No Max Pain, No Max Gain: Stock Price Predictability at Options Expiration

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This version: June 19, 2022

Abstract

Given all the options with the same expiration written on a particular stock, *Max Pain price* is the strike price at which the total payoff of all the expiring options is the lowest. We construct a measure of Max Pain, sort stock prices 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 alphas. Our results provide strong evidence of stock price predictability at the expiration of the options. We also find that there is significantly higher abnormal stock volume and order imbalances for high Max Pain portfolios. The strategy is not related to reversals of price trends that might have explained initial options volume. Our results are robust to a large number of tests.

Keywords: Max Pain, stock price clustering.

JEL Classification: G12, G13, G14, G23.

We would like to thank Neil D. Pearson and Aurelio Vasquez and seminar participants at ITAM for useful comments. 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.

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 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 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.

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 participants. We take one of the strike prices and compute what would be the cost for the short 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 short 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 and the stock price on the second Friday of the month, divided by the stock price on the second Friday of the month.

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 and sells low Max Pain stocks. 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.

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. We verify their findings and show that the Max Pain strategy can exploit stock price predictability close to options expiration.

We further test the 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, monthly reversals, weekly reversals, momentum, stock illiquidity, and idiosyncratic volatility. We find that the coefficients of Max Pain remain highly positive and statistically significant. We find similar results if we run this regression only for small, illiquid, or NASDAQ stocks. We also show that our results are not driven by previous month or week reversals. In addition, we establish that, on average, high Max Pain stocks are growth stocks, illiquid, with low stock volume and low prices. We find similar results if we use abnormal stock returns.

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 positive, but not statistically significant returns and CAPM or FF3 alphas. When the portfolios are formed two weeks before expiration long-short strategy offers positive and statistically significant returns, but the alphas are not statistically significant. Interestingly, returns increase as we get closer to the expiration of the options.

Additionally, we compute abnormal volume and order imbalances for the stocks, sorted on Max Pain, one week before the options expiration. Abnormal volume is defined as the difference between the daily volume of the third week of the month minus the average volume of the previous month.[1] Likewise, we compute abnormal order imbalance. We find significantly higher abnormal volume for high Max Pain stocks than for low Max Pain stocks. Similar results obtain for abnormal imbalances, for which we show that investors are net buyers of high Max Pain stocks.

To complement the previous results we compute a retail order imbalance measure (e.g., Boehmer, Jones, Zhang, and Zhang, 2021) and find that the difference in abnormal order imbalances is not statistically different from zero. This indicates that the Max Pain strategy is more relevant for institutional investors, which is consistent with the possibility that some market participants with exposure to the short positions manipulate stock prices before the options expiration. We also find that high Max Pain portfolios have higher put-to-call open interest than low Max Pain portfolios and the difference is statistically significant.

We established previously that high Max Pain stocks are on average growth stocks, small and illiquid. We further explore the implications of these characteristics for the Max Pain strategy's performance by constructing double-sorted portfolios based on size, or illiquidity, or book-to-market ratio, on one hand, and Max Pain on the other. We find that the Max Pain strategy is positive and statistically significant regardless of the level of size or illiquidity. However, it is significant only for growth stocks.

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 option. Recall that the baseline strategy is based on the last week before the expiration of the options. In particular, in this

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

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 last week is when it would have to take place.

We examine the performance of the Max Pain strategy one month and one week before and after its formation period. We find that the stocks we select on the third Friday of the month display a negative and statistically significant spread portfolio the week before and the month before the third week. On the other hand, the strategy is not significant one week and one month after the holding period.

We further verify these results in 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 Max Pain stocks become more negative the closer the expiration date. In principle, this could be the result of a reversal. We test that possibility and in cross-sectional regressions we verify that it is unrelated to the returns of the previous week. In addition, we find that both low and high Max Pain stocks offer positive but insignificant returns after the holding period.

Next, as it is standard on 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 the 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. 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.

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.

The rest of the paper is organized as follows: in section 2 we describe the theoretical framework and position this paper with respect to the relevant literature. In section 3 we describe the data and portfolio construction. Section 4 focuses on the empirical results. Section 5 provides a broad range of robustness and other specification tests, and section 6 concludes.

2 Theoretical Framework and Related Literature

Our work contributes to a recent strand of the literature which 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 lottery options. Filippou, Garcia-Ares, and Zapatero (2022) find that investors with lottery preferences bet on the possibility of a short squeeze. On the other hand, Ni, Pearson, Poteshman, and White (2021) offer evidence of a noninformational channel through which hedging rebalancing by the option market maker influences stock return volatility and the likelihood of stock price jumps.

Avellaneda and Lipkin (2003) describe a potential mechanism of our 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 towards the option strike price.

We also contribute to the literature which examines stock price manipulation. Ni et al. (2005) show that option trading changes can affect the price of the stocks. They show evidence of stock clustering before the expiration of the options. Ben-David, Franzoni, Landier, and Moussawi (2013) provide evidence of stock manipulation by hedge funds.

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 being as an informed trader.

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. We exclude stocks with prices below $5 at the end of the month. 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, 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 trading volume, 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.

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 of June 2006 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. We also consider an alternative measure of order imbalances that captures retail activity following Boehmer et al. (2021). The data span the period from January 1996 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. 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 simplicity, 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. 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 $(150-264.5)/264.5 = -43.29\%$.

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. 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 $(69.5-59.5)/59.5 = 17.75\%$.

[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 hold 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 -0.084 in the lowest decile and 0.076 in the highest decile rendering a difference of 0.160, 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 volume, 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.

[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. *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, 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.

[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), 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:

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

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. We also find that our results are robust to different subgroups, namely, small stocks, illiquid stocks, and NASDAQ stocks. It is worth mentioning that both monthly and weekly reversals cannot explain the cross-sectional predictive ability of Max Pain.

[Table 3 about here.]

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 to expiration. 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 positive but not statistically significant Max Pain spread portfolios. The only exception is the portfolio that is formed two weeks prior to the expiration of the option. However, the alphas of the spread portfolio in *Panel B* are not statistically significant. 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.

[Table 4 about here.]

4.5 Trading Activity during the Holding Period

Abnormal Volume. Table 5 reports time-series averages of median 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:

$$AbnormalVolume_{w,m} = Volume_{w,m} - \overline{Volume_{m-1 \rightarrow m-n}}, \quad (2)$$

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 $\overline{Volume_{m-1 \rightarrow m-n}}$ 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 increases with Max Pain statistically significantly. Specifically, the difference between the time-series average of P10 and P1 is positive and 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.

[Table 5 about here.]

Abnormal Order Imbalances. Table 6 reports time-series averages of median 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:

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

where OIB_w represents the average daily order imbalance over the last week w of month m before the expiration of the option and $\overline{OIB_{m-1\rightarrow m-n}}$ is the average daily volume over the months $m-n$ to $m-1$ where $n = 1, 3, 6, 12$. We report results for aggregated order imbalances (*Panel A*) as well as order imbalances that capture retail trading (*Panel B*) following (e.g., Boehmer et al., 2021).

We find in *Panel A* of Table 6 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 measure against average imbalances of the previous three, six, and twelve months. *Panel B* shows the corresponding results for order imbalances of retail investors. Retail investors tend to be net buyers of high Max Pain and net sellers of low Max Pain portfolios. However, we observe that the difference between portfolios P10 and P1 is not statistically different from zero. We observe a similar pattern for abnormal imbalances measured against order imbalances of the previous three, six, and twelve months. This finding might indicate that the Max Pain strategy is not a strategy that retail investors try to exploit and is somewhat more relevant for sophisticated investors.

[Table 6 about here.]

4.6 Double Sorts

We double sort stocks into portfolios based on size, illiquidity, book-to-market ratio, and Max Pain. Specifically, we allocate stocks into two quintiles based on size, illiquidity, or book-to-market ratio, and then within each portfolio, we form quintile portfolios sorted based on Max Pain. We report the average return of each portfolio and the corresponding spread portfolios.

Panel A of Table 7 shows that the Max Pain strategy is highly significant for low and high size portfolios. The return of the spread portfolio is slightly higher for small stocks as it is easier to be manipulated. *Panel B* shows that the Max Pain strategy is highly significant for low and high illiquidity stocks. The return of the spread portfolio is higher for more illiquid stocks. *Panel C* shows that the Max Pain strategy is highly significant only for low book-to-market stocks, which indicates that the strategy is more profitable for growth stocks while it is not significant for high book-to-market portfolios as it is harder to be manipulated.

[Table 7 about here.]

4.7 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 for two weeks to expiration (instead of one week to expiration) and hold the portfolio for one week.

Panel A of Table 8 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.

[Table 8 about here.]

4.8 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 one month before, one week before, one week after, and one month after the third week of the current month.

Panel A of Table 9 shows average stock returns of such portfolios. We find that high Max Pain stocks offered negative and significant returns the month and week before the formation period. We find that a spread portfolio between P10 and P1 offers negative and statistically significant returns. However, we find that the return of high Max Pain stocks is positive one week and one month after the formation period, but it is not economically and statistically significant. This finding indicates that Max Pain stocks performed poorly in the past, but our results are not related to stock reversals, as shown in Table 3 where weekly and monthly reversals cannot subsume the cross-sectional predictability of Max Pain for stock returns.

Panel B shows the spread portfolios' corresponding alphas. We find that the alphas are highly negative and significant for one month and one week before the formation period and insignificant for one week and one month after the third week of the current month.

[Table 9 about here.]

We further verify these results in an event study. Figure 3 shows 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 and do not offer significant returns after. 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 insignificant after the formation period.

[Figure 3 about here.]

5 Robustness

5.1 Put to Call Open Interest Ratios

Table 10 reports time-series average of 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 than call options for high Max Pain portfolios.

[Table 10 about here.]

5.2 Abnormal Returns

We show cross-sectional regressions of abnormal returns on Max Pain and control variables. Table 11 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:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1} \quad (4)$$

where $Ret_{i,t+1}$ represents the abnormal return of stock i at time $t+1$. We calculate abnormal stock returns based on the Fama and French (1993) model. Table 11 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.

[Table 11 about here.]

5.3 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 12 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.

[Table 12 about here.]

5.4 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 13 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.

[Table 13 about here.]

6 Conclusions

In this paper, we test the empirical validity of the maximum pain theory. We construct a measure of Max Pain 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.

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 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 compute the abnormal stock volume and order imbalances of stocks sorted based on Max Pain. High Max Pain stocks have higher abnormal volume and order imbalances. However, we do not find significant results for retail abnormal order imbalances, implying that this strategy is more relevant for institutional investors.

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.

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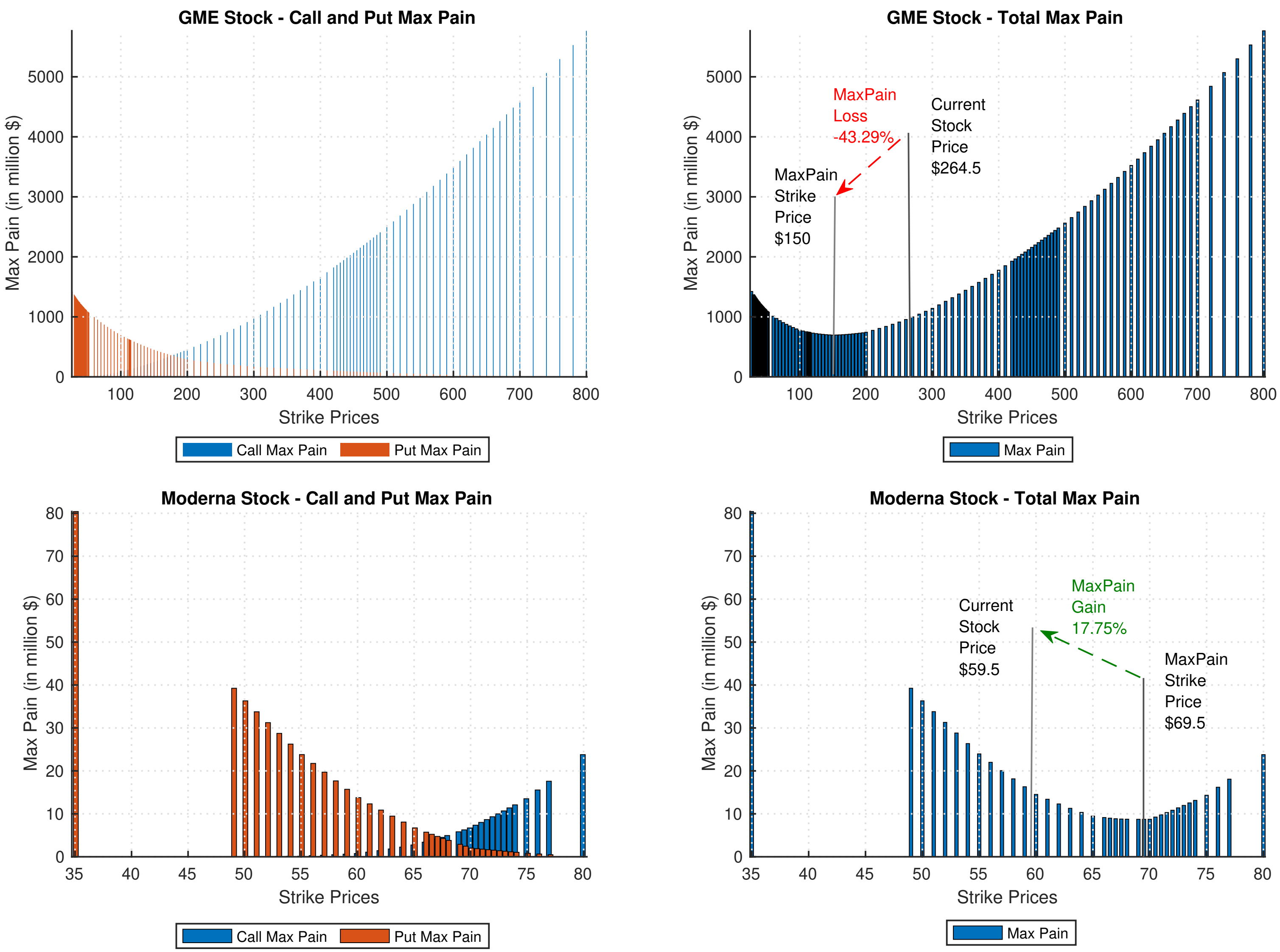
Figure 1. ***Example of the Construction of Max Pain***



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. The bottom panels use data of Moderna for a gain. The data are collected from OptionMetrics and CRSP and contain daily series from January 1996 to December 2021.

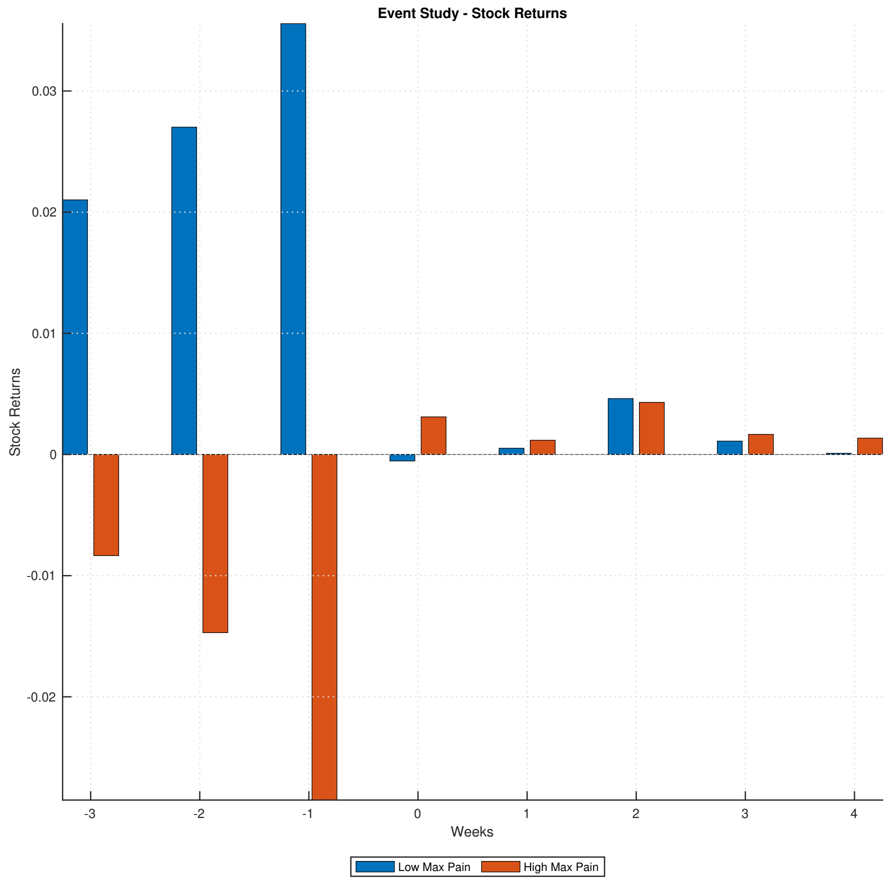
Figure 2. ***Example of Portfolio Formation and Holding Periods***

May 2012

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	1	2	3	4	5	6
7	8	9	10	Forming Portfolios 11	12	13
Holding Period 14	Holding Period 15	Holding Period 16	Holding Period 17	Holding Period 18	Options Expire 19	20
21	22	23	24	25	26	27
28	29	30	31			

The figure displays an example of the formation and holding period of the strategy for May 2012. The data are collected from OptionMetrics and CRSP and contain daily series from January 1996 to December 2021.

Figure 3. ***Event Study***



The figure displays an event study of stock returns around the week of the holding period. 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 stock 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, momentum (MOM), stock reversals (REV), illiquidity (ILLIQ) (in percent), a dummy variable that takes a value of one is the stock is traded in NASDAQ, institutional ownership (IOR), book to market (B/M), Size (in billion), Debt to assets (D/A), and idiosyncratic volatility (IVOL). 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
$MaxPain$	-0.084	-0.051	-0.034	-0.022	-0.011	-0.001	0.010	0.023	0.040	0.076	0.160	(17.43)

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
IOR	0.782	0.791	0.786	0.779	0.773	0.770	0.771	0.777	0.783	0.773	-0.009	(-2.85)
B/M	0.284	0.319	0.347	0.363	0.374	0.388	0.387	0.387	0.376	0.350	0.066	(9.18)
D/A	0.152	0.181	0.203	0.212	0.217	0.219	0.217	0.211	0.194	0.151	-0.001	(-0.19)
REV	0.047	0.032	0.023	0.018	0.013	0.009	0.004	-0.002	-0.010	-0.030	-0.077	(-10.46)
MOM	0.245	0.185	0.160	0.139	0.133	0.124	0.121	0.130	0.126	0.129	-0.115	(-5.24)
$IVOL$	0.024	0.020	0.017	0.016	0.016	0.016	0.016	0.017	0.019	0.024	-0.000	(-0.11)
Stock Volume	0.658	0.645	0.703	0.727	0.763	0.796	0.759	0.734	0.644	0.640	-0.018	(-11.99)
Stock Price	33.311	36.885	37.897	37.385	36.667	35.393	34.532	33.657	31.384	24.518	-8.792	(-11.99)
Size	1.586	2.207	2.680	2.979	3.149	3.102	2.886	2.569	1.974	1.181	-0.405	(-12.05)
$ILLIQ^{Stocks}$	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.000	(5.59)
Nasdaq	0.593	0.491	0.430	0.401	0.386	0.386	0.391	0.410	0.471	0.591	-0.002	(-0.21)

Table 2. Stocks sorted on Max Pain

This table average stock returns that are sorted based on max pain. *Panel A* shows call option returns. We estimate the option return which correspond to one week prior to 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. 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
EW	-0.001	0.001	0.002	0.002	0.003	0.002	0.003	0.002	0.002	0.004	0.004	(3.28)
VW	0.000	0.002	0.003	0.002	0.004	0.002	0.003	0.004	0.003	0.005	0.004	(3.01)

Panel B: Stock Returns of call options sorted based on Max Pain

	CAPM	FF3
EW	0.003	0.004
	(3.02)	(3.34)
VW	0.003	0.004
	(2.62)	(3.01)

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:

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

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 is the stock is traded in NASDAQ, 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 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*	
$MaxPain$	0.016	0.013	0.089	0.064	0.043	0.037	0.020	0.017
	(2.72)	(2.83)	(4.07)	(3.02)	(3.41)	(2.59)	(2.72)	(2.69)
$Price$		-0.000		-0.000		-0.000		-0.000
		(-2.14)		(-0.79)		(-0.23)		(-2.96)
$Size$		0.000		0.000		-0.000		0.000
		(0.82)		(1.47)		(-1.68)		(1.80)
$SVOL$		-0.000		-0.000		0.000		-0.000
		(-0.56)		(-1.65)		(3.10)		(-0.86)
IOR		0.001		-0.003		0.005		0.002
		(1.25)		(-1.01)		(1.40)		(1.57)
B/M		-0.008		-0.011		-0.015		-0.015
		(-10.33)		(-6.15)		(-8.53)		(-8.66)
D/A		0.001		0.001		0.005		0.001
		(1.06)		(0.52)		(1.31)		(0.75)
REV^{Weekly}		-0.006		-0.011		-0.017		-0.009
		(-1.26)		(-0.95)		(-1.59)		(-1.43)
$REV^{Monthly}$		-0.006		-0.006		-0.006		-0.003
		(-2.36)		(-1.11)		(-1.47)		(-1.05)
MOM		-0.001		-0.003		-0.003		-0.001
		(-1.91)		(-2.03)		(-2.25)		(-2.15)
$ILLIQ^{Stocks}$		0.039		0.269		-0.002		0.068
		(1.04)		(1.67)		(-0.02)		(1.51)
$IVOL$		-0.021		-0.040		-0.029		-0.000
		(-0.64)		(-0.76)		(-0.56)		(-0.00)
constant	0.002	0.007	0.006	0.012	0.002	0.010	0.002	0.008
	(1.43)	(5.44)	(2.49)	(3.55)	(1.00)	(2.46)	(1.47)	(4.93)
R-squared	0.006	0.087	0.021	0.254	0.019	0.232	0.008	0.095

Table 4. Stocks sorted on Max Pain: Different Weeks

This table average stock returns that are sorted based on max pain. We form portfolios the first, second, or third Friday of the month. We hold the portfolio until the expiration of option. *Panel A* shows call option returns. We estimate the option return which correspond to one week prior to 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. 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
						Two Weeks to Expiration						
EW	-0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	(2.01)
VW	0.001	0.002	0.003	0.003	0.002	0.003	0.003	0.005	0.004	0.006	0.005	(1.65)
						Three Weeks to Expiration						
EW	0.003	0.005	0.006	0.005	0.006	0.007	0.007	0.007	0.007	0.007	0.004	(1.75)
VW	0.006	0.006	0.006	0.006	0.007	0.007	0.008	0.009	0.007	0.009	0.003	(0.89)
						Four Weeks to Expiration						
EW	0.007	0.008	0.007	0.010	0.009	0.010	0.009	0.009	0.010	0.008	0.001	(0.41)
VW	0.005	0.007	0.007	0.008	0.006	0.008	0.009	0.010	0.012	0.010	0.004	(1.46)

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

	CAPM	FF3	CAPM	FF3	CAPM	FF3
	Two Weeks to Expiration		*Three Weeks to Expiration*		*Four Weeks to Expiration*	
EW	0.004	0.003	0.004	0.005	0.002	0.002
	(1.69)	(1.75)	(1.89)	(1.95)	(0.80)	(0.76)
VW	0.004	0.004	0.004	0.005	0.005	0.005
	(1.21)	(1.34)	(1.20)	(1.27)	(1.90)	(1.78)

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

This table reports average abnormal volume of stocks that are sorted based on max pain. We form portfolios the first, second, or third Friday of the month. We compute abnormal volume as:

$$AbnormalVolume_{w,m} = Volume_{w,m} - \overline{Volume_{m-1 \to m-n}}, \tag{6}$$

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 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.

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	0.184	0.066	0.045	0.026	0.033	0.025	0.002	0.058	0.080	0.235	0.051	0.203	0.151
	(7.79)	(3.46)	(2.17)	(1.13)	(1.43)	(1.01)	(0.10)	(2.23)	(3.51)	(3.58)	(0.86)	(3.28)	(6.09)
							Three Months						
EW	0.238	0.082	0.048	0.018	0.050	0.031	0.003	0.085	0.109	0.280	0.042	0.230	0.189
	(8.48)	(3.96)	(2.04)	(0.66)	(1.80)	(0.95)	(0.11)	(2.77)	(4.09)	(3.84)	(0.66)	(3.53)	(6.26)
							Six Months						
EW	0.308	0.107	0.059	0.019	0.055	0.040	0.003	0.096	0.133	0.337	0.029	0.282	0.253
	(7.78)	(4.46)	(1.90)	(0.50)	(1.54)	(0.97)	(0.08)	(2.53)	(4.00)	(4.17)	(0.43)	(4.02)	(5.93)
							Twelve Months						
EW	0.392	0.149	0.091	0.037	0.066	0.050	0.016	0.114	0.171	0.438	0.045	0.371	0.326
	(6.99)	(4.88)	(2.23)	(0.79)	(1.44)	(0.96)	(0.31)	(2.29)	(4.09)	(4.59)	(0.58)	(4.69)	(5.80)

Table 6. Stocks sorted on Max Pain: Abnormal Stock Order Imbalances

This table presents average abnormal order imbalances of stocks that are sorted based on max pain. We form portfolios the first, second, or third Friday of the month. We compute abnormal volume as:

$$AbnormalOIB_{w,m} = OIB_{w,m} - \overline{OIB_{m-1\to m-n}}, \quad (7)$$

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. *Panel A* shows results for total order imbalances and *Panel B* displays results for retail order imbalances. The data is from CRSP, Compustat and Optionmetrics and contains monthly series from January 1996 to December 2021. The retail order imbalance data span the period of June 2006 to December 2021.

Panel A: 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	-0.005	-0.003	-0.002	-0.001	-0.000	-0.000	0.001	0.001	0.001	0.004	0.009	0.005	-0.005
	(-3.56)	(-2.25)	(-1.83)	(-1.10)	(-0.14)	(-0.31)	(0.96)	(0.99)	(1.24)	(3.07)	(4.82)	(3.34)	(-4.75)
	Three Months												
EW	-0.004	-0.002	-0.002	-0.001	-0.000	-0.001	0.001	-0.000	0.000	0.003	0.006	0.003	-0.003
	(-2.70)	(-1.53)	(-1.20)	(-0.90)	(-0.22)	(-0.47)	(0.55)	(-0.35)	(0.28)	(1.90)	(3.64)	(2.27)	(-3.73)
	Six Months												
EW	-0.003	-0.002	-0.001	-0.001	-0.000	-0.001	0.000	-0.001	-0.000	0.002	0.005	0.002	-0.003
	(-1.96)	(-1.17)	(-1.04)	(-0.92)	(-0.23)	(-0.49)	(0.23)	(-0.70)	(-0.36)	(1.13)	(2.90)	(1.59)	(-2.75)
	Twelve Months												
EW	-0.002	-0.001	-0.001	-0.001	-0.000	-0.001	0.000	-0.001	-0.001	0.001	0.003	0.001	-0.002
	(-1.11)	(-0.56)	(-0.67)	(-0.64)	(-0.15)	(-0.46)	(0.11)	(-0.68)	(-0.62)	(0.50)	(2.06)	(0.90)	(-1.59)

Panel B: Abnormal Retail Order Imbalances 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	0.008	0.015	0.017	0.018	0.019	0.016	0.018	0.016	0.015	0.009	0.001	-0.010	-0.011
	(1.82)	(2.66)	(2.76)	(2.91)	(2.92)	(2.51)	(2.88)	(2.56)	(2.47)	(1.72)	(0.55)	(-4.28)	(-4.12)
	Three Months												
EW	0.008	0.015	0.017	0.018	0.019	0.017	0.018	0.017	0.015	0.010	0.002	-0.009	-0.011
	(1.79)	(2.67)	(2.88)	(2.85)	(2.95)	(2.61)	(2.91)	(2.61)	(2.65)	(1.85)	(1.09)	(-4.54)	(-4.26)
	Six Months												
EW	0.009	0.015	0.017	0.018	0.020	0.017	0.019	0.017	0.016	0.011	0.002	-0.009	-0.011
	(1.96)	(2.73)	(2.96)	(2.92)	(3.02)	(2.69)	(3.01)	(2.74)	(2.75)	(1.97)	(1.23)	(-4.35)	(-4.21)
	Twelve Months												
EW	0.010	0.016	0.019	0.019	0.021	0.019	0.020	0.018	0.017	0.012	0.003	-0.009	-0.011
	(2.27)	(2.98)	(3.23)	(3.00)	(3.19)	(2.89)	(3.25)	(2.97)	(2.96)	(2.33)	(1.62)	(-4.08)	(-4.21)

Table 7. Double Sorts: Size, Illiquidity and Book to Market Ratio

This table average stock returns that are sorted based on max pain and size (*Panel A*) or illiquidity (*Panel B*) or book to market (*Panel C*). We estimate the stock return which corresponds to one week prior to 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. 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: Size

	Low Max Pain	P2	P3	P4	High Max Pain	HML
Low Size	-0.000	0.001	0.003	0.003	0.004	0.004
	(-0.19)	(0.64)	(1.62)	(1.42)	(1.89)	(3.12)
High Size	0.002	0.003	0.003	0.003	0.004	0.002
	(1.19)	(2.50)	(2.52)	(2.63)	(2.67)	(2.52)

Panel B: Illiquidity

	Low Max Pain	P2	P3	P4	High Max Pain	HML
Low Illiquidity	0.002	0.003	0.003	0.004	0.004	0.003
	(1.10)	(2.60)	(2.76)	(2.70)	(2.55)	(2.36)
High Illiquidity	-0.002	0.002	0.002	0.002	0.003	0.005
	(-0.77)	(1.01)	(1.43)	(1.06)	(1.61)	(3.25)

Panel C: Book to Market

	Low Max Pain	P2	P3	P4	High Max Pain	HML
Low B/M	0.004	0.005	0.006	0.006	0.008	0.004
	(2.08)	(3.50)	(4.53)	(4.93)	(4.21)	(2.37)
High B/M	-0.004	-0.001	-0.001	0.000	-0.003	0.001
	(-1.80)	(-0.50)	(-0.37)	(0.05)	(-1.17)	(0.48)

Table 8. Stocks sorted on Max Pain: Placebo Test

This table average stock returns that are sorted based on max pain. We form a portfolio two weeks to expiration until one week to expiration. *Panel A* shows call option returns. We estimate the option return which correspond to one week prior to 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. 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
EW	-0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	(0.76)
VW	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.002	0.000	0.002	0.001	(0.48)

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

	CAPM	FF3
EW	0.001	0.001
	(0.64)	(0.47)
VW	0.001	0.001
	(0.35)	(0.32)

Table 9. Stocks sorted on Max Pain: Performance in other Periods

This table average stock returns that are sorted based on max pain. We show the performance of our strategy before and after. The same performance of the same stocks before and after the third week of the month. *Panel A* shows call option returns. We estimate the option return which correspond to one week prior to 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. 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
						One Month Before						
EW	0.064	0.039	0.029	0.025	0.018	0.013	0.010	0.003	-0.003	-0.020	-0.084	(-11.51)
						One Week Before						
EW	0.033	0.015	0.010	0.006	0.003	0.001	-0.002	-0.006	-0.012	-0.027	-0.060	(-12.03)
						One Week After						
EW	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.000	(0.46)
						One Month After						
EW	0.007	0.008	0.009	0.009	0.010	0.009	0.009	0.009	0.009	0.005	-0.002	(-0.67)

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

	CAPM	FF3	CAPM	FF3	CAPM	FF3	CAPM	FF3
	One Month Before		*One Week Before*		*One Week After*		*One Month After*	
EW	-0.085	-0.085	-0.060	-0.060	0.001	0.001	-0.001	-0.001
	(-11.51)	(-11.39)	(-12.13)	(-12.02)	(0.88)	(0.63)	(-0.43)	(-0.25)

Table 10. 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 correspond to one week prior to expiration of the option every month. 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
EW	0.321	0.342	0.360	0.370	0.371	0.383	0.390	0.400	0.419	0.450	0.129	(10.91)

Table 11. 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:

$$Ret_{i,t+1} = \alpha + \beta MaxPain_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t+1} \quad (8)$$

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), weekly reversals, 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.

Abnormal Stock Returns								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full Sample		*Small stocks*		*Illiquid Stocks*		*Nasdaq Stocks*	
$MaxPain$	0.016	0.013	0.087	0.063	0.041	0.034	0.019	0.017
	(2.66)	(2.74)	(4.02)	(2.96)	(3.22)	(2.38)	(2.61)	(2.58)
$Price$		-0.000		-0.000		-0.000		-0.000
		(-2.14)		(-0.80)		(-0.27)		(-2.97)
$Size$		0.000		0.000		-0.000		0.000
		(0.81)		(1.52)		(-1.59)		(1.80)
$SVOL$		-0.000		-0.000		0.000		-0.000
		(-0.59)		(-1.64)		(2.99)		(-0.92)
IOR		0.001		-0.003		0.004		0.002
		(1.10)		(-1.01)		(1.23)		(1.44)
B/M		-0.008		-0.011		-0.015		-0.015
		(-10.34)		(-6.14)		(-8.55)		(-8.68)
D/A		0.001		0.001		0.005		0.001
		(0.99)		(0.49)		(1.38)		(0.67)
REV^{Weekly}		-0.006		-0.011		-0.016		-0.009
		(-1.24)		(-0.93)		(-1.49)		(-1.40)
$REV^{Monthly}$		-0.006		-0.006		-0.005		-0.003
		(-2.32)		(-1.16)		(-1.35)		(-0.98)
MOM		-0.001		-0.003		-0.004		-0.001
		(-1.88)		(-1.97)		(-2.27)		(-2.12)
$ILLIQ^{Stocks}$		0.038		0.269		-0.007		0.065
		(0.99)		(1.67)		(-0.10)		(1.42)
$IVOL$		-0.021		-0.039		-0.032		-0.003
		(-0.65)		(-0.75)		(-0.61)		(-0.09)
constant	-0.001	0.004	0.003	0.010	-0.001	0.007	-0.000	0.006
	(-0.86)	(4.11)	(1.71)	(2.93)	(-0.72)	(1.82)	(-0.25)	(4.16)
R-squared	0.006	0.087	0.021	0.253	0.019	0.231	0.008	0.095

Table 12. Stocks with and without options sorted on Max Pain

This table average stock returns that are sorted based on max pain. *Panel A* shows call option returns. We estimate the option return which correspond to one week prior to expiration date until the expiration of the option every month. 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. 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	-0.002	0.001	0.002	0.003	0.002	0.002	0.002	0.003	0.003	0.004	0.005	(3.66)
VW	-0.000	0.001	0.003	0.003	0.003	0.002	0.003	0.004	0.004	0.004	0.004	(2.32)
	Stocks without Options											
EW	0.002	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.002	-0.000	(-0.61)
VW	0.002	0.002	0.005	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.000	(0.06)

Panel B: Stock Returns of call options sorted based on Max Pain

	CAPM	FF3	CAPM	FF3
	Stocks with Options		*Stocks without Options*	
EW	0.004	0.005	-0.000	-0.000
	(3.40)	(3.66)	(-0.80)	(-0.75)
VW	0.003	0.004	0.000	0.000
	(1.86)	(2.62)	(0.30)	(0.25)

Table 13. 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. 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: Stock Price Predictability at Options 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