SEEKING GAMMA: LESSONS FROM THE MEME FRENZY*

Ahmed Baig
Associate Professor of Finance
Department of Finance
College of Business and Economics
Boise State University
ahmedbaig@boisestate.edu

Cuyler Strong
Assistant Professor of Finance
Department of Finance
Mike Ilitch School of Business
Wayne State University
cuyler.strong@wayne.edu

Gulnara Zaynutdinova
Associate Professor of Finance
Department of Finance
John Chambers College of Business and Economics
West Virginia University
Gulnara.zaynutdinova@mail.wvu.edu

This Version: 12/19/2025

SEEKING GAMMA: LESSONS FROM THE MEME FRENZY[*]

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 this squeeze 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 to all U.S. stocks, we systematically identify 669 potential gamma squeeze events 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 2021, GameStop (GME) became the epicenter of a market phenomenon that challenged conventional asset pricing mechanics. It gained national attention when its share price soared from around $20 to an intraday high of over $500 in a matter of weeks. The event, retrospectively known as the "meme frenzy", became an economic touchstone, sparking intense media coverage, triggering congressional hearings, catalyzing a major regulatory response and aggressive rulemaking agenda by the SEC. Central policy debates focused on key market structures, including payment for order flow, transparency in financial markets, short selling, and the securities lending market. Yet, despite widespread analysis and official investigations, clear answers regarding the precise mechanism of the event remain debated.

The conventional narrative suggests that a "short squeeze" played a pivotal role, a view that is widely shared by market analysts and academic researchers (Mitts, Battalio, Brogaard, Cain, Glosten, Kochuba, 2022; and Hilliard and Hilliard, 2023; Zhou and Zhou, 2023). However, the SEC has officially 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. 26). Indeed, the initial environment for a squeeze was severe. The short interest reached an extraordinary 122.97% of float as retail traders, largely motivated and coordinated via social media platforms like Reddit, flocked to buy both stock and options on the stock, significantly impacting the market dynamics. (SEC, p. 21) Yet, the subsequent data shows a decoupling. Following the initial peak, short interest sharply fell to below 30% of float, even as prices remained elevated. This persistence in prices points to more complex underlying mechanisms than a traditional short squeeze mechanism can fully explain.

Another prominent explanation for the rise in GME stock is a "gamma squeeze", a market dynamic where increased options trading forces market makers into buying underlying stock shares to manage their delta-hedged positions, consequently creating a feedback loop that drives stock prices upward. However, the SEC's official report questioned this explanation as well.[1] The SEC report points out that the increase in options trading volume in January 2021 primarily was driven by the buying of put options rather than call options. Furthermore, the data indicate that market makers were net buyers of call options rather than writers, an observation seemingly inconsistent with the mechanical requirements for a typical gamma squeeze. Consequently, the SEC report ruled out this mechanism for the January period.

We argue that these conclusions, while factually accurate for the specific window of January 2021, are incomplete due to two critical limitations. First, the newly implemented Consolidated Audit Trail (CAT) data system was not fully operational for core equity reporting requirements until December 31, 2020, restricting the depth of available data.[2] Second, and most importantly, the SEC's investigation, along with subsequent academic studies, focused exclusively on the climactic events of January 2021, overlooking the critical preceding months. By restricting their analysis to the peak of the event these studies overlook the accumulation of delta-hedging pressure in the preceding months. We posit that a gamma squeeze is rarely a spontaneous event but rather a cumulative process established long before the headline volatility occurs.

In this paper, we address this gap by providing comprehensive empirical evidence that a gamma squeeze did indeed occur, but that it was initiated significantly earlier than previously recognized, beginning in the fall of 2020. The huge price rise in January overshadows the significant returns GME had already generated in the preceding months as well as the prolonged periods of high prices that persisted long after GME left the mainstream news cycle. For example, from September to November 2020, GME's stock price increased by 147.8%, climbing from \$6.68 to \$16.56. Then, prices spiked again on March 10th and June 9th of 2021, long after short interest had substantially dropped. We therefore propose that a persistent gamma squeeze was structurally established in GME stock during the last quarter of 2020. This underlying

[1] The report states: "[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….However, 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. 29).

[2] 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. For more information, see https://catnmsplan.com/sites/default/files/2021-02/CAT-Q4-2020-QPR.pdf

inventory pressure, that we defined as "slow burn", created a fragile market state that not only precipitated the January crisis, but also contributed to the subsequent price volatility observed in 2021.

Crucially, this dynamic was not unique to GameStop. We document clear signs of gamma squeeze dynamics not only in GameStop but across a broader set of so-called "meme stocks" identified during this period.[3] To test the prevalence of this phenomenon, we move beyond anecdotal evidence and develop a systematic framework to identify and quantify these events. We introduce two novel measures designed to capture the mechanics of the squeeze. The first is the Net Delta Volume, which estimates the daily trading volume of underlying shares generated by immediate delta hedging flow. The second is the Net Delta Open Interest, which estimates the total shares of the underlying stock held by option market makers to hedge their open option positions. While Net Delta Volume captures short-term speculative pressure, we argue that Net Delta Open Interest represents "mandatory buying power", an aggregate inventory that market makers are contractually obligated to maintain. Unlike a momentum trader who can exit a position at any time, a delta-hedger is a captive buyer who must maintain or increase their inventory as long as the options remain open and the price rises.

To rationalize our empirical focus on Net Delta Open Interest, we develop a dynamic market microstructure model that formalizes the gamma squeeze as an inventory constraint problem. We extend the framework of Kyle (1985) and show that this inventory liability, captured by Net Delta Open Interest, forces market makers to engage in pro-cyclical hedging that dominates random noise trading. This mandatory rebalancing converts exogenous shocks into a deterministic, positive serial correlation in returns. We show that when dealers are short gamma, an initial price shock triggers a deterministic feedback loop where hedging flows amplify the original move. Crucially, because dealers rebalance daily, this feedback unfolds over multiple periods, providing a theoretical foundation for the multi-day price persistence, the "slow burn" that we observe empirically in gamma squeeze episodes.

---

[3] The list of meme stocks we identified includes the following: AMC Entertainment Holdings (AMC), Blackberry (BB), Bed Bath and Beyond (BBBY), Vinco Ventures Inc (BBIG), Churchill Capital (CCIV), Carvana (CVNA), Express Inc (EXPR), Jaguar Health (JAGX), Naked Brand Group (NAKD), Nokia (NOK), Palantir Technologies Inc (PLTR), and SNAP Inc (SNAP).

Applying this framework, we first analyze the meme stock sample and find that Net Delta Volume is a significant predictor of stock returns. More importantly, we find that Net Delta Open Interest predicts returns with a "slow burn" effect. Unlike speculative volume, which dissipates quickly, high Net Delta Open Interest is associated with sustained cumulative abnormal returns over the subsequent month. This confirms that the mechanical rebalancing of existing positions (rather than new speculative flow) is the dominant driver of the long-term price distortion. 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 formally identify potential gamma squeeze events within meme stocks, we establish specific criteria: a gamma squeeze is initiated if the Net Delta Open Interest (the percentage of shares outstanding held for delta hedging) exceeds 7.5% and remains consistently above this threshold for at least a month (22 trading days). Using this identification method, we detect 15 gamma squeeze events among the meme stocks. These identified gamma squeezes demonstrate significant price impacts, with an average abnormal return of 19.5% on the initial day and a cumulative abnormal return of 16.6% over the subsequent 22 trading days.

Next, we extend our analysis beyond meme stocks and generalize our gamma squeeze identification method to the broader market sample of U.S. stocks from 2019 to 2023. We document 669 potential gamma squeeze events. These broader market events are highly impactful, yielding an average abnormal return of 5.02% on the first day, with cumulative abnormal returns averaging 5.79% over the subsequent month. 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 tighter bid-ask spreads. Similar to the meme stock analysis, Net Delta Volume is associated with higher range volatility, while the sustained pressure from Net Delta Open Interest is associated with lower range volatility, suggesting the long-term stabilizing effect of continuous delta hedging.

To strengthen the causal interpretation of our results and address potential endogeneity concerns, specifically regarding whether option activity drives returns or merely reflects momentum, we employ a propensity score matching (PSM) analysis. The findings from the matched sample analysis confirm our primary results, showing that gamma squeeze events lead to statistically and economically significant short-term distortions in returns, liquidity, and volatility that cannot be explained by momentum alone. Furthermore, our threshold sensitivity analysis reveals a symmetric "unwind" effect. We find that when the Net Delta Open Interest eventually drops, we observe negative abnormal returns, confirming that the initial price run-up was driven by temporary intermediary constraints rather than fundamental information.

While the SEC report ruled out the gamma squeeze explanation based on the specific flows observed in January, subsequent academic papers have pushed back on this conclusion, providing evidence that supports the occurrence of a gamma squeeze to varying degrees. Mitts, Battalio, Brogaard, Cain, Glosten, and Kochuba (2022), in a direct response to the SEC report, state that market conditions indeed created the possibility of a gamma squeeze, criticizing the SEC for an insufficient analysis of market maker transactions. Similarly, Zhou and Zhou (2023) find evidence for an "after-hours" 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 violations to put-call parity.

However, a common thread that unites these studies with the SEC report is a singular focus on the crisis month of January 2021. This temporal restriction prevents them from observing the squeeze's earlier origins. While both the SEC report and Mitts et al. (2022) briefly acknowledge the presence of option trading activities in early 2020, their discussions serve primarily as context, providing minimal detailed analysis of the pre-crisis period. Specifically, the figures they present, which are replicated in Panels A and B of our Figure 1, show only a slight increase in option activity in October 2020. However, we argue that these figures are somewhat misleading, as they scale the earlier trading activity relative to the colossal trading volumes that occurred in January 2021. By replotting this data without the January spike (Panels C and D), we demonstrate a clear and significant ramp-up in delta-hedging pressure as early as October 2020, suggesting that the structural trap was set months in advance.

By identifying this early accumulation phase, our study bridges a critical gap in the literature regarding the predictive power of options and intermediary constraints. Option trading is well-documented to contain information about future stock returns. For example, the option-to-stock volume ratio has been shown to be a powerful predictor (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 the information in option volume, such as that captured by put-call ratios, predicts future stock returns. However, 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, the mechanical inventory adjustment at the heart of a gamma squeeze, remains relatively unexplored over longer horizons. Hu (2014) shows that stocks with high order imbalances as a result of delta hedging can generate excess annualized returns of up to 22%, but his analysis is limited to the immediate impact on the day of the initial option trade. We extend this framework by distinguishing between the immediate impact (Hu, 2014's focus) and the cumulative impact of rebalancing these positions while the option trader holds them. Furthermore, whereas informed traders typically prefer at-the-money and in-the-money options (Hu, 2014), we show that gamma squeezes are fundamentally driven by out-of-the-money options due to their higher convexity.

Beyond price predictability, the inventory constraints inherent in a gamma squeeze have implications for market liquidity, connecting our work to studies on market quality (Kumar, Sarin, and Shastri, 1998) and hedging impediments, such as the 2008 short-selling ban (Battalio and Schultz, 2011; Grundy, Lim, and Verwijmeren, 2012; Jiang, Shimizu, and Strong, 2020). Kumar, Sarin, and Shastri (2002) show that the presence of listed options improves the underlying stock market quality. However, this relation breaks down when hedging mechanisms are impaired. For example, Battalio and Schultz (2011) and Grundy, Lim, and Verwijmeren (2012) show that during the 2008 short-selling ban, option market quality deteriorated significantly, 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. We identify the "inventory overhang" (high Net Delta Open Interest) of a gamma squeeze as a similar friction. Even in the absence of regulatory bans, when market makers are forced to hold massive delta-hedged positions relative to the float, their capacity to provide liquidity is constrained. This creates a "soft" impediment to hedging that distorts prices and spreads, similar to the findings of Jiang, Shimizu, and Strong (2020) regarding single-stock futures.

This paper contributes to the existing literature in three important ways. First, we provide novel evidence that the gamma squeeze originated months before the widely publicized January 2021 frenzy and continued to affect prices thereafter. By identifying the accumulation of hedging inventory in September and October 2020, we challenge the view that the event was solely a spontaneous coordination of retail traders in January. Second, we formally define a gamma squeeze and develop 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 a practical tool for regulators, market practitioners, and academic researchers to better understand, monitor associated market dynamics, and potentially mitigate associated risks. Third, our broader examination across the entire market shows that gamma squeezes are a much more widespread and economically impactful phenomenon than has been previously documented. We show that these events have a significant impact on market quality as well as generate significant cumulative abnormal returns, even after controlling for other well-known predictors such as the put-to-call ratio and the option-to-stock ratio.

The rest of the paper is as follows: Section 1 explains the data and variable construction. Section 2 provides a background for gamma squeezes. Section 3 provides a theoretical background. Section 4 explains the empirical results. Section 5 concludes.

2. Background on Gamma Squeezes

In options trading, market makers facilitate liquidity by taking the opposite side of trades and maintaining a directionally neutral portfolio through a process known as delta hedging. The parameters governing this process are derived from the Black-Scholes model. Two of the most critical parameters, or “Greeks”, are Delta (Δ) and Gamma (Γ). “Delta” is the first partial derivative of the option price with respect to the underlying asset price, and it quantifies the number of shares market makers must buy or sell to hedge their exposure to price changes in the underlying asset. Gamma, in turn, is the first derivative of Delta (i.e., the second derivative of the option's price) with respect to the underlying asset price. It measures the rate at which an option's Delta changes as the underlying asset price fluctuates. Therefore, when the underlying asset's price rises, Gamma dictates how much additional stock a market maker must buy to restore a neutral (delta-hedged) position.

A "Gamma Squeeze" is a self-reinforcing feedback loop that occurs when significant directional options trading activity forces market makers to continually purchase shares of the underlying asset, creating continued upward pressure on its price. Specifically, as the price of the underlying stock rises, the Delta of call options increases at the rate determined by their Gamma, which in turn requires delta hedgers to purchase more shares to rebalance their hedged positions, further adding to the buying pressure on the stock, causing its price to increase further. This creates a reinforcing demand cycle. Higher prices of underlying assets lead to increased Delta, which necessitates additional stock purchases by market makers, further elevating prices and perpetuating the cycle.

To engineer a gamma squeeze, a trader or group of option traders, typically will purchase large volumes of out-of-the-money call options.[4] These options are attractive for initiating a squeeze for two reasons. First, they are relatively cheap, making it less expensive to take large options positions. Second, while these options initially have a low Delta, they have a high Gamma. That is, as the stock price begins to move upward towards the strike price, the option's Delta rapidly increases due to high Gamma. Consequently, option traders can force a market maker into a squeeze fairly easily if the price begins to

[4] There are two additional mechanisms through which a trader might attempt to engineer a gamma squeeze using put options. First, a trader could purchase in-the-money put options. This forces the option market maker to hedge by initially shorting the underlying stock, but as the price goes up, the market maker would need to purchase the stock to rebalance their hedged position as delta increases. However, this strategy would initially create downward pressure on the underlying stock, and the market maker would only be unwinding their initial position as the underlying price goes up. Additionally, the squeezer lacks a direct mechanism to exert upward price pressure and must passively rely on external factors to trigger the rebalancing buy order. Second, a trader could write an out-of-the-money put option. This would initially require the market maker to buy the underlying stock to hedge, which creates useful upward pressure. However, as the price of the underlying stock rises, the delta of the put option approaches zero. This decay forces the market maker to sell their stock inventory to unwind the hedge, creating selling pressure on the stock that effectively dampens the rally. Consequently, strategies involving put options facilitate either an initial upward pressure or conditional rebalancing pressure, but never both simultaneously. Thus, a sustainable gamma squeeze relies fundamentally on the purchase of call options.

move upward. While an option's Delta is highest for in-the-money options, its Gamma potential is highest for out-of-the-money options, as shown in Figure 2. This suggests a nuanced strategy where a trader might use in-the-money options to quickly establish a large delta-hedging footprint for market makers, while simultaneously using out-of-the-money options to generate high gamma potential that sustains upward price pressure as the stock price rises.

Additionally, Gamma squeezes are particularly potent when market liquidity is limited, such as in scenarios where there are few shares readily available for purchase. In such thinly traded markets, even moderate additional buying by market makers, which is triggered by hedging demands, can significantly elevate prices, thus creating a more effective squeeze. The case of GameStop serves as a prime example. With short sellers having already sold short more than 100% of the shares available to trade, the available float for purchase was severely constrained. In this environment, incremental buying pressure from market makers fulfilling their delta-hedging obligations (representing an additional 10-25% of outstanding shares) could substantially and disproportionately increase stock prices.

It is important, however, to distinguish a gamma squeeze from a short squeeze. A short squeeze can lead to rapid increases in the stock price due to short sellers urgently covering their positions under margin pressures by buying back shares. This can create a frantic "race to the exits" among short sellers. In contrast, a gamma squeeze is typically a much slower process with incremental upward pressure over a more extended period. 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, a gamma squeeze does not create the same degree of urgency. Instead, it generates consistent upward pressure, as thousands of market makers across the market individually and gradually rebalance their positions, day after day, in response to rising prices and evolving delta exposures.

3. Theoretical Framework

We develop a theoretical framework that models the gamma squeeze as a deterministic, multi-period market microstructure phenomenon driven by the inventory constraints of market makers (K). This approach extends Kyle (1985) by modeling an explicit inventory channel for options dealers. Rather than price impact from informed trading, we focus on mechanical hedging constraints, which is the core driver of gamma squeezes.

We define a sequential trading model over discrete time periods, *t=1,2,…T*. S_t is the stock price at time t. The market consists of three agents:

1. Manipulator (M) is the strategic initiator of the squeeze (representing coordinated retail flow aka "crowd") who establishes a large directional options position in Period 1 to drive prices higher.
2. Market Maker (K) is a risk-neutral intermediary agent whose objective is to maintain a delta-neutral inventory. K manages the liability (NΔOI) created by M through mechanical hedging.
3. Noise Trader (N) represents exogenous, random buy/sell order flow, $Q_t^N \sim i.i.d,\ E[Q_t^N] = 0$, $Var[Q_t^N] = \sigma_N^2$.That flow provides the necessary small price shocks that can be amplified by K's short-gamma hedging into a full gamma squeeze episode.

We set the following key assumptions:

1. Total order flow consists of two independent components: (a) exogenous noise and (b) market maker hedging flow that combine additively ($Q_t^N + Q_t^H$).
2. Price response to net order flow is linear with constant illiquidity parameter λ over the squeeze window: $dS_t = \lambda \times Q_t$.
3. The noise trader flow Q_t^N is exogenous and uninformed. Market makers do not possess private information about future prices.
4. Market makers rebalance their delta-neutral positions at discrete intervals (typically end-of-day), not continuously. This hedging latency creates the multi-day persistence observed empirically.

Period 1. Inventory establishment (NΔOI trigger)

In Period 1, manipulator's action forces the market marker (K) to hold inventory. Specifically, M purchases a large volume of out-of-money call options from the market marker K. To hedge this short option position K immediately holds a long position in the underlying stock.

Let's define OI as open interest, measured as the number of option contracts outstanding and each contract controls 100 shares. The required inventory is summarized by the initial Net Delta Open Interest, NΔOI, defined as the delta-weighted notional exposure of options inventory, measured in share equivalents:

$$\mathrm{N\Delta OI}_t = \mathrm{OI} \times 100 \times \Delta_t \ , \tag{1}$$

where OI is the number of option contracts , Δ_1 is the option delta at time t and $\Delta \in (0,1)$, representing the sensitivity of the option's price to the underlying stock price S_t ($\frac{\partial C}{\partial S}$ aka hedge ratio). Thus, NDOI represents the number of shares a delta-neutral market maker must hold to hedge the outstanding options inventory. The key insight is that NDOI (and not raw open interest) captures the true hedging burden since delta weights each contract by its sensitivity to stock price moves. A contract deep out-of-money requires minimal hedging, whereas an at-the-money contract demands substantial hedging, despite both counting equally in raw open interest tallies.[5]

In Period 1, the initial hedging order flow is simply the establishment of this position. The manipulator M buys call options from the market maker K. The market maker M is thus short options and must take a long position in the underlying of size:

$$Q_1^N = \mathrm{N\Delta OI}_1 = \mathrm{OI} \times 100 \times \Delta_1 \tag{2}$$

By selling options, K holds a short position in call contracts that have positive gamma ($\Gamma > 0$). Although each call option contract itself has positive gamma, K's portfolio is short these contracts, creating a net short-gamma position. This short-gamma exposure results in pro-cyclical hedging. When stock price increases ($d\, S_t > 0$) then (a) option becomes more in-the-money, meaning its delta increases; (b) because

[5] For example, 10,000 contracts at-the-money ($\Delta = 0.5$) require $10{,}000 \times 100 \times 0.5 = 500{,}000$ shares of hedging, but the same 10,000 contracts deep out-of-money ($\Delta = 0.1$) requires only 100,000 shares. When price moves and delta changes from 0.5 to 0.6, dealer must rebalance by buying 100,000 additional shares. NΔOI therefore captures both position size and moneyness, making it the natural state variable for the hedging flow equation. Raw open interest would obscure how moneyness modulates hedge demand and squeeze intensity.

K is short the option, this increase in delta means K's net position delta becomes more negative; (c) to restore delta-neutrality, K must therefore buy underlying shares. Thus, a price increase forces the market maker to buy, and a price decrease forces them to sell. This mechanical response ($Q_t^H > 0$ when $dS_t > 0$) is the engine of the feedback loop. Because this hedging response is deterministic that is driven entirely by option greeks and inventory size, it dominates the random noise of exogenous order flow when NΔOI is sufficiently large. This leads to the self-reinforcing price momentum characteristic of gamma squeezes.

<u>Period t >=2. Persistent Feedback Loop</u>

In Period t≥2, price changes at each step ($dS_t = S_t - S_{t-1}$) are determined by a linear price impact function, consisting of total net order flow and market illiquidity λ:

$$dS_t = \lambda \times Q_t = \lambda \times (Q_t^N + Q_t^H), \tag{3}$$

where λ represents the price impact per unit of volume (aka Kyle (1985) lambda), $Q_t^N \sim N(0, \sigma^2)$ is exogenous noise trader flow, and Q_t^H is the market maker's mandatory hedging flow.

The hedging flow Q_t^H is determined by the need to rebalance the existing NΔOI inventory following the previous period's price change. To derive this flow explicitly, we rely on the market maker's delta-neutral constraint. The hedging flow is simply the change in required inventory from the previous period, *t-1,* to the current period, t:

$$Q_t^H = \mathrm{N\Delta OI}_t - \mathrm{N\Delta OI}_{t-1} = \mathrm{OI} \times 100 \times [\Delta_t - \Delta_{t-1}] \tag{4}$$

We approximate the change in Delta, $[\Delta_t - \Delta_{t-1}]$, using a first-order Taylor expansion around P_{t-1} as follows:

$$\Delta_t \approx \Delta_{t-1} + \frac{\partial \Delta}{\partial S}(S_{t-1}) \times (S_t - S_{t-1}) \tag{5}$$

Since the derivative of Delta with respect to price is Gamma ($\frac{\partial \Delta}{\partial S} = \Gamma$) and $(S_t - S_{t-1}) = dS_t$, this simplifies to:

$$\Delta_t - \Delta_{t-1} \approx \Gamma_{t-1} \times dS_{t-1} \tag{6}$$

Substituting this approximation back into Eq. (4):

$$Q_t^H \approx \text{OI} \times 100 \times \Gamma_{t-1} \times dS_{t-1}. \tag{7}$$

Next, we express flow as follows using Eq. (1):

$$\text{N}\Delta\text{OI}_{t-1} = \text{OI} \times 100 \times \Delta_{t-1} \;\Rightarrow\; \text{OI} \times 100 = \frac{\text{N}\Delta\text{OI}_{t-1}}{\Delta_{t-1}} \tag{8}$$

Substituting (8) into (7):

$$Q_t^H \approx \frac{\text{N}\Delta\text{OI}_{t-1}}{\Delta_{t-1}} \times \Gamma_{t-1} \times dS_{t-1} \tag{9}$$

Rearranging:

$$Q_t^H \approx \text{N}\Delta\text{OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right) \times dS_{t-1} \tag{10}$$

Eq. (10) shows the hedging demand that is proportional to past price changes, scaled by position size $\text{N}\Delta\text{OI}_{t-1}$ and the gamma-to-delta ratio $\Gamma_{t-1}/\Delta_{t-1}$. The gamma-to-delta ratio represents the convexity per unit of hedge, i.e., how fast the hedge requirement changes relative to the size of the hedge itself.

Next, the total price impact in Eq. (3) yields the core dynamic equation of the gamma squeeze:

$$dS_t \approx \lambda \times Q_t^N + \lambda \times \left[\text{N}\Delta\text{OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right) \times dS_{t-1}\right] \tag{11}$$

Then, defining the feedback coefficient, Φ_t, as follows:

$$dS_t \approx \lambda \times Q_t^N + \underbrace{\lambda \times \text{N}\Delta\text{OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right)}_{feedback\ coefficient} \times dS_{t-1} \tag{12}$$

Then Eq. (12) becomes:

$$dS_t \approx \lambda \times Q_t^N + \Phi_t \times dS_{t-1} \tag{13}$$

Eq. (13) is the core dynamic equation of the gamma squeeze. Price changes follow an AR(1) process whose autoregressive coefficient Φ_t is endogenously determined by inventory and option convexity. It demonstrates that as long as NΔOI and gamma exposure are substantial, the feedback coefficient is large and positive. That is, Eq (13) shows that a positive price shock (dS_{t-1}) forces positive hedging flow ($Q_t^H > 0$), which then contributes to a positive price change dS_t. Φ_t acts as amplification factor, driving the self-reinforcing dynamic. Furthermore, because market makers often rebalance their delta hedges primarily at the end of the trading day rather than continuously, this recursive feedback loop unfolds over a multi-day horizon. This structural latency in hedging explains why the price impact manifests as a persistent "slow burn" rather than an instantaneous adjustment. This dynamic persists until the aggregate gamma exposure diminishes (because either as options approach expiration or move deep in-the-money/out-of-the-money), eventually restoring a steady state equilibrium where Φ_t approaches zero.

Lemma 1 (Inventory dominance). Let Φ_t be defined in Eq. (12). Suppose there is a threshold $\overline{\Phi} > 0$ such that whenever $\Phi_t > \overline{\Phi}$, then expected magnitude of hedging flow exceeds the typical magnitude of noise flow:

$$\mathrm{E}[|\, Q_t^H \,|] > \mathrm{E}[|\, Q_t^N \,|] \tag{14}$$

Proof:

From Eq (10):

$$Q_t^H \approx \mathrm{N\Delta OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right) \times dS_{t-1} \tag{15}$$

Then using our definition of $\Phi_t = \lambda \times \mathrm{N\Delta OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right)$, then:

$$Q_t^H \approx \frac{\Phi_t}{\lambda} \times dS_{t-1} \tag{16}$$

Taking expectations of absolute values:

$$\mathrm{E}[|\, Q_t^H \,|] \approx \frac{\Phi_t}{\lambda} \times \mathrm{E}[|\, dS_{t-1} \,|] \tag{17}$$

Using linear price impact in Eq (3), a typical price change scale is proportional to the typical noise trade, i.e, there exists a constant $c > 0$ such that:

$$\mathrm{E}[|\, dS_{t-1} \,|] \approx \mathrm{c} \times \lambda \times \mathrm{E}[|\, Q_t^N \,|] \tag{18}$$

Plugging (18) into Eq. (17):

$$\mathrm{E}[|\, Q_t^H \,|] \approx \frac{\Phi_t}{\lambda} \times \mathrm{c} \times \lambda \times \mathrm{E}[|\, Q_t^N \,|] = \Phi_t \times \mathrm{c} \times \mathrm{E}[|\, Q_t^N \,|] \tag{19}$$

Choose $\overline{\Phi}$ so that $c \times \overline{\Phi} > 1$. Then, for all $\Phi_t > \overline{\Phi}$

$$\mathrm{E}[|\, Q_t^H \,|] \gtrsim \mathrm{c} \times \Phi_t \times \mathrm{E}[|\, Q_t^N \,|] > \mathrm{E}[|\, Q_t^N \,|] \tag{20}$$

Thus, when $\Phi_t > \overline{\Phi}$, deterministic hedging flow dominates noise flow in expected magnitudes.

Proposition 1 (Price Persistence). The expected instantaneous price change is positively correlated with the previous period's price change, leading to upward price drift. If $\Phi_t > 0$ and then $dS_{t-1} > 0$:

$$E[dS_t | dS_{t-1}] = \Phi_t \times dS_{t-1} > 0 \tag{21}$$

Proof of Proposition 1. We take the conditional expectation of dS_t from Eq. (13) with respect to dS_{t-1}.

$$E[dS_t | dS_{t-1}] = \lambda \times \mathrm{E}[Q_t^N | dS_{t-1}] + \Phi_t \times dS_{t-1} \tag{22}$$

Since Q_t^N is uncorrelated with dS_{t-1}, then $\mathrm{E}[Q_t^N | dS_{t-1}] = 0$. Then Eq. simplifies to:

$$E[dS_t | dS_{t-1}] = \Phi_t \times dS_{t-1} \tag{23}$$

If $\Phi_t > 0$ and then $dS_{t-1} > 0$, then $E[dS_t | dS_{t-1}] > 0$. This positive price serial correlation provides the mathematical formalization of "slow burn" phenomenon observed in our empirical results, where price momentum persists well beyond the initial shock.

We also can rewrite Eq (13) as AR(1) structure in price changes:

$$dS_t \approx \Phi_t \times dS_{t-1} + \varepsilon_t \quad , \tag{24}$$

Where $\varepsilon_t = \lambda \times Q_t^N$ is a zero-mean innovation. In model, $\Phi_t = \lambda \times \mathrm{N\Delta OI}_{t-1} \times \left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right)$, is large when $\mathrm{N\Delta OI}_{t-1}$ is large (heavy options positioning); $\left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right)$ is large (options near the strike, especially from below, i.e., out or near-the-money); and λ is high (illiquid underlying). As options migrate deep in or out-of-money or approach expiration, gamma decays and $\left(\frac{\Gamma_{t-1}}{\Delta_{t-1}}\right)$ falls, pulling Φ_t down and weakening persistence, which matches the unwinding of gamma squeeze episodes we empirically observe.

4. Data and Variable Construction

Data for this study come 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, following Mitts et al. (2022), we identify the delta volume for any given contract *k* as:

$$DeltaVolume_{k,t} = Delta_{k,t} \times Option\ Volume_{k,t} \times 100\ , \tag{25}$$

which measures 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*. Since market makers use delta to determine how much of the underlying asset they must trade in order to hedge the positions they hold due to being a counterparty in the options market. Thus, by multiplying the delta by the daily option volume, we can estimate the amount of volume that is due to delta hedging from that particular contract.[6] We then multiply that number by 100 as each option contract is written on 100 shares of stock. Similarly, we identify delta open interest for each contract *k* as:

$$DeltaOpenInterest_{k,t} = Delta_{k,t} \times OpenInterest_{k,t} \times 100\ , \tag{26}$$

which estimates the amount of shares being held by market makers as a result of delta hedging for the particular option contract. We use this estimate because option market makers must hold their delta hedged positions for as long as the option contract is open. Since open interest measures the number of open option contracts, we can multiply the open interest by delta to estimate the number of underlying shares being held by market makers in order to hedge their option market making activities in that particular contract. We then 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.

$$NetDeltaVolume_{i,t} = \sum_{k=1}^{n} DeltaVolume_{k,t} \tag{27}$$

and

[6] We recognize that the potential drawback of this methodology is that OptionMetrics does not allow us to see whether option traders bought or wrote options. Thus, our estimates run on the assumption that the majority of option traders are buying the options, an assumption that may not hold under normal circumstances. However, given the large spikes in trading that we see, we argue that it is likely that those spikes are driven by directional trades. While other datasets may provide better information on directional option trades, the advantage of OptionMetrics is that it is more widely available, and our methodology is fairly simple to use with OptionMetrics.

$$NetDeltaOpenInterest_{i,t} = \sum_{k=1}^{n} DeltaOpenInterest_{k,t} \tag{28}$$

We then estimate the percent of daily trading volume in the underlying security that is a result of delta hedging for that day's option trading activity as Net Delta Volume Percent (NΔV%):

$$NetDeltaVolume\% = \frac{NetDeltaVolume}{StockVolume} \tag{29}$$

Additionally, we estimate the percent of shares that are being held by market makers for delta hedging purposes relative to the total shares outstanding as Net Delta Open Interest Percent (NΔOI%).

$$NetDeltaOpenInterest\% = \frac{NetDeltaOpenInterest}{SharesOutstanding} \tag{30}$$

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 range volatility and turnover were 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 NΔV% of 5.74% and a NΔOI% 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 NΔOI% 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 O/S ratio measure compare option volume to stock volume in their own ways, so it makes sense that they are somewhat highly coordinated. However, Net Delta Open Interest is not correlated with the O/S measures.

5. Empirical Results

4.1. 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 3 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. For additional context Panel B plots the NΔV%, which shows that despite the large spike in Net Delta Volume in January 2021, when measured as a percent 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 NΔOI%, 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 2020, and stays high throughout the rest of the sample period.[7] 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, it is difficult to argue that that a gamma squeeze was started in January 2021 because it was already in place for a few months before that point.

Figure 4 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 days with dramatic spikes in at-the-money volume.

Figure 5 shows the plots of NΔOI% 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 Bed, Bath & Beyond, increase around the middle of 2020, though they

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

each spike at different times, and then 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 can explain at least part of the price run-up in meme stocks during the meme frenzy. To do this, we run the following regression:

$$\begin{aligned} Return_{i,t} = {} & \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} \\ & + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t} + \beta_{10} ShortIntRatio_{i,t} \\ & + \beta_{11}\, Amihud \end{aligned} \tag{31}$$

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 set of different measures for trading activity that come 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. P/C is the put-call ratio defined as the put volume divided by the total option volume. *C/S* is the call-to-stock volume ratio defined as the call volume divided by the stock volume. O/S is the option-to-stock volume ratio defined as the total option volume divided by the stock volume. *ShortIntRatio* is the short interest divided by shares outstanding.[8] *Amihud* is computed by scaling the absolute return by the dollar volume scaled up by a million.

[8] In unreported results we also ran the regression using the Short Volume Ratio instead of short interest and it did not materially change the results.

Table 3 shows the results of the regression for the meme sample. Net Delta Volume and NΔV% 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, NΔOI% is positive and significant at the 10% level, suggesting that when option traders hold their positions, forcing market makers to hold their positions and rebalance them, 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 returns are 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 the bid-ask spread and find that Net Delta Volume and NΔOI% 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, returns are 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 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. We use NΔOI% as our main measure of trading activity from delta hedging. Because a gamma squeeze does not require active option trading to be effective, once the gamma squeeze is initially in place, market makers must continue to rebalance their portfolios as the underlying price increases, even if there is no option volume, the measure of Net Delta Volume may not be appropriate. Additionally, both option and stock volume vary 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 characteristics. NΔOI% estimates how many shares of stock are being held for delta hedging purposes as a percentage 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 overlapping gamma squeeze events, we further require that at least 60 days pass before a new event can be identified.

We use NΔOI% over 7.5% because the standard deviation of NΔOI% is 4.5% across all stocks, with a median of 0.03%, so 7.5% is 1.66 standard deviations above the median, indicating a high threshold relative to the typical stock-day observation. We then require the average NΔOI% 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 15 gamma squeeze events among the meme sample. With these, we calculate the cumulative abnormal return from trading day t-5 to t+22 using Carhart (1997), with a 20-day estimation period and 2-day gap period. Table 4 shows the results for the CARs where t-statistics are calculated using cross-sectional standard errors. We see that across the 15 events, the average abnormal return on day 0 is 19.5% while the average CAR from [1, 22] is 16.6% with a t-stat of 1.85. It is also notable 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 the gamma squeeze is in effect.

4.2. Finding Gamma Squeezes in the Whole Sample of Stocks

We have thus far shown that a gamma squeeze did occur in GameStop stock prior to the meme frenzy, albeit earlier than previously thought, and that a gamma squeeze occurred in other meme stocks under similar conditions. We have also shown that this increase in trading activity as a result of delta hedging has led to large increases in 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 NΔOI% is associated with a 25-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 range volatility is higher 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. On subsequent days during the gamma squeeze when option trading volume is lower but 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 GameStop, gamma squeezes are a longer-term process. Accordingly, 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 overlapping gamma squeeze events, we further require that at least 60 days pass before a new event can be identified.

We identify 669 different potential gamma squeeze events across all stocks from 2019 to 2023.[9] Table 6 reports summary statistics for these stocks on the first day of the potential gamma squeeze. This gives us an idea of what characteristics firms with potential gamma squeezes have. We see that compared to the rest of the sample (Table 2) on the first day of the potential gamma squeeze, the return is high at 6.21%. Additionally, stocks that have potential gamma squeezes have lower market capitalization, with an average market capitalization of $9.9 billion and a median of $537 million compared to the whole market average of $11 billion and a median of $1,553 million. Additionally, the O/S ratio is much larger at 0.698 compared to just 0.111 for the whole market, where the majority of that difference comes from call option trading, with a C/S ratio of 0.517, compared to 0.069 for the whole market. While the short interest ratio for potential gamma squeezes is also higher, recorded at 18.9% compared to just 5.0% for the whole market.

In Panels F and G of Table 6, we also report a variety of options measures on the first day of a potential gamma squeeze based on the moneyness of the individual options. Typically, you would expect the most option trading activity to be concentrated in the at-the-money options. What we see in Table 6 is that the out-of-the-money and deep out-of-the-money options have the highest trading volume as well as open interest, which is what you would expect with a potential gamma squeeze.

Table 7 reports the cumulative abnormal returns for these potential gamma squeeze events using the Carhart (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 these events there is an average abnormal return of 5.02%. Additionally, we find that from day 0 to 22, the cumulative abnormal return was 10.8%, which means the cumulative abnormal return from day 1 to 22 was 5.79% with a t-stat of 3.73. This shows that potential gamma squeezes are much more prevalent than previously thought and do have a sizable impact on the market.

6. Robustness Checks

---

[9] In unreported results, we remove the stocks in the meme stock sample to make sure that these results are not driven by meme stocks. Removing the meme stocks did little to change the economic or statistical significance of the results.

5.1. Net Delta Open Interest

Hu (2014) shows that stocks with high order imbalances as a result of delta hedging have an excess return of up to 22% in annualized returns. Given Hu's results, it would be natural to question whether our results are just picking up the same thing as Hu (2014), 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 by order imbalances from delta hedging or if our results instead 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 NΔV% 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 NΔOI%, as the coefficient in each model stays both economically and statistically nearly unchanged.

5.2. Propensity score matching

To improve causal inference and address endogeneity concerns arising from observable firm characteristics, we next employ a Propensity Score Matching (PSM) analysis (Rosenbaum and Rubin, 1983; Dehejia and Wahba, 2002). The goal is to construct a comparable control group of non-squeeze firms that resemble treated firms (i.e., those experiencing a gamma squeeze) on relevant pre-treatment characteristics. Specifically, we estimate the probability of treatment using the following probit model:

$$\Pr(gamma\_squeeze_{it} = 1) = \mathbf{\Phi}\,(\beta_0 + \mathbf{X}'_{it}\beta + \epsilon_{it}) \tag{32}$$

where X_{it} is lagged market capitalization and lagged NΔV%. *Market capitalization* proxies for firm size, helping to control for liquidity and scale effects. *NΔV%* reflects pre-treatment directional positioning in the options market, allowing to match on speculative pressure prior to gamma squeeze events. To address the potential concern that treated and control firms may differ systematically across calendar time, we include calendar month fixed effects (Stata's i.month) to ensure matching occurs within the same calendar month for treated and control firms. We use nearest-neighbor matching with a 1:3 treated-to-control ratio, without replacement, as implemented in the psmatch2 module in Stata (Leuven and Sianesi, 2003). The PSM procedure results in a matched sample of 453 treated firm-day observations and 1,359 control firm-day observations.

Balance diagnostics reported in Table 9 show substantially improved balance between the treated and control groups after matching. The standardized mean bias for the two covariates is substantially reduced from 33.9% to 8.2% on average, and the p-values of mean differences become statistically insignificant. The variance ratios fall within acceptable bounds post-matching, suggesting improved balance and comparability between treated and control observations. Panels A and B of Table 9 show summary statistics of the matched and unmatched samples. After matching, key covariates such as lagged firm size and NΔV% show no statistically significant differences between treated and control firms, further confirming a successful match. Panel C shows matching quality statistics. The Pseudo R^2 dropped substantially (from 0.013 to 0.002), the p-value for the likelihood ratio test became insignificant (0.341 from 0.000), Rubin's B decreased to 10.2% (below the 25% threshold), and Rubin's R is 0.50 (within the acceptable [0.5, 2] range), all indicating that the covariates no longer jointly predict treatment and that the groups are well-balanced.

Using the matched sample, we estimate average treatment effects on the treated (ATT) via weighted least squares, with weights derived from the matching procedure. Table 10 reports the results. Models (1) and (2) show that gamma squeezes increase both raw and abnormal returns by approximately 4.8% ($t>7.5$), consistent with sharp price pressure. Model (3) indicates a tightening of quoted spreads by an economically meaningful 2 basis points ($t=–4.43$), suggesting an improvement in liquidity. Model (4) shows that intraday volatility rises by 2.6% ($t = 3.41$), consistent with intensified trading activity and delta-hedging feedback effects. Overall, these results confirm that gamma squeezes lead to statistically and economically significant short-term distortions in returns, liquidity, and volatility. The consistency of results across the unmatched and matched samples supports the robustness of the main findings.

5.3. Threshold Analysis

In our main analysis, we use a two-prong threshold for identifying a potential gamma squeeze events, where 1) NΔOI% increases above 7.5%; and 2) the average NΔOI% remain at or above 7.5% over the subsequent 22 trading days. We also require that there are at least 60 days between the events to ensure that we are not getting gamma squeeze events that overlap with each other. The initial 7.5% level has been justified as it lies at 1.66 standard deviations above the median for all observations, placing it well into the right tail of the distribution.

However, it is prudent to test other thresholds to be sure that the 7.5% threshold makes economic sense. To do this we performed a detailed sensitivity analysis using various threshold levels, from the mildest (1%) to the more extreme (10%), across both the levels of Day 0 and the 22-day average NΔOI%. This analysis serves two main purposes. First, we want to confirm that the gamma squeeze effect is not solely dependent on the $7.5% cutoff, and more importantly, to explore the price implications of both upward pressure (the squeeze) and the subsequent unwinding of the delta-hedged positions (the unwind). Table 11 reports the results.

Panel A of Table 11 reports the 22-day CARs when we vary both the initial NΔOI% trigger level (Day 0) and the average NΔOI% level maintained over the subsequent 22 trading days. One clear result from the table is that regardless of the level that we choose, if the NΔOI% rises to a new level that it has not been at in the prior 60 days, and on average stays at or above that level for the next 22 days, the stock will have very significant abnormal returns over the following month. We see this across all thresholds. For instance, a 10% increase of NΔOI% level is associated with an 8.6% CAR over 22 days (t=4.83).

Crucially, the cross-section of results reveals a clear and powerful economic mechanism. First, it demonstrates the gamma squeeze mechanism - how high did the mandatory stock holdings have to jump to start the squeeze? When the 22-day average NΔOI% exceeds the Day 0 trigger level (e.g., Day 0 is 1% and the 22-Day Average is 10%), the CARs are the highest, peaking at 17.1% (t=7.81). This confirms the presence of sustained pressure, where continued, incrementally rising delta hedging obligations force market makers to purchase more shares, resulting in maximal, sustained upward price pressure.

Second, Panel A also shows strong empirical evidence of a rapid unwinding mechanism. Did the mandatory stock holdings stay high, or did they drop off quickly over the next month? If the Day 0 NΔOI% is high (e.g., 7.5%), but the average 22-day level subsequently drops to a lower threshold (e.g., 2.5%), we observe significant negative CARs (-4.56%, t = -3.80). This substantial drop in NΔOI% suggests that option positions are being closed or expiring, which requires market makers to sell the shares they previously held as a hedge to restore their delta-neutral positions. This forced selling pressure generates the observed negative abnormal returns, and the magnitude of this negative CAR is economically consistent with the price distortion created by the initial squeeze being corrected by the subsequent forced selling.

One would assume that the sample that goes above 7.5% would be a subsample of the 2.5% sample, suggesting that these results are not consistent. However, there are two important factors to consider. First, we require that there are 60 days between the first day of the gamma squeeze and any previous squeeze for that stock, which means that as we change the thresholds, the gamma squeezes that we detect will be different, so the more stringent thresholds are not necessarily a subset of the less stringent thresholds. Second, if the NΔOI% increases to a certain level, then subsequently the average 22 day level drops to a lower threshold, that suggests that trading in the stock has decreased, in particular, the number of shares held by option market makers is dropping over those 22-days. If the average drops by 2.5%, that suggests that shares owned by option market makers potentially are dropping by up to 5% of shares. In this case, if 5% of shares have become available to trade that were previously owned, we should expect the price to drop.

We see from these results that the changes in trading after the initial threshold is met can play a large role in how the price reacts to the gamma squeeze. However, one important, but not necessarily characteristic of a gamma squeeze is that once the squeeze is in place the option trader putting on the squeeze does not need to continue to trade options, and the delta-hedging market maker will continue to purchase more of the stock to rebalance their hedge as the price moves up, thus continuing to put upward pressure on the stock. As stated, this is not a necessary characteristic of a gamma squeeze because the option trader who put on the squeeze or other option traders could continue to trade in options throughout the squeeze. However, we would expect that we could find instances of gamma squeezes that meet those conditions of continued high NΔOI%, even while option trading has decreased.

To test this, we report 22-day CARs for a second pair of thresholds. First, the NΔOI% must increase above a certain level (from 1% up to 10%) and stay above that same level over the following 22 days, therefore encompassing the first two-prong threshold. The second is that the Option-to-Stock (O/S) ratio over the 22-day period must drop below a certain percent relative to the Day 0 O/S ratio.

The constant upward price pressure is driven by the rebalancing of existing delta-hedged positions and not necessarily by continuous new options trading. To isolate the rebalancing effect, Panel B imposes a further restriction. We look at only the stocks where the squeeze holdings stayed high for a month. Then, we check what happened to the new options trading activity during that month (measured by the O/S ratio). Specifically, the Option-to-Stock (O/S) ratio over the 22-day period must fall relative to the Day 0 O/S ratio, indicating reduced new options trading. We hold the NΔOI% level to be at or above the initial trigger level for 22 days. Panel B of Table 11 reports the results. First, when the 22-day O/S ratio is restricted to be less than 100% of the Day 0 level (i.e., new options activity has slowed down), CARs remain high across all thresholds. Second, as the O/S ratio falls, the CARs also fall for the thresholds up to 5%. However, at the higher NΔOI% thresholds (7.5% and 10%), the CARs remain at similar levels as the O/S ratio falls to 25% from the 50% level. Specifically, for the 7.5% NΔOI% threshold, the CAR rises from 4.99% (in the 50% O/S bucket) to 5.37% in the 25% O/S bucket (t=2.98). Additionally, when we move to a reduction of O/S to 20% of the initial level, no threshold continues to be significant except for the 7.5% threshold which is significant at the 10% level. These findings are of particular significance. They demonstrate that at extreme levels of NΔOI% threshold gamma squeeze is sufficiently robust that even a dramatic reduction in new options trading volume (O/S ratio drops to 20 or 25%) does not mitigate the upward pressure. Instead, the persistent need for market makers to buy stock as the price moves (the rebalancing effect, or "slow burn") becomes the dominant factor driving the final price distortion, confirming our core hypothesis.

In sum, our sensitivity analysis suggests that our 7.5% threshold is a statistically appropriate starting point as the gamma squeeze is sufficiently strong. It confirms the upward price effect from sustained delta-hedging pressure and the corresponding downward correction from forced unwinding of those positions.

7. Conclusion

This paper investigates the controversial role of gamma squeezes in the 2021 "Meme Frenzy" and beyond. We show that a gamma squeeze did, in fact, occur in GameStop stock leading up to the 2021 Meme Frenzy, however the origins of this gamma squeeze trace back to September and October of 2020, months earlier than previously thought. This phenomenon was not isolated. We find similar dynamics also occurred in other meme stocks during the same time period. We show that these gamma squeeze events 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 counterparty 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.

Our primary contributions are threefold. First, we provide novel empirical evidence that reframes the timeline and core mechanism of the GameStop saga. Second, to achieve this, we develop and formalize a new framework for identifying and measuring gamma squeeze events. Third, by applying this framework systematically, we reveal that gamma squeezes are not a niche anomaly confined to meme stocks but a widespread market phenomenon. We identify 669 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 begins. Overall, our paper demonstrates that the "Meme Frenzy" was not an anomalous, speculative event, but rather the result of a mechanically driven process.

References

Battalio, R. and Schultz, P., 2011. Regulatory uncertainty and market liquidity: The 2008 short sale ban's impact on equity option markets. *The Journal of Finance*, *66*(6), pp.2013-2053.

Carhart, M.M., 1997. On persistence in mutual fund performance. *The Journal of finance*, *52*(1), pp.57-82.

Dehejia, R.H. and Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. *Review of Economics and statistics*, *84*(1), pp.151-161.

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

Grundy, B.D., Lim, B. and Verwijmeren, P., 2012. Do option markets undo restrictions on short sales? Evidence from the 2008 short-sale ban. *Journal of Financial Economics*, *106*(2), pp.331-348.

Hilliard, J.E. and Hilliard, J., 2023. The GameStop short squeeze: Put–call parity and the effect of frictions before, during and after the squeeze. *Journal of Futures Markets*, *43*(5), pp.635-661.

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

Jiang, G.J., Shimizu, Y. and Strong, C., 2020. When trading options is not the only option: The effects of single-stock futures trading on options market quality. *Journal of Futures Markets*, *40*(9), pp.1398-1419.

Johnson, T.L. and So, E.C., 2012. The option to stock volume ratio and future returns. *Journal of Financial Economics*, *106*(2), pp.262-286.

Kyle, A. S. (1985). Continuous auctions and insider trading, *Econometrica*, 53(6), pp.1315-1335.

Kumar, R., Sarin, A. and Shastri, K., 1998. The impact of options trading on the market quality of the underlying security: An empirical analysis. *The Journal of Finance*, *53*(2), pp.717-732.

Leuven, E. and Sianesi, B., 2018. PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing.

Mitts, J., Battalio, R.H., Brogaard, J., Cain, M.D., Glosten, L.R. and Kochuba, B., 2022. A report by the ad hoc academic committee on equity and options market structure conditions in early 2021. *Available at SSRN 4030179*.

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

Roll, R., Schwartz, E. and Subrahmanyam, A., 2010. O/S: The relative trading activity in options and stock. *Journal of Financial Economics*, *96*(1), pp.1-17.

Rosenbaum, P.R. and Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), pp.41-55.

Zhou, G. and Zhou, Z.C., 2023. What explains gamestop price surge? evidence from both stock and option tick-by-tick trading. *Evidence from Both Stock and Option Tick-by-tick Trading (August 1, 2023)*.

Table 1: Meme Stock Sample Summary Statistics

This table reports the summary statistics for the Meme Sample from 2019 to 2023. The Meme Sample includes AMC Entertainment Holdings (AMC), Blackberry (BB), Bed Bath and Beyond (BBBY), Vinco Ventures Inc (BBIG), Churchill Capital (CCIV), Carvana (CVNA), Express Inc (EXPR), GameStop (GME), Jaguar Health (JAGX), Naked Brand Group (NAKD), Nokia (NOK), Palantir Technologies Inc (PLTR), and 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, and Amihud Illiquidity measure computed by scaling the absolute return by the dollar volume scaled up by a billion. 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 divided by one billion. 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 divided by one billion. 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 volume ratios: *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume, *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume, *P/S* is the Put to Stock Volume Ratio defined as the put volume divided by the stock volume, and *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. Panel E reports the short selling measures, Short Volume divided by one million, Total Volume divided by one million and the Short Ratio that equals the Short Volume divided by the Total Volume. Short Int. Ratio is the short interest divided by shares outstanding.

Panel A:

	N	Mean	p50	SD	p25	p75
Return	9,233	0.18%	-0.19%	8.00%	-2.65%	2.32%
Abnormal Return	9,233	0.13%	-0.25%	7.78%	-2.41%	1.89%
Price	9,233	$32.21	$9.48	$60.53	$4.80	$24.54
MarketCap	9,233	$9,337,002	$3,201,403	$16,000,000	$608,294	$11,200,000

Panel B:

	N	Mean	p50	SD	p25	p75
Range Volatility	9,233	0.070	0.054	0.064	0.035	0.084
Turnover	9,233	0.082	0.035	0.239	0.019	0.068
Spread	9,233	0.002	0.001	0.002	0.001	0.002
Amihud	9,233	1.582	0.179	5.463	0.0519	0.755

Panel C:

	N	Mean	p50	SD	p25	p75
netΔvolume	9,228	1.4064	0.2895	3.5192	0.0336	1.3445
Net Δvolume%	9,228	6.56%	3.66%	12.59%	0.85%	9.21%
net Δ OI	9,228	10.1434	3.3426	21.817	0.1981	15.381
net Δ OI%	9,228	3.76%	1.80%	7.51%	0.16%	5.39%

Panel D:

	N	Mean	p50	SD	p25	p75
O/S	9,233	0.626	0.360	1.003	0.163	0.712
C/S	9,233	0.420	0.232	0.693	0.104	0.484
P/S	9,233	0.206	0.108	0.353	0.034	0.226
P/C	9,233	0.314	0.293	0.178	0.178	0.421

Panel E:

	N	Mean	p50	SD	p25	p75
Short Volume	9,233	8.67	3.73	17.00	1.48	10.30
Total Volume	9,233	17.50	7.29	36.10	2.67	20.70
Short Ratio	9,233	53.1%	52.8%	10.7%	45.1%	60.6%
Short Int. Ratio	9,137	20.1%	15.0%	19.9%	5.7%	26.1%

Table 2. Whole Sample 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, and Amihud Illiquidity measure computed by scaling the absolute return by the dollar volume scaled up by a billion. 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 divided by one billion. 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 divided by one billion. 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 volume ratios: : *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume, *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume, *P/S* is the Put to Stock Volume Ratio defined as the put volume divided by the stock volume, and *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. Panel E reports the short selling measures, Short Volume divided by one million, Total Volume divided by one million and the Short Ratio that equals the Short Volume divided by the Total Volume. Short Int. Ratio is the short interest divided by shares outstanding.

Panel A

	N	Mean	p50	SD	p25	p75
Return	4,289,345	0.04%	0.00%	4.06%	-1.43%	1.41%
Abnormal Return	4,289,345	0.00%	-0.05%	3.78%	-1.30%	1.16%
Price	4,289,424	$54.11	$26.76	$105.07	$9.98	$61.92
MarketCap	4,289,424	$11,000,000	$1,553,807	$56,500,000	$396,927	$5,752,954

Panel B:

	N	Mean	p50	SD	p25	p75
Range Volatility	4,289,424	0.042	0.032	0.038	0.019	0.053
Turnover	4,289,422	0.021	0.007	0.250	0.004	0.014
Spread	4,289,412	0.002	0.001	0.005	0.000	0.002
Amihud	4,289,325	35.051	0.921	2040	0.153	5.648

Panel C:

	N	Mean	p50	SD	p25	p75
netΔvol	4,147,282	0.0579	0.0003	1.2549	0.0000	0.0077
NetΔvol%	4,147,263	1.25%	0.08%	17.29%	0.00%	1.00%
net Δ OI	4,147,282	0.5598	0.0166	10.8827	-0.00176	0.204
net Δ OI%	4,147,281	0.33%	0.03%	4.47%	0.00%	0.26%

Panel D:

	N	Mean	p50	SD	p25	p75
O/S	4,289,404	0.111	0.015	0.508	0.001	0.079
C/S	4,289,404	0.069	0.008	0.321	0.000	0.048
P/S	4,289,404	0.042	0.003	0.323	0.000	0.021
P/C	3,467,709	0.348	0.282	0.313	0.063	0.546

Panel E:

	N	Mean	p50	SD	p25	p75
Short Volume	4,289,430	0.88	0.20	3.62	0.07	0.62
Total Volume	4,289,430	1.70	0.41	6.86	0.14	1.22
Short Ratio	4,289,430	51.0%	51.5%	14.7%	41.4%	61.1%
Short Int Ratio	4,248,463	5.0%	2.7%	11.5%	1.3%	5.9%

Table 3: Regression Analysis for the Meme Stocks Sample

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

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t} + \beta_{10} ShortIntRatio_{i,t} + \beta_{11}\ Amihud$$

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. *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. *ShortIntRatio* is the short interest divided by shares outstanding. *Amihud* is computed by scaling the absolute return by the dollar volume scaled up by a million. The sample period is from 2019 to 2023. Standard errors are clustered by firm.

Panel A: Return

VARIABLES	(1) Return	(2) Return	(3) Return	(4) Return
netΔvol	3.936***			
	(4.041)			
NetΔvol%		0.181***		
		(3.649)		
net Δ OI			0.086	
			(0.884)	
NetΔOI%				-0.067
				(-0.830)
Range Volatility	-0.038	-0.003	0.012	0.009
	(-0.330)	(-0.027)	(0.110)	(0.088)
Price	0.000***	0.000***	0.000***	0.000***
	(3.702)	(5.619)	(5.023)	(3.295)
MarketCap	-0.000	-0.000**	-0.000	-0.000
	(-1.271)	(-3.043)	(-0.967)	(-1.284)
Turnover	0.118*	0.132**	0.131**	0.139**
	(2.056)	(2.422)	(2.392)	(2.514)
Spread	-0.267	-1.007	-0.968	-1.375
	(-0.256)	(-1.074)	(-0.961)	(-1.797)
P/C	-0.046***	-0.042***	-0.053***	-0.057***
	(-6.648)	(-5.416)	(-8.456)	(-6.894)
C/S	0.021**	-0.055*	0.037***	0.039***
	(2.578)	(-2.124)	(4.867)	(4.456)
O/S	-0.016**	0.023	-0.026***	-0.026***
	(-2.889)	(1.748)	(-4.580)	(-4.487)
Short Int. Ratio	0.031***	0.020**	0.032***	0.038***
	(5.775)	(2.771)	(4.677)	(6.529)
Amihud	0.205	0.214	0.191	0.105
	(0.804)	(0.785)	(0.770)	(0.355)
Constant	-0.004	-0.004	-0.003	-0.001
	(-1.081)	(-0.920)	(-0.610)	(-0.131)
Observations	9,134	9,134	9,134	9,134
R-squared	0.202	0.204	0.182	0.183

Panel B: Abnormal Return

VARIABLES	(1) Ab. Return	(2) Ab. Return	(3) Ab. Return	(4) Ab. Return
netΔvol	3.788***			
	(4.196)			
NetΔvol%		0.167***		
		(3.708)		
net Δ OI			0.110	
			(1.163)	
NetΔOI%				-0.052
				(-0.612)
Range Volatility	-0.028	0.007	0.018	0.015
	(-0.248)	(0.067)	(0.171)	(0.138)
Price	0.000***	0.000***	0.000***	0.000***
	(4.465)	(13.178)	(7.685)	(3.758)
MarketCap	-0.000	-0.000***	-0.000	-0.000*
	(-1.527)	(-4.007)	(-1.604)	(-2.176)
Turnover	0.120*	0.133**	0.132**	0.139**
	(2.066)	(2.415)	(2.388)	(2.456)
Spread	-0.324	-1.081	-0.968	-1.309
	(-0.317)	(-1.176)	(-0.994)	(-1.748)
P/C	-0.040***	-0.038***	-0.046***	-0.049***
	(-5.837)	(-4.830)	(-6.987)	(-6.215)
C/S	0.020**	-0.050**	0.035***	0.038***
	(2.765)	(-2.279)	(4.367)	(3.857)
O/S	-0.018***	0.020	-0.027***	-0.028***
	(-3.465)	(1.763)	(-4.636)	(-4.317)
Short Int. Ratio	0.034***	0.035***	0.033***	0.025**
	(8.590)	(9.019)	(6.551)	(2.239)
Amihud	0.294	0.295	0.284	0.217
	(1.043)	(1.005)	(1.034)	(0.668)
Constant	-0.016***	-0.019***	-0.014**	-0.007
	(-3.605)	(-4.312)	(-2.374)	(-0.715)
Observations	9,228	9,228	9,228	9,228
R-squared	0.210	0.210	0.190	0.190

Panel C: Spread

VARIABLES	(1) Spread	(2) Spread	(3) Spread	(4) Spread
netΔvol	-0.055**			
	(-2.912)			
NetΔvol%		-0.000		
		(-1.025)		
net Δ OI			-0.009*	
			(-2.027)	
NetΔOI%				-0.005***
				(-5.983)
Range Volatility	0.009**	0.008*	0.008*	0.008*
	(2.280)	(2.091)	(2.084)	(1.907)
Price	0.000	0.000	0.000	0.000**
	(1.027)	(1.104)	(1.217)	(3.129)
MarketCap	-0.000**	-0.000**	-0.000**	-0.000**
	(-2.782)	(-2.308)	(-2.951)	(-2.697)
Turnover	-0.001	-0.001	-0.001	-0.001
	(-1.560)	(-1.742)	(-1.592)	(-0.843)
P/C	-0.000	-0.000	-0.000	-0.001
	(-1.377)	(-0.932)	(-1.250)	(-1.509)
C/S	-0.000	-0.000	-0.000	-0.000
	(-0.751)	(-1.020)	(-1.292)	(-1.215)
O/S	0.000	0.000	0.000	0.000
	(0.543)	(0.894)	(1.172)	(1.363)
Short Int. Ratio	0.001	0.001	0.001*	0.001**
	(1.734)	(1.621)	(2.010)	(2.685)
Constant	0.001***	0.001**	0.001***	0.001***
	(3.213)	(2.925)	(3.170)	(3.200)
Observations	9,134	9,134	9,134	9,134
R-squared	0.427	0.420	0.426	0.437

Panel D: Range Volatility

VARIABLES	(1) Range Volatility	(2) Range Volatility	(3) Range Volatility	(4) Range Volatility
netΔvol	3.017***			
	(6.385)			
NetΔvol%		0.041**		
		(3.168)		
net Δ OI			0.046	
			(0.459)	
NetΔOI%				-0.040
				(-0.716)
Price	-0.000	-0.000	-0.000	-0.000
	(-0.528)	(-0.649)	(-0.563)	(-0.492)
MarketCap	0.000	0.000	0.000	0.000
	(0.668)	(1.305)	(1.546)	(1.350)
Turnover	0.140***	0.155***	0.155***	0.160***
	(4.626)	(5.355)	(5.325)	(6.360)
Spread	7.792**	7.454*	7.515*	7.266*
	(2.271)	(2.146)	(2.145)	(1.951)
P/C	0.010	0.006	0.004	0.002
	(1.114)	(0.854)	(0.563)	(0.279)
C/S	-0.029***	-0.037***	-0.017***	-0.016***
	(-4.212)	(-4.620)	(-3.575)	(-3.661)
O/S	0.019***	0.023***	0.012***	0.012***
	(4.475)	(4.660)	(4.209)	(4.489)
Short Int. Ratio	-0.026	-0.028	-0.026	-0.023
	(-1.233)	(-1.335)	(-1.233)	(-1.154)
Amihud	0.380*	0.381	0.381	0.330
	(1.916)	(1.748)	(1.780)	(1.401)
Constant	0.045**	0.048***	0.048***	0.049***
	(3.148)	(3.526)	(3.498)	(3.442)
Observations	9,134	9,134	9,134	9,134
R-squared	0.519	0.502	0.501	0.501

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

This table reports the Cumulative Abnormal Return (CAR) 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=15)

	-5	-3	-1	0	1	3	5	10	15	22
Ab. Ret	-0.13%	-0.95%	3.86%	19.50%	3.35%	4.19%	-3.04%	-0.06%	1.85%	2.71%
T-Stat	(-0.06)	(-0.39)	(1.92)	(3.73)	(0.86)	(1.88)	(-2.11)	(-0.03)	(0.81)	(0.81)
CAR	-0.13%	-0.83%	3.20%	22.70%	26.10%	30.20%	28.10%	23.60%	32.20%	39.30%
T-Stat	(-0.06)	(-0.18)	(0.78)	(3.60)	(2.78)	(3.95)	(3.15)	(2.85)	(3.18)	(3.82)
CAR				19.50%	22.90%	27.00%	24.90%	20.40%	29.00%	36.10%
T-Stat				(3.73)	(2.73)	(4.12)	(3.41)	(2.92)	(3.32)	(3.29)
CAR					3.35%	7.48%	5.35%	0.86%	9.48%	16.60%
T-Stat					(0.86)	(1.97)	(1.05)	(0.15)	(1.54)	(1.85)

Table 5: Regression Analysis for the Whole Sample

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

$$\begin{aligned} Return_{i,t} = {} & \beta_1 NetDeltaTrading_{i,t} + \beta_2 RangeVolatility_{i,t} + \beta_3 Price_{i,t} + \beta_4 MarketCap_{i,t} \\ & + \beta_5 Turnover_{i,t} + \beta_6 Spread_{i,t} + \beta_7 PC_{i,t} + \beta_8 CS_{i,t} + \beta_9 OS_{i,t} + \beta_{10} ShortIntRatio_{i,t} \\ & + \beta_{11}\ Amihud \end{aligned}$$

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. *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. *ShortIntRatio* is the short interest divided by shares outstanding. *Amihud* is computed by scaling the absolute return by the dollar volume scaled up by a million. The sample period is from 2019 to 2023. Standard errors are clustered by firm.

Panel A: Return

VARIABLES	(1) Return	(2) Return	(3) Return	(4) Return
netΔvol	1.489***			
	(3.924)			
NetΔvol%		0.011***		
		(6.404)		
net Δ OI			0.075***	
			(2.999)	
NetΔOI%				0.028***
				(3.103)
Range Volatility	0.098***	0.100***	0.100***	0.100***
	(13.431)	(13.592)	(13.610)	(13.610)
Price	0.000***	0.000***	0.000***	0.000***
	(4.876)	(4.360)	(3.621)	(4.072)
MarketCap	-0.000***	-0.000*	-0.000***	-0.000*
	(-4.476)	(-1.863)	(-3.347)	(-1.933)
Turnover	0.007	0.007	0.007	0.007
	(1.227)	(1.226)	(1.226)	(1.217)
Spread	0.012	0.012	0.010	0.014
	(0.340)	(0.322)	(0.277)	(0.391)
P/C	-0.011***	-0.012***	-0.011***	-0.011***
	(-86.911)	(-83.232)	(-88.938)	(-87.410)
C/S	0.000	-0.007***	0.001***	0.001***
	(1.279)	(-6.602)	(4.857)	(4.209)
O/S	0.000***	0.004***	0.000	0.000
	(2.719)	(6.490)	(0.675)	(1.421)
Short Int. Ratio	-0.002	-0.002*	-0.002	0.000
	(-1.570)	(-1.718)	(-1.585)	(0.119)
Amihud	-0.001**	-0.002***	-0.002**	-0.002**
	(-2.374)	(-4.176)	(-2.472)	(-2.475)
Constant	-0.001	-0.001	-0.001	-0.001**
	(-1.530)	(-1.575)	(-1.346)	(-2.044)
Observations	3,403,254	3,403,254	3,403,254	3,403,254
R-squared	0.019	0.018	0.018	0.018

Panel B: Abnormal Return

VARIABLES	(1) Ab. Return	(2) Ab. Return	(3) Ab. Return	(4) Ab. Return
netΔvol	1.246***			
	(3.541)			
NetΔvol%		0.009***		
		(6.330)		
net Δ OI			0.060***	
			(2.881)	
NetΔOI%				0.025***
				(3.042)
Range Volatility	0.122***	0.124***	0.124***	0.124***
	(17.242)	(17.350)	(17.363)	(17.375)
Price	0.000***	0.000***	0.000***	0.000***
	(4.790)	(4.312)	(3.645)	(4.034)
MarketCap	-0.000***	-0.000*	-0.000***	-0.000*
	(-4.232)	(-1.818)	(-3.270)	(-1.881)
Turnover	0.007	0.007	0.007	0.007
	(1.224)	(1.223)	(1.223)	(1.214)
Spread	0.019	0.019	0.017	0.021
	(0.552)	(0.535)	(0.496)	(0.601)
P/C	-0.009***	-0.009***	-0.009***	-0.009***
	(-73.264)	(-71.194)	(-75.139)	(-73.774)
C/S	0.000*	-0.006***	0.001***	0.001***
	(1.669)	(-6.553)	(5.094)	(4.461)
O/S	0.000*	0.003***	-0.000	0.000
	(1.819)	(6.512)	(-0.382)	(0.377)
Short Int. Ratio	-0.003***	-0.003***	-0.003***	-0.001
	(-2.718)	(-2.843)	(-2.725)	(-0.753)
Amihud	-0.001**	-0.001***	-0.001**	-0.001**
	(-2.049)	(-3.737)	(-2.158)	(-2.152)
Constant	-0.003***	-0.003***	-0.003***	-0.003***
	(-8.449)	(-8.381)	(-7.973)	(-8.703)
Observations	3,403,254	3,403,254	3,403,254	3,403,254
R-squared	0.022	0.020	0.020	0.021

Panel C: Spread

VARIABLES	(1) Spread	(2) Spread	(3) Spread	(4) Spread
netΔvol	-0.016***			
	(-2.924)			
NetΔvol%		-0.000		
		(-1.372)		
net Δ OI			-0.002**	
			(-2.054)	
NetΔOI%				-0.001***
				(-3.462)
Range Volatility	0.009***	0.009***	0.009***	0.009***
	(16.796)	(16.763)	(16.758)	(16.778)
Price	-0.000**	-0.000**	-0.000**	-0.000*
	(-2.268)	(-2.146)	(-1.967)	(-1.889)
MarketCap	0.000	-0.000	0.000*	-0.000
	(1.134)	(-0.197)	(1.688)	(-0.291)
Turnover	-0.000	-0.000	-0.000	-0.000
	(-1.385)	(-1.383)	(-1.383)	(-1.365)
P/C	-0.000***	-0.000***	-0.000***	-0.000***
	(-7.016)	(-6.885)	(-6.952)	(-7.091)
C/S	-0.000***	-0.000	-0.000***	-0.000***
	(-2.617)	(-0.954)	(-2.936)	(-2.671)
O/S	0.000	-0.000	0.000	0.000
	(0.517)	(-0.573)	(0.694)	(0.465)
Short Int. Ratio	-0.001***	-0.001***	-0.001***	-0.001***
	(-2.670)	(-2.669)	(-2.669)	(-2.688)
Constant	0.002***	0.002***	0.002***	0.002***
	(45.114)	(45.092)	(44.981)	(43.835)
Observations	3,403,269	3,403,269	3,403,269	3,403,269
R-squared	0.416	0.416	0.416	0.416

Panel D: Range Volatility

VARIABLES	(1) Range Volatility	(2) Range Volatility	(3) Range Volatility	(4) Range Volatility
netΔvol	0.790***			
	(3.137)			
NetΔvol%		0.000		
		(1.020)		
net Δ OI			-0.017*	
			(-1.862)	
NetΔOI%				0.004*
				(1.804)
Price	-0.000***	-0.000***	-0.000***	-0.000***
	(-4.189)	(-4.352)	(-4.292)	(-4.350)
MarketCap	-0.000	0.000	0.000	0.000
	(-0.530)	(0.765)	(1.265)	(0.769)
Turnover	0.012	0.012	0.012	0.012
	(1.359)	(1.358)	(1.358)	(1.357)
Spread	0.818***	0.817***	0.817***	0.818***
	(8.150)	(8.151)	(8.151)	(8.150)
P/C	0.001***	0.000***	0.000***	0.000***
	(5.251)	(4.622)	(4.552)	(4.727)
C/S	-0.001***	-0.000*	-0.000	-0.000*
	(-3.636)	(-1.654)	(-1.436)	(-1.815)
O/S	-0.000***	-0.000*	-0.000***	-0.000***
	(-2.899)	(-1.688)	(-3.319)	(-3.267)
Short Int. Ratio	0.009***	0.009***	0.009***	0.009***
	(2.738)	(2.723)	(2.720)	(2.744)
Amihud	0.002**	0.002*	0.002*	0.002*
	(1.988)	(1.929)	(1.942)	(1.948)
Constant	0.042***	0.042***	0.042***	0.042***
	(77.320)	(78.251)	(78.161)	(77.984)
Observations	3,403,254	3,403,254	3,403,254	3,403,254
R-squared	0.352	0.352	0.352	0.352

Table 6 Summary Statistics

This table reports the summary statistics for the stocks with potential gamma squeezes on the first day of the potential squeeze from 2019 to 2023. The 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, and Amihud Illiquidity measure computed by scaling the absolute return by the dollar volume scaled up by a billion. 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 divided by one billion. 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 divided by one billion. 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 volume ratios: : *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume, *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume, *P/S* is the Put to Stock Volume Ratio defined as the put volume divided by the stock volume, and *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. Panel E reports the short selling measures, Short Volume divided by one million, Total Volume divided by one million and the Short Ratio that equals the Short Volume divided by the Total Volume. Short Int. Ratio is the short interest divided by shares outstanding. Panel F reports the mean for various variables for the individual call options. *Option Price* is the individual options ask price, *Bid-Ask Spread* is the ask price minus the bid price for the option. *Bid-Ask Spread Percent* is the option bid-ask spread divided by the option price. *Option Volume* is the number of contracts that were traded on that day. *Open Interest* is the number of open option contracts on that day. *Delta* measures the expected change in the option's price for a $1 change in the underlying asset's price. *Gamma* measures the rate of change in delta with respect to changes in the underlying asset's price. *Theta* measures the rate at which an option's value erodes as time passes. *Vega* measures how sensitive an option's price is to changes in the underlying asset's volatility. Implied Volatility is the volatility that is implied by the price using Black-Scholes Model.

Panel A:

	N	Mean	p50	SD	p25	p75
Return	668	6.21%	2.97%	12.23%	0.76%	8.14%
Abnormal Return	668	6.04%	2.90%	12.18%	0.54%	7.69%
Price	669	$48.38	$23.41	$73.58	$12.21	$ 50.13
MarketCap	669	$9,948,639	$537,120	$83,800,000	$172,691	$2,274,316

Panel B:

	N	Mean	p50	SD	p25	p75
Range Volatility	669	0.085	0.050	0.109	0.023	0.104
Turnover	669	0.331	0.123	0.781	0.047	0.290
Spread	669	0.002	0.001	0.005	0.000	0.002
Amihud	668	0.005	0.000	0.030	0.000	0.002

Panel C:

	N	Mean	p50	SD	p25	p75
netΔvolume	669	1.781	0.317	4.685	0.055	1.653
Net Δvolume%	669	19.18%	7.99%	48.30%	3.05%	20.06%
net Δ OI	669	9.379	2.935	23.604	0.854	7.841
net Δ OI%	669	10.47%	8.53%	9.49%	7.91%	10.13%

Panel D:

	N	Mean	p50	SD	p25	p75
O/S	669	0.698	0.381	1.256	0.154	0.752
C/S	669	0.517	0.243	1.092	0.108	0.571
P/S	669	0.181	0.065	0.374	0.023	0.182
P/C	667	0.268	0.233	0.200	0.106	0.390

Panel E:

	N	Mean	p50	SD	p25	p75
Short Volume	647	8.04	1.56	31.10	0.39	6.74
Total Volume	647	14.50	2.92	51.60	0.89	12.80
Short Ratio	646	52.08%	52.58%	14.13%	42.26%	61.10%
Short Interest Ratio	615	18.9%	8.2%	46.9%	3.5%	17.1%

Panel F: Calls

moneyness	<.8	0.8-0.95	0.95-1.05	1.05-1.20	>1.20
Option Price	3.75	7.92	9.58	14.72	29.38
Bid-Ask Spread	1.04	1.24	1.22	1.73	2.44
Bid-Ask Spread Percent	0.56	0.26	0.17	0.12	0.12
Option Volume	423.20	935.49	897.78	729.64	200.01
Open Interest	1,349.11	766.35	568.19	778.84	500.76
Delta	0.25	0.43	0.57	0.74	0.90
Gamma	0.03	0.04	0.04	0.03	0.02
Vega	8.92	11.58	10.53	8.65	5.58
Theta	-19.48	-54.02	-75.61	-56.03	-17.54
Implied Volatility	1.64	1.26	1.09	1.13	1.34
n	1,434	377	299	395	1,147

Panel G: Puts

moneyness	<.8	0.8-0.95	0.95-1.05	1.05-1.20	>1.20
Option Price	71.39	16.85	9.20	5.78	2.63
Bid-Ask Spread	2.87	1.74	1.12	1.10	0.91
Bid-Ask Spread Percent	0.05	0.12	0.22	0.42	0.87
Option Volume	49.55	229.77	373.13	548.45	382.79
Open Interest	342.37	423.57	340.44	456.29	1001.91
Delta	-0.68	-0.53	-0.42	-0.25	-0.09
Gamma	0.03	0.04	0.04	0.03	0.01
Vega	10.70	11.85	10.06	8.69	4.91
Theta	-25.59	-62.49	-82.25	-59.13	-20.31
Implied Volatility	1.68	1.41	1.15	1.14	1.55
n	1,001	281	264	410	1,538

Table 7: Cumulative Abnormal Returns Around Gamma Squeeze Events for Whole Sample

This Table Reports the Cumulative Abnormal Return for gamma squeezes identified from the Whole 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 reports the CARs for the potential Gamma Squeeze events in our "Whole" Sample. Panel B reports the CARs for a matched sample of stocks, matched on market cap and NetΔvol%, but that are not identified as being potential gamma squeezes based on their NetΔOI% on the event day or the 22 subsequent days.

Panel A:Whole Sample (n=669)

	-5	-3	-1	0	1	3	5	10	15	22
Ab.Ret	0.22%	0.81%	2.40%	5.02%	0.34%	0.78%	0.57%	0.08%	0.27%	0.17%
T-Stat	(1.22)	(3.25)	(6.78)	(10.71)	(1.10)	(3.14)	(1.36)	(0.27)	(0.98)	(0.65)
CAR	0.22%	2.05%	5.57%	10.60%	10.90%	12.10%	12.90%	14.20%	16.20%	16.40%
T-Stat	(1.22)	(4.08)	(7.97)	(12.56)	(12.34)	(12.17)	(11.36)	(9.77)	(9.61)	(8.58)
CAR				5.02%	5.36%	6.56%	7.36%	8.63%	10.60%	10.80%
T-Stat				(10.71)	(9.43)	(9.74)	(8.72)	(7.28)	(7.43)	(6.40)
CAR					0.34%	1.54%	2.34%	3.61%	5.54%	5.79%
T-Stat					(1.10)	(3.25)	(3.45)	(3.41)	(4.31)	(3.73)

Panel B: Matched Sample (n=1,359)

	-5	-3	-1	0	1	3	5	10	15	22
Ab. Ret	0.01%	0.02%	0.14%	-0.04%	0.17%	-0.14%	0.00%	0.15%	-0.15%	0.12%
T-Stat	(0.09)	(0.21)	(0.98)	(-0.36)	(1.41)	(-1.20)	(0.00)	(1.29)	(-1.29)	(0.71)
CAR	0.01%	0.15%	0.28%	0.24%	0.41%	0.16%	-0.10%	-0.07%	0.29%	0.79%
T-Stat	(0.09)	(0.73)	(1.04)	(0.81)	(1.27)	(0.42)	(-0.23)	(-0.12)	(0.41)	(0.88)
CAR				-0.04%	0.13%	-0.12%	-0.38%	-0.37%	-0.03%	0.46%
T-Stat				(-0.36)	(0.75)	(-0.45)	(-1.19)	(-0.81)	(-0.04)	(0.57)
CAR					0.17%	-0.08%	-0.34%	-0.32%	0.02%	0.52%
T-Stat					(1.41)	(-0.34)	(-1.16)	(-0.73)	(0.04)	(0.65)

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

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

$$Return_{i,t} = \beta_1 NetDeltaTrading_{i,t} + \beta_2 NetDeltaHolding_{i,t} + \beta_3 RangeVolatility_{i,t} + \beta_4 Price_{i,t} + \beta_5 MarketCap_{i,t} + \beta_6 Turnover_{i,t} + \beta_7 Spread_{i,t} + \beta_8 PC_{i,t} + \beta_9 CS_{i,t} + \beta_{10} OS_{i,t} + \beta_{11} ShortIntRatio_{i,t} + \beta_{12}\, Amihud$$

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 4. 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. *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. *ShortIntRatio* is the short interest divided by shares outstanding. *Amihud* is computed by scaling the absolute return by the dollar volume scaled up by a million. The sample period is from 2019 to 2023. Standard errors are clustered by firm.

Panel A: Net Delta Open Interest

VARIABLES	(1) Return	(2) Ab. Return	(3) Spread	(4) Range Volatility
netΔvol	-0.010	-0.011	-0.001	-0.074***
	(-0.470)	(-0.631)	(-1.242)	(-3.743)
net Δ OI	1.520***	1.281***	-0.013***	1.031***
	(4.189)	(3.717)	(-2.864)	(3.472)
Range Volatility	0.098***	0.122***	0.009***	
	(13.436)	(17.248)	(16.781)	
Price	0.000***	0.000***	-0.000**	-0.000***
	(4.936)	(4.878)	(-2.148)	(-3.887)
MarketCap	-0.000***	-0.000***	0.000*	0.000
	(-3.971)	(-3.802)	(1.804)	(0.781)
Turnover	0.007	0.007	-0.000	0.012
	(1.227)	(1.224)	(-1.384)	(1.359)
Spread	0.012	0.019		0.817***
	(0.338)	(0.549)		(8.151)
P/C	-0.011***	-0.009***	-0.000***	0.001***
	(-86.700)	(-73.150)	(-7.025)	(5.159)
C/S	0.000	0.000*	-0.000***	-0.001***
	(1.267)	(1.647)	(-2.636)	(-3.682)
O/S	0.000***	0.000*	0.000	-0.000***
	(2.793)	(1.889)	(0.541)	(-2.827)
Short Int. Ratio	-0.002	-0.003***	-0.001***	0.009***
	(-1.581)	(-2.732)	(-2.670)	(2.732)
Amihud	-0.001**	-0.001**		0.002**
	(-2.374)	(-2.049)		(1.988)
Constant	-0.001	-0.003***	0.002***	0.042***
	(-1.554)	(-8.475)	(45.080)	(76.415)
Observations	3,403,254	3,403,254	3,403,269	3,403,254
R-squared	0.019	0.022	0.416	0.353

Panel B: Net Delta Open Interest Percent

VARIABLES	(1) Return	(2) Ab.Return	(3) Spread	(4) Range Volatility
NetΔvol%	0.027***	0.024***	-0.001***	0.004*
	(3.077)	(3.016)	(-3.454)	(1.795)
NetΔOI%	0.011***	0.009***	-0.000	0.000
	(6.353)	(6.267)	(-0.718)	(0.801)
Range Volatility	0.100***	0.124***	0.009***	
	(13.614)	(17.380)	(16.779)	
Price	0.000***	0.000***	-0.000*	-0.000***
	(4.240)	(4.187)	(-1.892)	(-4.348)
MarketCap	-0.000*	-0.000*	-0.000	0.000
	(-1.793)	(-1.753)	(-0.304)	(0.772)
Turnover	0.007	0.007	-0.000	0.012
	(1.217)	(1.215)	(-1.365)	(1.357)
Spread	0.016	0.023		0.818***
	(0.456)	(0.656)		(8.149)
P/C	-0.011***	-0.009***	-0.000***	0.000***
	(-82.424)	(-70.352)	(-7.091)	(4.723)
C/S	-0.007***	-0.006***	-0.000	-0.000
	(-6.621)	(-6.570)	(-1.195)	(-1.580)
O/S	0.004***	0.003***	-0.000	-0.000*
	(6.442)	(6.465)	(-0.234)	(-1.839)
Short Int. Ratio	0.000	-0.001	-0.001***	0.009***
	(0.062)	(-0.827)	(-2.688)	(2.744)
Amihud	-0.002***	-0.001***		0.002*
	(-4.085)	(-3.633)		(1.936)
Constant	-0.001**	-0.003***	0.002***	0.042***
	(-2.022)	(-8.782)	(43.839)	(77.940)
Observations	3,403,254	3,403,254	3,403,269	3,403,254
R-squared	0.019	0.021	0.416	0.352

Table 9: Propensity Score Matching Balance

This table presents the balance diagnostics for the PSM analysis. Panel A displays the mean differences in pre-treatment characteristics (ln_mktcap, and net delta volume percent) between the treatment (gamma squeeze) and control firms before matching. Panel B shows these differences after 1:3 nearest-neighbor matching on the propensity score without replacement, within the region of common support. Panel C reports overall matching quality statistics, including the Pseudo R^2 from the probit estimation of the propensity score, the likelihood ratio (LR) chi^2 statistic, the p-value of the LR test, the mean and median standardized percentage bias across covariates (MeanBias, MedBias), Rubin's B statistic (percentage bias), and Rubin's R statistic (ratio of treated to control variances of the propensity score logits). Asterisks on Rubin's B and R in the "Unmatched" and "Matched" rows refer to common thresholds for assessing balance (e.g., B < 25% and 0.5 < R < 2 are considered good). The variables ln_mktcap and netdvol_pct are lagged with 22 days. The sample period is from 2019 to 2023. The sample includes the whole sample.

Panel A: Differences in Characteristics of Treatment and Control Firms Before Match

Variable	Control	Treatment	Difference	t-statistics
ln(MarketCap)	14.36	13.41	-0.955	-10.38
NetΔvol%	1.31%	6.30%	4.9%	6.03

Panel B: Differences in Characteristics of Treatment and Control Firms After Match

Variable	Control	Treatment	Difference	t-statistics
ln(MarketCap)	13.39	13.41	-0.02	0.15
NetΔvol%	2.49%	6.30%	3.9%	1.54

Panel C. matching quality statistics

Sample	Ps R^2	LR chi^2	$p>chi^2$	MeanBias	MedBias	B (%)	R	%Var
Unmatched	0.013	112.92	0.000	33.9	33.9	49.4*	1.07	50
Matched	0.002	2.15	0.341	8.2	8.2	10.2	0.50*	50

Table 10: Average Treatment Effects of Gamma Squeeze Events on Return and Market Quality Measures

This table presents the Average Treatment Effects on the Treated (ATT) from regressions of daily stock-level outcomes on the gamma_squeeze indicator using the matched sample constructed via propensity score matching. Columns (1) and (2) report effects on raw returns (ret) and abnormal returns (abret), respectively. Columns (3) and (4) report effects on the quoted bid-ask spread (spread) and intraday range-based volatility (rangevol). *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. *Turnover* is the trading volume scaled by the shares outstanding. *Spread* is the daily bid-ask spread, computed as the difference between ask and bid prices scaled by their mid-point. *P/C* is the Put/Call ratio defined as the put volume divided by the total option volume. *C/S* is the Call to Stock Volume Ratio defined as the call volume divided by the stock volume. *O/S* is the Option to Stock Volume Ratio defined as the total option volume divided by the stock volume. The sample period is from 2019 to 2023. The sample includes the whole sample. All models are estimated using weighted least squares, with weights derived from the matching procedure. Standard errors are clustered at the firm level (permno). Robust t-statistics are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	1	2	3	4
Variables	Return	Abret	Spread	RangeVol
gamma_squeeze	0.048***	0.048***	-0.002***	0.026***
	(7.697)	(7.591)	(-4.425)	(3.414)
Price	-0.000	-0.000*	-0.000***	-0.000***
	(-1.502)	(-1.680)	(-4.483)	(-3.376)
Turnover	0.014	0.018	0.001	0.033
	(0.818)	(0.985)	(0.879)	(1.421)
Spread	-2.392	-2.260		4.570***
	(-1.147)	(-1.143)		(4.349)
P/C	-0.013*	-0.013*	0.000	-0.005
	(-1.918)	(-1.875)	(0.029)	(-0.670)
C/S	0.001	0.003	0.002	0.002
	(0.142)	(0.427)	(0.761)	(0.421)
O/S	-0.004	-0.006	0.000	-0.006
	(-0.594)	(-1.015)	(-0.345)	(-1.256)
Constant	0.013**	0.012**	0.003***	0.040***
	(2.09)	(1.985)	(9.521)	(9.626)
Obs	1,539	1,539	1,539	1,539
R2	0.135	0.142	0.102	0.202

Table 11: Threshold Analysis

This table reports the 22-day CARs, following Carhart (1997), using different Thresholds. Panel A uses the 2-prong threshold used in the draft, where the first prong (moving from side to side) of the threshold is that Net Delta Open Interest Percent increases above a certain level. While the second prong (moving from top to bottom) is the average Net Delta OI percent over the following 22 days. In Panel B, the first prong (moving from side to side) is the same as Panel A, that is that the Net Delta Open Interest Percent must increase above a certain level, but also requires that the 22-day Net Delta Open Interest stays above that initial level. The second prong is that Option to Stock (O/S) ratio over the subsequent 22 days decreases to a certain level relative to the O/S ratio on Day 0. T-stats are calculated using Cross-Sectional standard errors and N is the number of events that qualify under the stated thresholds.

Panel A: 22-day CARs with different 2 Prong Threshold (The Squeeze and The Unwind)

		Day 0 Delta OI Percent Level				
22-day Delta OI Percent Level		1%	2.50%	5%	7.50%	10%
1.0%	CAR	5.46%	-2.09%	-3.03%	-5.17%	-4.36%
	t-stat	(9.19)	(-2.70)	(-3.12)	(-4.47)	(-3.05)
	N	4,507	3,078	1,697	1,164	851
2.5%	CAR	12.10%	5.30%	-1.23%	-4.56%	-3.84%
	t-stat	(12.74)	(5.76)	(-1.21)	(-3.80)	(-2.63)
	N	2,128	2,133	1,557	1,106	825
5.0%	CAR	16.20%	14.20%	6.81%	-1.00%	-2.11%
	t-stat	(-5.53)	(11.86)	(6.20)	(-0.77)	(-1.39)
	N	1,073	1,082	1,072	942	754
7.5%	CAR	12.70%	11.60%	9.45%	5.79%	1.05%
	t-stat	(7.49)	(6.92)	(6.10)	(3.73)	(0.67)
	N	674	675	676	669	624
10.0%	CAR	17.10%	17.10%	14.40%	11.80%	8.67%
	t-stat	(7.81)	(7.87)	(7.35)	(6.18)	(4.83)
	N	471	472	473	479	477

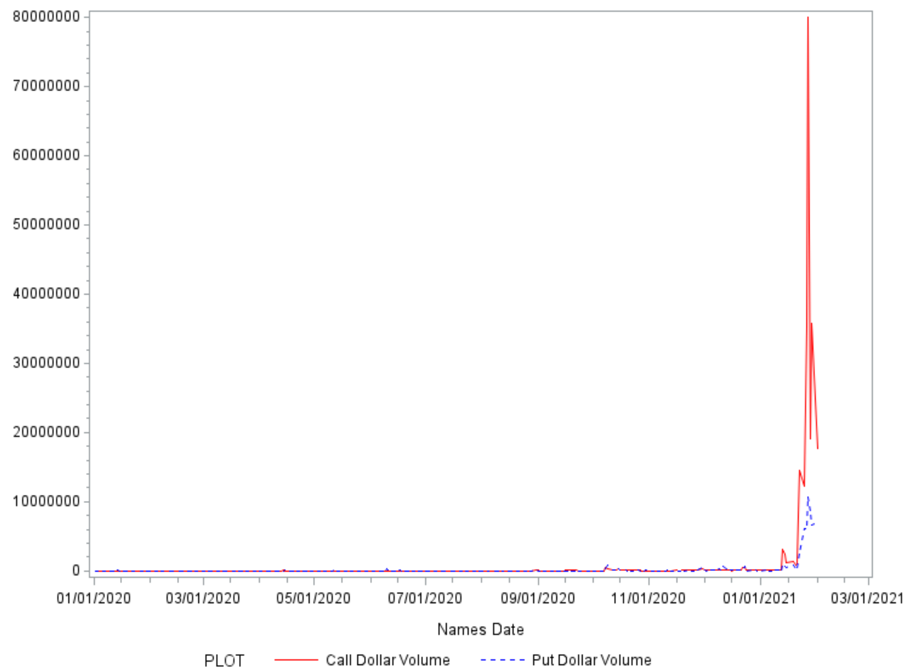
Panel B: 22-day CARs when Net Delta Open Interest remains high while O/S ratio falls (Rebalancing vs New Speculation)

		Delta OI Percent Level				
22-Day/ Day 0		1.0%	2.5%	5%	7.50%	10%
100%	CAR	5.23%	6.02%	5.20%	8.12%	7.64%
	t-stat	(8.98)	(6.95)	(4.42)	(5.21)	(4.00)
	N	4,565	2,031	989	612	424
50%	CAR	3.55%	3.43%	3.69%	4.99%	5.67%
	t-stat	(6.56)	(3.87)	(3.09)	(3.04)	(3.13)
	N	3,895	1,475	674	376	247
25%	CAR	2.89%	2.62%	2.85%	5.37%	5.51%
	t-stat	(3.49)	(1.62)	(1.54)	(2.98)	(2.39)
	N	1,641	506	196	103	58
20%	CAR	2.79%	1.97%	2.58%	3.42%	2.66%
	t-stat	(2.65)	(0.91)	(1.02)	(1.70)	(1.25)
	N	1,158	351	124	59	34

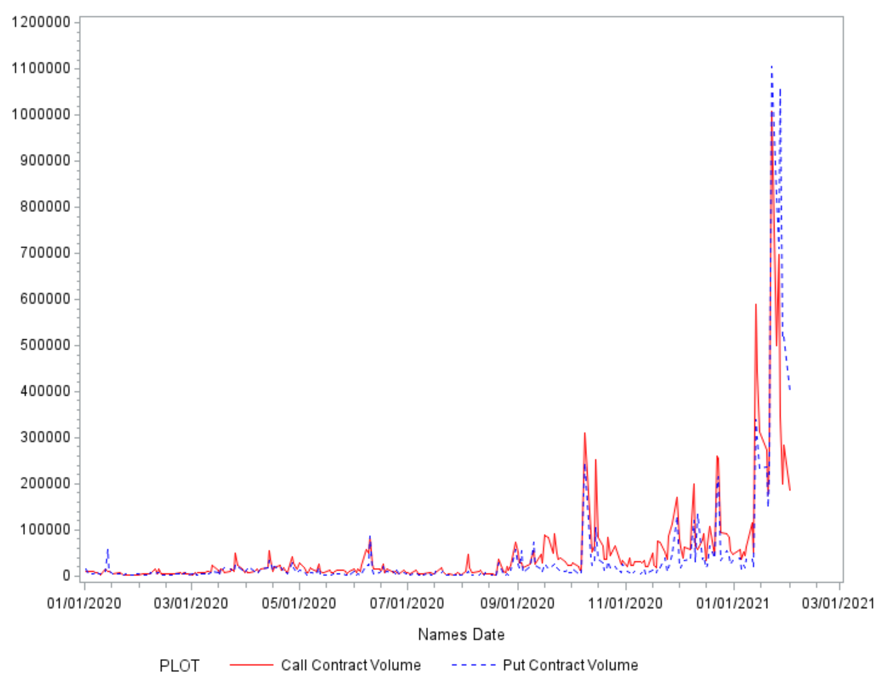
Figure 1: GME Option Volume

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.

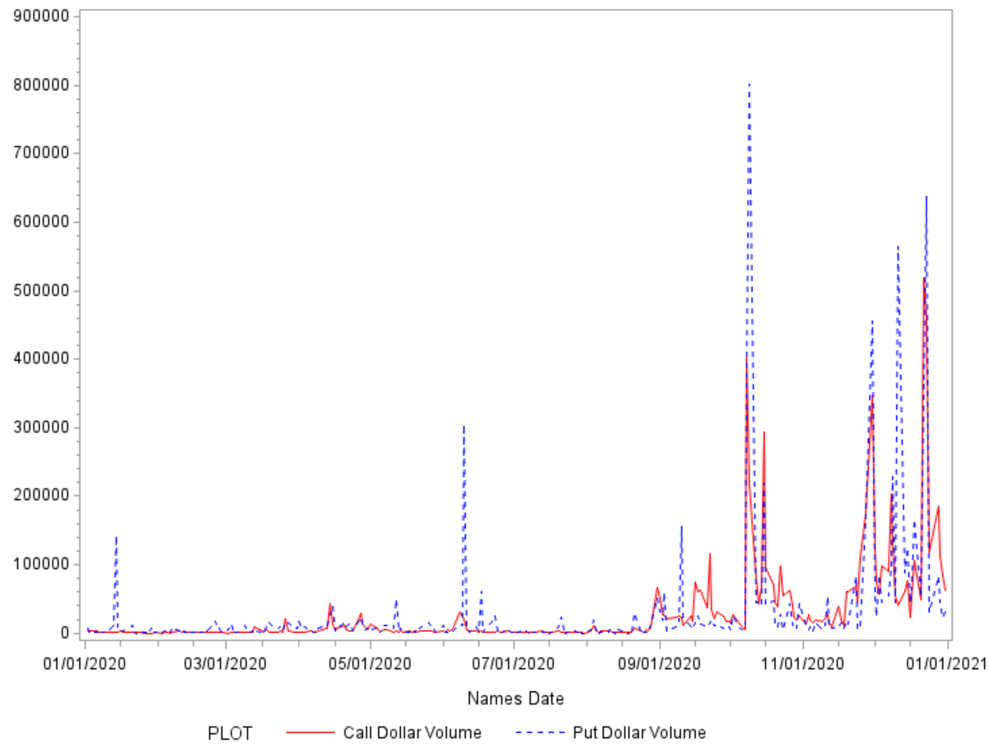
Panel A



Panel B



Panel C



Panel D

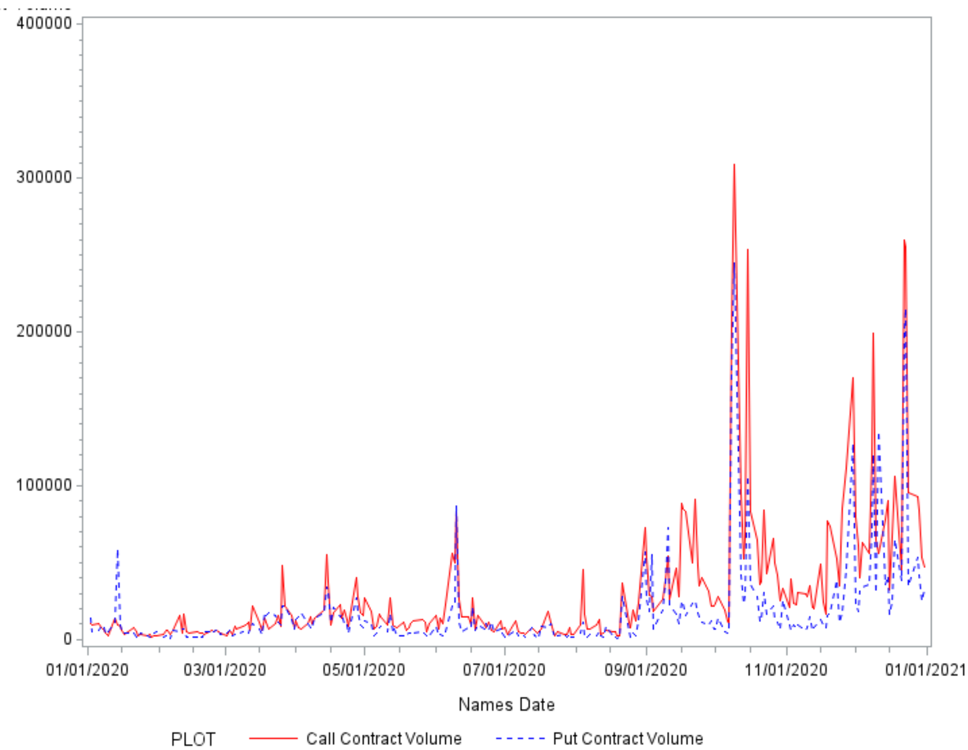


Figure 2

This figure plots Delta and Gamma for a generic Call option as the underlying stock price moves from 1 to 200. Delta and Gamma are calculated using a call option where the strike price equals 100, time to maturity equals 1 year, the risk-free rate is 5% and the volatility is 25%.

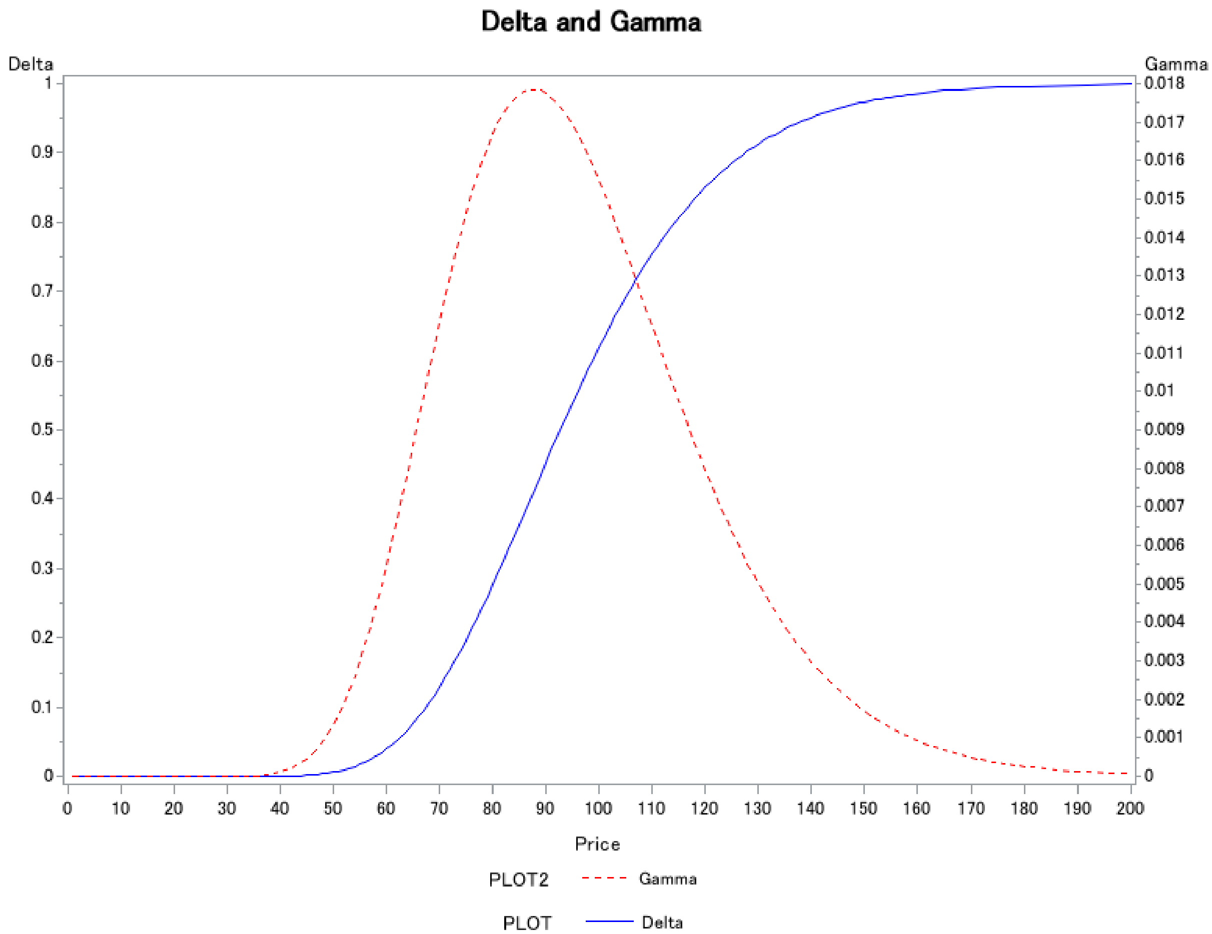
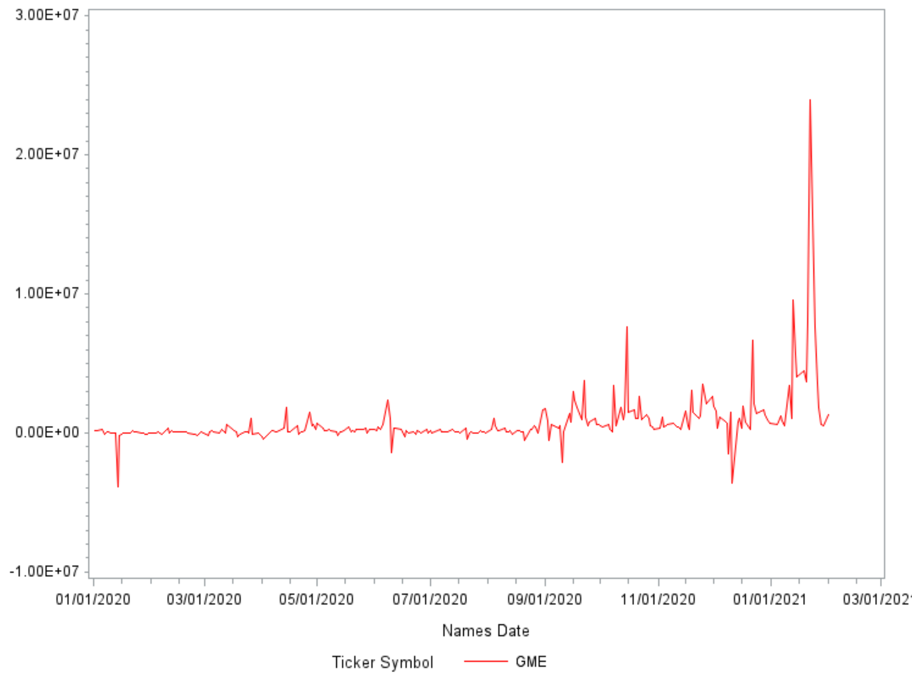


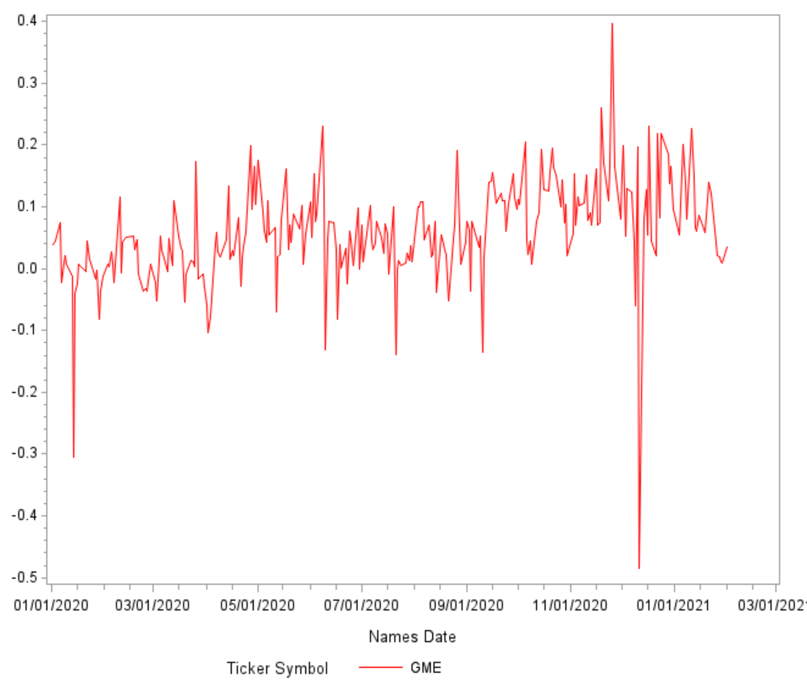
Figure 3: GME Delta Trading Estimates

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.

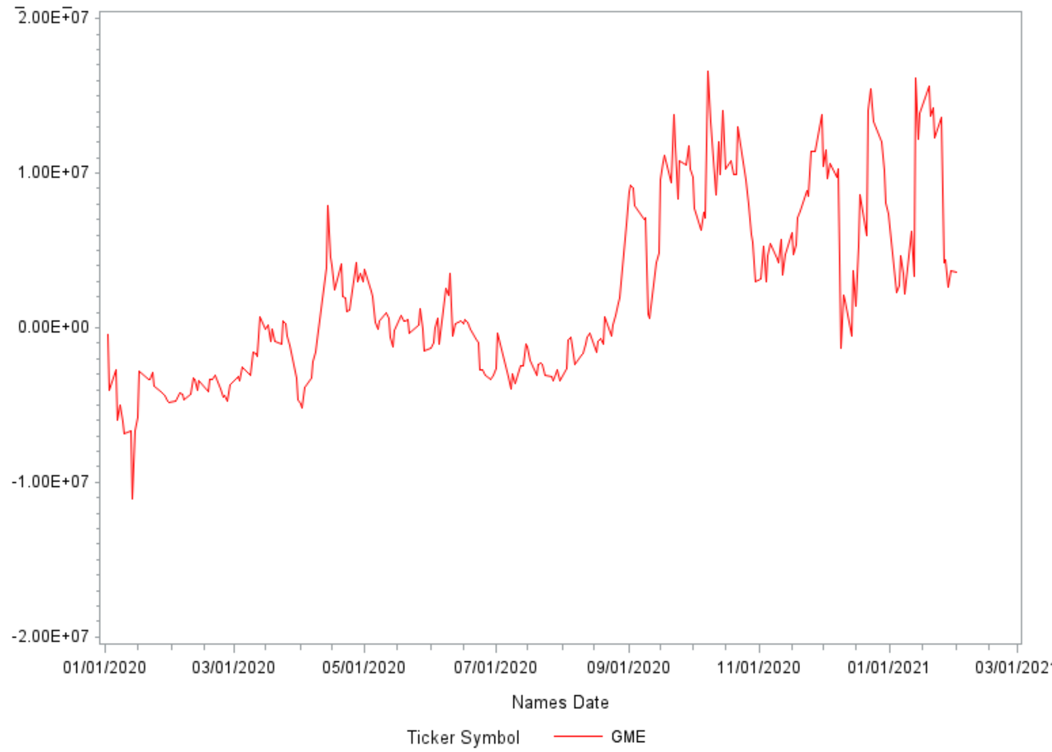
Panel A: Net Delta Volume



Panel B: Net Delta Volume Percent



Panel C: Net Delta Open Interest



Panel D: Net Delta Open Interest Percent

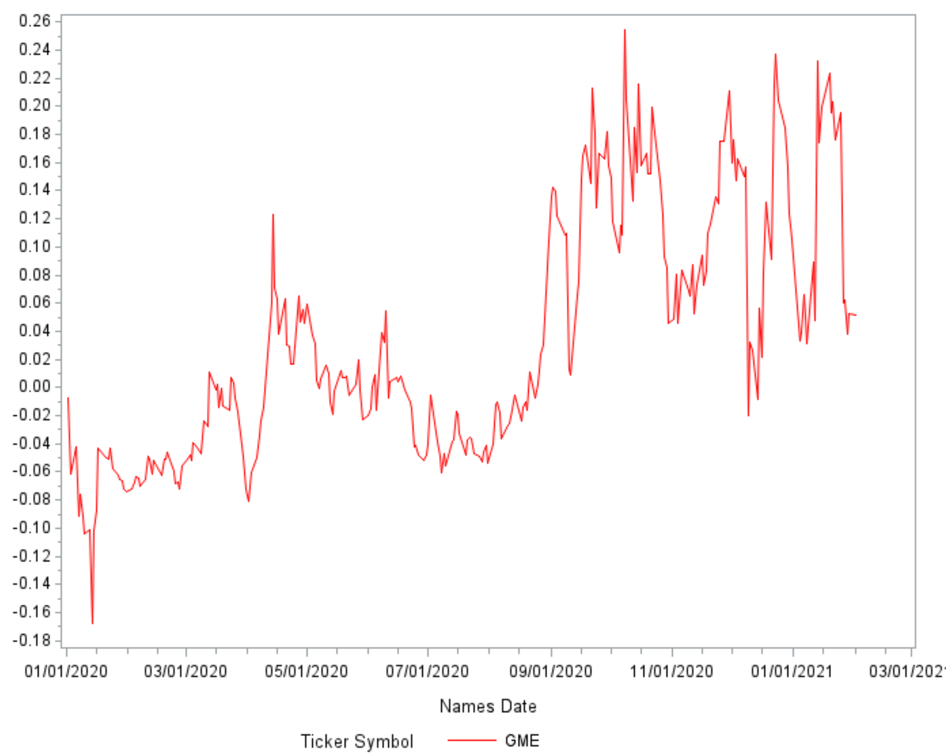
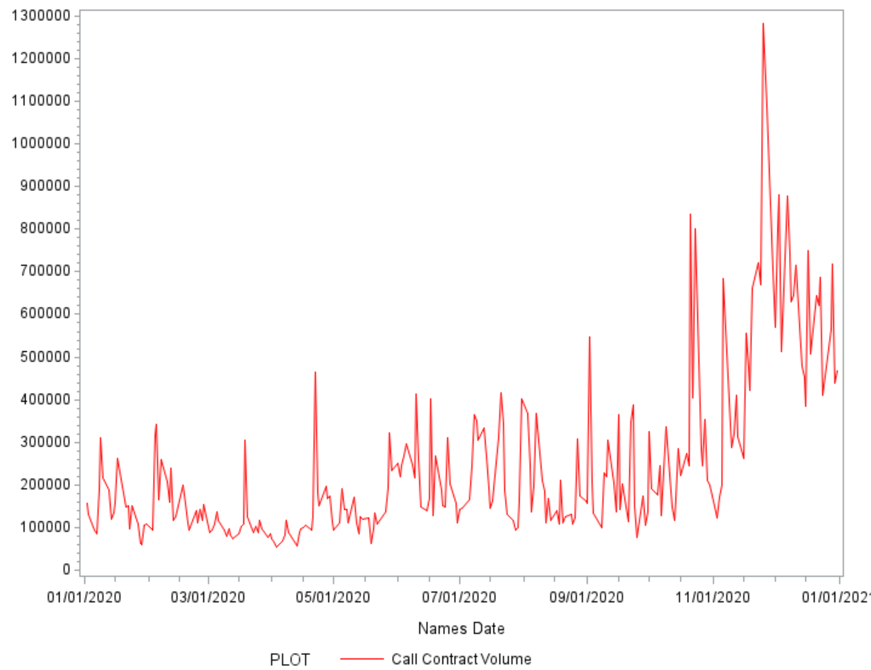


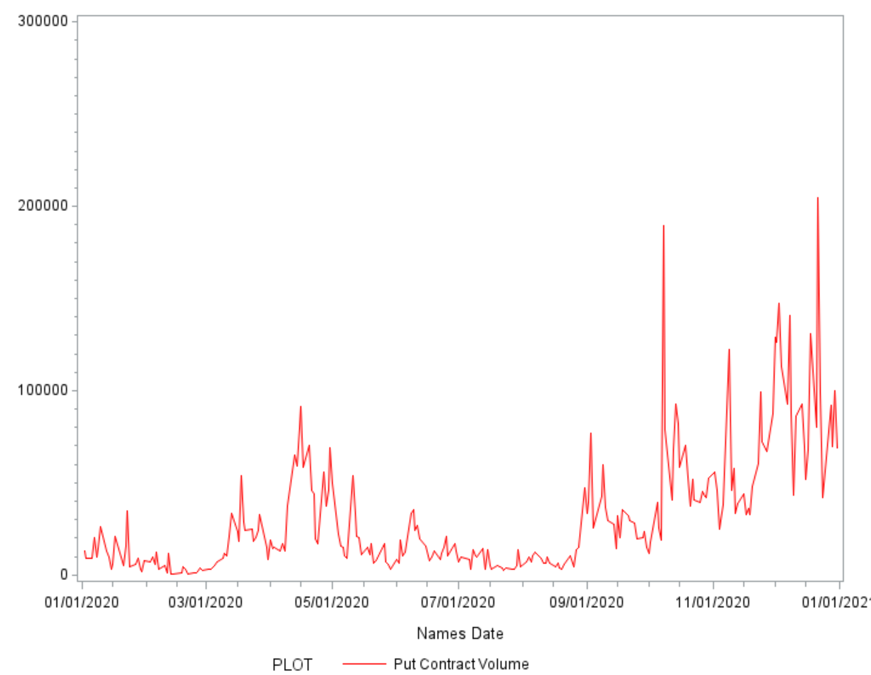
Figure 4: GME Volume by Moneyness

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.

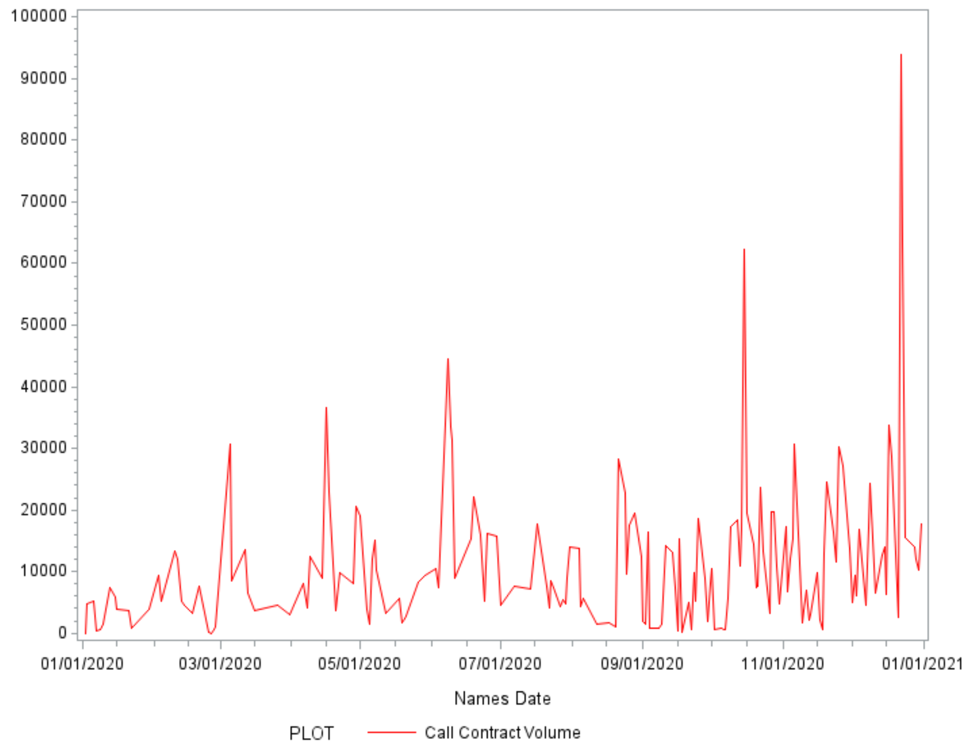
Panel A: OTM Calls



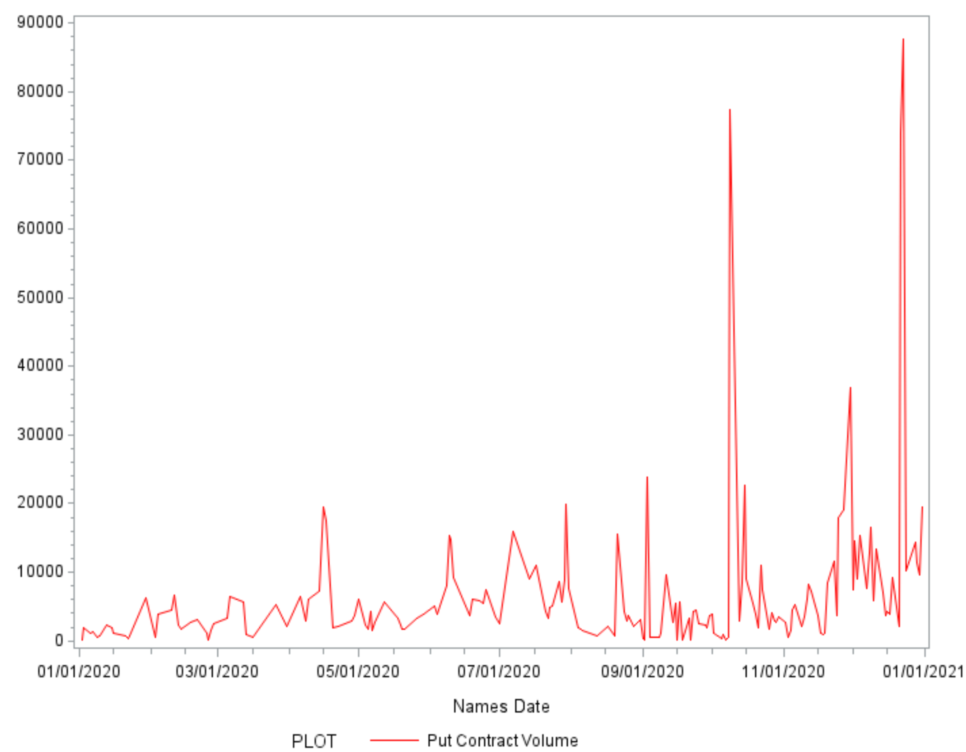
Panel B: OTM Puts



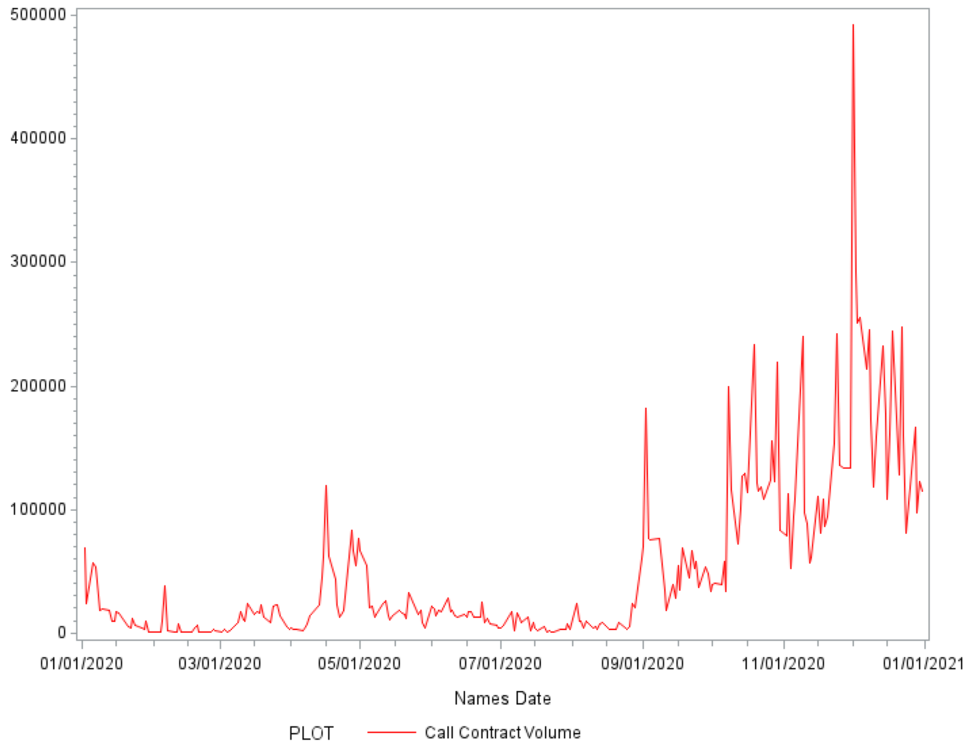
Panel C: ATM Calls



Panel D: ATM Puts



Panel E: ITM Calls



Panel F: ITM Puts

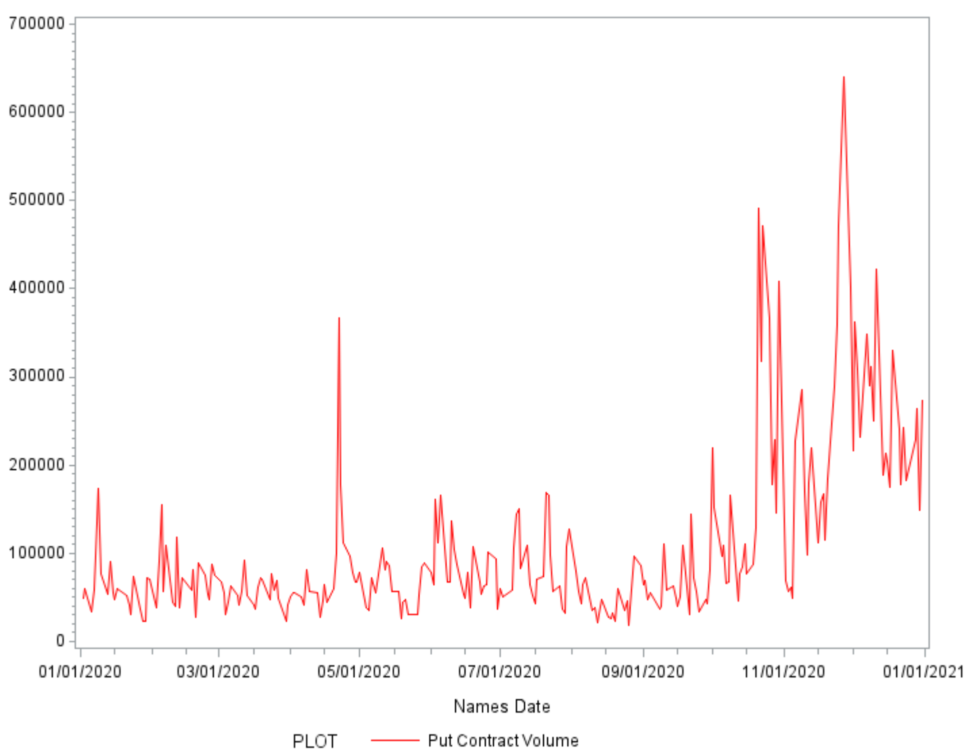


Figure 5: Net Delta Open Interest Percent for All Meme Stocks

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).