SEEKING GAMMA: LESSONS FROM THE MEME FRENZY*

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Abstract

There has been substantial debate about the existence and impact of a gamma squeeze during the GameStop price surge in January 2021. We provide novel empirical evidence confirming that a gamma squeeze indeed occurred, and suggest that these squeezes started earlier than previously documented, in the Fall of 2020. We also identify other gamma squeeze episodes across a broader set of meme stocks during the same time period. Extending our analysis beyond meme stocks, we systematically identify 641 gamma squeeze events across all U.S. stocks from 2019 to 2023. These gamma squeezes result in economically significant price impacts, generating an average cumulative abnormal return of 5.13% in the month following their initiation. Our findings offer valuable insights for researchers, regulators, and market participants.

Keywords: Gamma Squeeze; Meme Stocks; Delta Hedging; Option Markets

JEL classifications: G12; G13; G14

1. Introduction

In January of 2021, GameStop (GME) gained national attention when its share price soared from around $20 to over $500 in a matter of weeks. The event, known as the "meme frenzy", sparked intense media coverage, congressional hearings, a regulatory response by the SEC and was a major catalyst for an aggressive rule making agenda at the SEC. Central policy debates focused on key market structures, among other things, payment for order flow, transparency in financial markets, short selling, and securities lending. Despite widespread analysis and investigations, there are still no clear answers on what exactly caused it. The conventional narrative is that a "short squeeze" played at least in part a pivotal role and this opinion is widely spread. However, the SEC has challenged this explanation by pointing out that "GME prices continued to be high after the direct effects of covering short positions would have waned." (SEC, p. X) What we do know is that the short interest reached an extraordinary 122.97% of float, while retail traders, largely motivated and coordinated by platforms like Reddit, flocked to buy both the stock and options on the stock, significantly impacting the market dynamics. Following the initial peak, short interest sharply fell to below 30% of float, suggesting complex underlying mechanisms beyond a traditional short squeeze.

Another popular explanation of the rise in GME stock has been a "Gamma Squeeze", where increased options trading forces market makers into buying shares to manage their delta-hedged positions, consequently driving stock prices upward. The SEC questioned this explanation as well: "[the SEC] staff did find GME options trading volume from individual customers increased substantially, from only $58.5 million on January 21 to $563.4 million on January 22 until peaking at $2.4 billion on January 27, this increase in options trading volume was mostly driven by an increase in the buying of put, rather than call options. Further, data show that market-makers were buying, rather than writing, call options. These observations by themselves are not consistent with a gamma squeeze" (SEC, p. X). That is, the SEC report points out that that increased option volume in January 2021 primarily involved market makers buying rather than writing call options and an increased volume of put options, seemingly inconsistent with a typical gamma squeeze. However, the SEC's analysis was constrained by data limitations, as the

Consolidated Audit Trail (CAT) became fully operational with full implementation of core equity reporting requirements on December 31, 2020.[1] Importantly, the SEC focuses exclusively on January of 2021, overlooking critical preceding months.

In this paper, we address this gap by providing comprehensive evidence that a gamma squeeze occurred significantly earlier than previously recognized, beginning in the fall of 2020. The rise in price in January overshadows the significant returns in GME in the months prior to the Meme Frenzy, as well as the prolonged high prices after GME had moved out of the news cycle. For example, from September to November the price increased 147.8%, from $6.68 to $16.56. Indeed, these are large returns for such a short period of time. Then prices spiked again on March 10th and June 9th of 2021, after short interest had dropped. We propose that a gamma squeeze was put on GME stock during the last quarter of 2020 and may have also contributed to the subsequent spikes in GME stock.

We document clear signs of gamma squeeze dynamics not only in GameStop but across a broader set of so-called "meme stocks," including AMC Entertainment Holdings (AMC), Blackberry (BB), Bed Bath and Beyond (BBBY), Carvana (CVNA), Express Inc. (EXPR), Koss Corp (KOSS), Naked Brand Group (NAKD), Nokia (NOK), SNAP Inc. (SNAP). Beyond confirming the occurrence of gamma squeezes during the meme frenzy, our study extends the analysis to identify and quantify 641 gamma squeeze events across a comprehensive sample of U.S. stocks from 2019 to 2023, significantly expanding the scope of existing research.

While the SEC report ruled out the Gamma Squeeze explanation, many academic papers have provided evidence supporting the occurrence of gamma squeeze to varying degrees. In a direct response to the SEC report, Mitts, Battalio, Brogaard, Cain, Glosten, and Kochuba (2022) state that market conditions indeed created the possibility of a gamma squeeze, criticizing the SEC for insufficiently analyzing market

[1] As discussed later, the SEC did use OPRA data to look at the Option Contract volume and dollar volume throughout 2020 but this received very little attention. See https://catnmsplan.com/sites/default/files/2021-02/CAT-Q4-2020-QPR.pdf

makers transactions. Zhou and Zhou (2023) find evidence of an “after-hours gamma squeeze” that helped facilitate the short squeeze. Conversely, Hilliard and Hilliard (2023) examine the put-call parity during the GameStop event but find limited evidence of put-call parity violations. Importantly, all of these studies focus exclusively on January 2021, and do not allow for the possibility of a gamma squeeze occurring prior to that period.

The SEC report and Mitts et al. (2022) both briefly acknowledge the presence of option trading activities in early 2020. However, their discussions are primary for context, providing minimal detailed analysis of the period prior to January 2021. Specifically, Panels A and B of Figure 1 replicate the figures from the SEC report, showing only a slight increase in option activity in October of 2020. However, these figures are somewhat misleading as they scaled the earlier trading activity relative to the colossal trading volumes that occurred in January of 2021. Panels C and D in Figure 1 show the activity without January 2021, clearly demonstrating a significant rise in option trading as early as October 2020.

Option trading is well-documented to have predictive power of future stock returns. The Option-to-Stock Volume ratio has been shown to have incredible predictive power (e.g., Roll, Schwartz, and Subrahmanyam, 2010; Johnson and So, 2012; Ge, Lin, and Pearson, 2016), suggesting that periods of increased option trading activity compared to stock trading activity increase the predictability of future returns. Similarly, Pan and Poteshman (2006) show that put-call ratios predict future stock returns. While it is well documented that options trading has a positive impact on the underlying market quality and has predictive power for future returns, the role of delta hedging, particularly its longer-term impact, remains relatively unexplored. Hu (2014) shows that stocks with high order imbalances as a result of delta hedging can generate excess of up to 22% in annualized returns. However, Hu (2014) only focuses on the delta hedging activity that occurs on the day of the option trade, and not the impact of rebalancing delta hedged positions when the option trader holds the position. Furthermore, Hu (2014) shows that informed traders prefer at-the-money and in-the-money options, whereas gamma squeezes feature out-of-the-money options because of their higher gamma potential.

Furthermore, Kumar, Sarin, and Shastri (2002) show that the presence of listed options improves the underlying stock market quality. Similarly, during the 2008 short-selling ban, option market quality deteriorated, largely due to reduced option market liquidity and option market makers withdrawal from hedging activities as they had a reduced ability to hedge their positions (Battalio and Schultz, 2011; and Grundy, Lim, and Verwijmeren, 2012). However, market makers were able to hedge their positions in banned stocks that had single-stock futures, which led to higher option market quality for those firms (Jiang, Shimizu, and Strong, 2020).

This paper contributes to the existing literature in three important ways. First, we provide novel evidence that Gamma Squeezes in meme stocks, including GameStop, originated months before the widely publicized frenzy and persisted thereafter. Second, we first formally define a Gamma Squeeze and developed robust and intuitive metrics such as Net Delta Volume and Net Delta Open Interest to accurately identify gamma squeeze events and measure their intensity. Our proposed measures offer practical tool for regulators, market practitioners, and academic researchers to better understand and potentially mitigate associated risks. Third, our broader examination shows that gamma squeezes are much more prevalent and economically impactful than previously documented. We show that these events have a significant impact on market quality as well as provide significant cumulative abnormal returns, even when controlling for other options related variables that predict future returns, such as the put-to-call ratio and the option-to-stock ratio.

Our main results are as follows. We introduce novel measures specifically designed to identify gamma squeeze events. These measures include Net Delta Volume which estimates the trading volume of underlying shares traded that comes from delta hedging associated with daily options trades, and Net Delta Open Interest, that estimates the amount of underlying shares held by option market makers due for delta hedging purposes. Using these measures, we first analyze the meme stocks sample and find evidence that Net Delta Volume significantly predicts short term future stock returns. We also find weaker but statistically significant evidence that Net Delta Open Interest also predicts future stock returns. Additionally, among meme stocks, higher Net Delta Open Interest is associated with tighter bid-ask spreads, suggesting improved market liquidity, whereas Net Delta Volume is associated with higher range volatility, indicating higher short-term price uncertainty.

To clearly define gamma squeeze events within meme stocks, we establish specific criteria where a gamma squeeze is identified if the Net Delta Open Interest exceeds 7.5% of the total shares outstanding and remains consistently above this threshold for at least a month (22 trading days). Using this identification method, we detect 11 gamma squeeze events among the meme stocks. These identified gamma squeezes demonstrate significant price impacts, with the average abnormal return is 20.8% on initial day and the cumulative abnormal return of 28.9% over the subsequent 22 trading days.

Next, we extend our analysis beyond meme stocks, and generalize our gamma squeeze identification method to a broader market sample. Across all stocks, both Net Delta Volume and Net Delta Open Interest variables are positive and significantly associated with higher one-day returns and cumulative abnormal returns. Additionally, both metrics are associated with improved market quality, as evidenced by lower bid-ask spreads. Similar to the meme stock analysis, Net Delta volume is associated with higher range volatility and Net Delta Open Interest is associated with lower range volatility, , consistent with the long-term stabilizing effect of continuous delta hedging. We then use the same identification across a comprehensive dataset, we document 641 gamma squeeze events from 2019 to 2023. These broader market events yield an average abnormal return of 4.61% on the first day, with cumulative abnormal returns averaging 9.72% over the subsequent month.

The rest of the paper is as follows: Section 1 explains the data and variable construction. Section 2 provides a theoretical background for Gamma Squeezes. Section 3 explains the empirical results. While Section 4 concludes.

2. Background on Gamma Squeezes

In the options trading context Gamma is one of the Black-Scholes Greeks, it is the first order derivative of Delta with respect to the price of the underlying asset, and the second order derivative of the price of the option. Since Delta is used by market makers to determine how much of the underlying asset they must hold to hedge their exposure from being the counterparty of the options trade, Gamma measures the rate of change in Delta or how much the market maker will need to purchase of the underlying stock to rebalance their delta hedge if the price of the underlying stock increases.

The idea behind a Gamma Squeeze is that an option trader can put upward pressure on an underlying asset by squeezing or forcing market makers to continually need to rebalance their portfolios by purchasing more stock. Which starts an upward pressure cycle as the price increases, delta increases at the rate of gamma, which makes delta hedgers purchase more to rebalance their hedged position, which further increases demand for the stock, making the price increase.

In order to do this, an option trader looking to put in place a gamma squeeze will purchase out-of-the-money call options, or write out-of-the-money put options. These options have lower prices so it is less expensive to take a large option position. Additionally, these options have a low delta, however as the price increases delta increases at an increasing rate (gamma). Which means that the option trader can force a market maker into a squeeze fairly easily if the price begins to move upward. While delta is highest for in-the-money options the gamma potential is highest for out-of-the-money options, which means that while trying to put in a gamma squeeze a trader is likely to trade both in the money options to quickly raise the level of delta hedging and out of the money to keep the upward price pressure, even after the position is taken.

Additionally, a gamma squeeze will be more effective in a situation that there is not much depth or shares available to trade. If the option trader can force a market maker to purchase more of the underlying asset, when there are not many shares available for purchase, he will be able to create a more effective squeeze.

In the case of GameStop, short sellers had already sold short more than 100% of shares available to trade, so if option trader could force market makers to take another 10 to 25% of shares, they could create significant upward pressure. However, it is important to noticed that unlike a short squeeze, which can lead to rapid increases in the stock price, a gamma squeeze is comparable a much slower process. While a short squeeze creates an urgent situation where a short seller must buy-to-cover or increase their margin to maintain a losing position, leading to a race to the exits, a gamma squeeze does not create the same urgency but instead a consistent upward pressure, which may take more time to be fully realized.

3. Data and Variable Construction

Data for this study comes from OptionMetrics and CRSP, covering the period from 2019 to 2023.

We create multiple variables to estimate the amount of trading activity that can be attributed to delta hedging. First we identify the delta volume for any given contract k as:

$$DeltaVolume_{k,t} = Delta_{k,t} \times Option\,Volume_{k,t} \times 100 \tag{1}$$

Which measure the amount of trading volume of the underlying asset that occurs on a given day as a result of trading on that individual contract k. Similarly, we identify delta open interest for each contract k as:

$$DeltaOpenInterest_{k,t} = Delta_{k,t} \times OpenInterest_{k,t} \times 100 \tag{2}$$

Which estimates the amount of shares being held by market makers as a result of delta hedging on the particular option contract. We than sum each of these variables across all contracts for the underlying asset to find the total delta volume and total delta open interest for each stock on each day.

$$NetDeltaVolume_{i,t} = \sum_{k=1}^{n} DeltaVolume_{k,t} \tag{3}$$

and

$$NetDeltaOpenInterest_{i,t} = \sum_{k=1}^{n} DeltaOpenInterest_{k,t} \tag{4}$$

We then estimate the percent of daily trading volume in the underlying security that is a result of delta hedging for that days option trading activity as:

$$NetDeltaVolume\% = \frac{NetDeltaVolume}{StockVolume} \tag{5}$$

Additionally, we estimate the percent of shares that are being held by market makers for delta hedging purposes as a percent of the total shares outstanding.

$$NetDeltaOpenInterest\% = \frac{NetDeltaOpenInterest}{SharesOutstanding} \tag{6}$$

Table 1 shows the summary statistics for the meme sample, whereas Table 2 shows the summary statistics for the whole sample. By comparing the two samples, we see that the meme stocks had higher one day returns, which is unsurprising given that the meme frenzy is known for its unprecedented price run ups. We also see that the range volatility and turnover where much higher for the meme stocks while the bid-ask spread is about in line with the whole sample. In Panel C, we see that on a typical day the delta volume measures are much higher for meme stocks. For example, the meme stocks have a Net Delta Volume Percent of 5.74% and a Net Delta Open Interest Percent of 2.32% compared to 1.23% and 0.33% respectively for the whole sample. It is also of note that the 75th percentile for Net Delta Open Interest Percent for the meme sample is 4.1% compared to 0.25% for the whole sample. Panel E shows the correlation matrix for the variables. It is important to note that both the Net Delta Volume measures and the OS ratio measures both compare option volume to stock volume in there own ways, it makes sense that they are somewhat highly coordinated. However, Net Delta Open Interest is not correlated with the OS measures.

4. Empirical Results

a. Meme Stock Sample

Using the estimates of trading activity due to delta hedging we can look to see if there were any potential gamma squeezes in GameStop leading up to its price spike in January 2021, and also if there were gamma squeezes in other meme stocks around that time. Figure 2 plots the four measures of delta related trading activity from January 1, 2020 to February 1, 2021. Panel A shows that Net Delta Volume does start to increase in September 2020, however it has a massive spike during January 2021. Giving us more context Panel 2 plots the Net Delta Volume Percent, which shows that despite the large spike in Net Delta Volume in January 2021, in percent terms of the underlying stock volume, option trading activity is not that high. Perhaps this gives some credence to the SEC report that there is a lack of evidence of a gamma squeeze in January of 2021. However, when we look at Panel C which shows the Net Delta Open Interest, and Panel D which shows the Net Delta Open Interest Percent, we see that the amount of shares that market makers had to hold to keep their delta hedges on open option contracts begins to increase substantially in September and October of 2020, and stays high throughout the rest of the sample period.[2] In fact, the estimated number of shares held for delta hedging is about the same level in January 2021 as it was in October 2020. In this sense you cannot say that a gamma squeeze was started in January 2021 because it was already in place for a few months before that point.

[2] Panels C and D appear very similar, because the only difference is that Panel D is scaled by shares outstanding, which is a stable variable.

Figure 3 shows the option volume for GME options based on the Moneyness of the options traded. We see, that as predicted, the increase in option volume in the Fall of 2020 was mainly driven by out-of-the-money options and in-the-money-options while at-the-money option volume stays relatively stable with the daily volume staying mostly in line with the average volume earlier in the year, however there are a few day with dramatic spikes in at-the money-volume.

Figure 4 shows the plots of Net Delta Open Interest Percent for seven meme stocks from 2018 through 2023. We see that for most of the stocks, aside from Carvana, Net Delta Open Interest stays relatively low until 2020. Then all of them with the exception of Best Buy, increase in about the middle of 2020, though they each spike at different times, then each return to fairly normal levels by the end of 2021, with a few spikes here and there. This result shows that gamma squeezes were a common occurrence among meme stocks.

We now turn our attention to see if our estimates of trading and holdings due to delta hedging do explain at least a part of the price run up in meme stocks during the meme frenzy. To do this we run the following regression:

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t} \tag{7}$$

Where *Return* is the one-day nominal return in Panel A and the one-day S&P 500 abnormal return in Panel B. *NetDeltaTrading* is the different measures for trading activity that comes from Delta Hedging, depending on the column. *RangeVolatility* is the range-based volatility measure, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs. *MarketCap* is the market capitalization for each firm i on day t computed as stock price multiplied by shares outstanding. *Spread* is the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. *Turnover* is the trading volume scaled by the shares outstanding. PC is the Put/Call ratio defined as the put volume divided by the total option volume). *CS* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. OS is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume.

Table 3 shows the results for the regression for the meme sample. Net Delta Volume and Net Delta Volume Percent are both positive and significant, though, since these measures deal with the amount of volume that comes from delta hedging for option trades on that particular day, it could be argued that these are just picking up the impact of elevated option trading on that day. However, the results are significant even when controlling for the option volume ratios, meaning that Net Delta Volume leads to positive one day returns over and beyond the predictive power of the Option-to-stock and Put-Call Ratios. Additionally, Net Delta Open Interest Percent is positive and significant at a 10% level, suggesting that when option traders hold their positions, forcing market makers to hold their position and rebalance their position, the one-day returns are also higher, again, even while controlling for the option volume ratios. Unsurprisingly the results are similar in Panel B, where abnormal return is the dependent variable.

We then change our focus to the impact of delta hedging activity on market quality. In Panel C we change the dependent variable to Bid-Ask Spread and find that Net Delta Volume and Net Delta Open Interest Percent are both associated with tighter bid ask spreads. In Panel D we see that Net Delta Volume is associated with higher range volatility, however Net Delta Open Interest is negative and insignificant. These results make sense as on the days that Net Delta Volume is high, return is also very high leading to higher range volatility.

So far, we have examined the short-term impacts of trading volume associated with delta hedging activity. However, if the Net Delta Open Interest for GameStop increased in October of 2020, but the price did not spike until January 2021, we should be more interested in the long-term impact of a Gamma Squeeze. To do this we need to identify when a Gamma Squeeze was first put into place. For this we us Net Delta Open Interest Percent as our main measure of trading activity from delta hedging. Because a gamma squeeze does not require active option trading to be effective, instead once the gamma squeeze is initially in place, market makers must continue to rebalance their portfolio as the underlying price increases, even if there is not option volume, the measure of Net Delta Volume may not be appropriate. Additionally, the both option and stock volume varies widely from stock to stock, so just because there is high Net Delta Open Interest may not mean much unless we scale it by the underlying stock information. Net Delta Open Interest Percent estimates how many shares of stock are being held for delta hedging purposes as a percent of total shares outstanding. For our purposes here we use the following criteria to identify when a gamma squeeze begins:

1. Net Delta Open Interest Percent increases above 7.5%.
2. The Average Net Delta Open Interest Percent over the following 1 month period (22 trading days) stays above 7.5%.
3. Because we do not want overlap of the gamma squeeze events we further require at least 60 days to pass before a new event can be identified.

We use Det Delta Open Interest Percent over 7.5% because the Standard deviation of the is 4.5% across all stocks with a median of 0.03%, so 7.5% is 1.66 standard deviations above the median, meaning that roughly 95% of observations are bellow 7.5%. We then require the average Net Delta Open Interest Percent to stay above the threshold for at least a month because in order for the squeeze to work it takes constant upward pressure over a longer period.

Using these criteria we identify 11 gamma squeeze events among the meme sample. With these we calculate the cumulative abnormal return from trading day t-5 to t+22 using the Carhart (1997), with a 20 day estimation period and 2 day gap period. Table 4 shows the results for the CARs where t-stats are calculated using cross-sectional standard errors. We see that across the 11 events, the average abnormal return on day 0 is 20.8% while the average CAR from [0, 22] is 28.9% with a t-stat of 2.1. It is also of note that given the low number of observations we do not have as much statistical power with the meme sample.

However, these results do show a large increase in abnormal returns on the day that the gamma squeeze starts with continued upward drift during the month that they gamma squeeze is in effect.

b. Finding Gamma Squeeze's in the Whole Sample of Stocks

We have thus far show that a Gamma Squeeze did occur in Game Stop stock prior to the meme frenzy albeit earlier than previously thought, and that a gamma squeeze occurred in other meme stocks under s similar context. We have also shown that these increase in trading activity as a result of delta hedging leads to large increases in the stock prices. The question is now, can we generalize our measures for gamma squeezes and identify other gamma squeeze events that were not related to the meme frenzy?

To answer this, we repeat our analysis with the whole sample of stocks. Table 5 reports the regression results that correspond to equation 7. Panel A and B, show that across all four measures of delta volume and delta open interest, trading activity that comes from delta hedging is associated with higher one-day returns and abnormal returns. For example, a ten-percentage point increase in Net Delta Open Interest Percent in associated with a 24-basis point increase in daily abnormal returns. In Panel C, we see that across all four estimates, Delta trading activity leads to tighter bid-ask spreads, improving market quality. Finally in Panel D, we see that the range volatility is higher for when Net Delta Volume increases, but lower when Net Delta Open Interest increases, meaning that on the first day of the Gamma squeeze, range volatility is higher, which makes sense as the spike in call option volume on the first day of the gamma squeeze, is likely to be associated with a large increase in price. While the one the subsequent days during the gamma squeeze when option trading volume is lower but the delta hedgers still must hold their positions in the underlying stock, range volatility is lower. These results in Table 5 are similar to the results in Table 3, though Table 5 has more statistical significance, likely due to the larger sample size.

Again, as we learned from Game Stop, gamma squeezes are a longer-term process. So, we are interested in the long-term effect of a gamma squeeze. Following the same criteria as with the meme stock sample:

1. Net Delta Open Interest Percent increases above 7.5%.
2. The Average Net Delta Open Interest Percent over the following 1-month period (22 trading days) stays above 7.5%.
3. Because we do not want overlap of the gamma squeeze events, we further require at least 60 days to pass before a new event can be identified.

We identify 641 different gamma squeeze events across all stock from 2019 to 2023. Table 6 reports the cumulative abnormal returns for these gamma squeeze events using the Cahart (1997) model from day t-5 to day t+22, with an estimation window of 20 days and a 2 day gap period. We find that on the first day of the gamma squeeze there is an average abnormal return of 4.61%. Additionally, we find that from day 0 to 22, the cumulative abnormal return was 9.75%, which means the cumulative abnormal return from day 1 to 22 was 5.13% with a t-stat of 3.33. This shows that Gamma squeezes are much more prevalent than previously thought and do have a sizable impact on the market.

c. Robustness Checks

Hu (2014) shows that stocks with high order imbalances as a results of delta hedging have an excess return of up to 22% in annualized returns. Given Hu's results it would be natural to question if our results are just picking up the same think as Hu, that is that our results are driven entirely by order imbalances from delta hedging on the day of the original option trades. However, Hu (2014) only focuses on the delta hedging activity that occurs on the day of the option trade, and not the impact of rebalancing delta hedged positions when the option trader holds the position. In our study, Net Delta Open Interest measures for delta hedging holdings while Net Delta Volume measures the delta trading activity on the day of option trades. Using these we can test if our results are entirely driven my order imbalances from delta hedging or if our results do come from a gamma squeeze effect from holding option positions leading market makers to rebalance their hedged positions. In Table 8, we retest our short-term results for Net Delta Open Interest by also controlling for Net Delta Volume Percent for the whole sample. We find that our results from Table 5 hold for each of the dependent variables for both Net Delta Open Interest and Net Delta Open Interest Percent, as the coefficient in each model stays both economically and statistically nearly unchanged.

5. Conclusion

We show that a gamma squeeze did in fact occur in Game Stop stock leading up to the 2021 Meme Frenzy, however this gamma squeeze occurred much earlier than previously thought, in September and October of 2020. Gamma squeezes also occurred in other meme stocks in the same time period. These gamma squeezes tend to have a slow burn effect, meaning that although prices increase substantially on the first day of the squeeze due to the trading activity, the presence of the squeeze continues to put upward pressure on the stock price even after the option traders stop actively trading the stock and simply hold their positions. While the option traders hold their positions, the counter party must continue to rebalance their delta hedge for the position, leading to continual buying of the underlying stock by the market makers. This leads to constant upward pressure on the stock price. We then generalize these findings to identify 641 different gamma squeeze events from 2019 to 2023. The constant upward pressure of the gamma squeeze leads to an average CAR of 5.13% in the month after the gamma squeeze started.

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Table 1: Summary Stats Meme Sample

This table reports the summary statistics for the Meme Sample from 2019 to 2023. The Meme Sample includes GameStop (GME), AMC Entertainment Holdings (AMC), Blackberry (BB), Bed Bath and Beyond (BBBY), Carvana (CVNA), Express Inc. (EXPR), Koss Corp (KOSS), Naked Brand Group (NAKD), Nokia (NOK), SNAP Inc. (SNAP). Panel A reports summary statistics for stock trading activity: Return, Abnormal Return, Price and MarketCap. Panel B reports stock market quality measures: Range Volatility, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs; Turnover, the trading volume scaled by the shares outstanding. and Spread, the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. Panel C reports the summary statistics for the Gamma Squeeze measures: Net Delta Volume is the daily trading volume that comes as a results of delta hedging activities for options traded on that same day. Net Delta Volume Percent is the Net Delta Volume as a percent of total stock volume on that day. Net Delta Open Interest is the amount of stock that is being held by market makers as a result of delta hedging activity. While Net Delta Open Interest Percent is the Net Delta Open Interest as a percent of Shares Outstanding. Panel D reports the summary statistics for option trading ratios: Option to Stock Volume; Call to Stock Volume, Put to Stock Volume, and Put to Call ratio. Panel E reports the correlation between the variables.

Panel A:	N	Mean	p50	SD	p25	p75
ret	7,411	0.10%	-0.13%	6.56%	-2.42%	2.13%
abret	7,411	0.05%	-0.22%	6.28%	-2.13%	1.67%
price	7,411	$37.53	$10.60	$66.25	$5.14	$27.52
mktcap	7,411	$11,000,000	$3,565,920	$17,300,000	$ 1,927,712	$13,900,000

Panel B:	N	Mean	p50	SD	p25	p75
rangevol	7,411	0.064	0.049	0.060	0.032	0.077
turn	7,411	0.061	0.029	0.159	0.017	0.053
spread	7,411	0.002	0.001	0.003	0.001	0.002

Panel C:	N	Mean	p50	SD	p25	p75
netΔvolume	7,318	1,141,328	276,068	3,022,418	35,947	1,106,563
Net Δvolume%	7,318	5.74%	3.26%	9.76%	0.70%	8.37%
net Δ OI	7,318	8,990,912	3,198,556	22,200,000	183,192	12,500,000
net Δ OI%	7,318	2.32%	1.32%	4.34%	0.13%	4.10%

Panel D:	N	Mean	p50	SD	p25	p75
os	7,411	0.593	0.364	0.755	0.158	0.704
cs	7,411	0.391	0.226	0.515	0.099	0.463
ps	7,411	0.202	0.117	0.280	0.037	0.231
pc	7,393	0.317	0.300	0.177	0.188	0.428

Panel E:

	range vol	turn	sprea d	netΔv olum e	Net Δvol ume %	net Δ OI	net Δ OI%	os	cs	ps	pc
rangevol	1.00										
turn	0.68	1.00									
spread	0.18	0.06	1.00								
netΔvol	0.21	0.23	-0.08	1.00							
NetΔvol%	0.02	-0.03	-0.13	0.42	1.00						
net Δ OI	-0.14	0.03	-0.02	0.37	0.22	1.00					
net Δ OI%	0.09	0.33	-0.07	0.22	0.24	0.63	1.00				
os	0.12	0.00	-0.18	0.09	0.49	-0.03	0.09	1.00			
cs	0.08	-0.02	-0.18	0.15	0.63	0.01	0.10	0.97	1.00		
ps	0.16	0.04	-0.17	-0.02	0.18	-0.11	0.05	0.90	0.78	1.00	
pc	0.13	0.07	-0.26	-0.20	-0.37	-0.29	-0.13	0.09	-0.05	0.35	1.00

Table 2. Summary Statistics

This table reports the summary statistics for the Whole Sample from 2019 to 2023. The Whole Sample includes all stocks that are found in both CRSP and OptionMetrics. Panel A reports summary statistics for stock trading activity: Return, Abnormal Return, Price and MarketCap. Panel B reports stock market quality measures: Range Volatility, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs; Turnover, the trading volume scaled by the shares outstanding. and Spread, the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. Panel C reports the summary statistics for the Gamma Squeeze measures: Net Delta Volume is the daily trading volume that comes as a results of delta hedging activities for options traded on that same day. Net Delta Volume Percent is the Net Delta Volume as a percent of total stock volume on that day. Net Delta Open Interest is the amount of stock that is being held by market makers as a result of delta hedging activity. While Net Delta Open Interest Percent is the Net Delta Open Interest as a percent of Shares Outstanding. Panel D reports the summary statistics for option trading ratios: Option to Stock Volume; Call to Stock Volume, Put to Stock Volume, and Put to Call ratio.

Panel A	N	Mean	p50	SD	p25	p75
ret	4,194,770	0.05%	0.00%	4.00%	-1.41%	1.39%
abret	4,194,770	0.00%	-0.05%	3.72%	-1.28%	1.15%
price	4,194,844	55.11	27.53	106.01	10.50	63.06
mktcap	4,194,844	11,300,000	1,612,195	57,200,000	416,829	5,912,447

Panel B:	N	Mean	p50	SD	p25	p75
rangevol	4,194,844	0.041	0.031	0.037	0.019	0.052
turn	4,194,842	0.021	0.007	0.247	0.004	0.014
spread	4,194,833	0.002	0.001	0.005	0.000	0.002

Panel C:	N	Mean	p50	SD	p25	p75
netΔvol	4,058,626	57,723	287	1,264,558	0	7,520
NetΔvol%	4,058,484	1.23%	0.07%	17.45%	0.00%	0.98%
net Δ OI	4,058,626	565,760	15,759	11,000,000	(1,871)	198,264
net Δ OI%	4,058,624	0.33%	0.03%	4.50%	0.00%	0.25%

Panel D:	N	Mean	p50	SD	p25	p75
os	4,194,777	0.111	0.015	0.512	0.001	0.079
cs	4,194,777	0.069	0.008	0.321	0.000	0.048
ps	4,194,777	0.043	0.003	0.328	0.000	0.021
pc	3,384,495	0.350	0.286	0.314	0.066	0.550

Panel E. Correlation Table

	range vol	turn	sprea d	netΔ vol	NetΔ vol%	net Δ OI	net Δ OI%	os	cs	ps	pc
rangevol	1.00										
turn	0.10	1.00									
spread	0.28	0.00	1.00								
netΔvol	0.03	0.02	-0.01	1.00							
NetΔvol%	0.01	0.00	0.01	0.17	1.00						
net Δ OI	0.00	0.00	-0.01	0.49	0.07	1.00					
net Δ OI%	0.03	0.04	0.00	0.13	0.08	0.29	1.00				
os	-0.01	0.01	-0.01	0.09	0.05	0.11	0.05	1.00			
cs	0.00	0.01	0.00	0.15	0.57	0.13	0.08	0.78	1.00		
ps	-0.02	0.00	-0.02	0.00	-0.48	0.05	0.00	0.79	0.24	1.00	
pc	-0.09	-0.01	-0.09	-0.04	-0.12	-0.03	-0.05	0.03	-0.07	0.11	1.00

Table 3: Regression Analysis for the Meme Stocks Sample

This table reports the regression results for the following regression using the meme sample:

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t}$$

Where *Return* is the one-day nominal return in Panel A and the one-day S&P 500 abnormal return in Panel B. *NetDeltaTrading* is the different measures for trading activity that comes from Delta Hedging, depending on the column. *RangeVolatility* is the range-based volatility measure, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs. *MarketCap* is the market capitalization for each firm i on day t computed as stock price multiplied by shares outstanding. *Spread* is the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. *Turnover* is the trading volume scaled by the shares outstanding. PC is the Put/Call ratio defined as the put volume divided by the total option volume). *CS* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. OS is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. The sample period is from 2029 to 2023. Standard errors are clustered by firm.

Panel A: Return

VARIABLES	(1) ret	(2) ret	(3) ret	(4) ret
net_delta_volume	4.29e-09**			
	(2.743)			
Net_delta_volume_percent		0.244***		
		(6.937)		
net_delta_OI			1.64E-10	
			(1.353)	
net_delta_OI_percent				0.154
				(1.645)
rangevol	0.062	0.082	0.107	0.116
	(0.806)	(0.937)	(1.285)	(1.303)
price	0.000**	0.000***	0.000***	0.000***
	(3.265)	(5.660)	(4.261)	(3.569)
mktcap	-0.000	-0.000**	-0.000	0.000
	(-0.971)	(-3.364)	(-0.492)	(0.784)
turn	0.083	0.097*	0.095*	0.081
	(1.788)	(2.011)	(1.927)	(1.501)
spread	-1.462	-1.644	-1.685	-1.560
	(-1.408)	(-1.443)	(-1.451)	(-1.500)
pc	-0.032***	-0.020**	-0.038***	-0.034***
	(-6.003)	(-3.256)	(-7.558)	(-5.467)
cs	0.037*	-0.058*	0.054***	0.054***
	(1.910)	(-2.008)	(4.576)	(4.347)
os	-0.034**	0.017	-0.045***	-0.046***
	(-2.560)	(1.149)	(-5.002)	(-5.131)
Constant	0.002	-0.004*	0.003	0.000
	(0.611)	(-2.147)	(0.938)	(0.098)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	7,318	7,318	7,318	7,318
R-squared	0.143	0.159	0.118	0.123

Panel B: Abnormal Return

VARIABLES	(1) abret	(2) abret	(3) abret	(4) abret
net_delta_volume	4.04e-09**			
	(2.776)			
Net_delta_volume_percent		0.215***		
		(6.694)		
net_delta_OI			1.48E-10	
			(1.341)	
net_delta_OI_percent				0.144
				(1.609)
rangevol	0.075	0.095	0.117	0.125
	(0.948)	(1.062)	(1.370)	(1.379)
price	0.000**	0.000***	0.000***	0.000***
	(3.291)	(5.360)	(4.257)	(3.544)
mktcap	-0.000	-0.000**	-0.000	0.000
	(-1.032)	(-3.171)	(-0.681)	(0.296)
turn	0.082	0.095*	0.093*	0.080
	(1.770)	(1.978)	(1.903)	(1.496)
spread	-1.506	-1.684	-1.718	-1.600
	(-1.390)	(-1.412)	(-1.414)	(-1.451)
pc	-0.027***	-0.017**	-0.032***	-0.029***
	(-4.686)	(-2.883)	(-5.871)	(-4.755)
cs	0.033*	-0.050*	0.049***	0.049***
	(1.912)	(-1.980)	(4.611)	(4.295)
os	-0.031**	0.014	-0.041***	-0.042***
	(-2.599)	(1.042)	(-4.973)	(-5.019)
Constant	-0.000	-0.006**	0.000	-0.002
	(-0.118)	(-2.582)	(0.083)	(-0.570)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	7,318	7,318	7,318	7,318
R-squared	0.148	0.158	0.123	0.128

Panel C: Spread

VARIABLES	(1) spread	(2) spread	(3) spread	(4) spread
net_delta_volume	-3.36e-11			
	(-1.653)			
Net_delta_volume_percent		-0.0003885		
		(-0.902)		
net_delta_OI			-3.01e-12	
			(-1.413)	
net_delta_OI_percent				-.0029834**
				(-2.990)
rangevol	0.011	0.010	0.010	0.010
	(1.734)	(1.687)	(1.675)	(1.625)
price	0.000	0.000	0.000	0.000
	(0.973)	(1.101)	(0.983)	(1.603)
mktcap	-0.000***	-0.000***	-0.000***	-0.000***
	(-4.362)	(-4.259)	(-5.874)	(-4.221)
turn	-0.002	-0.002	-0.002	-0.001
	(-0.983)	(-1.014)	(-0.977)	(-0.802)
pc	-0.000	-0.000	-0.000	-0.000
	(-1.018)	(-0.821)	(-0.844)	(-1.104)
cs	-0.001	-0.000	-0.001	-0.001
	(-0.991)	(-0.799)	(-1.291)	(-1.233)
os	0.000	0.000	0.000	0.000
	(0.205)	(0.161)	(0.412)	(0.423)
Constant	0.001***	0.001***	0.001***	0.001***
	(3.859)	(3.655)	(3.613)	(3.874)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	7,318	7,318	7,318	7,318
R-squared	0.444	0.442	0.443	0.444

Panel D: Range Volatility

VARIABLES	(1) rangevol	(2) rangevol	(3) rangevol	(4) rangevol
net_delta_volume	2.29e-09**			
	(2.678)			
Net_delta_volume_percent		0.043		
		(1.345)		
net_delta_OI			-8.15e-11	
			(-0.851)	
net_delta_OI_percent				-0.092
				(-1.271)
price	-0.000	-0.000	-0.000	-0.000
	(-0.649)	(-0.791)	(-0.704)	(-0.601)
mktcap	-0.000	0.000	0.000	0.000
	(-0.233)	(0.274)	(1.256)	(0.971)
turn	0.227***	0.240***	0.242***	0.249***
	(3.895)	(4.193)	(4.179)	(4.303)
spread	4.670	4.626	4.599	4.494
	(1.171)	(1.174)	(1.166)	(1.145)
pc	-0.004	-0.005	-0.010	-0.013
	(-0.462)	(-0.857)	(-1.406)	(-1.623)
cs	-0.034***	-0.045**	-0.024**	-0.023**
	(-5.917)	(-2.374)	(-3.065)	(-2.842)
os	0.029***	0.035**	0.023***	0.023***
	(8.845)	(3.283)	(4.620)	(4.839)
Constant	0.040***	0.040***	0.043***	0.044***
	(3.637)	(3.683)	(4.138)	(4.057)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	7,318	7,318	7,318	7,318
R-squared	0.580	0.572	0.571	0.573

Table 4: Cumulative Abnormal Returns Around Identified Gamma Squeeze Events in Meme Stocks

This table reports the Cumulative Abnormal Return for Gamma Squeezes identified from the Meme Sample from 2019 to 2023. CARs are calculated using the Carhart (1997) model with a 20-day estimation window and an 2 day gap period. T-Stats are calculated using cross-sectional standard errors.

Panel A: Meme Sample (n=11)

	-5	-3	-1	0	1	3	5	10	15	22
Ab. Ret	-0.53%	-3.44%	3.82%	20.80%	4.15%	0.56%	-2.84%	-1.12%	4.95%	0.46%
T-Stat	(-0.20)	(-1.38)	(1.49)	(3.08)	(0.84)	(0.15)	(-1.61)	(-0.54)	(1.93)	(0.11)
CAR	-0.53%	-3.88%	0.26%	21.00%	25.20%	27.00%	23.80%	16.50%	26.40%	29.10%
T-Stat	(-0.20)	(-0.66)	(0.05)	(2.86)	(2.19)	(2.83)	(2.24)	(1.91)	(2.56)	(2.46)
CAR				20.80%	24.90%	26.80%	23.60%	16.20%	26.10%	28.90%
T-Stat				(3.08)	(2.32)	(3.18)	(2.64)	(2.19)	(2.82)	(2.10)
CAR					4.15%	5.98%	2.79%	-4.56%	5.36%	8.07%
T-Stat					(0.84)	(1.44)	(0.47)	(-0.74)	(0.88)	(0.73)

Table 5: Regression Analysis for the Whole Sample

This table reports the regression results for the following regression using the whole sample:

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t}$$

Where *Return* is the one-day nominal return in Panel A and the one-day S&P 500 abnormal return in Panel B. *NetDeltaTrading* is the different measures for trading activity that comes from Delta Hedging, depending on the column. *RangeVolatility* is the range-based volatility measure, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs. *MarketCap* is the market capitalization for each firm i on day t computed as stock price multiplied by shares outstanding. *Spread* is the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. *Turnover* is the trading volume scaled by the shares outstanding. PC is the Put/Call ratio defined as the put volume divided by the total option volume). *CS* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. OS is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. The sample period is from 2029 to 2023. Standard errors are clustered by firm.

Panel A: Return

VARIABLES	(1) ret	(2) ret	(3) ret	(4) ret
net_delta_volume	1.42e-09***			
	(3.964)			
Net_delta_volume_percent		0.011***		
		(6.390)		
net_delta_OI			7.21e-11***	
			(3.026)	
net_delta_OI_percent				0.027***
				(3.074)
rangevol	0.096***	0.098***	0.098***	0.098***
	(13.377)	(13.549)	(13.569)	(13.555)
price	0.000***	0.000***	0.000***	0.000***
	(4.914)	(4.396)	(3.665)	(4.122)
mktcap	-0.000***	-0.000*	-0.000***	-0.000*
	(-4.459)	(-1.841)	(-3.351)	(-1.918)
turn	0.006	0.006	0.006	0.006
	(1.234)	(1.233)	(1.233)	(1.225)
spread	0.035	0.032	0.033	0.036
	(1.143)	(1.034)	(1.055)	(1.170)
pc	-0.011***	-0.011***	-0.011***	-0.011***
	(-86.573)	(-82.802)	(-88.597)	(-87.162)
cs	0.000	-0.007***	0.001***	0.001***
	(1.230)	(-6.520)	(5.275)	(4.503)
os	0.000**	0.004***	-0.000	0.000
	(2.199)	(6.493)	(-0.083)	(0.708)
Constant	-0.000	-0.000	-0.000	-0.001
	(-1.319)	(-1.390)	(-1.142)	(-1.543)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	3,352,916	3,352,916	3,352,916	3,352,916
R-squared	0.018	0.017	0.017	0.017

Panel B: Abnormal Return

VARIABLES	(1) abret	(2) abret	(3) abret	(4) abret
net_delta_volume	1.18e-09 ***			
	(3.559)			
Net_delta_volume_percent		0.009***		
		(6.328)		
net_delta_OI			5.80e-11***	
			(2.906)	
net_delta_OI_percent				0.024***
				(3.067)
rangevol	0.121***	0.122***	0.122***	0.122***
	(17.284)	(17.407)	(17.422)	(17.416)
price	0.000***	0.000***	0.000***	0.000***
	(4.808)	(4.342)	(3.696)	(4.083)
mktcap	-0.000***	-0.000*	-0.000***	-0.000*
	(-4.169)	(-1.712)	(-3.247)	(-1.788)
turn	0.006	0.006	0.006	0.006
	(1.230)	(1.229)	(1.229)	(1.221)
spread	0.046	0.043	0.043	0.046
	(1.593)	(1.494)	(1.513)	(1.628)
pc	-0.009***	-0.009***	-0.009***	-0.009***
	(-72.905)	(-70.739)	(-74.742)	(-73.440)
cs	0.000	-0.006***	0.001***	0.001***
	(1.613)	(-6.493)	(5.368)	(4.637)
os	0.000	0.003***	-0.000	-0.000
	(1.055)	(6.523)	(-1.011)	(-0.305)
Constant	-0.003***	-0.003***	-0.003***	-0.003***
	(-8.765)	(-8.712)	(-8.292)	(-8.963)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	3,352,916	3,352,916	3,352,916	3,352,916
R-squared	0.021	0.020	0.019	0.020

Panel C: Spread

VARIABLES	(1) spread	(2) spread	(3) spread	(4) spread
net_delta_volume	-1.43e-11 *** (-2.887)			
Net_delta_volume_percent		-.000054* (-1.657)		
net_delta_OI			-1.58e-12** (-2.003)	
net_delta_OI_percent				-.000804 ** (-2.554)
rangevol	0.008***	0.008***	0.008***	0.008***
	(24.584)	(24.527)	(24.520)	(24.540)
price	-0.000*	-0.000*	-0.000	-0.000
	(-1.853)	(-1.727)	(-1.544)	(-1.427)
mktcap	0.000	-0.000	0.000*	-0.000
	(1.045)	(-0.290)	(1.658)	(-0.333)
turn	-0.000	-0.000	-0.000	-0.000
	(-1.445)	(-1.443)	(-1.443)	(-1.433)
pc	-0.000***	-0.000***	-0.000***	-0.000***
	(-6.255)	(-6.134)	(-6.204)	(-6.306)
cs	-0.000**	-0.000	-0.000**	-0.000**
	(-2.023)	(-0.326)	(-2.313)	(-2.112)
os	0.000	-0.000	0.000	0.000
	(0.560)	(-0.779)	(0.713)	(0.538)
Constant	0.002***	0.002***	0.002***	0.002***
	(87.796)	(87.561)	(87.046)	(88.469)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	3,352,965	3,352,965	3,352,965	3,352,965
R-squared	0.434	0.434	0.434	0.434

Panel D: Range Volatility

VARIABLES	(1) rangevol	(2) rangevol	(3) rangevol	(4) rangevol
net_delta_volume	7.36e-10***			
	(3.123)			
Net_delta_volume_percent		0.000361		
		(1.270)		
net_delta_OI			-1.92e-11**	
			(-2.069)	
net_delta_OI_percent				0.002408
				(1.050)
price	-0.000***	-0.000***	-0.000***	-0.000***
	(-4.247)	(-4.399)	(-4.330)	(-4.393)
mktcap	-0.000	0.000	0.000	0.000
	(-0.507)	(0.765)	(1.371)	(0.764)
turn	0.012	0.012	0.012	0.012
	(1.368)	(1.368)	(1.368)	(1.367)
spread	0.875***	0.874***	0.873***	0.874***
	(7.828)	(7.829)	(7.829)	(7.828)
pc	0.001***	0.000***	0.000***	0.000***
	(5.448)	(4.855)	(4.771)	(4.923)
cs	-0.001***	-0.000	-0.000	-0.000
	(-3.235)	(-1.484)	(-0.654)	(-1.026)
os	-0.000**	-0.000	-0.000***	-0.000***
	(-2.355)	(-1.100)	(-3.015)	(-2.957)
Constant	0.042***	0.042***	0.042***	0.042***
	(76.493)	(77.244)	(77.141)	(77.151)
Clustered SE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	3,352,965	3,352,965	3,352,965	3,352,965
R-squared	0.347	0.346	0.346	0.346

Table 6: Cumulative Abnormal Returns Around Gamma Squeeze Events for Whole Sample

This Table Reports the Cumulative Abnormal Return for Gamma Squeezes identified from the Meme Sample from 2019 to 2023. CARs are calculated using the Carhart (1997) model with a 20 day estimation window and an 2 day gap period. T-Stats are calculated using cross-sectional standard errors.

Panel A:Whole Sample (n=641)

	-5	-3	-1	0	1	3	5	10	15	22
Ab. Ret	0.30%	0.58%	2.09%	4.61%	0.50%	0.61%	0.31%	0.10%	0.30%	0.20%
T-Stat	(1.63)	(3.41)	(6.89)	(10.41)	(1.85)	(2.55)	(1.46)	(0.44)	(1.10)	(0.76)
CAR	0.30%	1.68%	4.84%	9.46%	9.96%	10.90%	11.40%	12.50%	14.30%	14.60%
T-Stat	(1.63)	(5.39)	(9.75)	(12.47)	(12.52)	(11.89)	(11.30)	(9.73)	(8.96)	(7.79)
CAR				4.61%	5.12%	6.09%	6.52%	7.68%	9.47%	9.72%
T-Stat				(10.41)	(10.12)	(9.39)	(8.59)	(7.20)	(6.84)	(5.77)
CAR					0.50%	1.47%	1.90%	3.06%	4.85%	5.13%
T-Stat					(1.85)	(3.16)	(3.37)	(3.42)	(3.95)	(3.33)

Table 8: Short Term Impacts of Delta Holding Controlling for Delta Trading

Panel A: Net Delta Open Interest

This table reports the regression results for the following regression using the whole sample:

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 NetDeltaHolding_{i,t} + \beta_3 RangeVolatility_{i,t} + \beta_4 Price_{i,t} + \beta_5 MarketCap_{i,t} + \beta_6 Turnover_{i,t} + \beta_7 Spread_{i,t} + \beta_8 PC_{i,t} + \beta_9 CS_{i,t} + \beta_{10} OS_{i,t}$$

Where *Return* is the one-day nominal return in model 1, the one-day S&P 500 abnormal return in model 2 , *Spread* in model 3, and *RangeVolatility* in model 3. In Panel A, *NetDeltaTrading* is the Net Delta Volume and *NetDeltaHolding* is the Net Delta Open Interest. In Panel B, we use *NetDeltaVolumePercent* and *NetDeltaOpenInterestPercent* different measures for trading activity that comes from Delta Hedging, depending on the column. *RangeVolatility* is the range-based volatility measure, computed as the natural logarithm of the highest trading price on that day or the closing ask if no trade occurs, minus the natural logarithm of the lowest trading price on that day or the closing bid if no trade occurs. *MarketCap* is the market capitalization for each firm i on day t computed as stock price multiplied by shares outstanding. *Spread* is the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. *Turnover* is the trading volume scaled by the shares outstanding. PC is the Put/Call ratio defined as the put volume divided by the total option volume). *CS* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. OS is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. The sample period is from 2029 to 2023. Standard errors are clustered by firm.

VARIABLES	(1) ret	(2) abret	(3) spread	(4) rangevol
Net_delta_volume	0.011***	0.009***	-0.000	0.000
	(6.380)	(6.315)	(-1.494)	(1.506)
net_delta_OI	6.80e-11***	5.47e-11 ***	-1.56e-12 **	-1.94e-11**
	(2.986)	(2.859)	(-1.986)	(-2.076)
rangevol	0.098***	0.122***	0.008***	
	(13.570)	(17.425)	(24.521)	
price	0.000***	0.000***	-0.000	-0.000***
	(3.823)	(3.842)	(-1.552)	(-4.326)
mktcap	-0.000***	-0.000***	0.000	0.000
	(-3.281)	(-3.176)	(1.611)	(1.382)
turn	0.006	0.006	-0.000	0.012
	(1.233)	(1.229)	(-1.443)	(1.368)
spread	0.033	0.044		0.873***
	(1.076)	(1.531)		(7.829)
pc	-0.011***	-0.009***	-0.000***	0.000***
	(-83.064)	(-70.914)	(-6.197)	(4.764)
cs	-0.007***	-0.006***	-0.000	-0.000
	(-6.535)	(-6.502)	(-0.381)	(-1.571)
os	0.004***	0.003***	-0.000	-0.000
	(6.475)	(6.506)	(-0.663)	(-0.923)
Constant	-0.000	-0.003***	0.002***	0.042***
	(-1.150)	(-8.415)	(87.134)	(77.086)
Observations	3,352,916	3,352,916	3,352,965	3,352,965
R-squared	0.017	0.020	0.434	0.346

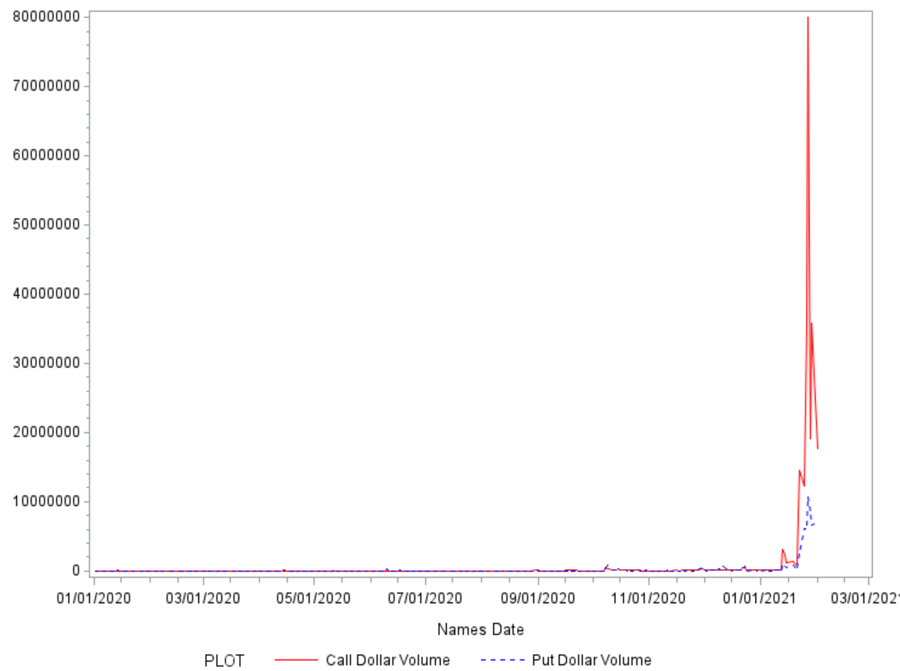
Panel B: Net Delta Open Interest Percent

VARIABLES	(1) ret	(2) abret	(3) spread	(4) rangevol
Net_delta_volume_percent	0.010***	0.008***	-0.000	0.000
	(6.334)	(6.260)	(-1.168)	(1.142)
net_delta_OI_percent	0.026***	0.023***	-0.001**	0.002
	(3.052)	(3.046)	(-2.546)	(1.037)
rangevol	0.098***	0.122***	0.008***	
	(13.557)	(17.419)	(24.541)	
price	0.000***	0.000***	-0.000	-0.000***
	(4.289)	(4.233)	(-1.432)	(-4.391)
mktcap	-0.000*	-0.000*	-0.000	0.000
	(-1.788)	(-1.663)	(-0.356)	(0.768)
turn	0.006	0.006	-0.000	0.012
	(1.225)	(1.222)	(-1.433)	(1.367)
spread	0.036	0.047		0.874***
	(1.186)	(1.642)		(7.828)
pc	-0.011***	-0.009***	-0.000***	0.000***
	(-82.062)	(-69.948)	(-6.302)	(4.918)
cs	-0.007***	-0.005***	-0.000	-0.000
	(-6.525)	(-6.494)	(-0.491)	(-1.442)
os	0.004***	0.003***	-0.000	-0.000
	(6.441)	(6.471)	(-0.525)	(-1.212)
Constant	-0.001	-0.003***	0.002***	0.042***
	(-1.533)	(-9.045)	(88.523)	(77.110)
Observations	3,352,916	3,352,916	3,352,965	3,352,965
R-squared	0.018	0.020	0.434	0.346

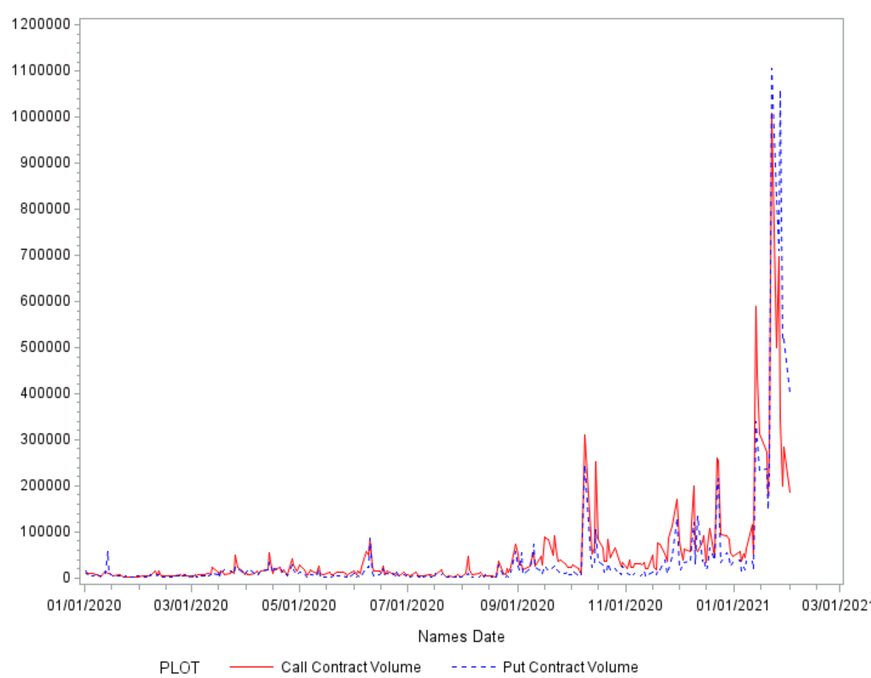
Figure 1 GME Option Volume

This figure reports the GameStop option volume before and during the price run-up from 2020 to January 2021. Panel A shows the call and put dollar volume through January 2021. Panel B shows the call and put contract volume through January 2021. Panel C shows the call and put dollar volume through December 2020. Panel D shows the call and put contract volume through December 2020.

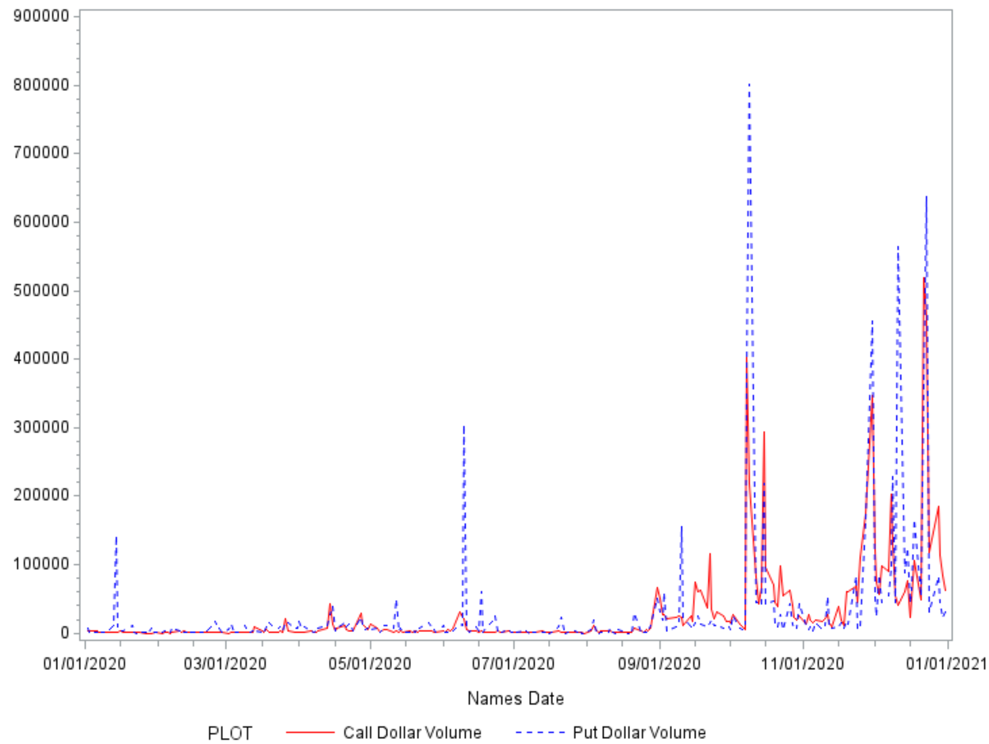
Panel A



Panel B



Panel C



Panel D

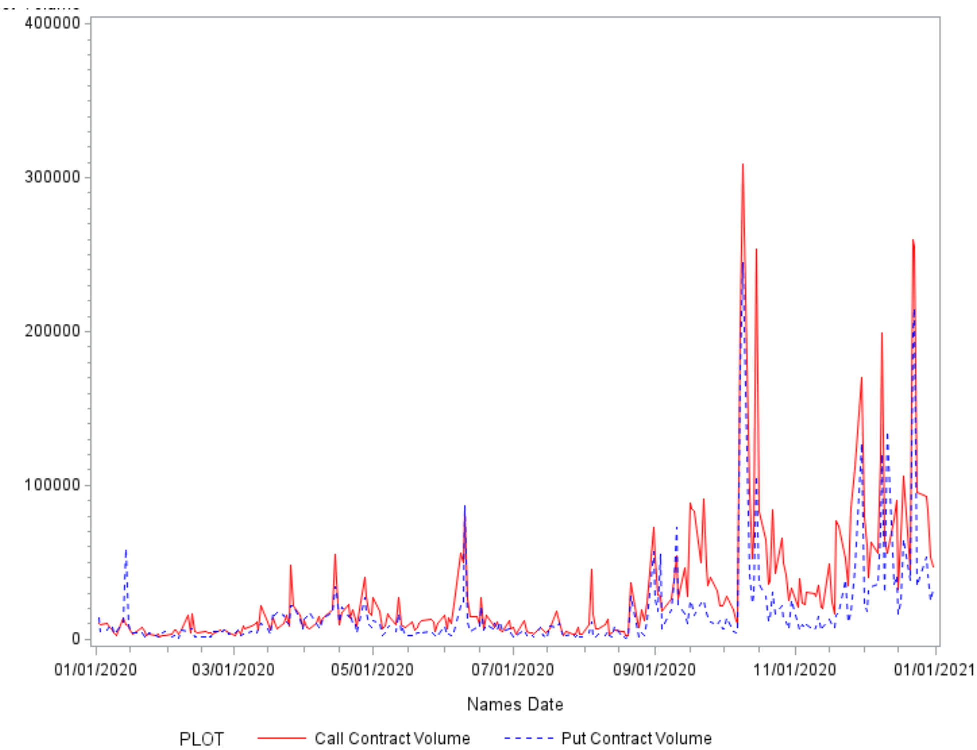
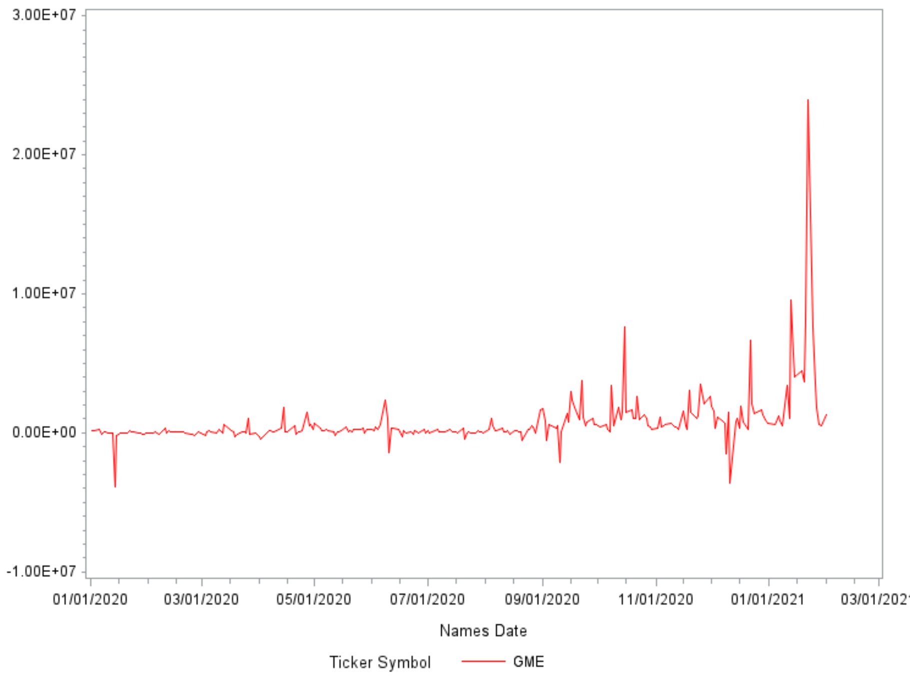


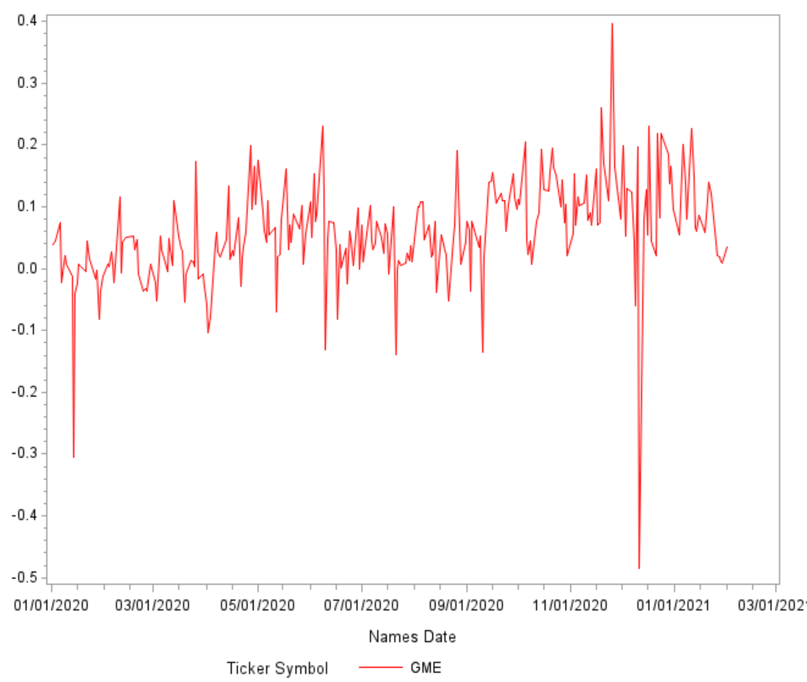
Figure 2 GME Delta Trading Estimates

This figure reports the GameStop volume and holdings as a result of delta hedging activities from 2020 to January 2021. Panel A shows the Net Delta Volume. Panel B reports the Net Delta Volume as a Percent of total volume. Panel C shows the Net Delta Open Interest. And Panel D shows the Net Delta Open Interest as a percent of shares outstanding.

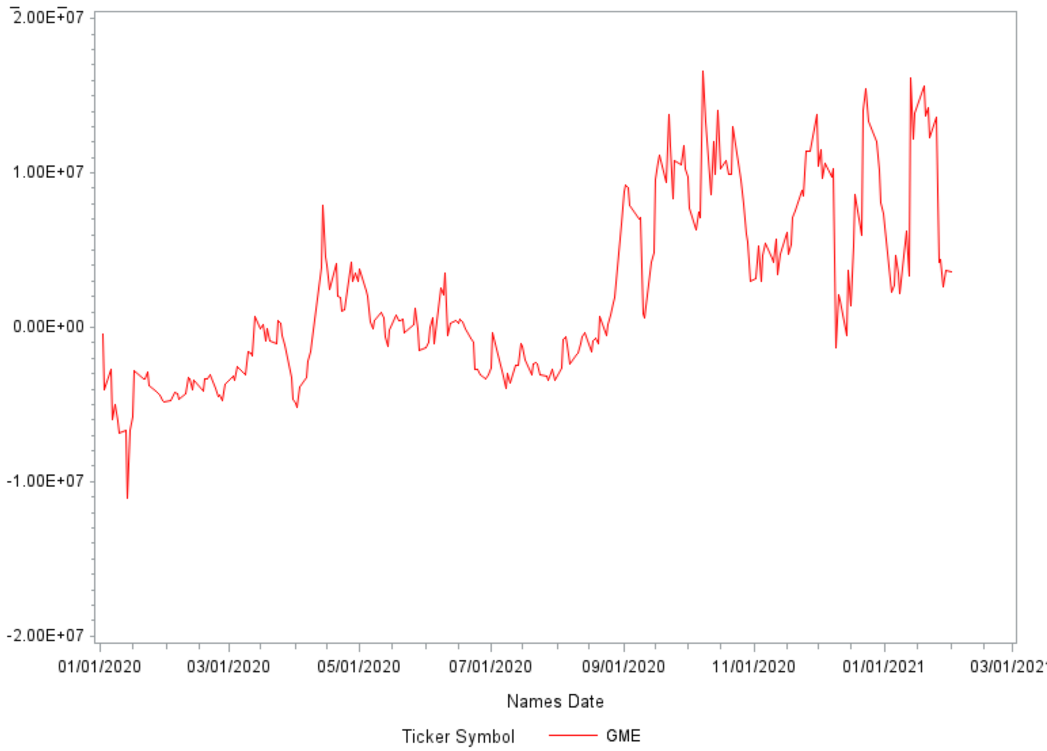
Panel A: Net Delta Volume



Panel B: Net Delta Volume Percent



Panel C: Net Delta Open Interest



Panel D Net Delta Open Interest Percent

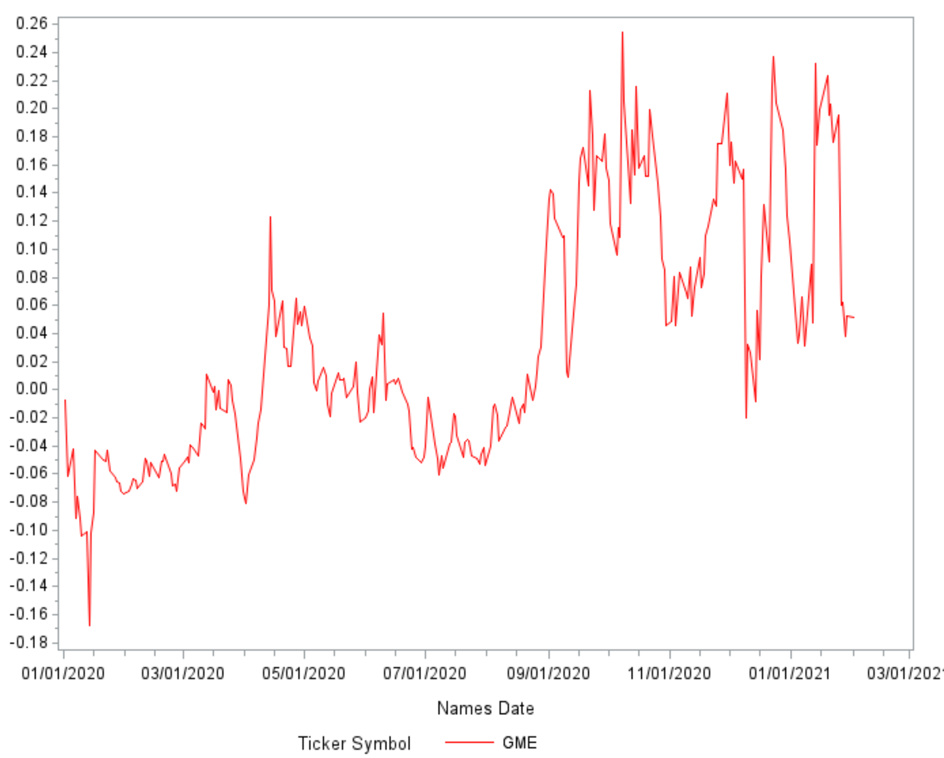
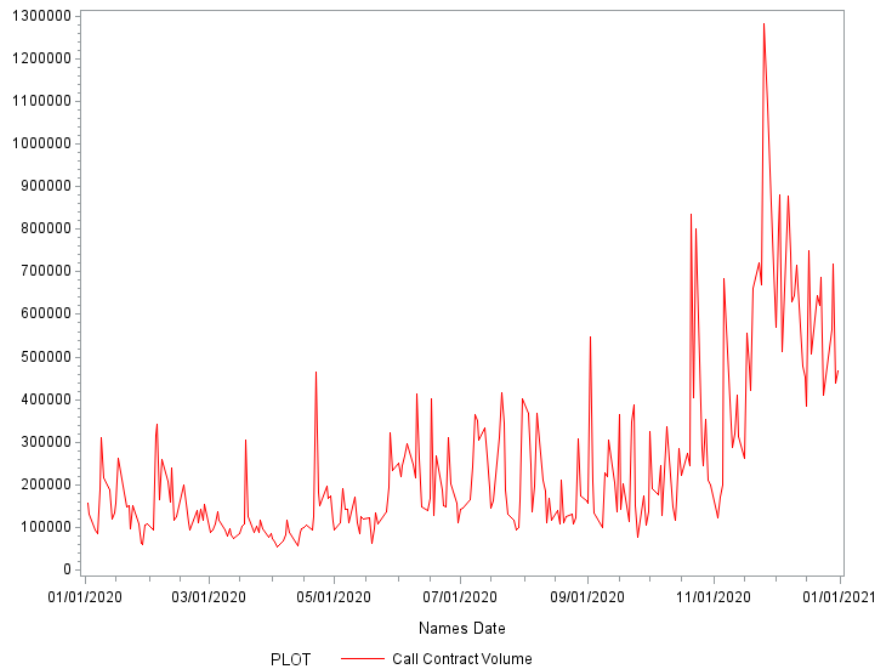


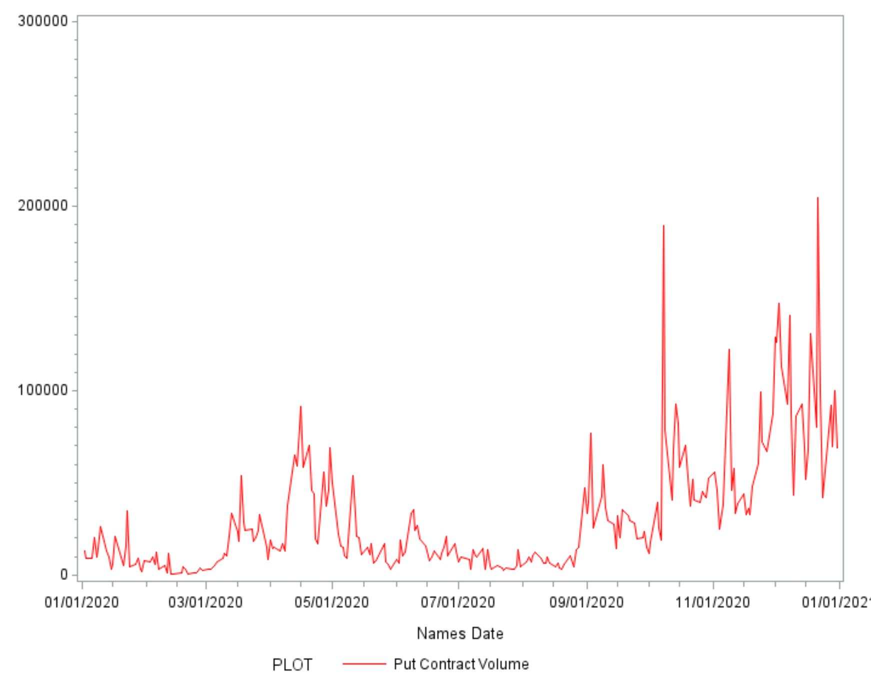
Figure 3 GME Volume by Moneyness

This figure reports the GameStop option volumes by option type and moneyness from January 2020 to December 2020. Panel A shows the out-of-the-money call option volumes. Panel B shows the out-of-the-money put option volume. Panel C shows the at-the-money call option volume. Panel D shows the at-the-money put option volume. Panel E shows the in-the-money call option volume. Panel F shows the in-the-money put option volume.

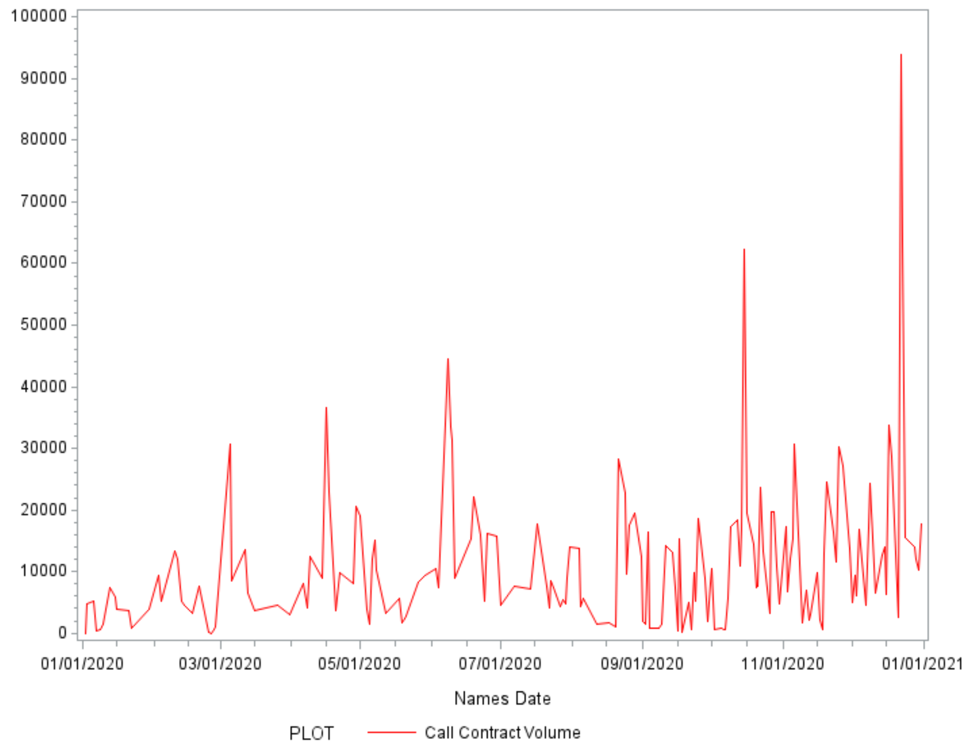
Panel A: OTM Calls



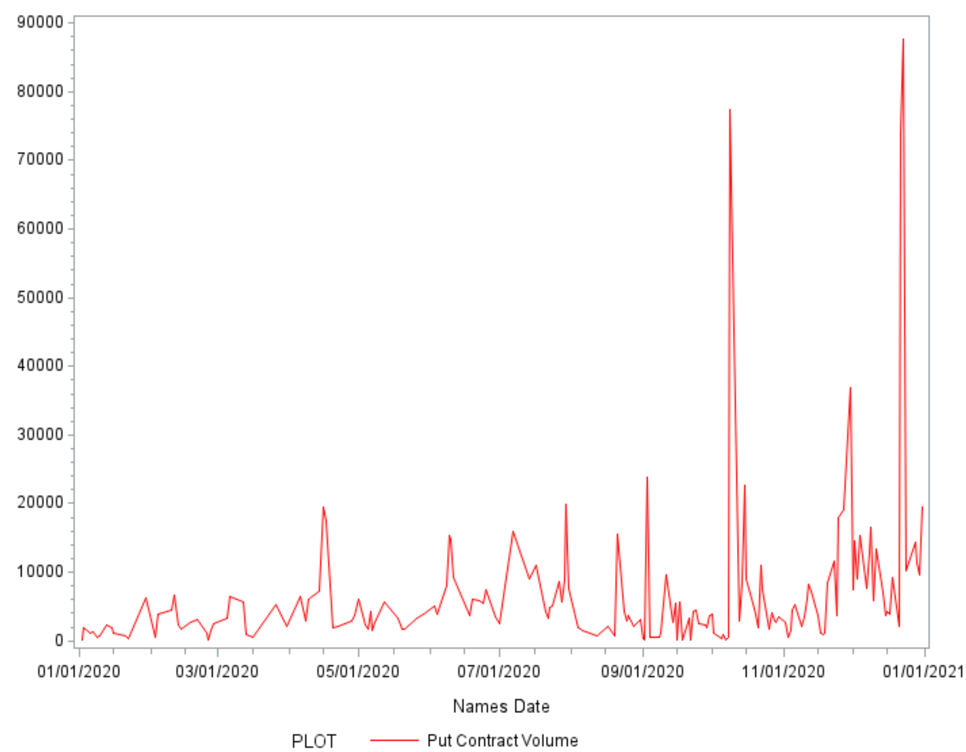
Panel B: OTM Puts



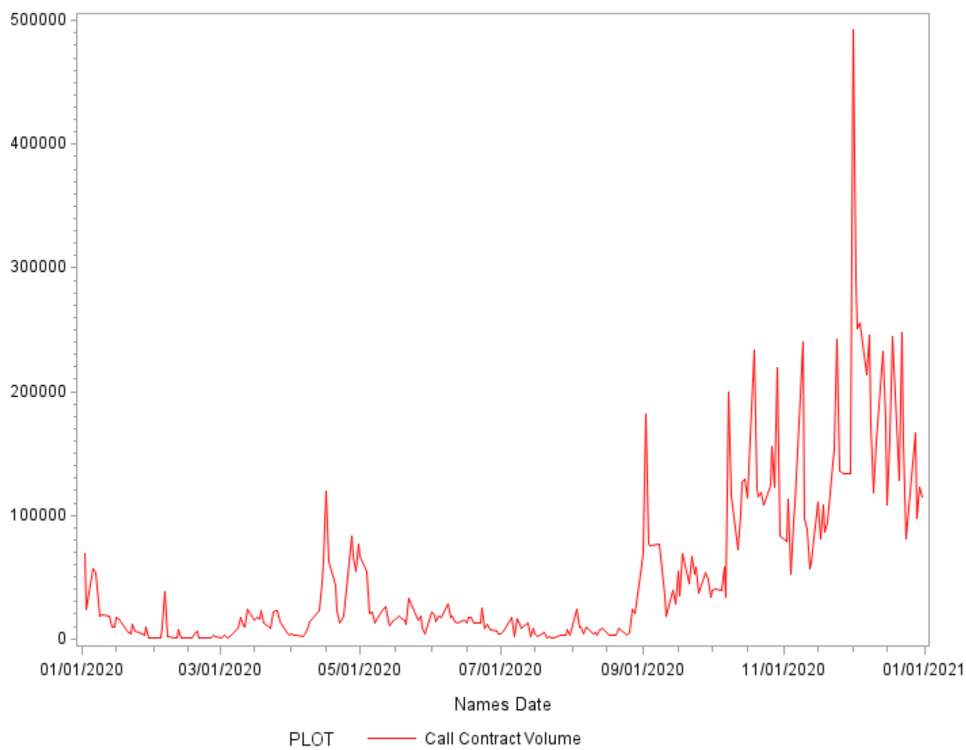
Panel C: ATM Calls



Panel D: ATM Puts



Panel E: ITM Calls



Panel F: ITM Puts

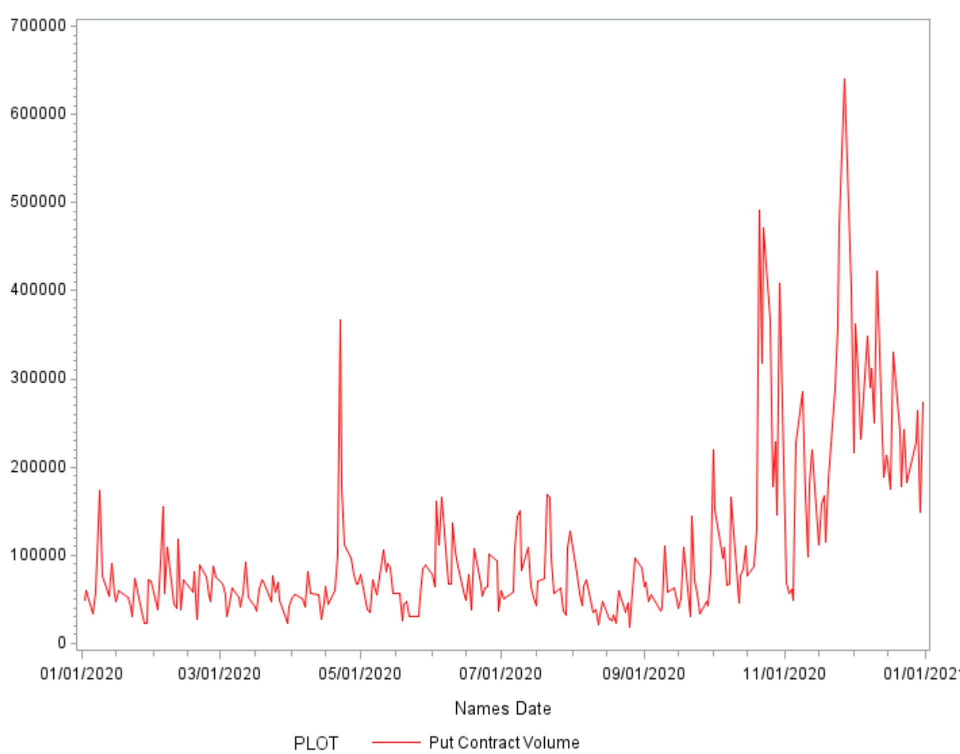


Figure 4: Net Delta Open Interest Percent for All Meme Stocks

This figure reports the Net Delta Open Interest Percent for each of the meme stocks in our sample from 2018 to 2013. The meme stocks includes GameStop (GME), AMC Entertainment Holdings (AMC), Blackberry (BB), Bed Bath and Beyond (BBBY), Carvana (CVNA), Express Inc. (EXPR), Koss Corp (KOSS), Naked Brand Group (NAKD), Nokia (NOK), SNAP Inc. (SNAP).