiration date approaches. They show that hedge rebalancing by option market makers and/or price manipulation may contribute to explain this. The theory of maximum pain goes further, saying that the stock price will tend to move toward the price where the total value of options contracts, both puts and calls together, is the lowest. This theory thus identifies the specific option strike price that will tend to attract the stock price. If the stock price closes at the strike that minimizes the total value of options contracts, this minimizes the value received by buyers and paid by option sellers when the options expire. We verify this and show that the Max Pain strategy can exploit stock return predictability close to options expiration. We also show that max pain is different from the clustering effect documented by Ni et al. (2005)

as pinning is more pronounced for those portfolios in which max pain gain/loss is near zero (portfolios P5, P6 and P7) as hedge rebalancing cluster the stock price around the strike price and this is translated to a small max pain gain/loss.

We further test our results in Fama and MacBeth (1973) regressions: We regress the cross-section of stock returns on Max Pain as well as on other drivers of stock returns such as price, size, stock volume, institutional ownership, book-to-market ratio, debt-to-assets, stock reversals, momentum, stock illiquidity, and idiosyncratic volatility. We find that the coefficients of Max Pain remain highly positive and statistically significant. We find stronger results if we run this regression only for small, illiquid, or NASDAQ stocks which are found to be stocks more prone to manipulation. We also show that our results are not driven by return reversals. In addition, we establish that, on average, Max Pain stocks are growth stocks, illiquid, with low stock volume and low prices. We find similar results if we use abnormal returns following Daniel, Grinblatt, Titman, and Wermers (1997) (DGTW).

We also analyze strategies with different formation and holding periods within the option's life. Specifically, we form decile portfolios two weeks, three weeks, and four weeks prior to expiration, and we hold the portfolios until the expiration of the options, which is the third Friday of the month. Recall that in our baseline strategy, we form a portfolio one week prior to expiration as it is more likely for stock manipulation to occur during this period. We find that the strategies formed three and four weeks to expiration offer economically positive but not statistically significant returns and CAPM or FF3 alphas. Interestingly, returns increase as we get closer to the expiration of the options.

Additionally, we compute abnormal volume and order imbalances for all the stocks, sorted on Max Pain, one week before the options expiration. Abnormal volume is defined as the difference between the average daily volume of the third week of the month minus the average volume of the previous month.[1] Likewise, we compute abnormal order imbalances.

[1]We also compute abnormal volume based on the previous three, six and twelve months.

We find significantly higher abnormal volume for high and low Max Pain stocks. Similar results are obtained for abnormal imbalances, for which we show that investors are net buyers of high Max Pain stocks and net sellers of low Max Pain stocks during the third week of the month.

We also perform a placebo test to check if the payoff of the Max Pain strategy can be generated in another week within the lifespan of the options. Recall that the baseline strategy is based on the last week before the expiration of the options (third week of the month). In particular, in this placebo test, we form a portfolio two weeks before expiration and hold the portfolio for one week. The resulting returns and alphas are not statistically significant. This reinforces the possibility that price manipulation to minimize the cost of the short positions is a factor, because the third week of the month is when it would have to take place.

We examine the performance of the Max Pain strategy three weeks before and three weeks after its formation period. We build an event study where week 0 is the third week of the month. In this analysis, low Max Pain stocks yield positive returns one to three weeks before the formation period, while high Max Pain stocks pay negative returns. Notably, and consistent with the previous tests, the returns of high (low) Max Pain stocks become more negative (positive) the closer to the expiration date.

This pattern of increasing (decreasing) returns for low (high) Max Pain portfolios one to three weeks before the option expiration week is related to the construction of our Max Pain portfolios. Low Max Pain portfolios consist of stocks that have performed well in the past and for which investors have been buying more call options. For these stocks, the max pain theory predicts that their prices will go down closer to expiration to avoid the exercise of these call options. The reverse is supposed to happen for those stocks with more negative returns. Investors will tend to buy more put options instead. Max pain predicts that the price of these stocks will go up to leave these put options unexercised. Consistent with this argument, we find that the put-to-call open interest ratio increases with Max Pain in a monotonic fashion.

We also test whether we find evidence of reversals in a shorter period than a week after the expiration of the options. To verify that the movement in prices we observe in the expiration week is due to manipulation rather than information-based trading, we determine whether prices reverse on the first trading day after the expiration of the options. We find that the return is significantly more negative for the highest Max Pain stocks on the following day after expiration. We also employ NYSE Trade and Quote data (TAQ) to examine intraday evidence on intraday price patterns. We compute the stock returns for each thirty-minute interval between 9:30 and 16:00 and find that the price impact of these reversals is the strongest earlier in the day. This evidence indicates the possibility that some option sellers are pumping up (down) the price of the stocks with high (low) Max Pain during the expiration week and consistent with the reversion of a pure price pressure effect, the return right after expiration is significantly more negative (positive) for the same stocks.

We also examine the types of market participants that trade Max Pain. We find that the Max Pain strategy is highly significant when firms and public customers have large written option positions on the Max Pain options during the expiration week. This is in line with our conjecture as those investors that intend to manipulate the underlying stock price before the expiration date also increase their written option positions during the same period. We also find the Max Pain strategy is significant for low written open interest of firms and customers on the expiration date which implies that investors close their positions right before the expiration of the options.

We also consider alternative explanations. Specifically, we double sort portfolios of stocks based on the Market Maker net open interest and find that the Max pain strategy is significant only for purchased net open interest positions (when customers and firms are net sellers of these max pain options) and not when market makers are net sellers of options. This might suggest that market markets are less likely to manipulate the underlying stock prices. We also show that new delta hedging and covered call and protective put unwinding around expiration cannot explain the profits generated by the Max Pain strategy.

Next, as it is standard in studies related to options, we check whether our results hold for similar stocks without options. If manipulation that tries to minimize the cost of short positions in options is a factor, the strategy we have presented should not work for similar but non-optionable stocks, and that is, in a nutshell, what we find. More explicitly, we match stocks with and without options according to a propensity score based on size and volume.[2] We assign the Max Pain value of the optionable stock to its non-optionable match. We find that non-optionable stocks offer spread portfolios with negative and not statistically significant returns. We also find that our results are stronger when we consider stocks with at least two, three or four strike prices. Our results are also stronger when we compute the max pain strike based on increments of one cent between the lowest and the highest strike price per stock. Finally, we sort index stocks based on Max Pain and find that the strategy is insignificant. This is not surprising because index stocks comprise bigger stocks that are harder to manipulate.

**Theoretical Framework and Related Literature.** Our work contributes to a recent strand of the literature that examines the role of information flows between stocks and options markets (e.g., Pan and Poteshman, 2006; Ni, 2008; Cremers and Weinbaum, 2010; Ge, Lin, and Pearson, 2016; Cremers, Fodor, and Weinbaum, 2017) . For example, Hu (2014) finds that option-induced stock imbalance strongly predicts the cross-section of stock returns. In addition, option order imbalances offer important information for stock returns. Filippou, Garcia-Ares, and Zapatero (2021) show a substitution effect between lottery stocks and

[2]Our results are robust to different matching methods.

lottery options. Filippou, Garcia-Ares, and Zapatero (2022) find that investors with lottery preferences bet on the possibility of a short squeeze by buying call options.

On the other hand, Ni et al. (2005) and Golez and Jackwerth (2012) present evidence of a non-informational channel consistent with the hypothesis that rebalancing and unwinding of option market makers' delta hedges on or near option expiration causes the prices of individual stocks and stock index futures, respectively, to cluster or "pin" at option strike prices on option expiration dates. Ni, Pearson, Poteshman, and White (2021) find that rehedging away from expiration also changes stock price movements and influences stock return volatility and the likelihood of stock price jumps. Avellaneda and Lipkin (2003) describe a potential mechanism for these findings by examining the time derivatives' role in the options delta. Specifically, investors with delta-hedge positions that are net buyers (sellers) of options will take opposite positions in the stock when the stock price exceeds the option strike price, and they will buy (sell) the stock otherwise. This way, they will drive the stock price toward the option strike price.

We also contribute to the literature which examines stock price manipulation. Ni et al. (2005) also show that stock price manipulation by investors who write options in the week leading up to expiration contributes to the expiration date clustering of optionable stocks at strike prices. Blocher, Engelberg, and Reed (2012) show that short-sellers exercise selling pressure in the last minutes of the year to inflate their returns. Ben-David, Franzoni, Landier, and Moussawi (2013) provide evidence of stock manipulation by hedge funds on reporting dates. Henderson, Pearson, and Wang (2020) show that some issuers of structured equity products (SEPs) manipulate underlying stock prices on the SEPs' pricing dates. Allen and Gale (1992), in a different setting, show that in a rational expectations model, where agents are utility maximizers, it is likely for an uninformed manipulator to generate profits, given that investors perceive the manipulator as an informed trader.

The rest of the paper is organized as follows: in section 2 we develop the hypotheses about the option writers incentive to manipulate security prices. In section 3 we describe the data and portfolio construction. Section 4 focuses on the empirical results. Section 5 develops alternative hypothesis. Section 6 provides a broad range of robustness and other specification tests, and section 7 concludes.

## 2 Development of the Hypotheses

Max pain occurs when market makers reach a net positive position of call and put options at a strike price where option holders stand to lose the most money. By contrast, option sellers may reap the most after selling more options than buying and causing them to expire worthless. We aim to test whether option sellers try to drive the underlying stock price toward this particular strike price. More formally,

**Hypothesis 1** (H1)**.** *Optionable Stocks with high (low) Max Pain gain/loss exhibit:*

*(a.) abnormal positive (negative) returns during the third week of the month.*

*(b.) abnormal negative (positive) returns following the turn of the following week.*

We expect that optionable stocks exhibit returns that are abnormally higher (lower) during the expiration week of the options (third week of the month) for high (low) max pain portfolios. These returns are due to price pressure, so we expect that prices revert following the turn of the following week.

**Hypothesis 2** (H2)**.** *Optionable Stocks with high (low) Max Pain gain/loss exhibit:*

*(a.) abnormal volume during the third week of the month.*

*(b.) abnormal buying (selling) pressure during the third week of the month.*

*(c.) significantly more demand from institutional investors.*

*(d.) less demand from retail investors.*

According to our second hypothesis, some option sellers such as large institutions that hedge large positions of their portfolios will attempt to manipulate the underlying stocks in where they have large short positions by buying or selling shares of those stocks up the third week of the month. If our conjecture is valid, we would observe abnormal volume and buying (selling) pressure in stocks with high (low) max pain gain/loss the third week of the month and abnormal volume and selling (buying) pressure the week after expiration.

**Hypothesis 3** (H3)**.** *Small, illiquid and growth stocks are more likely to be manipulated.*

To assess whether the predicted patterns are the result of intentional manipulation, we examine whether such patterns are more evident in settings where manipulation is likely to be most effective. In particular, we expect the manipulation to be stronger and more effective on small and illiquid stocks as they tend to be more mispriced and easier to manipulate. In other words, the bang for the buck is higher for this type of stocks and there is a lower cost of manipulation. These stocks exhibit a high degree of information asymmetry are the more prone to manipulation (e.g. Aggarwal and Wu (2006)).

**Hypothesis 4** (H4)**.** *Stocks without options are less likely to be manipulated.*

Next, we expect stocks without options to be less manipulated as investors do not have the incentive to manipulate these stocks.

**Hypothesis 5** (H5)**.** *Manipulation is more likely as we get closer to the expiration of the options.*

We also expect the possibility of manipulation to increase as we get closer to the expiration of the options because option sellers have higher incentives to manipulate the underlying stocks. Doing so would cause most of the options to expire worthless and thus inflict "max pain".

**Hypothesis 6** (H6)**.** *Max Pain profits will be higher when option sellers have large written option positions in the days leading up to expiration.*

We expect the Max Pain strategy to be more profitable for high written volume positions of Max Pain options because traders who intend to manipulate also have an incentive to increase their selling positions before expiration.

Overall, our hypothesis test the basic idea that as the option expiration approaches, option writers will try to buy or sell shares of stock to drive the price toward a closing price that is profitable for them, or at least to hedge their payouts to option holders.

# 3 Data and Portfolio Construction

## 3.1 Stock and Option Data

**Stock Data.** Our daily and monthly stock returns and daily trading volume are obtained from the Center for Research in Security Prices (CRSP), including New York Stock Exchange (NYSE), American Stock Exchange (AMEX), and NASDAQ markets, as well as common stocks with share codes 10 and 11, financials and non-financials. The data span the period from January 1996 to December 2021. We also use accounting information for these stocks from the Compustat database.

**Option Data.** We collect options data from the OptionMetrics IvyDB database and for all exchange-listed options on U.S equities. We focus on the end-of-day bid and ask quotes, trading volume, open interest, strike prices, deltas, gammas, and implied volatility. The data span the period from January 1996 to December 2021.

We eliminate observations not satisfying several criteria to guard against tradability concerns. First, to avoid illiquidity concerns, we remove options with no option interest, options for which the ask price is lower than the bid price, the bid price is equal to zero, or the average of the bid and ask quote is less than 0.125 dollars. Second, to remove the effect of the early exercise premium in American options, we exclude options whose underlying stock pays a dividend during the remaining life of the option. Finally, we exclude all options that violate arbitrage restrictions.

**High Frequency Data.** We collect intraday stock prices from TAQ. We consider 30 minute intervals between 9:30 and 16:00. We apply standard filters to clean the data as in Ben-David et al. (2013). Firstly, we eliminate the corrected trades and all trades with conditions O, B, Z, T, L, G, W, J or K. Second, we drop trades with missing size and no price information, that satisfy the condition that they are made before 16:00 or before a closing price (trade condition of 6, @6, or M), is created. Intraday returns are calculated as the difference between the log price of the last trade during the 30-minute window and the last trade log price before the start of the 30-minute window. We set to zero the returns with no trading during the 30-minute window. The data span the period of January 1996 to December 2014.

**Stock Imbalances.** We collect buy and sell trades from TAQ. The trades are signed following the Lee and Ready (1991) procedure. The data span the period from January 1996 to December 2021. We define the order imbalance of stock $i$ at time $t$ as $OIB_{i,t} = (Buy_{i,t} - Sell_{i,t})/(Buy_{i,t} + Sell_{i,t})$ where $Buy_{i,t}$ ($Sell_{i,t}$) denotes the dollar value of buy (sell) orders of stock $i$ at time $t$.

**Signed Option Volume.** We also collect daily option buy and sell volume from four exchanges: NASDAQ GEMX (GEMX), NASDAQ International Security Exchange (ISE), NASDAQ Options Market (NOTO), and NASDAQ PHLX (PHOTO). Specifically, the dataset includes option volume of open buy, open sell, close buy and close sell orders. Each category include different types of participants: broker/dealer, proprietary firms, and public customers. Then, we sum the buy and sell trades to compute the long and short open interest at the participant level. The four exchanges account for significant portion of the options market. However, we do not consider other exchanges and OTC markets. The datasets cover different time periods. Specifically, ISE covers the period of May 2005 to December 2021, GEMINI is from August 2013 to December 2021, NOTO is from November 2011 to December 2021 and PHOTO is from January 2009 to December 2021.

**Max Pain Strike Price.** One component of the Max Pain Gain Loss is the strike price associated with the minimum loss of Max Pain. Specifically, for each stock, we collect all the strike prices of the attached options. Then we compute the loss of call and put writers assuming that the stock price at expiration is equal to each of the strike prices of the attached options. We multiply the losses by open interest.[3] Intuitively, the strike price with the highest number of outstanding contracts is the price at which the stock could create the biggest losses for option buyers. For example, if a stock has only one call and one put option attached, we compute the loss of the call and put writer, assuming that the stock's price at expiration will equal the strike price of the call option. Then we sum the losses for the two options. We repeat the same exercise for the put option's strike price (e.g., we assume that the stock price at expiration will be equal to the put option's strike price) and calculate the corresponding total call and put loss for an option writer. The Max Pain will be the minimum loss across the two strike prices. The Max Pain strike price will be the strike price associated with the minimum loss.

**Max Pain.** We define as Max Pain the gain/loss implied by the max pain strategy. Specifically, the Max Pain gain/loss (our sorting variable) will be the difference between the Max Pain strike price and the stock price (e.g., $MaxPain = (X^{MaxPain} - S^{2ndFriday})/S^{2ndFriday}$) the second Friday of the month which is the day that we form our portfolios. For simplic-

[3] We take into account that open interest from Optionmetrics is lagged by one day after November 28, 2000. Prior to this date, the open interest is not lagged.

ity, we label the Max Pain gain/loss as Max Pain. We provide a detailed example of the construction of the measure in Section 2 of the Internet Appendix.

Figure 1 offers two examples of Max Pain gains and losses. The top left panel shows the Max Pain (in millions) of put and call options of GameStop Corp. (GME) for different strike prices on March 12, 2021. The top right panel shows the total Max Pain. We find that the strike price, associated with the minimum loss (e.g., Max Pain strike price), is \$150, and the stock price on the second Friday of the month (formation period) is \$264.5. Thus, the Max pain loss or Max Pain for GME is $(150-264.5)/264.5 = -43.29\%$. GME stock price is supposed to go down by more than 43% in order to minimize losses for the option sellers.

We also show an example of Max Pain gain. The bottom left panel shows the Max Pain (in millions) for calls and puts of Moderna Inc. (MRNA) for different strike prices on September 11, 2020. The bottom right panel shows the total Max Pain. The Max Pain strike price is \$69.5 and the stock price on the second Friday of the month is \$59.5. Thus, the Max Pain gain is $(69.5-59.5)/59.5 = 17.75\%$. According to max pain, Moderna stock price is expected to go up by 18% to reduce option seller losses.

[Figure 1 about here.]

**Institutional Ownership.** We collect end-of-quarter institutional stock holdings from the 13F form of the SEC (Thomson Reuters Institutional, included in WRDS). The data span the period from January 1996 to September 2021.

## 3.2 Max Pain Portfolios

We form decile portfolios of stocks that are sorted based on the Max Pain (e.g., the difference between the strike price of Max Pain with the stock price on the second Friday of the month) one week before the expiration of the options, which is typically the third Friday of the month. In particular, we form portfolios on the second Friday of each month and hold them for one week, which refers to the expiration date of the attached options. We offer results of equally-weighted and value-weighted portfolios. We construct a zero-cost portfolio that buys stocks with high Max Pain and sells stocks with low Max Pain.

In Figure 2 we present an example of the construction of our portfolios in May 2012. Specifically, we build our portfolio on Friday 11th of May, 2012, and holds it until the 18th of May, which refers to the option's last trading day.

[Figure 2 about here.]

# 4 Empirical Results

## 4.1 Summary Statistics

We first present time-series averages of median characteristics of stocks sorted into deciles based on Max Pain. *Panel A* of Table 1 shows time-series averages of the median Max Pain of decile portfolios of call options sorted based on Max Pain every month, as well as the spread in Max Pain between the extreme portfolios. We find that the median max pain is -0.081 in the lowest decile and 0.076 in the highest decile rendering a difference of 0.157, which is statically significant.

*Panel B* of table 1 reports additional characteristics of such portfolios. In particular, we find that high Max Pain portfolios tend to have lower institutional ownership ($IOR$), debt-to-assets ($D/A$), reversals (previous month return), momentum, idiosyncratic volatility, stock price, size in comparison to low Max Pain portfolios. At the same time, we find that the high Max Pain portfolios exhibit high book-to-market ratios and illiquidity. We do not observe statistical differences between low and high Max Pain portfolios in the NASDAQ membership, stock volume, idiosyncratic volatility and debt-to-assets.

Finally, we observe that the absolute difference between closing prices (closing pricing the third Friday of the month) and nearest strike prices is the lowest for the middle portfolios (P5, P6 and P7) compare to stocks with high and low Max Pain.

[Table 1 about here.]

## 4.2 Univariate Sorts

We allocate stocks into portfolios on the second Friday of each month and hold the portfolio until the expiration of the underlying options, typically the third Friday of the month. We repeat this exercise every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits using the the CRSP Cumulative Factor to Adjust Price (cfacpr).

*Panel A* of table 2 reports returns of equally-weighted and value-weighted decile portfolios that are sorted every month based on Max Pain. We find that the return of the spread portfolio is positive and statistically significant (0.4%) , which indicates a strong economic value of max pain for the cross-sectional stock returns. In other words, our findings shed more light on the role of options in the mispricing of the underlying securities. We find similar results also in *Panel A* for value-weighted portfolios. *Panel B* of Table 2 reports alphas of the risk-adjusted spread portfolios based on CAPM and FF3 asset pricing models. In all cases, the strategy offers positive and statistically significant alphas of the spread portfolios. This is the first piece of evidence consistent with Hypothesis H1a, indicating the possibility that some option sellers are pumping up (down) the price of the stocks for which they are selling options when the expiration of these options approaches.

[Table 2 about here.]

## 4.3 Cross-Sectional Regressions

In the previous subsection, we have studied the cross-sectional predictive ability of Max Pain without taking into consideration other factors that might drive the cross-sectional variation of stock returns. To further explore the relationship between Max Pain and stock returns, we perform a cross-sectional regression that projects stock returns at time $t+1$

on several predictor variables at time $t$. Table 3 reports the average coefficient of such regression and the corresponding average adjusted R-squared. The set of predictor variables (e.g., $Controls$) includes the stock illiquidity, price, size, book to market, debt to assets, stock volume (SVOL), institutional ownership (IOR), idiosyncratic volatility (IVOL), stock reversals, and momentum. We show results for the entire sample and for small, illiquid, and Nasdaq stocks. Specifically, we focus on the model below:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1} \tag{1}$$

where $Ret_{i,t+1}$ represents the return of stock $i$ at time $t+1$. Table 3 shows that Max Pain is a strong positive predictor of the cross-section of stock returns even after controlling for other drivers of stock returns. It is worth mentioning that reversals cannot explain the cross-sectional predictive ability of Max Pain. This finding also reinforces our first hypothesis (H1a).

Aggarwal and Wu (2006) demonstrate that manipulation is not equally likely across all stocks. Specifically, they show that manipulation is more likely among NASDAQ stocks, illiquid stocks, and small stocks. In line with this, we find that our max pain coefficients are more economically and statistically significant for small stocks, illiquid stocks, and NASDAQ stocks.[4] This is consistent with the idea that manipulators would focus on stocks on which they can have large price impact. These results are strongly consistent with the prediction of Hypothesis H3.

[Table 3 about here.]

[4]We sort all stocks in our sample in quintiles and we run the cross-sectional regressions for all the stocks that belong to the smallest quintile in terms of size and the highest quintile for stock illiquidity.

## 4.4 Different Holding and Formation Periods

Here, we consider the different formation and holding periods. In our main analysis, we buy a stock a week before expiration and hold it until expiration. Table 4 shows average stock returns sorted based on max pain for different holding and formation periods. We form portfolios two, three, or four weeks before expiration. In all cases we hold the portfolios until expiration. We show results for equally-weighted and value-weighted portfolios. *Panel A* of Table 4 shows average stock returns of such portfolios. In any case, we find that the strategies that consider the different formation and holding periods within the life of the options offer economically positive but not statistically significant Max Pain spread portfolios. Interestingly, we observe that the return of the spread portfolios in *Panel A* decreases, and it is less significant the farther we are from the expiration date of the attached options as the likelihood of stock manipulation decreases. This finding is line with our fifth hypothesis (H5) which states that manipulation is stronger as we get closer to the expiration of the options.

[Table 4 about here.]

## 4.5 Trading Activity during the Holding Period

**Abnormal Volume.** *Panel A* of Table 5 reports time-series averages of abnormal volume of stocks sorted into deciles based on Max Pain. We form portfolios on the first, second, or third Friday of the month. We compute abnormal volume as:

$$AbnormalVolume_{w,m} = Volume_{w,m} - \overline{Volume_{m-1 \to m-n}}, \tag{2}$$

where $Volume_w$ represents the average daily volume (expressed in millions) over the last week $w$ of month $m$ before the expiration of the option and $\overline{Volume_{m-1 \to m-n}}$ is the average daily volume over the months $m-n$ to $m-1$ where $n = 1, 3, 6, 12$. We find that the abnormal stock volume is concentrated in low and high max pain portfolios. These portfolios contain stocks that are supposed to go up or go down significantly according to the max pain theory. Specifically, the difference between the time-series average of P10 and P1 is positive and not statistically significant, but the differences between portfolios P10 and P5 and P1 and P5 are also highly positive and significant. The results are similar if we compute the abnormal volume against the previous three, six, or twelve-month average stock volume. This finding supports our second hypothesis (H2).

**Abnormal Order Imbalances.** Our second hypothesis (H2) also highlights that optionable stocks with high (low) Max Pain gain/loss exhibit abnormal buying (selling) during the third week of the month. *Panel B* of Table 5 reports time-series averages of abnormal order imbalances of stocks sorted into deciles based on Max Pain. We form portfolios on the first, second, or third Friday of the month. We compute abnormal volume as:

$$AbnormalOIB_{w,m} = OIB_{w,m} - \overline{OIB_{m-1 \to m-n}}, \tag{3}$$

where $OIB_w$ represents the average daily order imbalance over the last week $w$ of month $m$ before the expiration of the option and $\overline{OIB_{m-1 \to m-n}}$ is the average daily volume over the months $m-n$ to $m-1$ where $n = 1, 3, 6, 12$. We find that investors are net buyers of high Max Pain portfolios and net sellers of low Max Pain portfolios. The difference in order imbalances between high and low Max Pain portfolios is statistically significant. We find similar results for abnormal order imbalances that are measured against average imbalances of the previous three, six, and twelve months.

[Table 5 about here.]

### 4.6 Placebo Test

Our previous results indicate that the Max Pain strategy is more significant the closer we are to the expiration of the attached options. Here we consider a placebo test where we form a portfolio two weeks to expiration (instead of one week to expiration) and hold the portfolio for one week instead of waiting until the expiration of the options.

*Panel A* of Table 6 report average stock returns of portfolios sorted based on Max Pain two weeks to the expiration of the attached options. We show results for equally-weighted and value-weighted portfolios. In line with our conjecture, we find that a strategy that is lagged by one week (in comparison to the previously reported Max Pain strategy) offers spread portfolios that are not economically and statistically significant. We find in *Panel B* that the corresponding alphas are not statistically significant. This finding indicates that the return pattern observed in Table 2 is not mechanical and reflects the trading activity of investors attempting to manipulate the attached stocks. This finding supports our fifth hypothesis (H5) because the possibility of a manipulation is stronger as we get closer to the expiration of the option.

[Table 6 about here.]

### 4.7 Weekly Performance of Max Pain before and after the Formation Period

In this section, we examine the performance of the Max Pain strategy in periods before and after the third week of the month. We form decile portfolios of stocks that are sorted on Max Pain on the second Friday of each month. Then we compute the average return of the same portfolios three weeks before and the three weeks after the third week of the current month.

Figure 3 shows weekly stock returns of stocks with low and high Max Pain. Week 0 refers to our formation period, the second Friday of the month. We form decile portfolios in Week 0 and report the return of low and high Max Pain portfolios. Then we report in weeks -3 to -1 and Week 1 to Week 4 the returns of the low and high Max Portfolios we selected in Week 0. In this way, we examine the performance of low and high Max Pain stocks three weeks before and four weeks after the formation period. Our findings verify our previous findings. Specifically, we find that low Max Pain stocks exhibit very positive returns the weeks before the formation period that reverse during the third week of the month. We also find that high Max Pain portfolios offer very negative returns that become more negative as we get closer to the formation period and their returns reverse and become positive during the holding period. This is in line with our first hypothesis (H1a).

The pattern of returns before the third week of the month is related to the construction of our max pain portfolios. In the case of those stocks that performed well in the past, investors will tend to buy more calls options at lower prices as they believe that these stocks will continue going up in the future. For these stocks, the max pain theory predicts that they will go down closer to expiration to avoid the exercise of these call options. The reverse is supposed to happen for those stocks that performed badly in the past. Investors will tend to buy more put options at higher prices as they believe that the downward trend will continue. Max pain predicts that the price of these stocks will go up to leave these put options unexercised.

[Figure 3 about here.]

## 4.8 Daily Returns after the Options Expiration date

We now examine whether there are reversals after the option expiration date. If the movements in the week prior to option expiration are due to manipulation of the underlying stock price, then the stock price movement should reverse right after the option expiration date. We now test whether we find evidence of reversals in a shorter period after the expiration of the options. In other words, we are testing our first hypothesis (H1b).

To examine the performance of stocks after the expiration date, we run a cross-sectional regression of stock returns 1, 2 and 3 days after expiration on Max Pain computed the second Friday of the month (formation period). Specifically, our cross-sectional regression takes the following form:

$$AbRet_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1} \tag{4}$$

where $AbRet_{i,t+1}$ represents the stock abnormal return at time $t+1$. We compute abnormal returns following Daniel et al. (1997) (DGTW). We partition the stock data into low and high Max Pain stocks as they exhibit different characteristics. In this way, we can identify the group of stocks that reverses after the expiration date. To this end, we report results for stocks with Max Pain above or below its median. *Panel A* shows results for stocks with Max Pain above the median. We find that there is a strong reversal the day after expiration as the coefficient of the Max Pain is -1.3%, and it is statistically significant. We do not observe statistically significant coefficients for the subsequent days. *Panel B* shows results for stocks with Max Pain below the median. We do not find daily reversals for low Max Pain portfolios.

[Table 7 about here.]

## 4.9 Intraday Returns after the Options Expiration date

We also employ NYSE Trade and Quote data (TAQ) to examine intraday evidence on price patterns. We compute the stock returns for each thirty-minute interval between 9:30 and 16:00. We expect a reversal to occur after the opening of the market.

Table 8 shows results for cross-sectional regressions of thirty-minute interval returns on Max Pain computed on the second Friday of the month. Specifically, our cross-sectional regression takes the following form:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1} \tag{5}$$

where $Ret_{i,t+1}$ represents the stock return at time $t+1$. *Panel A* shows results for stocks with Max Pain above the median. We find that there is a strong reversal in the first half an hour of the market opening. *Panel B* shows results for stocks with Max Pain below the median. Interestingly, we find a positive and statistically significant coefficient for the first half an hour which shows evidence of a reversal for low Max Pain stocks using intraday data. This pattern shows strong evidence of return reversal in line with our hypothesis 1 (H1b).

Overall, our results show that stocks with high (low) max pain exhibit abnormally high (low) returns in the expiration week of the options and abnormally low (high) returns in the first hours of the following day after expiration.

[Table 8 about here.]

## 4.10 Who Trades Max Pain?

In this section, we show further evidence of potential stock price manipulation before the expiration date of the options. We show the performance of the Max Pain strategy for low and high written volume and open interest for proprietary firms and public customers during the expiration week. We focus on the volume of the options with a strike price that is associated with the minimum loss of the option sellers (e.g., Max Pain) and that we used to compute the Max Pain gain loss. These variables offer measures of either the possible intention or the incentive of the different market participants to manipulate stock prices. In other words, investors who intend to manipulate prices before the expiration date might write options in the days before expiration and/or try to close their written positions right before expiration (e.g, Ni et al. (2005)). Specifically, our hypothesis is that if option sellers are the manipulators, then one would expect to see higher profits for our Max Pain portfolios when these traders have large written positions and not see any profits when they do not.

*Panel A* of Table 9 shows average returns of stocks that are sorted into quintiles based on the firms written volume of Max Pain options during the expiration week, and then within each portfolio, we sort into quintiles based on Max Pain Gain/Loss. We find that the Max Pain strategy offers positive and statistically significant returns only for high written volume portfolios. This is in line with our conjecture (H6) that large players such as firms would have more incentive to manipulate prices before the expiration of the options by placing sell orders. *Panel B* show similar results for public customers.

*Panel C* and *Panel D* of Table 9 shows the corresponding results for firms and public customers written open interest that is computed on the third Friday of the month. We find that the Max Pain strategy is profitable for low-written open-interest portfolios. This is in line with our conjecture that investors close their written positions right before expiration.

[Table 9 about here.]

# 5 Alternative Hypotheses

In the previous sections, we find that the Max Pain strategy is highly profitable and it reverses the day after expiration. This finding is stronger for option sellers. This is in line with price pressure from market participants who attempt to manipulate prices before the expiration. Here, we examine alternative explanations of this finding.

**Market Maker Net Open Interest.** *Panel A* of Table 10 shows average returns of portfolios of stocks that are sorted into quintiles based on the market makers' net open interest and then within each portfolio we sort based on the Max Pain. We focus on stocks with options with a strike price that is associated with the minimum loss of the option sellers (e.g., Max Pain) and that we used to compute the Max Pain gain loss. We find that the Max Pain strategy is significant only for high net open interest portfolios. This might indicate that market makers are not involved in price manipulation as they have a purchased net position as firms and customers are net sellers of Max Pain options.

**New Delta Hedging.** *Panel B* of Table 10 presents the corresponding results for new delta hedging positions which is defined as the delta-adjusted Thursday-to-Friday change in net market maker open interest that is aggregated across all calls and puts on the underlying stock. We find that the Max Pain strategy is significant for high new delta hedging, but the spread portfolio is significant at the 10% significance level. This finding indicates that new purchase delta hedging positions cannot explain the Max Pain strategy.

**Covered Call and Protective Put Unwinding.** *Panel C* shows results for unwinding of covered call and protective put positions on the third Friday of the month. For protective puts, we consider the purchased open interest of expiring OTM puts at the close on Friday. For covered calls, we include the written open interest of expiring OTM calls at the close on Friday. We find that the Max Pain strategy is significant for both low and high unwinding portfolios. This finding indicates that the unwinding of covered calls and protective puts cannot explain the Max Pain strategy.

[Table 10 about here.]

# 6 Robustness

## 6.1 Reversals and Written Option Volume

In a previous section, we show that the Max Pain strategy is significant for high written volume which indicates that investors who attempt to manipulate the stock have also an incentive to write max pain options before expiration. Thus, we expect the reversal to be stronger for these stocks. We examine this hypothesis in Table A6 and Table A7 of the Internet Appendix. Specifically, we run a cross-sectional regression of abnormal stock returns 1, 2 and 3 days after expiration on the Max Pain on the second Friday of the month. We show results for low and high written sell volume. *Panel A* of Table A6 shows results for firms with high sell volume. We find strong evidence of a reversal the first day after expiration. *Panel B* shows results for low sell volume. In line with our conjecture, we do not observe a reversal for these stocks. Table A7 shows similar results for customers.

## 6.2 Put to Call Open Interest Ratios

Table A8 of the Internet Appendix reports time-series average of the median put to call open interest portfolios. We find that the put-to-call open interest ratio increases with Max Pain in a monotonic fashion. The difference between high and low Max Pain portfolios is highly positive and significant, indicating higher open interest for put (call) options for high (low) Max Pain portfolios. These results are in line with the role of options and the performance of max pain before the third week of the month.

## 6.3 Abnormal Returns

We show cross-sectional regressions of abnormal returns on Max Pain and control variables. Table A9 of the Internet Appendix reports the average coefficient of such regressions and the corresponding average adjusted R-squared. The set of predictor variables (e.g., $Controls$) includes the stock illiquidity, price, size, book to market, debt to assets, stock volume (SVOL), institutional ownership (IOR), idiosyncratic volatility (IVOL), weekly reversals, monthly reversals, and momentum. We show results for the entire sample, small, illiquid, and Nasdaq stocks. Specifically, we focus on the model below:

$$AbRet_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1} \tag{6}$$

where $AbRet_{i,t+1}$ represents the abnormal return of stock $i$ at time $t+1$. We compute abnormal returns following Daniel et al. (1997) (DGTW). Table A9 of the Internet Appendix shows that Max Pain is a strong positive predictor of the cross-section of stock returns even after controlling for other drivers of stock returns. We also find that our results are robust to different subgroups, namely, small stocks, illiquid stocks and NASDAQ stocks. This finding supports our second hypothesis (H2).

## 6.4 Stocks with and without Options

Our main analysis focuses on stocks with options. Here we test whether the stock pattern we observe in Max Pain sorted portfolios is solely related to the information of the attached options, which correspond to Max Pain. In other words, similar stocks without options should not render a significant pattern. To this end, we match stocks with and without options based on size and volume using propensity score matching. We apply a one-to-one matching without replacement. Then we assign the Max Pain values of each optionable stock to a non-optionable stock with similar characteristics. We sort stocks with and without options based on Max Pain for the matched samples. We find in *Panel A* of Table 11 that only stocks with options render a positive and statistically significant return, indicating that our finding is inherited from the options market. We find similar results, in Panel B, for the CAPM and FF3 alphas of the spread portfolios. This finding supports our fourth hypothesis (H4).

[Table 11 about here.]

## 6.5 Max Pain with Different Number of Strike Prices per Stock

In our main analysis, we consider all stocks, regardless of the number of the attached options. Here we examine if our results are affected by the number of strike prices for the attached options.

*Panel A* of Table 12 reports average returns of stocks sorted based on Max Pain when we only consider stocks that have at least 2, 3 or 4 strikes available. We find that our results hold regardless of the minimum number of available strike prices. All portfolios are value-weighted. *Panel B* shows the alphas of the portfolios that are positive and statistically significant.

[Table 12 about here.]

### 6.6 Max Pain with More Strike Prices

To account for a larger variation of strikes, we consider strike prices between the lowest and highest strike price per stock in increments of one cent. In this way, we consider all possible strike prices within the range of the observed strikes and effectively look for the max pain price in where the losses of the option writers are the lowest. Then, we calculate the Max Pain based on this set of strikes.

*Panel A* of Table 13 shows stock returns of portfolios that are sorted on Max Pain that is constructed based on a larger number of strikes. We find that the Max Pain strategy offers positive and statistically significant spread portfolios. *Panel B* shows the corresponding alphas that are positive and statistically significant.

[Table 13 about here.]

### 6.7 Index Options

Our previous analysis indicates that the Max Pain strategy is more concentrated in groups of illiquid stocks with low book-to-market ratios. Thus, we expect the strategy to perform poorly for index options as they comprise large stocks. *Panel A* of Table 14 shows returns of index options that are sorted into terciles based on Max Pain. We find the average index return to the Max Pain strategy decreases with Max Pain rendering a spread portfolio that is negative and not statistically significant. We also report the corresponding average values of Max Pain, which significantly increase with Max Pain pain, but this pattern does not translate to significant return spread portfolios. We find similar results, in *Panel B*, for the alphas of the spread portfolio. This finding supports our third hypothesis (H3) because index options include large and liquid stocks.

[Table 14 about here.]

# 7 Conclusions

In this paper, we test the empirical validity of the maximum pain theory. We construct a measure of Max Pain price increases and/or decreases and form decile portfolios on the second Friday of each month. We hold the portfolios for one week. We find that a spread portfolio that buys high Max Pain stocks and sells low Max Pain stocks offers very positive and statistically significant returns. We find similar results for alphas. We also show that these abnormal returns revert following the turn of the following week. We then examine the types of market participants that trade Max Pain and find that the Max Pain strategy and the reversals are highly significant when firms and public customers have large written option positions. This is in line with our conjecture as those investors that intend to manipulate the underlying stock price before the expiration date also increase their written option positions during the same period.

Our results are similar in cross-sectional regressions when we control for other drivers of stocks returns. We find that high Max Pain portfolios tend to be growth stocks that are small and illiquid. We compute abnormal stock volume and order imbalances of stocks sorted based on Max Pain and find that High (Low) Max Pain stocks have higher abnormal volume and order imbalances. We also construct a placebo test where the formation period is the first Friday of the month and we hold the portfolios for one week. We find that the spread portfolio of this strategy is not statistically significant.

We also show that the strategy is insignificant if we form portfolios two, three, or four weeks to expiration and hold them until expiration. However, the strategies' returns become more significant the closer we get to the expiration of the options. We also construct a similar strategy for stocks without options. Specifically, we match stocks with and without options based on size and volume and assign each optionable stock's Max Pain value to its non-optionable pair. We form decile portfolios on the second Friday of the month based on Max Pain for both groups of stocks, and we find that the strategy is significant only for stocks with options. In this way, we verify that our results depend on the information obtained from the options market.

# References


Aggarwal, R. and G. Wu (2006). Stock market manipulations. *The Journal of Business 79*, 1915–1953.

Allen, F. and D. Gale (1992). Stock-price manipulation. *The Review of Financial Studies 5*(3), 503–529.

Avellaneda, M. and M. D. Lipkin (2003). A market-induced mechanism for stock pinning. *Quantitative Finance 3*(6), 417.

Ben-David, I., F. Franzoni, A. Landier, and R. Moussawi (2013). Do hedge funds manipulate stock prices? *The Journal of Finance 68*(6), 2383–2434.

Blocher, J., J. Engelberg, and A. V. Reed (2012). The long-short wars: Evidence of end-of-year manipulation by short sellers. *Available at SSRN 1364835*.

Cremers, M., A. Fodor, and D. Weinbaum (2017). How do informed option traders trade. *Option trading activity, news releases, and stock return predictability. University of Notre Dame Working Paper*.

Cremers, M. and D. Weinbaum (2010). Deviations from put-call parity and stock return predictability. *Journal of Financial and Quantitative Analysis 45*(2), 335–367.

Daniel, K., M. Grinblatt, S. Titman, and R. Wermers (1997). Measuring mutual fund performance with characteristic-based benchmarks. *The Journal of finance 52*(3), 1035–1058.

Fama, E. F. and K. R. French (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics 33*(1), 3–56.

Fama, E. F. and J. D. MacBeth (1973). Risk, return, and equilibrium: Empirical tests. *The Journal of Political Economy*, 607–636.

Filippou, I., P. A. Garcia-Ares, and F. Zapatero (2021). Demand for lotteries: The choice between stocks and options. *Available at SSRN 3016462*.

Filippou, I., P. A. Garcia-Ares, and F. Zapatero (2022). Betting on the likelihood of a short squeeze. *Available at SSRN 3437085*.

Ge, L., T.-C. Lin, and N. D. Pearson (2016). Why does the option to stock volume ratio predict stock returns? *Journal of Financial Economics 120*(3), 601–622.

Golez, B. and J. Jackwerth (2012). Pinning in the s&p 500 futures. *Journal of Financial Economics 106*(1), 566–588.

Henderson, B. J., N. D. Pearson, and L. Wang (2020). Pre-trade hedging: Evidence from the issuance of retail structured products. *Journal of financial Economics 137*(1), 108–128.

Hu, J. (2014). Does option trading convey stock price information? *Journal of Financial Economics 111*(3), 625–645.

Lee, C. and M. J. Ready (1991). Inferring trade direction from intraday data. *The Journal of Finance 46*(2), 733–746.

Newey, W. K. and K. D. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica 55*(3), 703–708.

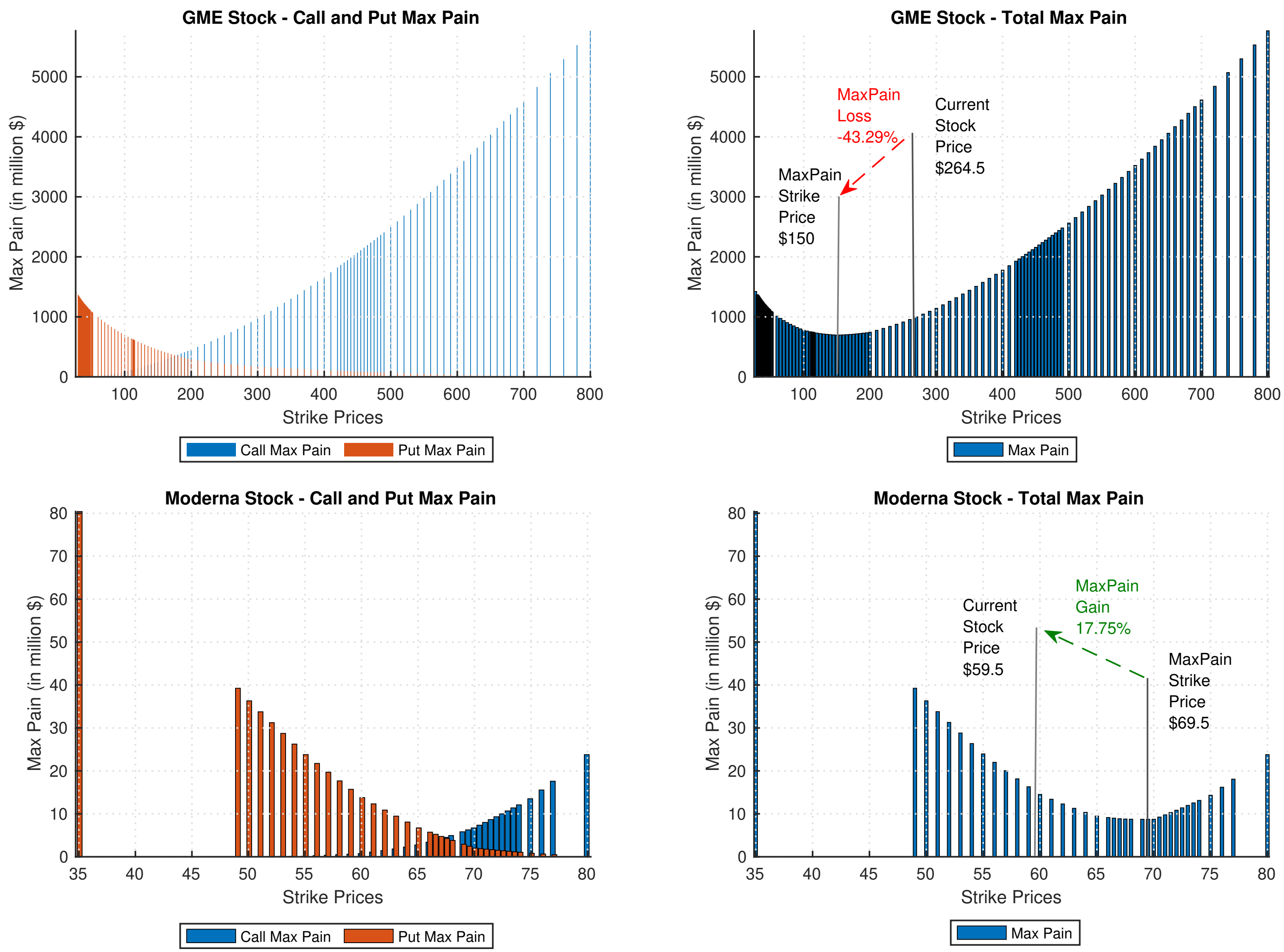
Ni, S. X. (2008). Stock option returns: A puzzle. *Available at SSRN 1340767*.

Ni, S. X., N. D. Pearson, and A. M. Poteshman (2005). Stock price clustering on option expiration dates. *Journal of Financial Economics 78*(1), 49–87.

Ni, S. X., N. D. Pearson, A. M. Poteshman, and J. White (2021). Does option trading have a pervasive impact on underlying stock prices? *The Review of Financial Studies 34*(4), 1952–1986.

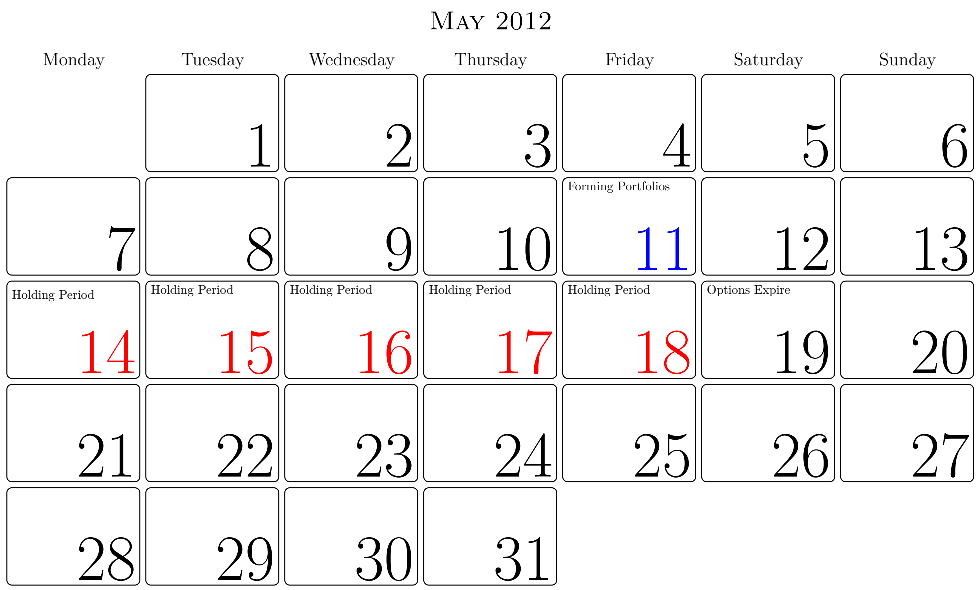
Pan, J. and A. M. Poteshman (2006). The information in option volume for future stock prices. *Review of Financial Studies 19*(3), 871–908.

**Figure 1.** ***Example of the Construction of Max Pain***



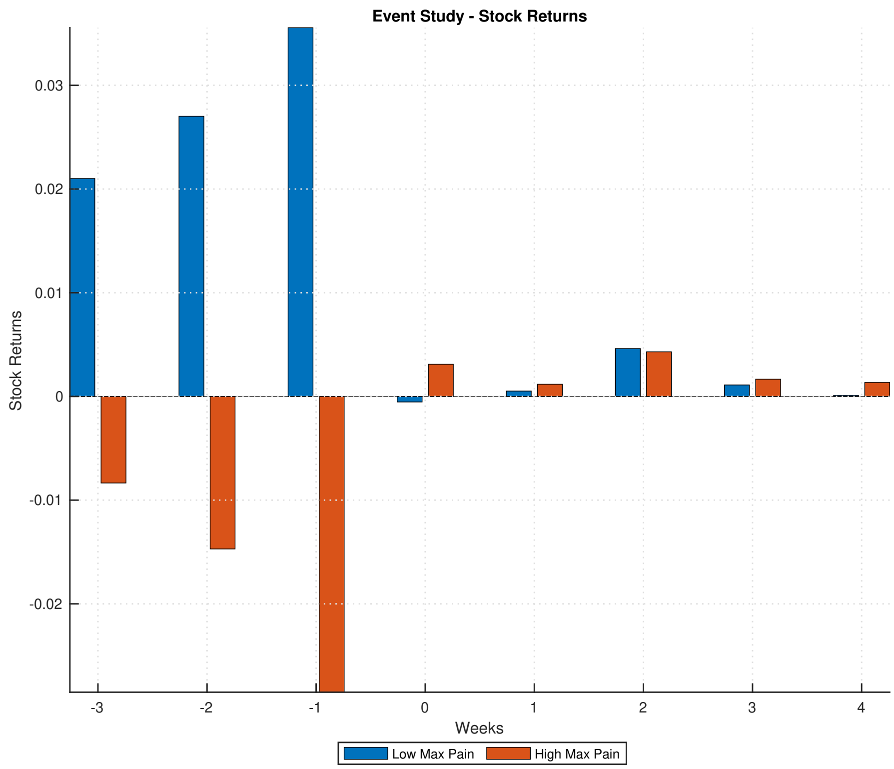

The figure displays two example of the construction of the Max Pain gain loss measure. The top figure show an example of Max Pain loss using data from the GME stock on March 12, 2021. The bottom panels use data of Moderna for a gain on September 11, 2020. The data are collected from OptionMetrics and CRSP.

**Figure 2.** ***Example of Portfolio Formation and Holding Periods***




The figure displays an example of the formation and holding period of the strategy for May 2012.

**Figure 3.** ***Weekly Event Study***




The figure displays an event study of weekly stock returns around the week of the holding period for low and high max pain portfolios. The data are collected from OptionMetrics and CRSP and contain daily series from January 1996 to December 2021.

## Table 1. Characteristics of Max Pain Portfolios

This table displays time-series averages of median characteristics of stocks sorted into deciles on the last week before the expiration Friday of the month based on max pain. *Panel A* shows time-series averages of median max pain (in millions) of portfolios sorted based on the max pain measure. We report in *Panel B* the stock price, stock volume (SVOL), momentum (MOM), stock reversals (REV), illiquidity (ILLIQ) (in percent), institutional ownership (IOR), book to market (B/M), Size (in billion), Debt to assets (D/A), idiosyncratic volatility (IVOL), a Nasdaq variable that takes a value of one if the stock is a Nasdaq stock and the absolute difference between closing prices and nearest strike price (AD prices). We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Portfolios sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $MaxPain$ | -0.081 | -0.049 | -0.033 | -0.021 | -0.010 | -0.000 | 0.011 | 0.023 | 0.040 | 0.076 | 0.157 | (17.67) |

*Panel B*: Stock Characteristics of Portfolios sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SVOL$ | 0.619 | 0.596 | 0.631 | 0.657 | 0.672 | 0.700 | 0.659 | 0.633 | 0.574 | 0.595 | -0.024 | (-1.17) |
| $IOR$ | 0.778 | 0.784 | 0.780 | 0.772 | 0.764 | 0.762 | 0.762 | 0.770 | 0.777 | 0.759 | -0.019 | (-5.87) |
| $B/M$ | 0.300 | 0.334 | 0.360 | 0.377 | 0.384 | 0.397 | 0.398 | 0.393 | 0.380 | 0.348 | 0.048 | (6.30) |
| $D/A$ | 0.154 | 0.184 | 0.204 | 0.211 | 0.217 | 0.217 | 0.217 | 0.209 | 0.192 | 0.151 | -0.003 | (-0.44) |
| $REV$ | 0.044 | 0.030 | 0.022 | 0.018 | 0.013 | 0.008 | 0.005 | -0.001 | -0.008 | -0.028 | -0.072 | (-10.08) |
| $MOM$ | 0.235 | 0.175 | 0.153 | 0.134 | 0.128 | 0.120 | 0.118 | 0.123 | 0.121 | 0.110 | -0.126 | (-5.51) |
| $IVOL$ | 0.024 | 0.019 | 0.017 | 0.016 | 0.016 | 0.016 | 0.016 | 0.017 | 0.019 | 0.025 | 0.001 | (1.69) |
| $StockPrice$ | 33.360 | 37.146 | 38.466 | 37.816 | 36.864 | 35.742 | 34.909 | 33.817 | 30.949 | 23.631 | -9.729 | (-11.90) |
| $Size$ | 1.587 | 2.292 | 2.788 | 3.095 | 3.193 | 3.169 | 2.889 | 2.514 | 1.928 | 1.114 | -0.473 | (-11.46) |
| $ILLIQ^{Stocks}$ | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | (5.51) |
| $Nasdaq$ | 0.590 | 0.486 | 0.426 | 0.398 | 0.388 | 0.392 | 0.395 | 0.415 | 0.475 | 0.596 | 0.006 | (0.62) |
| AD Prices | 0.968 | 0.950 | 0.893 | 0.813 | 0.761 | 0.711 | 0.722 | 0.775 | 0.852 | 0.932 | -0.036 | (-1.91) |

## Table 2. Stocks sorted on Max Pain

This table displays average returns of stocks sorted into deciles on the last week before the expiration Friday of the month based on max pain. In particular, we form portfolios on the second Friday of each month and hold them for one week, which refers to the expiration date of the attached options. *Panel A* shows average stock returns. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stock returns of portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW | -0.001 | 0.001 | 0.002 | 0.003 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | (3.66) |
| VW | 0.000 | 0.002 | 0.003 | 0.003 | 0.004 | 0.002 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 | (2.65) |

*Panel B*: Alphas of portfolios of stocks sorted based on Max Pain

| | CAPM | FF3 |
|---|---|---|
| EW | 0.004 | 0.004 |
| | (3.40) | (3.68) |
| VW | 0.003 | 0.004 |
| | (2.19) | (2.83) |

## Table 3. Cross-Sectional Regressions

This table displays cross-sectional regressions of stock returns on the max pain and a number of controls. Specifically, our cross-sectional regression takes the following form:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1}$$

where $Ret_{i,t+1}$ represents the stock return at time $t+1$ and the set of controls include the stock illiquidity, a dummy variable that takes a value of one if the stock is traded in NASDAQ, price, size, book to market, debt to assets, stock volume (SVOL), institutional ownership (IOR), idiosyncratic volatility (IVOL), stock reversals, and momentum. We show results for the full sample, small stocks, illiquid stocks and Nasdaq stocks. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

| | Stock Returns | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | *Full Sample* | | *Small stocks* | | *Illiquid Stocks* | | *Nasdaq Stocks* | |
| $MaxPain$ | 0.017 | 0.016 | 0.027 | 0.028 | 0.028 | 0.028 | 0.019 | 0.019 |
| | (2.94) | (3.15) | (3.41) | (3.49) | (3.12) | (3.08) | (2.69) | (2.90) |
| $Price$ | | -0.000 | | -0.000 | | -0.000 | | -0.000 |
| | | (-0.93) | | (-1.22) | | (-1.52) | | (-0.91) |
| $Size$ | | 0.000 | | -0.000 | | -0.000 | | 0.000 |
| | | (0.92) | | (-0.50) | | (-0.13) | | (2.20) |
| $SVOL$ | | -0.000 | | 0.000 | | 0.000 | | -0.000 |
| | | (-0.58) | | (1.30) | | (2.18) | | (-0.90) |
| $IOR$ | | 0.000 | | 0.002 | | 0.000 | | 0.001 |
| | | (0.39) | | (0.63) | | (0.17) | | (0.53) |
| $B/M$ | | 0.000 | | 0.000 | | 0.001 | | -0.000 |
| | | (0.02) | | (0.26) | | (0.53) | | (-0.14) |
| $D/A$ | | -0.002 | | -0.004 | | -0.005 | | -0.002 |
| | | (-1.43) | | (-1.76) | | (-2.16) | | (-1.20) |
| $REV$ | | -0.002 | | -0.001 | | 0.001 | | 0.000 |
| | | (-0.93) | | (-0.20) | | (0.33) | | (0.14) |
| $MOM$ | | 0.001 | | -0.000 | | 0.001 | | 0.000 |
| | | (0.70) | | (-0.53) | | (0.66) | | (0.51) |
| $ILLIQ^{Stocks}$ | | -0.020 | | -0.022 | | -0.025 | | -0.016 |
| | | (-0.93) | | (-0.70) | | (-0.80) | | (-0.64) |
| $IVOL$ | | -0.024 | | -0.006 | | -0.042 | | -0.001 |
| | | (-0.69) | | (-0.16) | | (-1.06) | | (-0.03) |
| cons | 0.002 | 0.003 | 0.001 | 0.004 | 0.002 | 0.005 | 0.002 | 0.003 |
| | (1.47) | (2.94) | (0.84) | (1.26) | (0.92) | (2.21) | (1.58) | (2.27) |
| R-squared | 0.006 | 0.072 | 0.011 | 0.120 | 0.012 | 0.117 | 0.007 | 0.075 |

## Table 4. Stocks sorted on Max Pain: Different Weeks

This table displays average stock returns that are sorted based on max pain. We form portfolios on the first, second, or third Friday of the month. We hold the portfolio until the expiration of the option. *Panel A* shows weekly stock returns. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stock returns of portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Two Weeks to Expiration* | | | | | | |
| EW | -0.001 | 0.001 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | (1.88) |
| VW | 0.001 | 0.002 | 0.003 | 0.004 | 0.002 | 0.003 | 0.003 | 0.005 | 0.005 | 0.005 | 0.004 | (1.44) |
| | | | | | | *Three Weeks to Expiration* | | | | | | |
| EW | 0.003 | 0.005 | 0.006 | 0.006 | 0.007 | 0.007 | 0.007 | 0.007 | 0.007 | 0.007 | 0.004 | (1.85) |
| VW | 0.006 | 0.006 | 0.005 | 0.007 | 0.007 | 0.007 | 0.008 | 0.009 | 0.007 | 0.009 | 0.004 | (1.23) |
| | | | | | | *Four Weeks to Expiration* | | | | | | |
| EW | 0.008 | 0.009 | 0.008 | 0.010 | 0.009 | 0.009 | 0.010 | 0.009 | 0.010 | 0.010 | 0.002 | (0.67) |
| VW | 0.007 | 0.008 | 0.007 | 0.008 | 0.006 | 0.008 | 0.009 | 0.010 | 0.012 | 0.011 | 0.004 | (1.45) |

*Panel B*: Alphas of portfolios of stocks sorted based on Max Pain

| | CAPM | FF3 | CAPM | FF3 | CAPM | FF3 |
|---|---|---|---|---|---|---|
| | *Two Weeks to Expiration* | | *Three Weeks to Expiration* | | *Four Weeks to Expiration* | |
| EW | 0.003 | 0.003 | 0.005 | 0.005 | 0.003 | 0.002 |
| | (1.54) | (1.63) | (2.01) | (1.98)) | (1.00) | (0.92) |
| VW | 0.003 | 0.003 | 0.005 | 0.005 | 0.005 | 0.005 |
| | (1.02) | (1.17) | (1.55) | (1.54) | (1.82) | (1.65) |

## Table 5. Stocks sorted on Max Pain: Abnormal Stock Volume

This table reports the average abnormal volume and order imbalances of stocks that are sorted based on max pain. We form portfolios on the first, second, or third Friday of the month. In Panel A, we show results for abnormal volume. We compute abnormal volume as:

$$AbnormalVolume_{w,m} = Volume_{w,m} - \overline{Volume_{m-1\to m-n}},$$

where $Volume_w$ represents the average daily volume (expressed in millions) over the last week $w$ of month $m$ before the expiration of the option and $\overline{Volume_{m-1\to m-n}}$ is the average daily volume over the months $m-n$ to $m-1$ where $n = 1, 3, 6, 12$. In Panel B, we present results for order imbalances. We form portfolios on the first, second, or third Friday of the month. We compute abnormal order imbalances as:

$$AbnormalOIB_{w,m} = OIB_{w,m} - \overline{OIB_{m-1\to m-n}},$$

where $OIB_w$ represents the average daily order imbalance over the last week $w$ of month $m$ before the expiration of the option and $\overline{OIB_{m-1\to m-n}}$ is the average daily volume over the months $m-n$ to $m-1$ where $n = 1, 3, 6, 12$.
We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, TAQ and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Abnormal Volume of Portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | P10-P5 | P1-P5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *One Month* | | | | | | |
| EW | 0.191 | 0.064 | 0.040 | 0.027 | 0.016 | 0.030 | 0.007 | 0.052 | 0.087 | 0.234 | 0.043 | 0.219 | 0.175 |
| | (7.69) | (3.61) | (1.93) | (1.48) | (0.74) | (1.25) | (0.34) | (2.05) | (3.98) | (3.54) | (0.72) | (3.30) | (6.59) |
| | | | | | | | *Three Months* | | | | | | |
| EW | 0.245 | 0.075 | 0.045 | 0.022 | 0.034 | 0.033 | 0.014 | 0.082 | 0.114 | 0.289 | 0.045 | 0.255 | 0.211 |
| | (8.60) | (3.91) | (1.97) | (0.92) | (1.37) | (1.06) | (0.51) | (2.92) | (4.39) | (3.94) | (0.70) | (3.82) | (6.84) |
| | | | | | | | *Six Months* | | | | | | |
| EW | 0.313 | 0.095 | 0.057 | 0.023 | 0.036 | 0.045 | 0.019 | 0.094 | 0.135 | 0.353 | 0.040 | 0.317 | 0.277 |
| | (8.00) | (4.13) | (1.85) | (0.68) | (1.06) | (1.13) | (0.54) | (2.76) | (4.23) | (4.39) | (0.60) | (4.47) | (6.22) |
| | | | | | | | *Twelve Months* | | | | | | |
| EW | 0.396 | 0.133 | 0.084 | 0.039 | 0.045 | 0.053 | 0.036 | 0.114 | 0.170 | 0.457 | 0.061 | 0.412 | 0.351 |
| | (7.25) | (4.60) | (2.09) | (0.94) | (1.04) | (1.04) | (0.75) | (2.56) | (4.37) | (4.75) | (0.78) | (5.05) | (6.03) |

*Panel B*: Abnormal Order Imbalance of Portfolios of Stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | P10-P5 | P1-P5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *One Month* | | | | | | |
| EW | -0.004 | -0.002 | -0.001 | -0.000 | 0.001 | 0.000 | 0.002 | 0.002 | 0.001 | 0.005 | 0.009 | 0.004 | -0.005 |
| | (-3.32) | (-1.97) | (-1.17) | (-0.11) | (0.78) | (0.26) | (1.84) | (1.83) | (1.40) | (3.46) | (5.10) | (3.07) | (-5.62) |
| | | | | | | | *Three Months* | | | | | | |
| EW | -0.003 | -0.001 | -0.001 | -0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | 0.003 | 0.007 | 0.003 | -0.004 |
| | (-2.53) | (-1.13) | (-0.64) | (-0.01) | (0.71) | (0.02) | (1.37) | (0.83) | (0.63) | (2.46) | (4.08) | (2.16) | (-4.86) |
| | | | | | | | *Six Months* | | | | | | |
| EW | -0.002 | -0.001 | -0.001 | -0.000 | 0.001 | -0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.005 | 0.002 | -0.003 |
| | (-1.70) | (-0.81) | (-0.58) | (-0.05) | (0.53) | (-0.10) | (0.98) | (0.26) | (0.19) | (1.63) | (3.27) | (1.46) | (-3.41) |
| | | | | | | | *Twelve Months* | | | | | | |
| EW | -0.002 | -0.001 | -0.000 | 0.000 | 0.001 | -0.000 | 0.001 | -0.000 | -0.000 | 0.001 | 0.003 | 0.001 | -0.002 |
| | (-0.99) | (-0.33) | (-0.24) | (0.03) | (0.42) | (-0.05) | (0.69) | (-0.07) | (-0.23) | (0.87) | (2.51) | (0.71) | (-2.31) |

## Table 6. Stocks sorted on Max Pain: Placebo Test

This table shows average stock returns that are sorted based on max pain. We form a portfolio from two weeks to expiration until one week to expiration. *Panel A* shows weekly stock returns. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors, and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat, and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stock returns of portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.002 | 0.002 | (1.06) |
| VW | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 | (0.08) |

*Panel B*: Alphas of portfolios of stocks sorted based on Max Pain

| | CAPM | FF3 |
|---|---|---|
| EW | 0.001 | 0.001 |
| | (0.91) | (0.79) |
| VW | -0.000 | -0.000 |
| | (-0.09) | (-0.13)) |

## Table 7. Cross-Sectional Regressions: Daily Reversal

This table displays cross-sectional regressions of stock returns on the max pain. We report results for one to three days after expiration. Specifically, our cross-sectional regression takes the following form:

$$AbRet_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1}$$

where $AbRet_{i,t+1}$ represents the daily abnormal stock return at time $t+1$. We compute abnormal returns following Daniel et al. (1997) (DGTW). *Panel A* shows results for stocks with Max Pain above the median. *Panel B* displays results for stocks with Max Pain below the median. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stocks with Max Pain above the Median

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | -0.013 | -0.001 | 0.004 |
| | (-2.87) | (-0.24) | (1.12) |
| constant | 0.000 | 0.000 | 0.000 |
| | (1.41) | (0.31) | (0.84) |
| R-squared | 0.010 | 0.008 | 0.008 |

*Panel B*: Stocks with Max Pain below the Median

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | 0.001 | 0.001 | -0.002 |
| | (0.19) | (0.33) | (-0.48) |
| constant | -0.000 | -0.000 | 0.000 |
| | (-0.25) | (-0.59) | (1.15) |
| R-squared | 0.009 | 0.007 | 0.007 |

## Table 8. Cross-Sectional Regressions: Intraday Reversal

This table displays cross-sectional regressions of stock returns on the max pain. We report results for the day after expiration for hours from 10 am to 4 pm with 30-minute intervals. Specifically, our cross-sectional regression takes the following form:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1}$$

where $Ret_{i,t+1}$ represents the stock return at time $t+1$. *Panel A* shows results for stocks with Max Pain above the median. *Panel B* displays results for stocks with Max Pain below the median. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, TAQ, and Optionmetrics and contains thirty-minute interval series from January 2003 to December 2014.

*Panel A*: Stocks with Max Pain above the Median

| | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $MaxPain$ | -0.010 | -0.002 | -0.001 | 0.000 | -0.002 | -0.000 | 0.001 | -0.000 | -0.002 | -0.000 | -0.001 | -0.001 | -0.003 |
| | (-3.03) | (-1.11) | (-0.58) | (0.18) | (-1.25) | (-0.23) | (0.84) | (-0.35) | (-1.58) | (-0.39) | (-0.64) | (-1.14) | (-1.77) |
| Constant | -0.001 | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 | 0.000 | -0.000 | 0.000 | -0.000 | 0.000 | 0.000 |
| | (-1.11) | (-0.24) | (-0.97) | (-0.76) | (-0.84) | (0.23) | (0.30) | (0.11) | (-0.58) | (0.38) | (-0.35) | (1.10) | (1.06) |
| R-squared | 0.008 | 0.011 | 0.009 | 0.006 | 0.009 | 0.007 | 0.009 | 0.007 | 0.010 | 0.009 | 0.010 | 0.008 | 0.007 |

*Panel B*: Stocks with Max Pain below the Median

| | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $MaxPain$ | 0.009 | 0.002 | 0.001 | 0.000 | -0.000 | -0.001 | -0.000 | 0.000 | 0.002 | -0.001 | 0.001 | -0.000 | -0.002 |
| | (2.22) | (0.93) | (0.61) | (0.33) | (-0.10) | (-0.64) | (-0.24) | (0.31) | (1.60) | (-1.08) | (0.94) | (-0.00) | (-2.41) |
| Constant | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 |
| | (-0.59) | (-0.27) | (-1.27) | (-0.47) | (-1.30) | (0.10) | (0.43) | (-0.20) | (-0.77) | (-0.01) | (-0.07) | (0.85) | (0.63) |
| R-squared | 0.007 | 0.008 | 0.008 | 0.005 | 0.007 | 0.006 | 0.006 | 0.006 | 0.007 | 0.008 | 0.008 | 0.006 | 0.007 |

## Table 9. Double Sorts: Sell Volume, Open Interest and Max Pain

This table displays average stock returns that are double sorted based on max pain and sell volume and open interest. *Panel A* shows results for the written volume of firms and *Panel B* shows results for the written volume of customers during the expiration week. *Panel C* presents results for written open interest of firms that is computed the third Friday of the month. *Panel D* shows results for the written open interest of public customers. We estimate the stock return which corresponds to one week prior to the expiration date until the expiration of the option every month. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors, and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, NASDAQ option markets, and Optionmetrics and contains monthly series from May 2005 to December 2021.

*Panel A*: Firms Sell Volume

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Sell Volume (P1) | 0.004 | 0.005 | 0.003 | 0.001 | -0.001 | -0.004 |
| | (1.88) | (3.39) | (2.47) | (0.89) | (-0.34) | (-2.78) |
| High Sell Volume (P5) | -0.004 | -0.001 | 0.001 | 0.004 | 0.009 | 0.013 |
| | (-1.67) | (-0.49) | (0.77) | (2.43) | (3.74) | (5.52) |

*Panel B*: Public Customers Sell Volume

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Sell Volume (P1) | 0.008 | 0.007 | 0.004 | 0.000 | -0.003 | -0.011 |
| | (4.69) | (4.58) | (2.57) | (0.10) | (-1.41) | (-8.14) |
| High Sell Volume (P5) | -0.004 | -0.000 | 0.002 | 0.005 | 0.008 | 0.012 |
| | (-1.97) | (-0.22) | (1.08) | (2.91) | (3.26) | (4.93) |

*Panel C*: Firm Proprietary Written Open Interest

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Written Open Interest (P1) | -0.001 | 0.001 | 0.005 | 0.005 | 0.006 | 0.007 |
| | (-0.36) | (0.51) | (3.86) | (2.76) | (2.23) | (3.10) |
| High Written Open Interest (P5) | 0.000 | 0.001 | 0.002 | 0.003 | 0.004 | 0.004 |
| | (0.07) | (0.48) | (1.17) | (1.65) | (1.45) | (1.77) |

*Panel D*: Public Customer Written Open Interest

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Written Open Interest (P1) | -0.004 | -0.000 | 0.003 | 0.004 | 0.008 | 0.012 |
| | (-1.88) | (-0.22) | (2.07) | (2.53) | (3.64) | (7.40) |
| High Written Open Interest (P5) | 0.002 | 0.001 | 0.002 | 0.002 | 0.003 | 0.001 |
| | (0.73) | (0.72) | (1.56) | (1.05) | (0.93) | (0.49) |

## Table 10. Double Sorts: Alternative Explanations

This table displays average stock returns that are sorted based on max pain and market makers net open interest (*Panel A*), new delta hedging (*Panel B*), and covered call and protective put unwinding (*Panel C*). We estimate the stock return which corresponds to one week prior to the expiration date until the expiration of the option every month. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors, and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, NASDAQ option markets, and Optionmetrics and contains monthly series from May 2005 to December 2021.

*Panel A*: Marker Makers Net Open Interest

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Net Open Interest (P1) | -0.001 | 0.002 | 0.003 | 0.004 | 0.000 | 0.002 |
| | (-0.79) | (1.10) | (1.89) | (2.16) | (0.08) | (0.83) |
| High Net Open Interest (P5) | 0.000 | 0.001 | 0.003 | 0.002 | 0.006 | 0.006 |
| | (0.01) | (0.60) | (1.99) | (1.47) | (2.50) | (2.90) |

*Panel B*: New Delta Hedging

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low New Delta Hedging (P1) | 0.001 | 0.001 | 0.001 | 0.005 | 0.005 | 0.003 |
| | (0.55) | (0.53) | (0.74) | (2.94) | (1.74) | (1.53) |
| High New Delta Hedging (P5) | 0.000 | 0.004 | 0.003 | 0.002 | 0.004 | 0.004 |
| | (0.04) | (2.83) | (1.85) | (1.38) | (1.61) | (1.93) |

*Panel C*: Covered Call and Protective Put Unwinding

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Low Unwinding (P1) | 0.002 | 0.002 | 0.003 | 0.004 | 0.005 | 0.003 |
| | (1.35) | (1.06) | (1.97) | (2.03) | (2.32) | (1.90) |
| High Unwinding (P5) | -0.001 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 |
| | (-0.28) | (1.16) | (1.70) | (1.34) | (1.06) | (1.67) |

## Table 11. Stocks with and without options sorted on Max Pain

This table presents average weekly stock returns that are sorted based on max pain. *Panel A* shows weekly stock returns. We report results for stocks with and without options that are matched based on size and volume using propensity score matching. For stocks without options, we use a sorting variable the Max Pain value of the corresponding stock pair with options and similar size and volume. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors, and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat, and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Stocks with Options* | | | | | | |
| EW | -0.001 | 0.001 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.005 | (3.42) |
| VW | -0.000 | 0.001 | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 | 0.005 | 0.004 | 0.004 | 0.004 | (2.40) |
| | | | | | | *Stocks without Options* | | | | | | |
| EW | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | -0.001 | (-0.56) |
| VW | 0.002 | 0.002 | 0.001 | 0.003 | 0.003 | 0.002 | 0.003 | 0.003 | 0.002 | 0.002 | -0.000 | (-0.30) |

*Panel B*: Alphas of Stock Returns sorted based on Max Pain

| | CAPM | FF3 | CAPM | FF3 |
|---|---|---|---|---|
| | *Stocks with Options* | | *Stocks without Options* | |
| EW | 0.004 | 0.004 | -0.001 | -0.001 |
| | (3.12) | (3.39) | (-0.66) | (-1.03) |
| VW | 0.003 | 0.004 | -0.001 | -0.001 |
| | (1.93) | (2.73) | (-0.74) | (-0.88) |

## Table 12. Different Number of Strikes per Stock

This table shows average stock returns that are sorted based on max pain. We keep stock with at least two, three, or four strikes. We estimate the stock return which corresponds to one week prior to the expiration date until the expiration of the option every month. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. All portfolios are value-weighted. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Portfolios of stocks sorted based on Max Pain

| | Low Max Pain | P2 | P3 | P4 | High Max Pain | HML |
|---|---|---|---|---|---|---|
| Two Strikes | 0.000 | 0.002 | 0.003 | 0.004 | 0.004 | 0.004 |
| | (0.31) | (1.41) | (2.53) | (2.65) | (2.20) | (2.58) |
| Three Strikes | -0.003 | 0.002 | 0.004 | 0.005 | 0.005 | 0.008 |
| | (-1.39) | (1.14) | (2.48) | (2.80) | (2.35) | (3.82) |
| Four Strikes | -0.002 | 0.001 | 0.004 | 0.005 | 0.005 | 0.007 |
| | (-0.66) | (0.54) | (2.50) | (2.53) | (1.70) | (2.37) |

*Panel B*: Alphas of Stock Returns sorted based on Max Pain

| | CAPM | FF3 | CAPM | FF3 | CAPM | FF3 |
|---|---|---|---|---|---|---|
| | *Two Strikes* | | *Three Strikes* | | *Four Strikes* | |
| Alphas | 0.003 | 0.004 | 0.007 | 0.008 | 0.006 | 0.007 |
| | (2.25) | (2.87) | (3.61) | (4.41) | (2.08) | (2.67) |

## Table 13. Stocks sorted on Max Pain: Strikes based on One Cent Increments

This table display average returns of stocks sorted into deciles on the last week before the expiration Friday of the month based on max pain. The Max Pain is based on strikes that are one-cent increments between the lowest and highest observed strike prices. In particular, we form portfolios on the second Friday of each month and hold them for one week, which refers to the expiration date of the attached options. *Panel A* shows average stock returns. *Panel B* shows alphas based on CAPM and the Fama and French (1993) 3-factor model. We use weekly factors and we use the third weekly return of every month. Stock returns are calculated using the midpoint of the bid and ask prices at market close adjusted for stock splits. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stock returns of portfolios of stocks sorted based on Max Pain

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW | -0.003 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 | 0.003 | 0.002 | 0.003 | 0.003 | 0.006 | (3.57) |
| VW | -0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.004 | 0.003 | 0.004 | 0.005 | 0.007 | (3.38) |

*Panel B*: Alphas of portfolios of stocks sorted based on Max Pain

| | CAPM | FF3 |
|---|---|---|
| EW | 0.005 | 0.006 |
| | (3.41) | (3.82) |
| VW | 0.006 | 0.007 |
| | (3.08) | (3.76) |

## Table 14. Max Pain of Index Options

This table presents time-series averages of median put to call open interest of portfolios of stocks that are sorted based on max pain. We compute the ratio the day which correspond to one week prior to expiration of the option every month. Index returns are calculated using the midpoint of the bid and ask prices at market close. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Portfolios of stock indices sorted based on Max Pain

| | P1 | P2 | P3 | HML | t-stat |
|---|---|---|---|---|---|
| | | | | *Returns* | |
| EW | 0.002 | 0.002 | 0.001 | -0.000 | (-0.23) |
| | | | | *Max Pain Gain/Loss* | |
| EW | -0.058 | -0.003 | 0.141 | 0.199 | (4.42) |

*Panel B*: Alphas of Index Returns sorted based on Max Pain

| | CAPM | FF3 |
|---|---|---|
| EW | -0.001 | -0.001 |
| | (-0.81) | (-0.59) |

*Internet Appendix to*

# "No Max Pain, No Max Gain: Price Clustering at Option Expiration"

by

Ilias Filippou     Pedro A. Garcia-Ares     Fernando Zapatero

(Not for publication)

# 1 Example of Max Pain Calculation

In this section, we offer an example of the Max Pain gain/loss calculation, which is the sorting variable of our main analysis. Let us assume that one stock has three attached call options and three put options. As it is explained in Table A1, the strike prices for the call option are $25, $50, and $100 with a corresponding open interest of 10, 20, and 10 outstanding contracts. For simplicity, we assume that put and call options have the same strike prices but a different number of outstanding contracts. Specifically, the put options have open interest of 50, 25, and 1.

**Table A1. Option Series for Stock A**

| Strike Price | Call Open Interest | Put Open Interest |
|---|---|---|
| 25 | 10 | 50 |
| 50 | 20 | 25 |
| 100 | 10 | 1 |

In Table A2, we compute the total loss assuming that the stock price at expiration will equal the first strike price, which is $25. We offer the strike prices of the calls and puts and the open interest. In the Call Loss and Put Loss columns, we calculate the potential loss for each option. At an expiration price of $25, the payoff of the call options will be zero as the strike price exceeds or is equal to the exercise price. On the other hand, the put options will be exercised for the strike prices of $50 and $100. In these cases, the writer of the put will have a loss of (Stock Price-Strike Price)*Open Interest or (50-25)*25 and (100-25)*1, respectively. Thus, the total loss will be $700. It is worth mentioning that we label as Stock Price the assumed or theoretical stock price of $25.

**Table A2. Stock Price Expires at 25**

| Price | Strike | Call OI | Put OI | Call Loss | Put Loss | Total Loss |
|---|---|---|---|---|---|---|
| 25 | 25 | 10 | 50 | 0 | 0 | 0 |
| | 50 | 20 | 25 | 0 | (50-25) x 25 | 625 |
| | 100 | 10 | 1 | 0 | (100-25) x 1 | 75 |
| | | | | | | 700 |

In Table A3, we continue with the calculation of the call and put loss, assuming that the stock price at expiration will equal the second strike price, which is $50. Here, the call option will be exercised for a strike price of $25 because the assumed stock price at expiration is larger. In this case, the writer of the call option will suffer a loss of (50-25)*10. Similarly, the put option will be exercised when the strike price is equal to $100 because the strike price will be greater than the assumed price at expiration. The potential loss for the put option will be (100-50)*1. Thus, the potential total loss for call and put options will be $300.

**Table A3. Stock Price Expires at 50**

| Price | Strike | Call OI | Put OI | Call Loss | Put Loss | Total Loss |
|---|---|---|---|---|---|---|
| 50 | 25 | 10 | 50 | (50-25)x10 | 0 | 250 |
| | 50 | 20 | 25 | 0 | 0 | 0 |
| | 100 | 10 | 1 | 0 | (100-50)x1 | 50 |
| | | | | | | 300 |

In Table A4, we show results for the last strike price. We assume that the stock will expire at $100. Only the call option will be exercised at this price, and the call option writer will suffer a loss of $1750.

**Table A4. Stock Price Expires at 100**

| Price | Strike | Call OI | Put OI | Call Loss | Put Loss | Total Loss |
|---|---|---|---|---|---|---|
| 100 | 25 | 10 | 50 | (100-25)x10 | 0 | 750 |
| | 50 | 20 | 25 | (100-50)x20 | 0 | 1000 |
| | 100 | 10 | 1 | 0 | 0 | 0 |
| | | | | | | 1750 |

In Table A5, we summarize the information obtained in the previous tables. Thus, we report the loss of call and put writers for the three strike prices if we assume that the stock price at expiration will equal each strike price. In the last column, we sum the call, put losses per strike price, and select the smaller value, our Max Pain value for this stock. The Max Pain strike price is the one that is associated with the minimum loss, which is $50. Thus, the Max Pain Gain/Loss will be the difference between the Max Pain strike price ($50) and the stock price on the second Friday of the month –which is the day that we form our portfolios– over the stock price the second Friday of the month.

**Table A5. Max Pain Price for Stock A**

| Strike Price | Call Loss | Put Loss | Total Loss |
|---|---|---|---|
| 25 | 0 | 700 | 700 |
| 50 | 250 | 50 | 300 |
| 100 | 1750 | 0 | 1750 |

**Table A6. Cross-Sectional Regressions: Reversal based on Sell Volume of Firms**

This table displays cross-sectional regressions of stock returns on the max pain. We report results for one to three days after expiration. Specifically, our cross-sectional regression takes the following form:

$$AbRet_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1}$$

where $AbRet_{i,t+1}$ represents the abnormal stock return at time $t+1$. *Panel A* shows results for stocks with a low Sell Volume of firms. *Panel B* displays results for stocks with a high Sell volume of firms. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stocks with High Sell Volume

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | -0.018 | -0.002 | -0.001 |
| | (-2.22) | (-0.31) | (-0.10) |
| constant | -0.000 | -0.000 | 0.000 |
| | (-1.23) | (-0.83) | (1.35) |
| R-squared | 0.023 | 0.016 | 0.016 |

*Panel B*: Stocks with Low Sell Volume

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | -0.000 | 0.006 | 0.008 |
| | (-0.05) | (1.40) | (1.78) |
| constant | 0.000 | -0.000 | 0.000 |
| | (0.08) | (-0.76) | (1.24) |
| R-squared | 0.014 | 0.013 | 0.013 |

## Table A7. Cross-Sectional Regressions: Reversal based on Sell Volume of Customers

This table displays cross-sectional regressions of stock returns on the max pain. We report results for one to three days after expiration. Specifically, our cross-sectional regression takes the following form:

$$AbRet_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \varepsilon_{i,t+1}$$

where $AbRet_{i,t+1}$ represents the abnormal stock return at time $t+1$. *Panel A* shows results for stocks with a low Sell Volume of public customers. *Panel B* displays results for stocks with a high Sell volume of public customers. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat, and Optionmetrics and contains monthly series from January 1996 to December 2021.

*Panel A*: Stocks with High Sell Volume

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | -0.020 | 0.004 | -0.005 |
| | (-1.95) | (0.56) | (-0.45) |
| constant | -0.000 | -0.000 | 0.000 |
| | (-0.96) | (-0.43) | (1.37) |
| R-squared | 0.022 | 0.019 | 0.020 |

*Panel B*: Stocks with Low Sell Volume

| | (1) | (2) | (3) |
|---|---|---|---|
| | *Expiration Date +1* | *Expiration Date +2* | *Expiration Date +3* |
| $MaxPain$ | -0.001 | 0.004 | 0.005 |
| | (-0.20) | (1.03) | (1.11) |
| constant | 0.000 | -0.000 | 0.000 |
| | (0.33) | (-1.11) | (1.19) |
| R-squared | 0.014 | 0.013 | 0.014 |

## Table A8. Put to Call Open Interest Ratios of Portfolios sorted on Max Pain

This table presents time-series averages of median put to call open interest of portfolios of stocks that are sorted based on max pain. We compute the ratio the day which corresponds to one week prior to the expiration of the option every month. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP and Optionmetrics and contains monthly series from January 1996 to December 2021.

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P10-P1 | $t$-stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.356 | 0.372 | 0.378 | 0.382 | 0.382 | 0.386 | 0.387 | 0.394 | 0.406 | 0.422 | 0.066 | (6.65) |

## Table A9. Cross-Sectional Regressions: Abnormal Returns

This table displays cross-sectional regressions of abnormal stock returns on the max pain and a number of controls. Specifically, our cross-sectional regression takes the following form:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1} \tag{7}$$

where $Ret_{i,t+1}$ represents the abnormal stock return at time $t+1$ and the set of controls include the stock illiquidity, a dummy variable that takes a value of one is the stock is traded in NASDAQ, price, size, book to market, debt to assets, stock volume (SVOL), institutional ownership (IOR), idiosyncratic volatility (IVOL), monthly reversals and momentum. We show results for the full sample, small stocks, illiquid stocks and Nasdaq stocks. We report Newey and West (1987) $t$-statistics with 6 lags in parenthesis. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | *Full Sample* | | *Small stocks* | | *Illiquid Stocks* | | *Nasdaq Stocks* | |
| $MaxPain$ | 0.016 | 0.012 | 0.029 | 0.027 | 0.027 | 0.025 | 0.017 | 0.016 |
| | (2.98) | (2.81) | (3.41) | (3.55) | (2.85) | (2.85) | (2.51) | (2.75) |
| $Price$ | | -0.000 | | -0.000 | | -0.000 | | -0.000 |
| | | (-0.48) | | (-0.87) | | (-1.74) | | (-0.53) |
| $Size$ | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | | (0.28) | | (0.01) | | (0.19) | | (1.72) |
| $SVOL$ | | -0.000 | | 0.000 | | 0.000 | | -0.000 |
| | | (-0.50) | | (0.99) | | (1.87) | | (-0.95) |
| $REV^{Weekly}$ | | -0.005 | | -0.005 | | -0.004 | | -0.008 |
| | | (-1.18) | | (-0.69) | | (-0.55) | | (-1.44) |
| $IOR$ | | 0.001 | | 0.002 | | 0.001 | | 0.001 |
| | | (0.55) | | (0.61) | | (0.45) | | (0.58) |
| $B/M$ | | 0.000 | | -0.000 | | 0.000 | | -0.000 |
| | | (0.06) | | (-0.45) | | (0.01) | | (-0.35) |
| $D/A$ | | -0.002 | | -0.003 | | -0.004 | | -0.002 |
| | | (-1.32) | | (-1.30) | | (-1.59) | | (-1.04) |
| $REV$ | | -0.003 | | -0.001 | | 0.002 | | -0.001 |
| | | (-1.39) | | (-0.21) | | (0.71) | | (-0.46) |
| $MOM$ | | 0.000 | | -0.001 | | -0.000 | | -0.000 |
| | | (0.35) | | (-1.21) | | (-0.07) | | (-0.08) |
| $ILLIQ^{Stocks}$ | | -0.003 | | -0.021 | | -0.022 | | -0.007 |
| | | (-0.14) | | (-0.67) | | (-0.67) | | (-0.25) |
| $IVOL$ | | -0.016 | | -0.015 | | -0.052 | | 0.004 |
| | | (-0.62) | | (-0.41) | | (-1.36) | | (0.14) |
| constant | -0.000 | 0.001 | -0.001 | 0.002 | -0.001 | 0.003 | 0.000 | 0.001 |
| | (-1.69) | (0.91) | (-2.21) | (0.67) | (-2.28) | (1.49) | (0.08) | (0.77) |
| R-squared | 0.005 | 0.054 | 0.013 | 0.123 | 0.014 | 0.119 | 0.007 | 0.068 |