

When Brokerages Restrict Retail Investors, Does the Game Stop?

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ABSTRACT

We study a set of trading restrictions that limit equity and/or options positions imposed by retail-oriented broker-dealers in 38 stocks, including GameStop. Using brokerages' capital requirements from the National Securities Clearing Corporation (NSCC) and the exact timing of restrictions, for identification, we find large stock price effects: CARs average -13.54% within two hours following a stock's first trading restrictions and -51.97% after five trading days. When restrictions are lifted, share prices do not rebound. When traders substitute options for equities, options volume and open interest spike, as do implied volatilities, which rise more than realized volatilities. Options purchasers overpay, creating large transfers to options sellers and market-makers. Margin increases show similarities and differences relative to trading restrictions.

JEL classification: G12, G14, G24

Keywords: GameStop, retail investors, trading restrictions, margin increases, abnormal returns, equity and options bid-ask spreads, open interest, implied volatilities, realized volatilities.

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1. Introduction

During the Covid-19 pandemic, retail stock investments became a significantly larger percentage of U.S. equity trading volume. Joe Mecane of Citadel, a sizeable trading firm that also acts as an important off-exchange broker-dealer, estimates that retail investors now account for about 20% of all stock trading volume in the U.S.,¹ though there is little hard data on these percentages or on retail trading activity more generally.

In this paper, we study a set of trading and margin restrictions, specifically targeting these retail investors, which to our knowledge have not been imposed before. These restrictions were imposed in early 2021 by Robinhood, TD Ameritrade, and other retail-oriented brokerage firms in dozens of stocks, including GameStop (ticker symbol GME), a videogame retailer. These restrictions have been well-covered by the financial press as well as in subsequent Congressional and other hearings. Since the restrictions do not apply to a broader set of institutional traders and are implemented at the individual brokerage level, this setting provides a natural laboratory for studying the effects of severe limits to retail trading activity on stock returns and volume, as well as the effects of substitutions that investors may undertake to circumvent or otherwise respond to such limits on trading.

Our identification approach uses the specific details of the institutional setting in which the National Securities Clearing Corporation (NSCC) calculates a daily stock-specific collateral requirement for each brokerage, along with hand-collected data on the exact timing of the

¹ <https://www.bloomberg.com/news/articles/2020-07-09/citadel-securities-says-retail-is-25-of-the-market-during-peaks>

restrictions. We find that the restrictions on long-side exposure lead to a dramatic decrease in stock prices that does not reverse once restrictions are lifted. We also document a marked increase in the relative prices of options and an increase in options trading volume.

In the lead-up to these restrictions, many stocks that had been prominently discussed on the social media platform Reddit experienced very high volatility, with sharply increasing and decreasing share prices on successive days and even within a single trading day. GME was one of the most visible among these stocks, attracting many short sellers who bet against it. GME ended 2020 with a share price of \$18.84, and by January 22, 2021, its share price had more than tripled to \$65.01. By the end of the trading day on Tuesday, January 26, 2021, its share price more than doubled again, closing at \$147.98. Another doubling occurred the following day, with GME's share price closing at \$347.51.

Before trading opened on Thursday, January 28, 2021, several retail-oriented brokerage firms, including Robinhood, imposed equity and options trading restrictions on GME and eventually on approximately 30 additional stocks. Robinhood's restrictions were the most stringent, allowing the liquidation of existing positions but forbidding the purchase of any stock or options contracts in GME and four other companies; these trading restrictions were then expanded to other companies over the next few days. The restrictions exerted a large effect on stock prices. On the first day of trading restrictions, for example, GME's share price fell by about half, to \$193.60.

As it turns out, these restrictions were related to Robinhood's unusually large collateral call, which they received at 7 AM EST on the morning of January 28 from the NSCC. While

Robinhood deposited \$1.4 billion with the NSCC, this amount fell short of the \$3 billion total collateral call requested by the NSCC. Robinhood then restricted trading in a number of stocks to allow for trades to settle, which would reduce their collateral call and resolve this shortfall.

We use the fact that certain stocks had larger contributions to that collateral call than others as a source of identification. Although the exact formula the NSCC uses to calculate a brokerage's collateral call is proprietary, we have obtained guidance from regulatory filings and conversations with regulators as to how it is calculated. Then using publicly available data sources (such as Rule 605/606 disclosure data), we calculate a proxy for the NSCC's collateral call attributable to a given stock on a daily basis and use it as an instrument for whether Robinhood chose to restrict a given stock. We show that our instrument satisfies the exclusion restriction, and we find that the instrument easily passes the relevance criterion, with a first-stage F -statistic exceeding 180.

Although the NSCC capital call provides us a valuable source of identification, we can also exploit the granularity of our data sources to use intra-daily timing as an alternative source of identification. The imposition of the restrictions, as well as their loosening and removal, occur at different times for different stocks. We hand-collect the intra-daily timestamps for the imposition, loosening, and removal of each restriction from the Internet Archive Wayback Machine. This timing information, combined with intra-daily data on equity and options markets, allows us to compare trading activity, bid-ask spreads, and asset prices in the minutes *before* a change with the same quantities in the minutes *after* a change. This time-based identification is especially valuable because the set of restricted stocks differs across brokerages and because the restrictions come in several distinct waves occurring, in some cases, over a month apart.

We also study margin increases and restrictions imposed by TD Ameritrade and other brokerages on many of the same stocks. We find that equity and options trading restrictions have large and significant impacts across several dimensions of the affected markets. Margin restrictions also have discernible but somewhat smaller effects, consistent with their smaller reach. Somewhat surprisingly, we find that trading volume in equities does not change much when trading restrictions are put in place. Similarly, bid-ask spreads in equity markets exhibit little change in response to the imposition of trading restrictions.

Even though we see little change in total volume, we find that both trading and margin restrictions are associated with lasting and sharp share price declines. Specifically, in the first two hours of equity trading restrictions, restricted stocks experience a statistically significant and economically large average value-weighted cumulative abnormal return (CAR) of -13.54%. Over the first five trading days following the first introduction of equity trading restrictions by Robinhood and other brokers, the CAR is -51.97%. When these equity restrictions are lifted (which happens from a day to just over a week later), these share price declines do not reverse.

When equity restrictions are introduced, investors tend to move from trading the underlying equities to trading the associated options contracts. Options trading volume is roughly 32% higher for stocks restricted by Robinhood. We also find that bid-ask spreads in options narrow by an average of 3.53 percentage points for a round-trip trade, with similar effect magnitudes for purchases of both calls and puts. One likely explanation is that, faced with Robinhood-like equity trading restrictions, retail investors shift to options markets in the affected stocks. Because options are bought primarily by retail investors who are generally less informed than institutions, options

market-makers may face a less adverse selection in options markets during equity trading restrictions, and they might pass this on to options buyers in the form of narrower bid-ask spreads.

However, the options pricing effects are dramatic. We find that implied volatilities increase by 23.76 percentage points of annualized volatility for stocks restricted by Robinhood and others, which is a proportional increase of 18.6%. When we compare implied volatility with realized volatility, we find that options are dramatically overpriced when equity trading restrictions are in place.² In that case, the average increase in the difference between implied and realized volatility is 37.44 percentage points of annualized volatility, which represents a massive increase (more than doubling).

Although much of the press attention has focused on only a small number of high-profile stocks such as GameStop, the equity trading restrictions affect a total of 38 stocks. Our key results are similar across the majority of the individual stocks, and the direction of the individual stock results parallels the panel averages. In other words, the trading restriction effects we identify are much broader than one or two individual stocks.

These results could not have been anticipated by examining the existing literature, which has found that investors do not move from equities to options when equity trading is restricted. Perhaps the study most similar to ours is Battalio and Schultz (2011). They find that when equity trading is restricted, which in their case is the 2008 restrictions on short selling financial stocks,

² To the extent that retail traders are more likely to be options buyers and institutional traders are more likely to be options sellers, this evidence can be viewed as consistent with media coverage suggesting that in these episodes retail traders lost money to institutional traders. One example of this coverage is “Goldman, JPMorgan Chase stick it to the WallStreetBets crowd with knockout trading results,” <https://fortune.com/2021/04/15/goldman-jpmorgan-results-wallstreetbets/>.

investors do not migrate to the options market, and bid-ask spreads in the options market increase. The opposite trend in our results is surprising and may be related to Battalio and Schultz's (2011) focus on restrictions aimed at curbing short selling, which can be dominated by institutional trading, whereas our restrictions are likely to have the largest effect on retail traders. Nevertheless, this paper clearly shows that, while the two events both restricted equity trading, they led to dramatically different investor behavior, especially with respect to options markets. These differences give us a more detailed picture of retail investor trading responses.

The paper is structured as follows. Section 2 provides context from the literature on the connections between equity and options markets, while Section 3 more thoroughly details the trading restrictions and margin increases put in place in early 2021. Section 4 describes the data and details our specifications. Section 5 presents preliminary results. Section 6 details our main identification approach, which is based on the NSCC's collateral requirements and describes our main findings. Section 7 provides additional tests, including placebo tests based on Reddit activity, and interpretations. Finally, Section 8 concludes.

2. Related literature

The connection between the stock market and options markets has been studied extensively. In one strand of the literature, researchers have compared the two markets through the lens of information revelation. Papers such as Manaster and Rendleman (1982) ask which market reflects information more quickly. Similarly, several papers have used put-call parity as a measure of connectedness between the two markets. Evans, Geczy, Musto, and Reed (2009) and Ofek, Richardson, and Whitelaw (2003), for instance, find that short sale constraints can be a leading

driver of differences between the two markets as measured by put-call parity. More recently, Muravyev, Pearson, and Pollet (2021) derive the risk premium associated with short selling through the put-call parity relationship.

Perhaps the closest paper to ours is Battalio and Schultz (2011), who study the connection between stock markets and options markets around the time of the 2008 short sale ban. Although the questions they ask are similar to the ones we are asking here, our answers are quite different. First, whereas they show that investors do not migrate to the options market when short selling is restricted, we find that investors move dramatically into options markets when equity trading restrictions are in place. Second, they show that bid-ask spreads in the options market increase when equity market restrictions are in place; however, we find that bid-ask spreads decrease with equity restrictions.

The fact that our results are the opposite those of Battalio and Schultz (2011) is surprising. The differences highlight how specific features of equity trading restrictions can have a large impact on how investors behave, thus giving us a more nuanced understanding of the market as a whole. Comparing the two equity restrictions reveals, among other things, that the 2008 short sale ban restricts only short selling, whereas the Robinhood and other brokerage restrictions mainly restrict equity purchases. Furthermore, the 2008 short sale ban affects all market participants, whereas the trading and margin restrictions affect only those market participants at a small set of retail brokerages.

The fact that investors move to the options market in early 2021 but not around the 2008 short sale ban is consistent with the idea that retail market participants are more likely to shift into options on the same stocks rather than into other stocks.

3. Brokerage trading restrictions (institutional details)

Robinhood, founded in 2013, is a privately-held brokerage firm and electronic trading platform that offers commission-free trades of stocks and exchange-traded funds (ETFs), mainly via a mobile app that was officially introduced in March 2015. It has become wildly successful with over 13 million users as of 2020. As a broker-dealer regulated by the Financial Industry Regulatory Authority (FINRA) that does not charge commissions on stock and ETF trades, Robinhood's business model relies on three other main sources of revenue: interest on customer cash balances, payment for order flow that is sold to high-frequency traders and other wholesale brokerage firms that typically take the other side of Robinhood customer orders, and interest charged on margin loans. Robinhood is currently valued at approximately \$9 billion and focuses its marketing on the "millennial" demographic, with an average customer age of 26.

Competition from Robinhood has led other retail-oriented brokerage firms to substantially reduce retail commissions. For example, E-Trade, TD Ameritrade, and Charles Schwab have all eliminated most brokerage fees and commissions in response to Robinhood's rapid growth and business model.³ However, Robinhood's growth has also garnered controversy. In 2019, FINRA fined Robinhood \$1.25 million for failing to ensure that its customers received best execution for

³ Section 1 of the Internet Appendix provides details on the relative size of these brokerages obtained from disclosures on the net payments to brokerages for routing order flow to specific venues.

their orders. In December 2020, Robinhood paid \$65 million to settle Securities and Exchange Commission (SEC) charges that it did not fully disclose its practice of selling order flow to high-speed trading firms.

At the end of January 2021, on the social media platform Reddit, a subreddit called r/wallstreetbets encouraged followers to purchase shares in several firms that had recently been the targets of short sellers. These short sellers would make profits from share price declines in these stocks. Due to the resulting share price volatility in the affected stocks, U.S. clearinghouses required Robinhood and other retail-oriented brokerage firms to make substantial deposits with the clearinghouses to continue operating. Brokerages responded in different ways. Robinhood, for example, imposed equity and options trading restrictions on a total of 30 firms starting on January 28, 2021. These restrictions, while quite tight (in some cases forbidding additional share or options purchases), were relatively short-lived. Several other brokerages, including Interactive Brokers, followed suit placing similar restrictions on at least a subset of these stocks. Another set of brokers, led by TD Ameritrade, increased required margins or limited the use of margin. The restrictions by TD Ameritrade remained in place in some cases until our sample ends on March 12, 2021. Although TD Ameritrade and Charles Schwab later released a statement that “neither Charles Schwab & Co. nor TD Ameritrade halted buying or selling ANY stocks this week” and that “neither firm restricted buying or selling basic options,” none of the brokerage firms’ decisions to restrict trade were well-received. Sen. Ted Cruz, Rep. Alexandria Ocasio-Cortez, Elon Musk, and others sharply criticized the restrictions, and Congress has held hearing to investigate the decision of Robinhood and other brokerage firms to restrict trading in this set of stocks.

Robinhood communicated the restrictions to investors via two public facing URLs. Before trading hours on January 28, 2021, Robinhood posted “Keeping Customers Informed Through Market Volatility” to their blog.⁴ In this post, the Robinhood Team stated, “We continuously monitor the markets and make changes where necessary. In light of recent volatility, we are restricting transactions for certain securities to position closing only, including \$AMC, \$BB, \$BBBY, \$EXPR, \$GME, \$KOSS, \$NAKD and \$NOK. We also raised margin requirements for certain securities.” The restricted securities include five firms with common stock listed on the NYSE, the NYSE American, or the Nasdaq exchange: AMC Entertainment Holdings, Inc. (AMC), Bed Bath & Beyond Inc. (BBBY), Express, Inc. (EXPR), GameStop Corp. (GME), and Koss Corporation (KOSS). This webpage was updated to reflect changes in the securities set to “position closing only” throughout the day on January 28.

Later that day Robinhood posted “Changes due to ongoing market volatility” to their Help Center.⁵ In this new webpage, Robinhood clarified that “[position closing only] means you can sell and close your positions, but you can’t open new positions.” Before markets opened on January 29, 2021, the webpage was redesigned to present a table of tickers along with “the maximum number of shares and options contracts to which you can increase your positions. Please note that these are aggregate limits for each security and not per-order limits and include shares and options contracts that you already hold. These limits may be subject to change throughout the day.” The new webpage also featured several frequently-asked questions, such as: “What if my existing

⁴ <https://blog.robinhood.com/news/2021/1/28/keeping-customers-informed-through-market-volatility>.

⁵ <https://robinhood.com/us/en/support/articles/changes-due-to-recent-market-volatility>.

positions already exceed the limits? If you already hold a greater number of shares or contracts than the limits listed above, your positions will not be sold or closed. However, you will not be able to open more positions of each of these securities unless you sell enough of your holdings such that you are below the respective limit.” As an example, this new webpage listed a limit of five equity shares and ten option contracts in GameStop Corp. (GME). By February 5, 2021, all trading restrictions at Robinhood were completely lifted.

Other brokerages implemented similar restrictions. At 9:05 a.m. EST, January 28, 2021, Interactive Brokers tweeted: “Interactive Brokers has put AMC, BB, EXPR, GME, and KOSS option trading into liquidation only due to the extraordinary volatility in the markets. In addition, long stock positions will require 100% margin and short stock positions will require 300% margin until further notice”.⁶ While traders may have encountered these restrictions prior to this announcement, this tweet appears to be the first public-facing statement by Interactive Brokers regarding the restrictions. In fact, later reporting on January 28, 2021 confirms that Interactive Brokers “today announced that as of midday yesterday” these restrictions were in place. Similarly, E-Trade limited activity in GME and AMC “late in the trading day” on January 28, 2021,⁷ and “Webull also restricted trades of GameStop and other stocks on Thursday,” January 28.⁸ They later tweeted at 2:35 p.m. EST Friday, January 29, 2021 that “UPDATE: GME, AMC and KOSS are no longer restricted”.⁹

⁶ <https://twitter.com/IBKR/status/1354792600004386818>

⁷ <https://www.theverge.com/2021/1/28/22254863/etrade-gamestop-amc-stock-reddit-wallstreetbets-robinhood>

⁸ <https://www.fastcompany.com/90599420/robinhoods-gamestop-restrictions-were-a-rocket-boost-for-webull>

⁹ <https://twitter.com/WebullGlobal/status/1354875836810342400>

Another set of brokerages, including TD Ameritrade and Charles Schwab, implemented other types of restrictions such as increased margin requirements, notably for options writers and short sellers. These restrictions were distinct from the restrictions put in place by brokerages, such as Robinhood and Interactive Brokers, with TD Ameritrade and Charles Schwab releasing a statement that, “Neither Charles Schwab & Co. nor TD Ameritrade halted buying or selling ANY stocks this week. Neither firm restricted buying or selling basic options”.¹⁰ TD Ameritrade communicated these changes to its margin requirements on the webpage, stating that while “[t]hese restrictions will not prevent clients from making basic buy and sell transactions,” certain stocks were no longer marginable and short puts required “the maintenance/cash to cover the entire exercise amount of the short puts.”¹¹ The restrictions by TD Ameritrade remained in place in some cases until our sample ends on March 12, 2021.

4. Data

Our sample period for the implementation of these trading restrictions and increased margin requirements runs from Friday, January 22, 2021 through Friday, March 12, 2021 and focuses on firms with common shares in CRSP listed on the NYSE, NYSE American, or Nasdaq exchanges as of year-end 2020. We combine standard high-frequency financial data from the Trade and Quote (TAQ) database with two novel datasets: one detailing Robinhood’s equity and options trading restrictions, another detailing margin changes at TD Ameritrade.

¹⁰ <https://www.businesswire.com/news/home/20210129005408/en>

¹¹ <https://tdameritrade.com/td-ameritrade-trading-restrictions-stocks.page>.

We hand collect 111 snapshots of the two Robinhood webpages that convey information regarding the then-current restrictions on investor holdings using the Internet Archive Wayback Machine. Figure 1 provides an example of one such snapshot. These snapshots begin before trading on Thursday, January 28, 2021 at 9:03:57 AM EST and continue until after the end of the two waves of our sample period. The last snapshot containing a trading restriction is taken on Thursday, February 4, 2021 at 6:14:09 EST. A snapshot stating that “There are currently no temporary limits to increasing your positions” was archived before trading on Friday, February 5, 2021 at 0:22:00 EST. No subsequent restrictions on trading have been archived on either of these webpages.

Our dataset of TD Ameritrade restrictions is similarly comprised of 37 snapshots of the webpage TD Ameritrade used to communicate their restrictions from the Internet Archive Wayback Machine. These snapshots begin with a list of restrictions “as of January 28, 2021 4:00PM ET” and end with a list “as of March 12, 2021 4:00 PM ET” when our sample ends.

We focus on restrictions at these two brokerages for several reasons. First, both Robinhood and TD Ameritrade communicated their restrictions via public facing webpages that were archived to document changes in the restrictions through time. Second, to our knowledge, these brokers placed restrictions on the broadest set of stocks for the longest period of time. We know of no other brokerage that publicly announced a limit to the maximum number of shares or contracts an investor could hold in their account before Robinhood’s announcement. Moreover, no other restrictions are likely to be as stringent as Robinhood’s trading restrictions, and the Robinhood restrictions are a superset of all such restrictions on the maximum number of long shares or long

options contracts held. Likewise, TD Ameritrade’s margin changes compare similarly to those at other firms.

We start in Table 1 with a timeline of the brokerage trading restrictions and increased margin requirements put in place at the end of January 2021. If Robinhood (and potentially other brokerage firms) impose a trading restriction in a given stock during a given time interval, that stock-interval is labeled Set 1. If TD Ameritrade (and potentially other brokerages) increase margin requirements for a given stock-interval, that stock-interval is labeled Set 2. If both types of restrictions are in place, the stock-interval is labeled “Both.” The first set of restrictions (Set 1) are trading restrictions put in place by Robinhood, Interactive Brokers, and a few other brokerage firms. These begin before trading opens on January 28. The first set of stocks affected include AMC, BBBY (Bed Bath and Beyond), BBY (Best Buy), EXPR (Express), GME (GameStop), and KOSS. After the close of trading on January 28, additional stocks are added to the Set 1 brokerage trading restriction list from Robinhood and other brokerages. Increases in margin are then imposed by a second set of brokerage firms (Set 2), notably TD Ameritrade. Table 1 reports the timeline of the trading restrictions and increased margin requirements using our Set 1/Set 2/Both notation. Based on the snapshots from the Wayback Machine, trading restrictions by Set 1 brokerage firms in equities and options change 16 times between January 28 and February 5, 2021 and affect a total of 30 firms. Table 1 also reveals that margin restrictions and increases by TD Ameritrade and other Set 2 brokerage firms affect a total of 15 stocks during this period.

Additional details regarding the timeline of restrictions for both Robinhood and TD Ameritrade are in Section 2 of the Internet Appendix. Broadly, Robinhood and other Set 1 trading

restrictions are gradually rolled back at the end of January and during the first week of February. These restrictions are removed entirely by the opening of trading on February 5. TD Ameritrade and other Set 2 brokerage firms also gradually roll back the margin requirements they had increased or tightened, removing all such margin increases after market close on February 24. A second wave of increased margin requirements imposed by TD Ameritrade and other Set 2 brokerage firms begins at 4:00 PM EST on February 25 and lasts through the end of our sample on March 12. In general, these increased margin requirements apply to option sellers, short sellers, and some long positions in the underlying equities. Together, these trading risk restrictions and increased margin requirements apply to a total of 38 different stocks.

Several features of these data notably aid in identification. First, the imposition and relaxation of restrictions is staggered across firms. Second, within a firm, the stringency of the restriction varies through time, and there is considerable cross-sectional variation in both when these changes occur for a given firm and in how large the changes are. Moreover, we observe changes in the restrictions in both directions: looser restrictions at certain times and more stringent restrictions at other times. Finally, not all firms restricted by Set 1 brokerages are restricted by Set 2 brokerages and vice versa.

Equity returns, volume bid-ask spreads, and 15-minute realized volatilities are from the daily TAQ database. Following the literature, we keep trades during normal market hours, delete abnormal trades, and focus on the typical sixteen exchanges. Bid-ask spreads are the percentage effective spread for a round-trip trade and are aggregated through time by volume-weighting. We winsorize equity bid-ask spreads and average trade sizes at the 99th percentile.

Equity options data (including trading volume, implied volatilities, options bid-ask spreads, open interest, and options deltas) are from Cboe LiveVol DataShop. We exclude canceled trades, trades outside of normal exchange hours, trades in options that expire in seven days or fewer, and trades with a size of 0 contracts. We follow Doan, Foster, and Yang (2020) in keeping trades with trade conditions that are similar to those used in equity research. Again, we aggregate variables such as implied volatilities through time by volume-weighting. Bid-ask spreads are the percentage effective spread for a round-trip trade. We winsorize implied volatilities at the 99th percentile. Additionally, we winsorize options bid-ask spreads and the difference between implied volatility and realized volatility at the 5th and 95th percentiles.

We face a tradeoff in choosing an interval of time to aggregate trades up to observations. A shorter window might sharpen the cutoff between the time when a security is un/restricted. A longer window allows for measurement error in the time that a restriction is put in place for a firm versus when a snapshot of a webpage containing the restrictions is taken. Additionally, a longer window allows more time for an options trade to occur in a given observation and may help us better control for date-time effects in our research design. We therefore conduct tests on two datasets: one consisting of firm-day observations and another aggregating trades to 15-minute intervals during the trading day. For each firm in our sample, we have a time series of 36 trading day observations in our daily panel and 936 observations of 26 observations per trading day over 36 trading days in this high-frequency sample. For the daily panel, we require a restricted firm to be subject to restrictions for at least two hours during the trading day to be included in the sample.

Returning to the potential issue of measurement error in the time that a restriction is placed on a firm, we reiterate that we observe many more snapshots than we observe changes in restrictions and that snapshots between changes in restrictions suggest that restrictions are static for long stretches during this period. Many of the potential times during which restrictions could have changed occur outside of trading hours. Additionally, to the extent that we measure changes in restrictions with error, this measurement error should attenuate our coefficients of interest, biasing us against finding an effect around the introduction or removal of a restriction.

We also face a tradeoff in choosing the length of our sample period. As is often the case with market bubbles, the frenzy period can be difficult to define, and a shorter window might improve our ability to disentangle the general effect of the retail frenzy stemming from *r/wallstreetbets* and other subreddits. Conversely, a longer window might allow us to better control for time-invariant firm effects. Unless otherwise noted, we confine our attention to the first time a firm faces any type of trading restriction and consider only the ten-trading day window relative to the first restriction. Specifically, we include a restricted firm in our daily panel if the observation is in the (-5,4)-trading day window relative to its first restriction and in our 15-minute interval panel if the observation is in the (-130,129)-trading interval window relative to its first restriction. If the trading restriction is not in place for a firm for the full post-event window, then the observation is dropped from the sample.

Our research design features two primary types of tests: time-series regressions for individual firms subject to restrictions and two-way fixed effects regressions on the panel of common stocks or options. Our two-way fixed effect panel regressions take the following form:

$$Y_{i,t} = \beta \times Restricted_{i,t} + \mu_i + \nu_t + \varepsilon_{i,t}$$

where μ_i is the time-invariant fixed effect for firm i , ν_t is the firm-invariant fixed effect at time t , and $Restricted_{i,t}$ is a binary variable equal to one if security I is subject to an equity restriction at time t and zero otherwise. We cluster the estimate of the covariance matrix of $\varepsilon_{i,t}$ at the firm level.

The time-series regressions are estimated for each individual firm and take the following form:

$$Y_{i,t} - \bar{Y}_t = \alpha_i + \beta_i \times Restricted_{i,t} + \varepsilon_{i,t}$$

where \bar{Y}_t is the cross-sectional mean across all common stocks at time t ; $Restricted_{i,t}$ is a binary variable equal to one if security i is subject to an equity restriction at time t and zero otherwise; and the estimate of the covariance matrix of $\varepsilon_{i,t}$ is the Newey-West estimator with lag length four. Similar to our two-way fixed effects estimates, \bar{Y}_t controls for a firm-invariant time effect, and α_i controls for a time-invariant firm effect. We also report Fama-MacBeth (1973) type estimates that are the equal-weighted aggregate of β_i across restricted firms, and the standard error of β_i is calculated using the cross-section of estimates of β_i .

5. Results

Our general goal is to characterize the behavior of affected stocks and their related options before, during, and after 1) the Robinhood and other Set 1 brokerage firm trading restrictions and 2) the margin restrictions and increases imposed by TD Ameritrade and other Set 2 brokerages. Our sample extends from January 22, 2021 through March 12, 2021. Robinhood and other Set 1

brokerages restrict equity and/or options trading in a total of 29 firms.¹² The first restrictions are imposed prior to the market open on Thursday, January 28, 2021 and all Set 1 trading restrictions are removed by the start of regular trading on Friday, February 5, 2021. The margin increases and limits imposed by TD Ameritrade and other Set 2 brokerages are implemented in two waves: the first wave of restrictions beginning on January 28 is removed by the end of trading on February 24 and the second wave of restrictions is still in place for two firms, GME and RKT, when our sample ends on March 12, 2021. Overall, some trading restrictions are in place at Robinhood for just over a week (six trading days in total), while margin restrictions last in some cases almost a month (January 28 through February 24). A total of 3,712 National Market System (NMS) firms meet our filters where equity and options trading are never restricted, and we sometimes use these as a comparison or control sample. Elsewhere in the paper we compare the behavior of firms during trading and/or margin restrictions to that of the same firms during periods without restrictions.

5.1. Summary statistics

Summary statistics for most of our variables of interest are contained in Table 2 and are tabulated using the 15-minute interval panel. The first two columns feature firms with actual trading restrictions imposed by Robinhood and other Set 1 brokerages and provide summary statistics comparing these firms while they are restricted from trading to intervals during which they are not restricted from trading. The table also provides summary statistics for Set 2 restricted firms during the margin restrictions and during other times when they are not restricted. Recall

¹² One firm (ticker: UONE) is only restricted outside of normal trading hours.

that these are firms that experience increased or tightened margin requirements from TD Ameritrade and other Set 2 brokerage firms. We also compare the two sets of restricted firms to 3,712 other firms that never experience trading restrictions or increased margin requirements, though these never-restricted firms are probably quite different on average from firms that experience some sort of restriction during this episode.

We find that open interest in options is much higher when restrictions are in place compared to times when trading restrictions or increased margin requirements are not in place. For example, options open interest averages 1.096 million contracts for Set 1 restricted firms when restrictions are in place, which is more than twice the average open interest for these same firms when they are unrestricted (about 542,000 contracts). For Set 2 restricted firms, open interest during the margin restrictions is also more than double open interest when restrictions are not in place (about 479,000 vs. less than 224,000 contracts on average). Proportional differences for options volume in firms during restrictions vs. the same firms without restrictions are of similar magnitudes, as are equity volumes.

We also provide summary statistics for average returns; the fraction of trading volume that can be attributed to retail investors; options and equity bid-ask spreads; and implied volatilities of options and implied volatilities relative to actual realized volatilities. In general, we find that implied volatilities are much higher for restricted firms and for those with increased margin requirements. The same is true for implied volatilities relative to realized volatilities, suggesting that option prices for stocks with trading restrictions and those with increased margin requirements are much higher relative to actuarially fair values than for unrestricted stocks. We return to these

option pricing results later in the paper to confirm that these results hold when we apply more carefully constructed regression specifications.

The stock returns we calculate are average 15-minute returns from TAQ during the sample period, and we find that these average returns are slightly positive for restricted firms when the restrictions are not in place (mean 15-minute return = 2 basis points), while average returns are more negative for restricted firms when restrictions are in place (mean 15-minute return = -0.51%). When the restrictions are not in place, 15-minute equity volume for restricted firms averages 1.021 million shares, while the corresponding share volume for restricted firms during trading restrictions averages 4.046 million shares per 15 minutes. Options volume for the two groups averages 1,521 and 6,352 contracts per 15 minutes, respectively.

We use the algorithm in Boehmer, Jones, Zhang, and Zhang (2021) to identify a broad swath of retail marketable order flow based on off-exchange executions that exhibit sub-penny price improvement. We find that over 25% of total TAQ volume is classified as retail marketable order flow during Set 1 restrictions based on our algorithm. For the 29 firms where trading is restricted at some point, the exact retail percentages are 23.31% of volume when trading is unrestricted and 27.79% when a firm has a brokerage Set 1 trading restriction in place. In general, we find these high fractions of retail trading to be notable, particularly since our algorithm covers a large fraction of (although certainly not all) marketable retail order flow and thus represents a lower bound on the prevalence of marketable retail order flow in these stocks during this time period.

Our final equity summary statistic in Table 2 is the average effective equity bid-ask spread for the 29 firms with Set 1 trading restrictions. When these firms have a trading restriction in place, bid-ask spreads average 0.37% vs. 0.21% for those same firms when there are no restrictions. While this table admittedly applies no other controls, we still find that this more than 50% increase in bid-ask spreads during Robinhood-type restrictions to be substantial, suggesting a marked change in adverse selection associated with the trading restrictions (see, for example, Glosten and Milgrom (1985) and Kyle (1985) for canonical microstructure models of price discovery and trading costs in the presence of adverse selection). Interestingly, these comparative results do not appear in Set 2 restricted firms, which speaks to either the generalizability of this result, the mechanism at work, or both.

Our other main summary statistics are associated with options trading in these same 29 Set 1 firms. For these options, volume-weighted effective bid-ask spreads average 9.68% when Robinhood restrictions are in place vs. 11.49% for those same firms when there are no restrictions. The main message here is that single-name option positions are expensive to enter and exit, with surprisingly wide bid-ask spreads.

Implied volatilities are also quite high in these particular firms. Following most of the options literature, we focus on options with 7 to 30 days to expiration and log moneyness (share price relative to strike price) of -20% to 20%. When a stock is outside its time interval of Robinhood and other Set 1 trading restrictions, the average annualized implied volatility is 127.5%, and when one of these 29 stocks has trading restrictions in place, the analogous implied volatility is a breathtaking 228%! We examine this discrepancy more formally in Section 5.4, but

it suggests that options in these firms become markedly more expensive when there are Robinhood and other Set 1 trading restrictions in place.

Another volatility calculation of interest is the difference between the implied volatility of options in our sample and the daily realized volatility over the interval to option expiration. We report these average differences in annualized return volatility terms, and this quantity is on average quite positive: even excluding costs associated with options bid-ask spreads, call and put buyers on average are paying far more than ex post actuarially fair values for the options they purchase. When there are no Robinhood trading restrictions in these 29 firms, the average difference between implied and ex post realized volatilities is an annualized 25.73%. In contrast, when there are trading restrictions imposed by Set 1 brokerages, including Robinhood, the difference between the implied and ex post realized volatilities more than doubles, averaging 63.3% on an annualized basis.

Robinhood trading restrictions are also associated with modest changes in options deltas. For these 29 firms, the absolute value of options deltas averages 0.328 when trading restrictions are in place vs. 0.387 when they are not. This means that options buyers trade in options that are slightly further out of the money when there are Robinhood trading restrictions. Finally, we reiterate that Robinhood restrictions are associated with big increases in option open interest in these 29 firms. Open interest averages about 542,000 contracts without trading restrictions and is more than double (about 1.096 million contracts total) when restrictions are in place. We investigate these changes in more detail later, but these open interest numbers suggest that when there are Robinhood-type trading restrictions, investors interested in the affected stocks substitute

sharply toward options trading and away from the underlying equities, despite the higher options prices and wide bid-ask spreads associated with options in this case.

5.2. Stock returns associated with equity restrictions

Next, we look at stock returns immediately before, during, and after the Set 1 (Robinhood-like) equity trading restrictions and the Set 2 (TD Ameritrade-like) margin increases. In the left half of Table 3, we apply a daily panel regression approach with three dummy variables. The first is turned on if and only if some sort of trading or margin restriction is in place, the second is set to one iff a trading restriction is in place from Robinhood or another Set 1 brokerage, and the third dummy is set to one iff margin restrictions are in place from TD Ameritrade or another Set 2 brokerage firm. The coefficient measures the one-time daily return effect of activating a particular dummy. The estimated return effects are large and negative, which is likely consistent with expectations given that these restrictions are usually designed to limit or prohibit equity purchases. For example, the imposition of a Robinhood-like trading restriction by a Set 1 brokerage firm leads to a one-time daily return of -59.4%. The imposition of TD Ameritrade-like margin restrictions by a Set 2 brokerage is associated with a daily return of -24.9%, and when we include both Set 1 and Set 2 restrictions in the same regression, both coefficients remain strongly significant. Since these panel regressions omit any observations after restrictions are lifted, these tests say nothing about whether price declines fully reverse when the restrictions are lifted. The event study approach that we introduce below relaxes this constraint and allows us to gauge whether and to what extent these price declines reverse when restrictions are lifted.

The right half of Table 3 zooms in on intraday data and measures the immediate 15-minute returns associated with the same three types of restrictions. The imposition of any sort of restriction leads to an immediate 15-minute return of -0.64%, a Robinhood-like Set 1 trading restriction is associated with a 15-minute return of -0.80%, and a TD Ameritrade-like Set 2 margin restriction leads to an immediate 15-minute return of -0.64%. All are significant at the 1% level, and both Set 1 and Set 2 restrictions are separately significant and negative when both dummies are included in the same specification.

Next, we move to an event study approach to measuring the effect of brokerage restrictions on share prices. Here the unit of event time is a 15-minute interval. Event period zero refers to the 15-minute interval associated with the imposition of the specified trading or margin restriction. Table 4 Panel A reports results before and after the first restriction applied to a firm. Abnormal returns are calculated on a market-adjusted basis by subtracting the 15-minute value-weighted market return from the relevant 15-minute firm return. CARs are then calculated by cumulating ARs over the relevant number of periods. For example, in the hour before the first restriction is imposed on a stock (event periods -5 to -1), it experiences a CAR of 1.66%, which is not statistically significant. Perhaps more relevant are the returns after the first restriction is imposed. In general, while some of these returns are economically large in magnitude, they tend to be less statistically significant. For example, in the hour following the first restriction in a given stock, the average CAR is -6.21%, but this is only significant at the 10% level. The share price continues to fall as event time passes, and five trading days later, the CAR is about -52%, which is economically large but statistically significant only at the 10% level.

Table 4 Panel B separates out restrictions of various sorts. For example, the two-hour post-event CAR associated with a Set 1 (Robinhood-like) trading restriction is -18.54%, significant at the 5% level. The analogous two-hour CAR for the first Set 2 (TD Ameritrade-like) margin restriction or increase is -4.44%, which is not significant at conventional levels. There is also no reliable evidence of price reversals when restrictions are relaxed or removed. Removal of all restrictions leads to a two-hour post-event CAR of 2.89%, which is not statistically significant at standard levels.

Figure 2 shows this same information graphically. Again, for each 15-minute interval in the event window (or until the firm's restriction is lifted), the equally-weighted portfolio is long the restricted stock and short the value-weighted market return. Event time zero is the 15-minute interval when a restriction is imposed, and we report portfolio CARs for successive 15-minute intervals thereafter. Within one trading day after the restriction is imposed (event time +25), the portfolio CAR is about -20%, and within 5 trading days (event time +129) the portfolio CAR is about -50%. These CARs are sharply negative, indicating that the imposition of restrictions leads to strong negative share price effects.

These CARs are even more negative when we consider the most severe Set 1 equity restrictions, as shown in Panel B. When Robinhood forbids any equity purchase in a name, the two-hour CAR is -34.80%. Set 2 margin restrictions have much smaller and often insignificant return effects. It is clear that Robinhood-like trading restrictions are extremely bad news for a stock at horizons measured in hours. However, there is no stock price reversal going the other way. In other words, lifting the restrictions has no stock price benefit that we can discern.

5.3. Trading volume results

While share price effects are perhaps the most important findings, it seems likely that other trading and market quality measures are strongly affected by these restrictions. Table 5 returns to our panel regression framework to measure the impact of these restrictions on options and equity trading volume. We again use three dummy variables—one for any restriction, one for a Set 1 (Robinhood-like) trading restriction, and one for a Set 2 (TD Ameritrade-like) margin tightening—to measure each one’s impact on both equity and options trading volume.

The results are in Table 5. In the daily panel, only Set 2 restrictions seem to affect options trading volume, reducing it by over 31%. Set 2 restrictions also reduce equity trading volume by over 40%. In the 15-minute interval panel, Set 1 trading restrictions increase options volume by almost 45% and have no reliable effects on equity trading volume. We thus do not see evidence of a substitution away from equity trading, but we do see increases in option trading volume over short horizons when there are Set 1 Robinhood-like trading restrictions.

5.4. Implied volatilities and restrictions

In the previous sections, we have seen evidence consistent with the idea that retail investors shift over to options markets in the stocks that experience Robinhood equity restrictions. One important aspect of this shift is how much investors are paying for options. If investors are paying fair prices for the newly purchased options, then we can conclude that retail investors’ shift to options is a relatively benign activity. On the other hand, if retail investors are overpaying to buy options, then we might be concerned that this shift to options is associated with an economic loss on the part of retail investors and, potentially, a gain that would accrue to options market-makers.

The results in Table 6. We use the same empirical approach as in the previous tables; we use a panel regression framework and look at how these implied volatilities change in the treated sample. In particular, we are interested in the coefficients on the three dummy variables--one for any restriction, one for a Set 1 (Robinhood-like) trading restriction, and one for a Set 2 (TD Ameritrade-like) margin tightening-- to measure each one's impact on implied volatilities.

Following our previous approach, we look at changes at the daily level and at the 15-minute interval level. Our approach, which is similar to Dumas, Fleming, and Whaley (1998); Bakshi, Cao, and Chen (1997); and Muravyev, Pearson, and Pollet (2021), is to limit the sample to those options most likely to have reasonably high volume, in order to reduce measurement error. Specifically, we consider options with 7 to 30 days to expiration and log moneyness (share price relative to strike price) of -20% to 20%. Our results are robust to alternative maturity and moneyness ranges and are discussed in Section 3 of the Internet Appendix.

The key finding in Table 6 is that options implied volatilities increase significantly when equity restrictions are in place. The magnitude of the increase is somewhat similar across the restriction definitions. Take, for example, the overall restriction, or *Restricted*. The coefficient on *Restricted* in the daily panel indicates that annualized implied volatilities are increasing by 17.84%, which is significant at the one percent level. In the daily panel, Set 1 trading restrictions are large and statistically significant with a 23.76% increase, while Set 2 (margin) restrictions seem to have a slightly weaker, yet, still borderline statistically significant, effect of 13.37%. In the 15-minute interval panel, the pattern is repeated: overall restrictions are significant, with Set 1 restrictions demonstrating a larger and stronger effect than Set 2 restrictions.

These findings are consistent with several possible interpretations. The most basic interpretation is that market participants are anticipating an increase in volatility over the life of the options, and they are agreeing to pay more for those options to reflect this increase in volatility. In this tumultuous time for the restricted stocks, this explanation makes sense. However, as we see in the following tables, another interpretation may offer a better fit for these findings: options sellers are charging higher prices for options even though underlying equity volatility does not increase enough to explain the higher transaction prices.

Although it is useful to view implied volatility as a measure of options pricing, if underlying volatility is increasing at the same time, then the increase in implied volatility could be fair in an actuarial sense. On the other hand, if implied volatility is increasing beyond any increase in underlying volatility, then that increase could be seen as actuarially unfair; in other words, the options would be overpriced. In Panel B we introduce another measure of options pricing: implied volatility relative to realized volatility, calculated as implied volatility minus realized volatility. We calculate realized volatility using 5-minute returns during trading hours until option maturity.

Using this measure, we find that options are dramatically overpriced when the overall restriction measure, *Restriction*, is in place. The average increase of this difference across our daily panel is 36.97%, which is statistically significant at the one-percent level. Looking at the Set 1 trading restrictions unconditionally (the results in Table 2), we see that the difference between implied and realized volatility in the unrestricted sample is 25.73%, while it is 63.28% in the restricted sample, which represents a tremendous increase, more than doubling. The results are remarkably consistent across the two types of restrictions (Set 1 and Set 2) and across the two

measurement frequencies (daily and 15-minute). Overall, we find a huge increase in the relative overpricing of options for restricted stocks, which is displayed graphically in Figure 3. This figure graphs the pre- and during restriction effects in event time. In the four trading hours before restrictions begin, the difference between implied and realized volatilities for the set of restricted firms is indistinguishable from the difference in the set of control firms. $IV-RV$ increases modestly in the first hour that restrictions are in place before increasing to roughly 15 to 20% in the next four hours.

5.5. Bid-ask spreads and restrictions

Market participants may be concerned that these trading restrictions might worsen market quality measures. To address that concern, we collect proportional effective bid-ask spreads on both the underlying equities and the associated equity options series. We assess whether the trading restrictions improved or worsened market quality, as measured by these bid-ask spreads. As before, we are interested in the coefficients on the three dummy variables--one for any restriction, one for a Set 1 (Robinhood-like) trading restriction, and one for a Set 2 (TD Ameritrade-like) margin tightening-- to measure each restriction's impact on bid-ask spreads.

The results are in Table 7. Panels A and B contain the results for options bid-ask spreads and equity bid-ask spreads, respectively. Panel A shows that Set 1 trading restrictions narrow options bid-ask spreads by an average of 3.53 percentage points for the daily panel and 2.80 percentage points for the 15-minute panel. Both results are strongly statistically significant at the 5% and 1% levels, respectively.

Thus, it appears that the Set 1 trading restrictions improve options market quality. We are not sure why this is so. One possibility is that, faced with Robinhood equity trading restrictions, retail investors shift over to options markets in the affected stocks. Because options are bought mainly by retail investors who are generally less informed than institutions, options market-makers face less adverse selection in options markets while there are equity restrictions, and they pass this on to options buyers in the form of narrower bid-ask spreads. Other market quality measures such as price impacts may help us confirm that there is less adverse selection in options markets at these times, and we are currently collecting additional options market data that will help us test whether this is indeed the case.

Panel B shows similar measures for equity bid-ask spreads for the Set 2 margin tightening restrictions. In this case, the regressions show that the Set 2 restrictions narrow bid ask spreads by an average of nine basis points for the daily panel and six basis points for the 15-minute panel. The daily panel has borderline statistical significance while the 15-minute panel's narrowing is statistically significant at the 5% levels.

6. Identification

Our test up to this point have failed to account for the fact that the set of restricted stocks was not randomly assigned. In this section, we tackle this endogeneity problem by revisiting our main results within the context of an instrumental variables estimation.

To motivate our instrument, we begin with reporting in the financial press¹³ as to the reason that Robinhood restricted trading in a set of stocks. At 7 AM EST on the morning of January 28, Robinhood received a daily collateral call from the National Securities Clearing Corporation (NSCC) to help mitigate clearinghouse risk faced by the NSCC during the settlement process. While Robinhood deposited \$1.4 billion with the NSCC, this amount fell short of the \$3 billion total collateral call requested by the NSCC. Robinhood then restricted trading in a number of stocks to allow for trades to settle which would reduce their collateral call and resolve this shortfall. It is natural to think that, in choosing which stocks to restrict, Robinhood ranked stocks in the order in which they contributed to their collateral call and restricted stocks following this rank order until their collateral call shortfall was covered.

While the exact formula the NSCC uses to calculate a brokerage's collateral call is proprietary, there is some public guidance on how the collateral call is calculated.¹⁴ In brief, the NSCC calculates a collateral call separately for each of four equity market capitalization-based subcategories¹⁵ by multiplying four components: “(1) an impact cost coefficient that is a multiple of the one-day market volatility of that subgroup..., (2) the gross market value of the Net Unsettled Position in that subgroup, (3) the square root of the gross market value of the Net Unsettled Position in that subgroup in the portfolio divided by an assumed percentage of the average daily

¹³ <https://fortune.com/2021/02/02/robinhood-gamestop-restricted-trading-meme-stocks-gme-amc-vlad-tenev-nbcc/>

¹⁴ See for example p. 9-10 of <https://www.sec.gov/rules/sro/nbcc/2020/34-89558.pdf>

¹⁵ The four subcategories are: “(i) micro- capitalization equities would be less than \$300 million, (ii) small capitalization equities would be equal to or greater than \$300 million and less than \$2 billion, (iii) medium capitalization equities would be equal to or greater than \$2 billion and less than \$10 billion, and (iv) large capitalization equities would be equal to or greater than \$10 billion.” (p. 9)

trading volume of that subgroup, and (4) a measurement of the concentration of the Net Unsettled Position in that subgroup in the portfolio” with the last component calculated by “aggregating the relative weight of each CUSIP in that Net Unsettled Position relative to the weight of that CUSIP in the subgroup.” (p. 9-10)

In the tests that follow, we instrument our *Restricted_{SI}* variable with a proxy for this collateral call variable calculated at the firm-level for Robinhood. Since the collateral call occurs daily and is based on unsettled positions, we do not observe any variation in the collateral call at the intraday frequency and restrict our analysis to our firm-day panel. Specifically, we calculate the collateral call Robinhood faced for firm i on day t as

$$CCall_{RH,i,t} = \sigma_{i,t-1} \sqrt{\frac{Net\ Unsettled\ Position_{RH,i,t-1}}{\$Volume_{i,t-1}}} \times Net\ Unsettled\ Position_{RH,i,t-1} \times Conc_{RH,i,t-1}$$

where $\sigma_{i,t-1}$ is the realized volatility for firm i on day $t-1$ calculated using 5-minute returns and $\$Volume_{i,t-1}$ is the dollar volume for firm i on day $t-1$. *Net Unsettled Position_{RH,i,t-1}* is the dollar net unsettled position for Robinhood and is defined as follows to reflect the two-day settlement process

$$Net\ Unsettled\ Position_{RH,i,t-1} = P_{i,t-1} \omega_{RH,i,\underline{t}} (Volume_{i,t-1} + Volume_{i,t-2})$$

where $P_{i,t-1}$ is the stock price for firm i on day $t-1$, $Volume_{i,t-1}$ is the trading volume in shares, and $\omega_{RH,i,\underline{t}}$ is the proportion of volume attributable to Robinhood traders in firm i at the end of the month prior to day $t-1$, which we denote as \underline{t} . This last variable is calculated using Rule 605/606 disclosure data and is calculated as

$$\omega_{RH,i,\underline{t}} = \frac{Rule\ 605\ Volume_{RH,i,\underline{t}}}{Volume_{i,\underline{t}}}$$

where the construction of $Rule\ 605\ Volume_{RH,i,t}$ is discussed in detail in Section 4 of the Internet Appendix. Finally,

$$Conc_{RH,i,t-1} = \frac{Net\ Unsettled\ Position_{RH,i,t-1} / \sum_{s \in S} Net\ Unsettled\ Position_{RH,s,t-1}}{MktCap_{i,t-1} / \sum_{s \in S} MktCap_{s,t-1}}$$

where the summation is taken across firms in the same market capitalization-based subcategory defined by the NSCC to which firm i belongs.

Our instrumental variables approach estimates the following two stages. The first stage estimates the linear probability model

$$Restricted_{S1,i,t} = \sum_{M=1}^4 \delta_M \times I_{i,t}(i \in M) \times CCall_{RH,i,t} + \mu_i + \nu_t + \varepsilon_{i,t}$$

where μ_i is the time-invariant fixed effect for firm i , ν_t is the firm-invariant fixed effect at time t , $I_{i,t}(i \in M)$ is a binary variable equal to one if firm i belongs to market capitalization-based subcategory M at time t and zero otherwise, and $Restricted_{S1,i,t}$ is a binary variable equal to one if firm i is subject to a Set 1 equity restriction at time t and zero otherwise. We estimate separate coefficients for each of the market capitalization-based subcategories to account for the separate collateral calls for each subcategories.¹⁶ The second stage estimates the following equation

$$Y_{i,t} = \beta \times \widehat{Restricted}_{S1,i,t} + \mu_i + \nu_t + \varepsilon_{i,t}$$

¹⁶ This treatment of the subcategories seems consistent with the actual restrictions imposed by Robinhood. Namely, Robinhood restricted stocks across each of the subcategories with the percentage of restricted firms in subcategory 1 being roughly 19 percent, in subcategory 2 being roughly 44 percent, in subcategory 3 being roughly 25 percent and in subcategory 4 being roughly 12 percent.

where the value for $Restricted_{SL,i,t}$ is replaced with the fitted value from the first stage.

In order for $I_{i,t}(i \in M) \times CCall_{RH,i,t}$ to be a valid instrument, it needs to meet both the exclusion restriction and the relevance criterion. Regarding the exclusion restriction, we note that the instrument is comprised of lagged transformations of publicly observable market variables (price, volatility and volume) and the proportion of volume attributable to Robinhood traders at the end of the prior month.¹⁷ With the exception of lagged realized volatility, which is known to predict future returns, these variables should be largely impounded into prices by semi-strong form market efficiency, and we are able to explicitly control for lagged realized volatility in both the first- and second-stage regressions. Regarding the relevance criterion, this instrument should be correlated with the stock being restricted in that the collateral call is set by regulators and our instrument should proxy for what Robinhood was evaluating at the firm-level as they were attempting to reconcile their collateral call shortfall with the NSCC. We also note that the first-stage F -statistics presented in Table 8 all exceed 180.

Table 8 presents the results for the two-stage least squares estimation outlined above. We begin with the first-stage results for the regressions using returns as the outcome variable. The loading on each of our instruments is positive indicating that stocks that have high collateral call contributions on a given day are more likely to be restricted by Robinhood, even after controlling for lagged realized volatility. In both cases, the first-stage F -statistic is highly significant with values of 181.98 and 191.16 for the two different specifications. Turning to our second-stage

¹⁷ This variable is slow moving (varies by month), lagged, and may be publicly available or highly predictable at the time restrictions were implemented (venues and brokerages report quarterly so December values should have been posted by the end of January).

results in these specifications, magnitudes of the estimated coefficients on Set 1 trading restrictions are similar to those from our previous panel regressions. Moreover after controlling for lagged realized volatility in the second-stage, we fail to reject the null hypothesis of the overidentifying restrictions test.

Results for option prices, as measured by implied volatility minus realized volatility, are also quantitatively similar to the results in Table 6. In the specifications controlling for lagged realized volatility, annualized implied volatility relative to realized volatility increases by roughly 25 percentage points on stock-days with Set 1 trading restrictions compared to roughly 37 percentage points using a two-way fixed effects estimator. Again, the first-stage F -statistic greatly exceeds standard thresholds for weak instrument tests, and we fail to reject the overidentifying restrictions test in this specification.

7. Additional Tests

In this section, we explore additional tests including individual firm regressions designed to explore heterogeneity in the effects of the restrictions across firms, the effect of the restrictions on exempt short sale volume, which should be comprised in part by trades made by options market makers, and two additional sets of tests to bolster our claims of identification. In the first of these latter two tests, we perform a set of placebo tests on stocks that were heavily mentioned on subreddits, such as r/wallstreetbets, but not subjected to any brokerage restrictions. In the second, we replicate our main results using an alternative window definition that uses the removal of

restrictions to identify the effects of restrictions rather than relying on the pre-restriction period as in our previous tests.

7.1. Individual firm results

In the previous results, we have primarily taken a panel approach where we pool across stocks, and to some extent, across restrictions. Although this approach is standard, especially when so much attention has focused on a small number of stocks such as GameStop, it also makes sense to ask whether the results are widespread among our reasonably large sample of 37 individual stocks. In Table 9, we show that our key results are similar across the majority of the individual stocks, and the direction of the individual stock results parallel the panel averages. In other words, the market changes we identify are not driven by a small subset of individual stocks.

One way to compare the individual results to the pooled results is by comparing the Fama-MacBeth (1973), or F-M, estimates to the pooled estimates. The F-M estimates are the equal-weighted averages of the coefficient estimates on the restriction dummy variables in each of the individual firm regressions, while the pooled estimates are taken directly from the pooled regressions presented in earlier tables.

Take, for example, the estimates of the Set 1 (Robinhood-like) trading restrictions on returns. We see that the pooled estimate (from Table 3, Model 8) is a statistically significant -0.0060, while the F-M estimate is a statistically significant -0.0033. In other words, the individual-stock based estimates match the results we see in the pooled regression approach in terms of the direction of the result and order of magnitude.

Another way to gauge the result's robustness is to count the number of significant individual stock estimates. In the case of returns, there are 29 individual stocks affected by the Set 1 restrictions. Of these, 21 have negative coefficient estimates and 10 have statistically significant negative coefficient estimates. We find that the number of positive individual firm estimates is significantly less than the number we would expect by chance.¹⁸

7.2. Options open interest

We also explore the impact of restrictions on options open interest. Open interest data is available at a daily frequency, so our panel is populated by stock-day observations. As before, our key variables are the three dummy variables--one for any restriction, one for a Set 1 (Robinhood-like) trading restriction, and one for a Set 2 (TD Ameritrade-like) margin tightening-- to measure each restriction's impact on bid-ask spreads.

Table 10 reports the results of these regressions. On days in which the stock is subject to any brokerage restriction, *Restricted*, log open interest is 0.3930 higher than on days in which trading in the stock is unrestricted, and it is similar in magnitude to the results we find for log options trading volume. When we split the dummy variable up into Set 1 trading restrictions and

¹⁸ In order to gauge the significance of these count variables, we randomly draw 2,500 sets of 37 firm and re-estimate the individual firm regressions presented in Table 9 on these bootstrap samples. Firms are drawn from the full set of common stocks in CRSP listed on the NYSE, NYSE American, or Nasdaq exchanges as of year-end 2020, including both firms subject to brokerage restrictions and our set of control firms. Firms are drawn without replacement and with equal probability. The timing of restrictions in these bootstrap draws match those presented in Table 1. Significance is based on a one-sided test informed by the sign of the pooled and F-M estimates. Specifically when the pooled estimate is positive, our null hypotheses are that the number of (significantly) positive estimates in our sample is less than or equal to the number of (significantly) positive estimates in our bootstrap samples and that the number of (significantly) negative estimates in our sample is greater than or equal to the number of (significantly) negative estimates in our bootstrap samples. In the case of negative pooled estimates, the directions of these inequalities are flipped. In all cases, we use the empirical distribution of bootstrapped estimates to calculate our bootstrapped p-values.

Set 2 increased margin requirements, we find estimates of 0.4590 and 0.3735, respectively, which indicate a similar order of magnitude for the two types of restrictions. Overall, we find that options open interest goes up dramatically after the restrictions are put in place. Given our results on options trading volume, this is not a surprise, but it indicates that the options trading volume is not in-and-out within the day: investors seem to be buying somewhat longer-term exposure to stock price movements through options.

7.3. Changes in options deltas

Another aspect of trading activity is whether it happens close to the money. In Table 11, we aggregate options deltas across transactions on a volume-weighted basis. More specifically, we take the absolute value of each option's delta so that the delta ranges from zero to one, where zero represents an infinitely far out of the money option and one represents an option guaranteed to finish in the money. When we view the results, again with our three restriction dummy variables, we find that most of the changes in average deltas are negative and statically significant.

One area where we see perhaps the most consistent decrease in deltas is in the 15-minute panel setting. We see a 5.57% decrease in the absolute value of delta for any restriction and similar coefficient estimates for the Set 1 and Set 2 restriction categories. In other words, traders in options seem to be moving toward more out of the money options.

Part of this movement could be mechanical; as we saw in our previous results, prices for underlying stocks change at nearly the same time as the restrictions take effect. Nevertheless, the findings are also consistent with investors buying options to lock in their gains relatively cheaply when they might expect future declines in the prices of underlying equities.

7.4. Exempt short sales volume

In our previous results, we have seen a number of indicators of retail investors moving from the stock market to the options market when restrictions take effect. Furthermore, we have seen results indicating that as retail investors move into the options market, implied volatilities increase (both on a relative and an absolute basis), giving rise to the narrative that institutional options sellers are charging relatively high prices compared to an actuarially fair value. To shed further light on this narrative, we examine exempt short sale volume¹⁹ in Table 12.

Ofek, Richardson & Whitelaw (2003) and Evans, Geczy, Musto and Reed (2003) both examine the practice of options market makers short selling without locating stock to borrow, as long as their trading is part of bona-fide market making. In other words, designated options market makers are exempt from the rules surrounding borrowing in some cases. With this insight, we can make a reasonably well-supported identification that exempt short sales volume is coming from institutional traders and not retail traders.

Panel A shows that exempt short sales volume increases. The strongest set of results are in the Set 1 restrictions, where, in the daily panel, short sales volume goes up by 1.414, and in the 15-minute panel, where short sales volume goes up by 1.77.

¹⁹ Short sale volume is obtained from Monthly Short Sale Transaction Files posted publicly by exchanges and FINRA. Our set includes the Nasdaq OMX BX exchange, the Nasdaq BATS exchange, the Nasdaq BATS Y exchange, the EDGA exchange, the EDGX exchange, and the off-exchange tapes posted by FINRA. We exclude the Nasdaq PHLX exchange because Nasdaq has an empty file (size 0 KB) posted for February 2021 as of the writing of this draft.

Of course, our previous results show that there is a large increase in volume around the time these restrictions are put into place. To address this confounding factor, in Panel B we look at the percentage of short sales volume that is exempt. In this more careful setting, the same result emerges: across the daily panel and the 15-minute panel we see that exempt short sales volume increases as a fraction of total volume. For example, with the Set 1 restrictions in the daily panel the percentage increases by 1.61%, and in the 15-minute panel the percentage increases by 1.47%.

Overall, these results indicate that exempt short selling is increasing at the same time the restrictions are coming into place. Since this exemption applies to options market makers, the indication is fairly clear that as retail traders move from the stock market to the options market, institutional options market makers step in to fill those retail traders' demand, and they hedge that demand in part by short selling. In other words, the exempt short sales volume gives us an indication that the activity of institutional market-makers increases around the time the restrictions are put in place.

7.5. Placebo tests

One potential concern with our results is that a brokerage restriction in a given name is simply proxying for firms that are heavily mentioned in Reddit posts. Thus, rather than our results capturing the effect of brokerage restrictions on stock and options trading, we are simply capturing selection on names that are being "talked up" on Reddit.

To address this concern, we first need data on the frequency that specific tickers are mentioned on Reddit over this period. To this end, we collect a set of 822,908 Reddit posts from November 28, 2020 to February 5, 2021 across six subreddits: r/wallstreetbets, r/stocks,

r/investing, r/stockmarket, r/options, and r/thetagang. Of these posts, 515,637 include a specific ticker.²⁰ Panel A of Figure 4 plots the cumulative density function of the (log) number of Reddit posts that mention a given ticker for the sample period January 1, 2021 to the time of the first restriction at market open on January 28, 2021. A total of 2,257 tickers are mentioned in at least one post on Reddit during this period. Roughly 20% of those tickers are only mentioned in one post. Interestingly, the set of restricted firms in our main results is not simply the set of most frequently mentioned tickers on Reddit. In fact, only two of the twenty most mentioned tickers on Reddit are subject to any sort of restriction in our sample. GameStop (GME) is second with mentions in 31,722 posts, and AMC is fourth with mentions in 10,813 posts. One of the restricted firms (SIEB) is only mentioned once in a Reddit post during this period.

We draw 2,500 samples of 30 firms (to mirror our sample of Set 1 restricted firms) without replacement from the set of firms mentioned in Reddit posts but not subjected to any trading restrictions. Each placebo sample maintains the same timing as our Set 1 restricted firms in terms of restrictions being put in place and removed. To mirror the central tendencies of the number of mentions in our set of restricted firms, we draw firms with a probability equal to $\log(\# \text{ of posts})^{0.7}$. Panel B of Figure 4 plots the mean of the mean (median) log number of Reddit posts for our set of placebo samples along with the 90 percent confidence intervals. For both our Set 1 and Set 2 restricted firms, we do not find a statistically significant difference in the number

²⁰ We search Reddit posts for the tickers in our sample of common stocks on CRSP listed on the NYSE, AMEX, or Nasdaq exchanges. Some tickers, such as “A,” may also be common English words. To minimize false positives, we obtain a list of frequently used lemmas in the Corpus of Contemporary American English (COCA) from www.wordfrequency.info. For tickers in the set of 1,000 most frequently used lemmas in the COCA, we require that the ticker be preceded by a dollar sign, “\$”, in order for that post to be counted as a mention of that ticker.

of Reddit posts compared to our set of placebo samples, suggesting that both our sample of restricted firms and the firms in our placebo samples were mentioned on Reddit to a similar degree.

Figure 5 plots the distribution of the treatment effect for these placebo samples obtained from the two-way fixed effect estimate on the 15-minute trading interval panel. In each of our results in which either $Restricted_{S1}$ or $Restricted_{S2}$ is statistically significant, we find that the estimates remain significant when the p -value is calculated relative to the set of placebo sample estimates. For instance, in the return results, the estimates for both $Restricted_{S1}$ and $Restricted_{S2}$ are less than all of the placebo sample estimates. Overall, these results suggest that our main results are not solely driven by selection on the number of mentions on Reddit.

7.6. Alternative window definition results

In our main tests, restricted firms only enter the sample within the period (-5,4) trading days relative to the implementation of the first restriction. Thus, the effect of the restriction is identified by comparing the dependent variable before the restriction to the dependent variable in a small window after the restriction is put in place. While this panel construction is common in the literature, the fact that restrictions are removed within our sample period offers an alternative window over which to estimate the effects of restrictions. In other words, rather than simply comparing dependent variables before the restrictions were implemented to those values when the restrictions are in place, our setting allows us to also compare dependent variables after the restrictions were removed to those values when the restrictions are in place to identify the effects of restrictions.

Table 13 presents the results of our main tests using the 15-minute trading interval panel and dropping any pre-restriction observations for the set of restricted firms. Broadly, we find similar estimates to our main results for our restriction variables in this setting. In the case of Set 1 Restrictions, we find quantitatively similar results for many of our main results. Namely, returns fall, options volume rises, the difference between implied volatility and realized volatility rises, and options bid-ask spreads fall while trading is restricted. While Set 2 Restrictions are in place, returns fall and the difference between implied volatility and realized volatility rises, which is consistent with our main results.

8. Conclusion

The Covid-19 pandemic is associated with an increase in trading volumes at retail-oriented brokerage firms such as Robinhood. In January 2021, a set of stocks including GameStop experienced a sharp increase in volatility. In late January, several retail-oriented brokerage firms impose equity and options trading restrictions on a number of these stocks, sharply limiting and sometimes completely forbidding purchases of shares in the affected companies. In this paper, we examine how these restrictions affect returns, trading volume, options trading, and market quality measures such as bid-ask spreads in both the options markets and the underlying equity markets.

We find that equity and options trading restrictions have large and significant effects on the affected asset markets. In the equity markets, we find that the restrictions are associated with

sharp price declines, and we find that when these equity restrictions are lifted, the price declines are not reversed.

In options markets, we find that there is an economically large shift from restricted equities to options. Specifically, we find an increase of more than 35% in both options market volume and open interest immediately after the imposition of a restriction. We find that spreads narrow in those options, but the price of those options goes up sharply relative to either previous implied volatility or relative to realized volatilities. Our findings suggest that there are large transfers from options buyers to options sellers, the latter of which tend to consist of professional, often institutional market-makers.

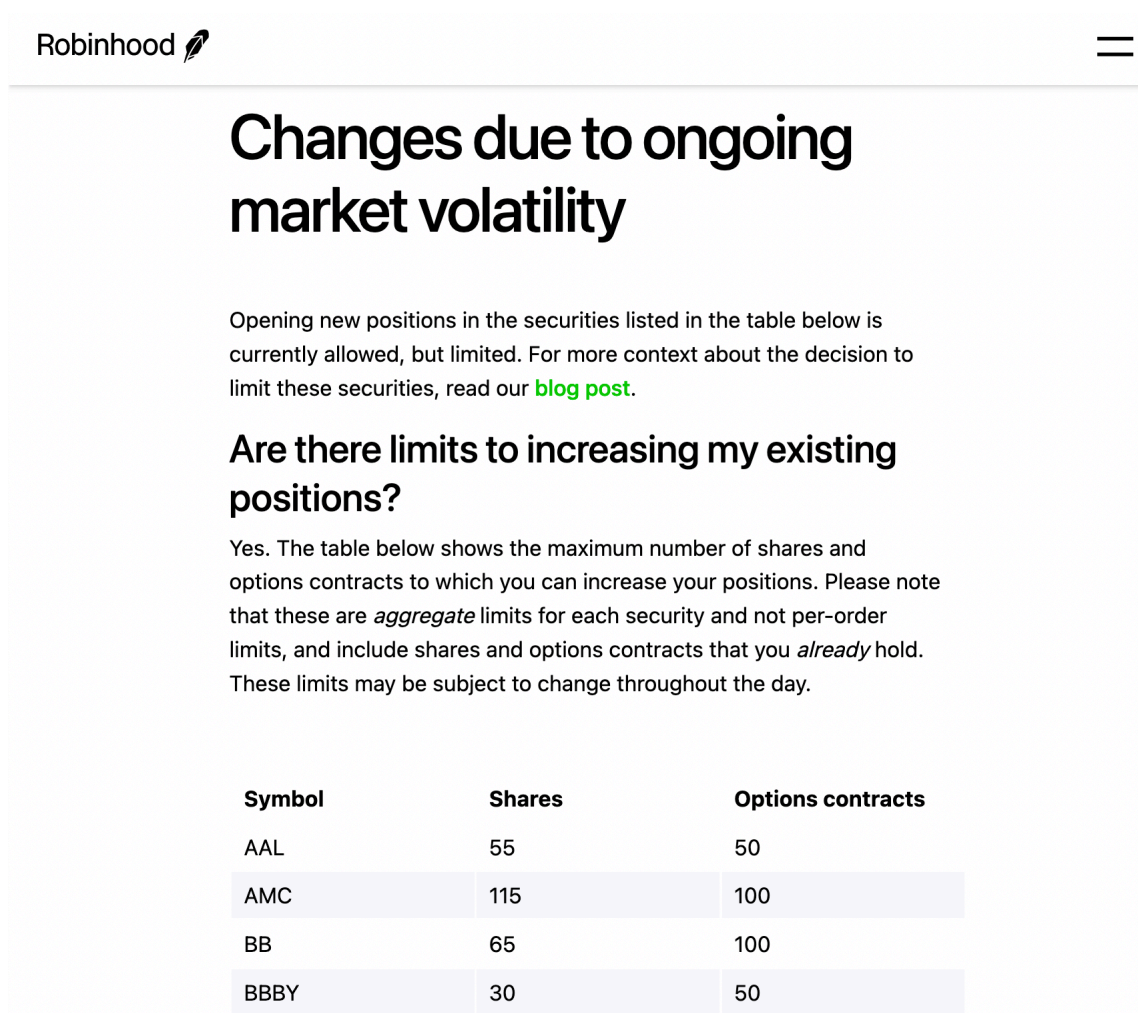
From a regulatory perspective, this paper adds to our understanding of how trading restrictions affect markets. Specifically, we find a somewhat surprising result, especially when compared to the existing literature, that when brokerages restrict trading in equities, these traders are likely to move into the options market. Furthermore, our findings suggest that such options trading can lead to large transfers, from an actuarial perspective, from those looking to buy options to those looking to sell them.

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Figure 1: Sample Restriction Website

This figure presents a sample of the restrictions communicated by Robinhood during the first quarter of 2021 on the website: <https://robinhood.com/us/en/support/articles/changes-due-to-recent-market-volatility>. This snapshot was retrieved from the Internet Archive Wayback Machine and was captured at 9:50:54 Eastern on January 29, 2021.



The screenshot shows the Robinhood logo in the top left and a hamburger menu icon in the top right. The main heading is "Changes due to ongoing market volatility". Below the heading, there is a paragraph explaining that opening new positions is limited and a link to a "blog post". The next section is titled "Are there limits to increasing my existing positions?" and contains a paragraph explaining aggregate limits. At the bottom, there is a table with three columns: Symbol, Shares, and Options contracts.

Symbol	Shares	Options contracts
AAL	55	50
AMC	115	100
BB	65	100
BBBY	30	50

Figure 2: Portfolio Cumulative Abnormal Returns

This figure plots the cumulative abnormal returns generated by the trading strategy presented in Panel A of Table 4. Specifically, for each 15-minute interval in the event window (or until the firm's restriction is lifted), the equally-weighted portfolio is long the restricted stock and short the value-weighted market return. The event window is relative to the 15-minute interval where trades in the firm's securities were initially restricted. *CAR* is the mean daily abnormal return multiplied by the length of the event window. Restricted firms are as defined in the text.

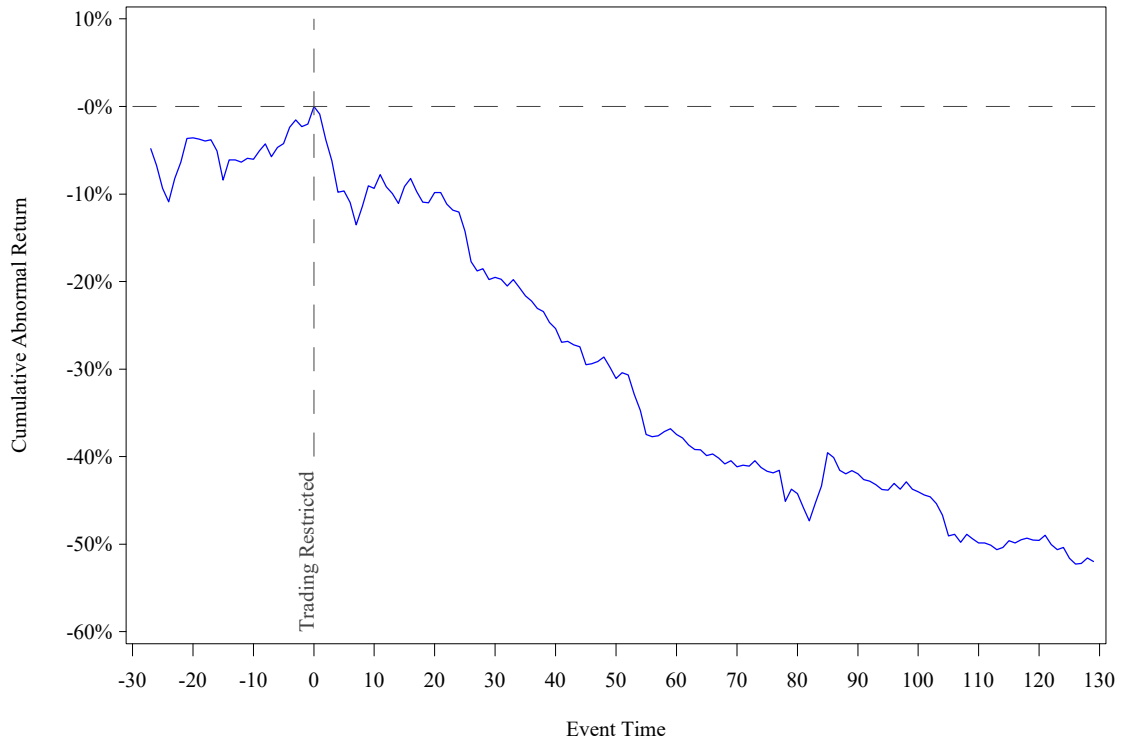


Figure 3: Event Time IV–RV

This figure plots the event time coefficients generated by the two-way fixed effect panel regression presented in the fourth column of Panel B of Table 6. The black squares are the estimated coefficient, and the black bars plot the 90 percent confidence intervals. The coefficient for the -1 event time window is the omitted variable for the pre-restriction periods.

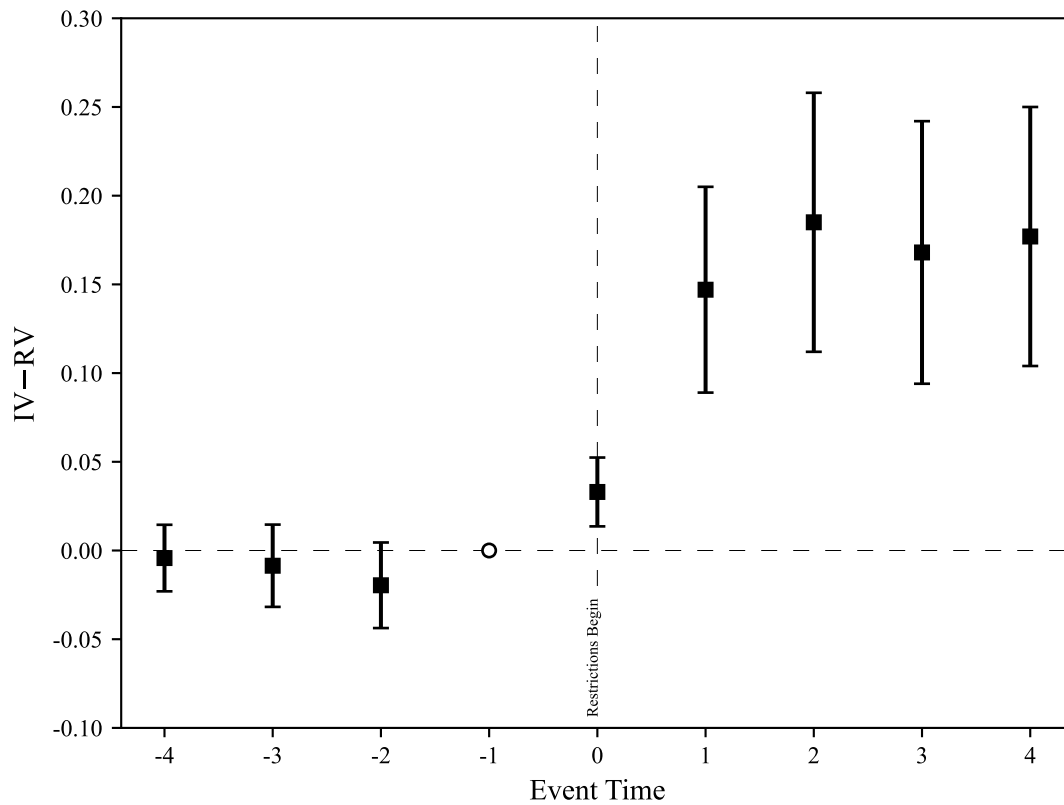
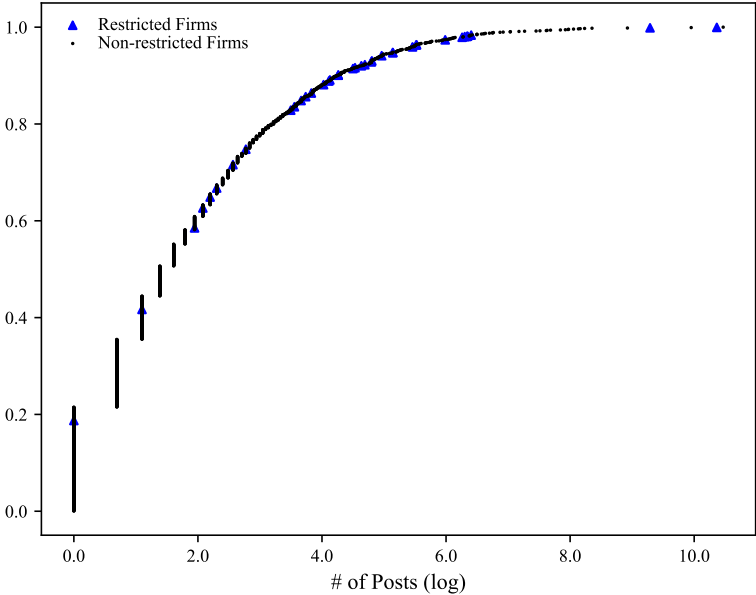


Figure 4: Distribution of Reddit Posts

Panel A of this figure plots the distribution of the (log) number of posts on finance-oriented subreddits for the period January 1, 2021 to the instance of the first brokerage restriction at market open on January 28, 2021. Section 6.1 of the text provides additional details. Panel B of the figure plots the mean (median) and the 90 percent confidence intervals for the placebo draws detailed in Section 6.1 of the text.

Panel A: Distribution of Number of Reddit Posts



Panel B: Central Tendencies of Placebo Draws

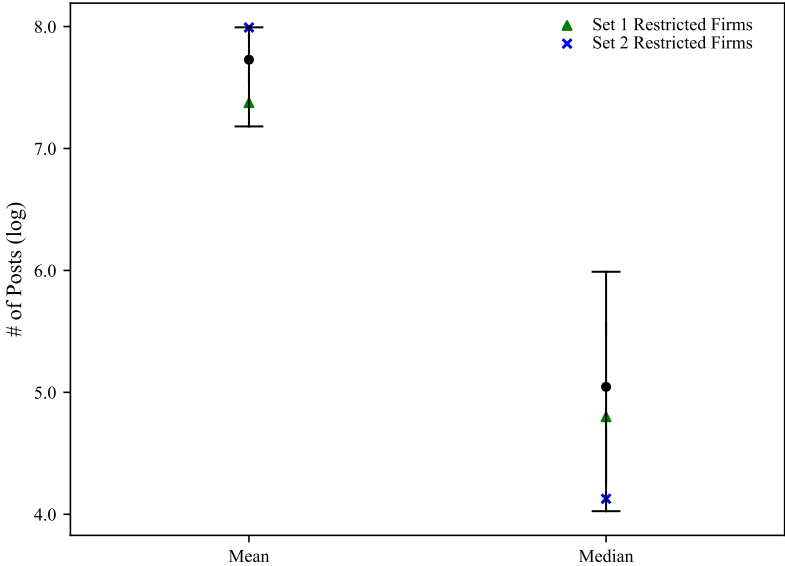


Figure 5: Placebo Distributions

This figure plots the distribution of coefficient estimates obtained from two-way fixed effect panel regressions on the placebo samples described in Section 6.1 of the text. The coefficient estimates from our sample are also plotted along with their empirical p -values calculated from the distribution of placebo coefficient estimates.

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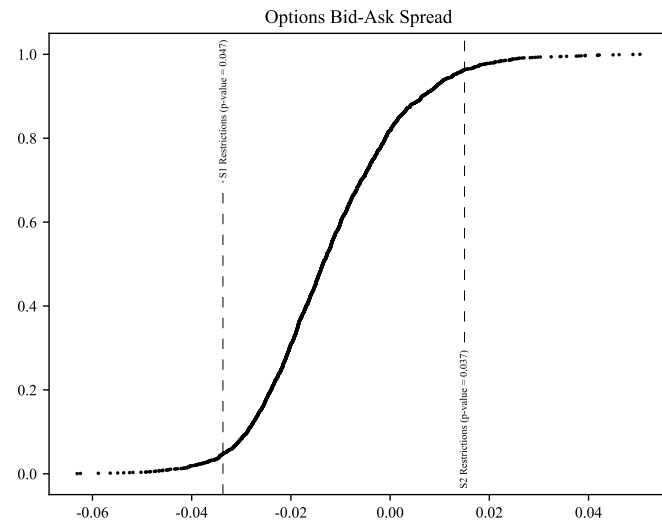
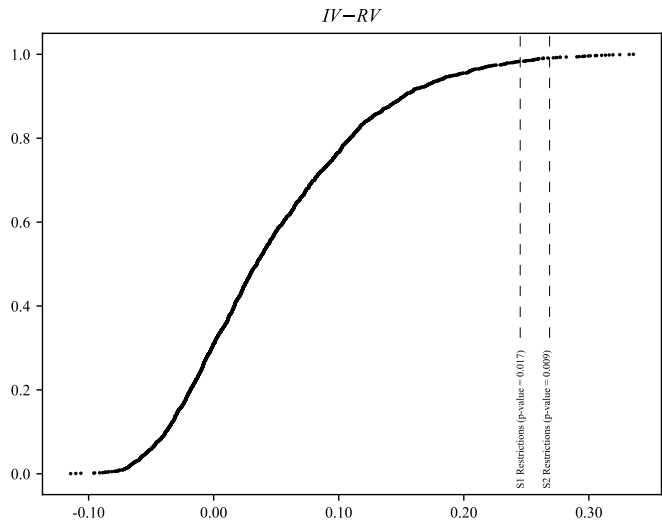
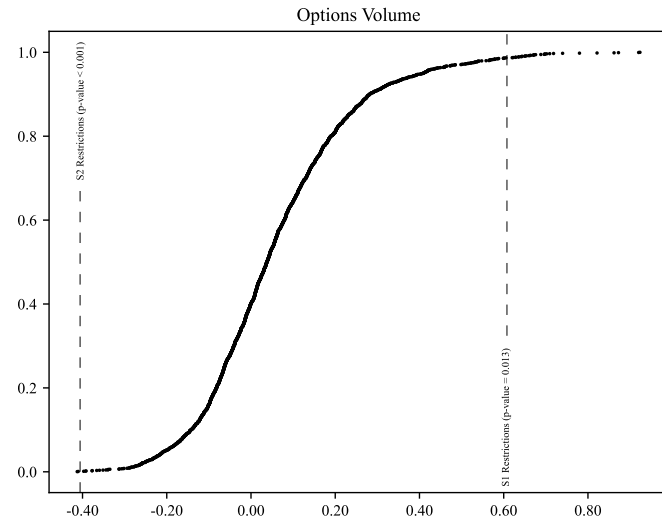
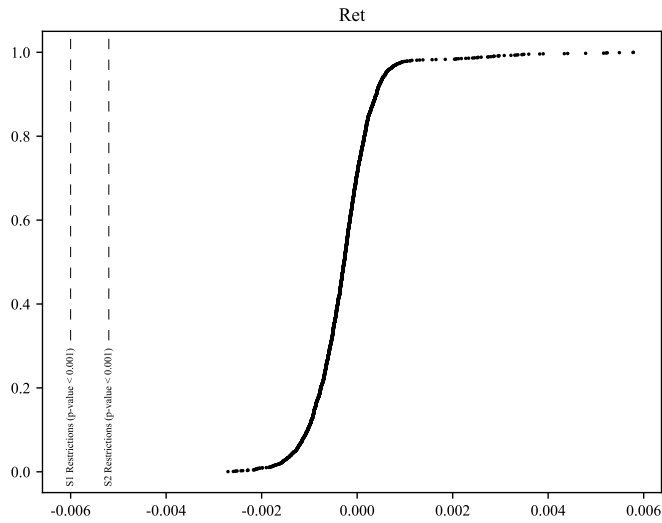


Table 1: Overview of Restrictions

This table presents a timeline of restrictions put in place by Set 1 and Set 2 brokerages during the first quarter of 2021. We recover snapshots of the webpages these brokerages used to communicate these restrictions through time using the Internet Archive Wayback Machine. Additional details are in Section 4 of the text. *S1* (*S2*) denotes that a firm was subject to Set 1 (Set 2) brokerage restrictions during the specified interval. *Both* denotes that a firm was subject to both Set 1 and Set 2 brokerage restrictions during the specified interval. As an example, GameStop (GME) was subject to Set 1 brokerage restrictions as of 9:03:57 on January 28, 2021. As of 16:00:00 on January 28, 2021, GME was subject to both Set 1 and Set 2 brokerage restrictions. The Set 1 restrictions were lifted as of 0:22:00 on February 5, 2021, and the Set 2 restrictions were lifted as of 19:13:45 on February 24, 2021.

	1/28 9:03:57	1/28 10:50:20	1/28 11:42:34	1/28 16:00:00	1/29 14:59:17	1/29 15:35:11	1/29 16:06:53	1/31 4:37:20	2/2 11:42:52	2/2 20:44:35	2/5 0:22:00	2/8 9:00:00	2/24 19:13:45	2/25 16:00:00	2/26 22:39:22	3/4 16:30:00
AAL		S1	S1		S1	S1	S1									
AMC	S1	S1	S1	Both	Both	Both	Both	Both	Both	Both	S2	S2			S2	
AMD					S1	S1	S1									
BBBY	S1	S1	S1	Both	Both	Both	Both	S2	S2	S2	S2					
BBY		S1														
BYND							S1	S1								
CCIV							S1	S1								
CRIS							S1	S1								
CVM				S2	S2	S2	S2	S2	S2	S2	S2	S2			S2	
DDS				S2	S2	S2	S2	S2	S2	S2	S2	S2			S2	
EXPR	S1	S1	S1	Both	Both	Both	Both	Both	Both	S2	S2	S2			S2	
FIZZ				S2	S2	S2	S2	S2	S2	S2	S2					
FOSL				S2	S2	S2	S2	S2	S2	S2	S2					
GM						S1	S1									
GME	S1	S1	S1	Both	Both	Both	Both	Both	Both	Both	S2	S2		S2	S2	S2
GNUS								S1								
GTE					S1	S1	S1									
INO								S1	S1							
IRBT				S2	S2	S2	S2	S2	S2	S2	S2					
JAGX					S1	S1	S1									
KOSS	S1	S1	S1	Both	Both	Both	Both	Both	S2	S2	S2					
MRNA					S1	S1	S1									
MUX						S1	S1									
NCMI				S2	S2	S2	S2	S2	S2	S2	S2	S2			S2	
NVAX						S1	S1									
OPEN						S1	S1									
RKT						S1	S1									S2
SBUX						S1	S1									
SIEB						S1	S1									
SRNE						S1	S1									
STPK						S1	S1									
TGC						S1	S1									
TR		S1	S1	Both	Both	Both	Both	S2	S2	S2	S2					
TRXC								S1								
UONE				S2	S2	S2	S2	S2	S2	S2	S2					
VIR				S2	S2	S2	S2	S2	S2	S2	S2	S2			S2	
WKHS					S1	S1	S1									
ZOM						S1	S1									

Table 2: Summary Statistics

This table reports summary statistics from our sample of firm- 15-minute trading interval observations. Restricted firms are firms subject to a brokerage restriction during our sample. *While Restricted* are observations where a restricted firm was subject to a brokerage restriction. *Open Interest* is the mean open interest at the end of the day. *Options (Equity) Volume* is the mean volume in contracts (shares) in a 15-minute interval within trading hours. *Ret* is the mean 15-minute return. *% Retail Volume* is the mean fraction of total volume classified as retail trades using subpenny improvements as in Boehmer, Jones, Zhang, and Zhang (2021). *Options (Equity) Bid-Ask Spread* is the mean volume-weighted percentage effective bid-ask spread for a round-trip trade in the options (equity) market aggregated over a 15-minute interval within trading hours. *IV* is the mean volume-weighted implied volatility in annualized standard deviations. To be included in this aggregation, an option must have days to maturity in the interval (7, 30] and have log moneyness in the interval $[-.2, .2]$. *IV-RV* is this implied volatility in excess of the realized volatilities calculated using 5-minute returns. $|\delta|$ is the mean volume-weighted absolute value of delta for traded options aggregated over a 15-minute interval within trading hours.

	<u>Set 1 Restricted Firms</u>		<u>Set 2 Restricted Firms</u>		All Other Firms
	While Restricted	Unrestricted	While Restricted	Unrestricted	
# of firms	29	–	15	–	3,712
# of obs	740	26,404	5,378	8,662	3,474,432
Open Interest	1,095,769.62	541,935.27	479,069.19	223,582.77	54,648.38
Options Volume	6,352.00	1,521.18	2,040.34	1,276.04	70.64
Equity Volume	4,046,070.85	1,020,813.31	928,287.53	854,288.35	65,228.54
Ret	-0.0051	0.0002	-0.0008	0.0010	0.0000
% Retail Volume	0.2779	0.2331	0.1929	0.1638	0.1239
Options Bid-Ask Spread	0.0968	0.1149	0.1747	0.1559	0.1727
Equity Bid-Ask Spread	0.0037	0.0021	0.0024	0.0026	0.0030
<i>IV</i>	2.2750	1.2746	1.9334	1.3372	0.7375
<i>IV – RV</i>	0.6328	0.2573	0.4370	0.2124	0.1349
$ \delta $	0.3275	0.3865	0.3273	0.3730	0.4056

Table 3: Returns

This table reports the estimates for the impact of a brokerage restriction on equity returns. Observations are for a given firm in a given day or 15-minute interval within trading hours. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted_{S1}* (*Restricted_{S2}*) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Equity data are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	-0.3301*** (0.0996)				-0.0064*** (0.0013)			
<i>Restricted_{S1}</i>		-0.5938*** (0.1482)		-0.5313*** (0.1363)		-0.0080*** (0.0015)		-0.0060*** (0.0012)
<i>Restricted_{S2}</i>			-0.2492*** (0.0729)	-0.1381*** (0.0370)			-0.0064*** (0.0014)	-0.0052*** (0.0010)
N	133,293	133,293	133,293	133,293	3,430,328	3,430,328	3,430,328	3,430,328
R_{adj}^2	0.079	0.082	0.076	0.083	0.002	0.002	0.002	0.002
Pr($S1 = S2$)	-	-	-	0.006	-	-	-	0.544

Table 4: Returns Around Brokerage Restrictions

This table reports the mean abnormal returns from a calendar-time portfolio holding restricted stocks for the specified interval. For each 15-minute interval in the event window (or until the firm's restriction is lifted), the equally-weighted portfolio is long the restricted stock and short the value-weighted market return. *CAR* is the mean abnormal return over the 15-minute interval multiplied by the length of the event window. Restricted firms are defined in the text. For Panel A, the event window is relative to the 15-minute interval where trades in the firm's securities were initially restricted. This panel has 37 firms subject to a brokerage restriction. For Panel B, the (0,7) 15-minute interval (two trading hours) event window is presented for a set of alternative event definitions. *Any Restriction* uses the first restriction in each stock and is the event used in Panel A. *First Set 1 (2) Restriction* uses the event of the first restriction in a given stock if it was made by a Set 1 (Set 2) brokerage. *Forbidding All Share Purchases* uses the event of the first restriction in a given stock if it was made by a Set 1 brokerage and forbade all share (contract) purchases. *Second Set 2 Restriction* uses the event of the second restriction in a given stock made by a Set 2 brokerage. *Removal of All Restrictions* uses the event of the removal of all brokerage restrictions. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Panel A: First Restriction in Each Stock

	CAR	15-minute Abnormal Return	Std Err
(-27,-1) Previous Trading Day	0.0281	0.0010	0.0035
(-5,-1) Previous Hour	0.0166	0.0033	0.0061
(0,1) First Half Hour	-0.0089	-0.0044	0.0052
(0,3) First Hour	-0.0621*	-0.0155*	0.0081
(0,7) First Two Hours	-0.1354**	-0.0169**	0.0080
(0,11) First Three Hours	-0.0778	-0.0065	0.0071
(0,25) First Trading Day	-0.1427	-0.0055	0.0044
(0,129) First Five Trading Days	-0.5197*	-0.0040*	0.0024

Panel B: (0,7) First Two Hours Around Alternative Events

	CAR	15-minute Abnormal Return	Std Err
Any Restriction	-0.1354**	-0.0169**	0.0080
First Set 1 Restriction	-0.1854**	-0.0232**	0.0102
Forbidding All Share Purchases	-0.3480**	-0.0435**	0.0196
First Set 2 Restriction	-0.0444	-0.0056	0.0049
Second Set 2 Restriction	-0.1138**	-0.0142**	0.0065
Removal of All Restrictions	0.0289	0.0036	0.0026

Table 5: Volume

This table reports the estimates for the impact of a brokerage restriction on log trading volume. Observations are for a given firm in a given day or 15-minute interval within trading hours. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted*_{S1} (*Restricted*_{S2}) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Options data are from Cboe LiveVol DataShop, and equity data are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Panel A: Options Volume

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	-0.2051 (0.1699)				-0.1351 (0.1875)			
<i>Restricted</i> _{S1}		0.3179* (0.1842)		0.5093*** (0.1812)		0.4476** (0.2181)		0.6077*** (0.2124)
<i>Restricted</i> _{S2}			-0.3162** (0.1515)	-0.4227*** (0.1415)			-0.2856 (0.1786)	-0.4058*** (0.1539)
N	133,891	133,891	133,891	133,891	3,481,201	3,481,201	3,481,201	3,481,201
R^2_{adj}	0.892	0.892	0.892	0.892	0.734	0.734	0.734	0.734
Pr(S1 = S2)	-	-	-	0.000	-	-	-	0.000

Panel B: Equity Volume

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	-0.2918 (0.1816)				-0.1912 (0.1761)			
<i>Restricted</i> _{S1}		0.2038 (0.2694)		0.4279* (0.2349)		0.2413 (0.2325)		0.3896** (0.1892)
<i>Restricted</i> _{S2}			-0.4055** (0.1695)	-0.4950*** (0.1348)			-0.2987 (0.1907)	-0.3758** (0.1658)
N	133,891	133,891	133,891	133,891	3,481,201	3,481,201	3,481,201	3,481,201
R^2_{adj}	0.870	0.870	0.870	0.870	0.767	0.767	0.767	0.767
Pr(S1 = S2)	-	-	-	0.000	-	-	-	0.000

Table 6: Implied Volatility

This table reports the estimates for the impact of a brokerage restriction on implied volatilities for traded options. Observations are the volume-weighted implied volatilities for traded options in a given firm aggregated over the day or 15-minute interval within trading hours. The units are annualized standard deviations. To be included in this aggregation, an option must have days to maturity in the interval (7, 30] and have log moneyness in the interval [-.2, 2]. Realized volatilities are calculated using 5-minute returns. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted*_{S1} (*Restricted*_{S2}) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Options data are from Cboe LiveVol DataShop, and 5-minute returns are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Panel A: Implied Volatility

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	0.1784*** (0.0599)				0.1526*** (0.0538)			
<i>Restricted</i> _{S1}		0.2376** (0.0979)		0.1975* (0.1187)		0.2180*** (0.0780)		0.1902* (0.0981)
<i>Restricted</i> _{S2}			0.1337* (0.0684)	0.0935 (0.0832)			0.1169* (0.0680)	0.0749 (0.0828)
N	71,610	71,610	71,610	71,610	866,389	866,389	866,389	866,389
R^2_{adj}	0.873	0.873	0.873	0.873	0.895	0.895	0.895	0.895
Pr(S1 = S2)	-	-	-	0.547	-	-	-	0.479

Panel B: Implied Volatility Minus Realized Volatility

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	0.3697*** (0.0332)				0.3417*** (0.0336)			
<i>Restricted</i> _{S1}		0.3744*** (0.0549)		0.2492*** (0.0421)		0.3446*** (0.0602)		0.2451*** (0.0414)
<i>Restricted</i> _{S2}			0.3424*** (0.0312)	0.2917*** (0.0365)			0.3227*** (0.0317)	0.2686*** (0.0280)
N	71,610	71,610	71,610	71,610	866,389	866,389	866,389	866,389
R^2_{adj}	0.594	0.593	0.594	0.594	0.601	0.600	0.600	0.601
Pr(S1 = S2)	-	-	-	0.502	-	-	-	0.670

Table 7: Bid-ask Spreads

This table reports the estimates for the impact of a brokerage restriction on the percentage effective bid-ask spread for a round-trip trade. Observations are the volume-weighted bid-ask spreads for trades in a given firm aggregated over the day or 15-minute interval within trading hours. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted*_{S1} (*Restricted*_{S2}) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Options data are from Cboe LiveVol DataShop, and equity data are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Panel A: Options Bid-ask Spreads

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	-0.0007 (0.0181)				0.0031 (0.0116)			
<i>Restricted</i> _{S1}		-0.0353** (0.0144)		-0.0396*** (0.0143)		-0.0280*** (0.0076)		-0.0337*** (0.0079)
<i>Restricted</i> _{S2}			0.0022 (0.0189)	0.0100 (0.0187)			0.0082 (0.0131)	0.0150 (0.0124)
N	88,285	88,285	88,285	88,285	1,285,043	1,285,043	1,285,043	1,285,043
R^2_{adj}	0.435	0.435	0.435	0.435	0.260	0.260	0.260	0.260
Pr(S1 = S2)	-	-	-	0.065	-	-	-	0.005

Panel B: Equity Bid-ask Spreads

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	0.0001 (0.0004)				-0.0003 (0.0002)			
<i>Restricted</i> _{S1}		0.0007 (0.0006)		0.0012 (0.0008)		0.0001 (0.0003)		0.0003 (0.0004)
<i>Restricted</i> _{S2}			-0.0009* (0.0005)	-0.0011* (0.0006)			-0.0006** (0.0003)	-0.0007** (0.0003)
N	131,832	131,832	131,832	131,832	3,329,729	3,329,729	3,329,729	3,329,729
R^2_{adj}	0.610	0.610	0.610	0.610	0.304	0.304	0.304	0.304
Pr(S1 = S2)	-	-	-	0.073	-	-	-	0.072

Table 8: Two-stage Least Squares Results

This table presents the coefficient estimates from the 2SLS regression discussed in Section 6 of the text. *Ret* is the firm's return. *Options (Equity) Volume* is the excess trading volume in log contracts (shares). *Options (Equity) Bid-Ask Spread* is the excess volume-weighted percentage bid-ask spread for a round-trip trade. *IV-RV* is the excess volume-weighted implied volatility minus the realized volatility calculated using five-minute returns. To be included in this aggregation, an option must have days to maturity in the interval (7, 30] and have log moneyness in the interval (-.2, 2). *Subgroup = M* is a binary variable equal to one if the firm belongs to market capitalization-based subgroup *M* on that day and zero otherwise. *CCall* is the firm-level collateral call calculated as described in Section 6 of the text. *Realized Vol* is the previous firm's realized volatility calculated using five-minute returns from the previous day. *emphRestricted_{S1}* is a binary variable equal to one if the firm is subject to a Set 1 brokerage restriction at any point during the day and zero otherwise. *Pr(J)* presents the probability of the test of overidentifying restrictions. Options data are from Cboe LiveVol DataShop, and equity data are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and day interval. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	Ret		Options Volume		Equity Volume		IV-RV		Options Bid-Ask Spread		Equity Bid-Ask Spread	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: First-stage Results												
<i>(Subgroup = 1) × CCall</i>	0.0656 (0.0665)	0.0473 (0.0591)	0.0656 (0.0665)	0.0473 (0.0591)	0.0656 (0.0665)	0.0473 (0.0591)	0.3534 (0.3304)	0.1499 (0.3071)	0.3129 (0.2949)	0.1404 (0.2768)	0.0656 (0.0665)	0.0469 (0.0589)
<i>(Subgroup = 2) × CCall</i>	0.1662* (0.0935)	0.1591* (0.0925)	0.1662* (0.0935)	0.1591* (0.0925)	0.1662* (0.0935)	0.1591* (0.0925)	0.2122*** (0.0790)	0.1958** (0.0801)	0.2118*** (0.0792)	0.1987** (0.0801)	0.1663* (0.0936)	0.1591* (0.0926)
<i>(Subgroup = 3) × CCall</i>	0.0351 (0.1018)	0.0290 (0.1009)	0.0351 (0.1018)	0.0290 (0.1009)	0.0351 (0.1018)	0.0290 (0.1009)	0.0387 (0.1076)	0.0235 (0.1060)	0.0386 (0.1076)	0.0267 (0.1064)	0.0352 (0.1019)	0.0289 (0.1009)
<i>(Subgroup = 4) × CCall</i>	0.1424*** (0.0144)	0.1392*** (0.0142)	0.1424*** (0.0144)	0.1392*** (0.0142)	0.1424*** (0.0144)	0.1392*** (0.0142)	0.1429*** (0.0153)	0.1350*** (0.0153)	0.1429*** (0.0153)	0.1367*** (0.0153)	0.1424*** (0.0144)	0.1391*** (0.0143)
<i>RealizedVol</i>		0.0299** (0.0137)		0.0299** (0.0137)		0.0299** (0.0137)		0.0728** (0.0365)		0.0567* (0.0291)		0.0306** (0.0140)
Panel B: Second-stage Results												
<i>Restricted_{S1}</i>	-0.8492*** -0.2957	-0.7027*** -0.2422	0.2012 -1.3733	-3.0507 -1.9072	3.8099 -3.6038	-3.8874*** -1.0465	1.0447*** -0.3872	0.2643* -0.1573	-0.0906 -0.081	0.0476 -0.0365	0.0094*** -0.0016	0.0039 -0.0029
<i>RealizedVol</i>		-0.1440*** -0.0358		3.3454*** -0.2886		7.5348*** -0.5634		0.8920*** -0.0719		-0.1305*** -0.0329		0.0060*** -0.0007
N	131,839	131,839	131,857	131,857	131,857	131,857	71,244	71,244	87,830	87,830	130,563	130,563
First-stage <i>F</i> -stat	181.979	191.156	181.979	191.156	181.979	191.156	181.83	213.134	181.237	219.168	181.966	191.181
<i>Pr(J)</i>	0.088	0.297	0.078	0.101	0.030	0.251	0.037	0.720	0.008	<0.001	0.037	<0.001

Table 9: Individual Firm Regressions

This table reports the time-series estimates for the impact of a brokerage restriction for individual firms. Observations are for a given firm in a given 15-minute interval within trading hours and are relative to the cross-sectional equal-weighted mean in the interval. *Ret* is the excess 15-minute return. *Options (Equity) Volume* is the excess trading volume in log contracts (shares). *Options (Equity) Bid-Ask Spread* is the excess volume-weighted percentage bid-ask spread for a round-trip trade. *IV-RV* is the excess volume-weighted implied volatility minus the realized volatility calculated using five-minute returns. To be included in this aggregation, an option must have days to maturity in the interval $(7, 30]$ and have log moneyness in the interval $(-2, 2)$. The estimates presented are the coefficients of a regression containing both our *S1* and *S2* variables jointly. *S1* (*S2*) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the 15-minute interval and zero otherwise. Options data are from Cboe LiveVol DataShop, and equity data are from TAQ. Newey-West standard errors computed at 4 lags are reported. We also report pooled estimates that include fixed effects to control for firm and 15-minute interval. The standard errors for these pooled estimates are clustered at the firm-level. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Significance for the count variables at the bottom of the table are calculated from the bootstrap samples described in Section 5.6 of the text.

Table 9: Individual Firm Regressions (cont.)

	Ret		Options Volume		Equity Volume		IV-RV		Options Bid-Ask Spread		Equity Bid-Ask Spread	
	S1 Est	S2 Est	S1 Est	S2 Est	S1 Est	S2 Est	S1 Est	S2 Est	S1 Est	S2 Est	S1 Est	S2 Est
AAL	-0.0019		1.0423***		0.9535***		0.3799***		-0.0229***		-0.0001	
AMC	-0.0035	-0.0017	0.7223***	-0.2203**	1.2364***	-0.6235***	0.2620***	-0.0408	-0.0497***	0.0407***	0.0005	-0.0003
AMD	0.0009		0.1090		-0.2062		0.0213***		-0.0126***		0.0001**	
BBBY	-0.0056	-0.0020	1.1697***	0.7716***	1.4161***	0.3857***	0.2618***	0.1951***	-0.0208***	-0.0401***	-0.0001	0.0002
BBY	-0.0000		0.8894***		0.0251		0.0459***		-0.0309***		-0.0001**	
BYND	-0.0005		-0.3969**		-0.7816**		-0.0589***		-0.0448***		-0.0002***	
CCIV	-0.0031***		-0.0827*		-1.1821***		0.0379**		-0.0389***		0.0004**	
CRIS	-0.0034***		2.3671***		0.0896		0.1056***		-0.0515***		-0.0009***	
CVM		-0.0014		-0.2536**		0.1774		0.3473***		-0.0259***		-0.0005**
DDS		-0.0006		-0.5491***		-0.2041*		0.1697***		0.0425**		-0.0001
EXPR	-0.0076	-0.0043	2.2566***	-0.9373***	1.2938***	-1.1634***	0.3270***	-0.0807*	-0.1261***	0.0734***	0.0000	-0.0005*
FIZZ		-0.0026		0.9271***		0.3376***		0.2021***		-0.0033		0.0001
FOSL		-0.0005		0.3415*		0.6378***		0.1956***		0.0529**		-0.0001
GM	-0.0018***		0.2483**		-0.5444***		0.1342***		-0.0288***		0.0002***	
GME	-0.0093	-0.0101	0.8388***	-1.0805***	0.4576**	-1.3447***	0.2754***	0.1807***	-0.0179**	0.0047	0.0021***	-0.0012***
GNUS	-0.0049*		0.4698***		0.5605***		0.1974***		-0.0453***		-0.0004*	
GTE	0.0028*		0.9951***		-0.2519				0.0481***		-0.0002	
INO	-0.0001		1.0211***		-0.1261		0.0887***		-0.0416***		0.0001	
IRBT		-0.0010		0.4386**		0.2654**		0.2963***		0.0428**		-0.0003***
JAGX	0.0005		0.2086		-0.2200		-0.0764***		-0.0892***		-0.0003***	
KOSS	-0.0046	-0.0059	-0.0189	0.0043	0.5264	0.7375***					0.0041***	-0.0005
MRNA	0.0013		0.2562		0.0087		0.0615***		-0.0735***		0.0000	
MUX	-0.0198***		3.5522***		0.6688***		0.1954***		-0.0750***		-0.0017***	
NCMI		-0.0003		-0.4602***		-0.5838***		0.0873**		-0.0144		0.0002*
NVAX	-0.0028**		1.2163***		0.7146***		0.1695***		-0.0848***		-0.0004***	
OPEN	0.0044***		-0.1892		-1.0986***		-0.2006***		0.0278***		0.0003***	
RKT	-0.0038***	-0.0008	-0.2359	0.1478	-0.5541***	0.5375***	0.2187***	0.2687***	-0.0155***	0.0021	0.0002**	-0.0001
SBUX	0.0009		0.3517***		0.2710***		-0.0358***		-0.0016		0.0001**	
SIEB	-0.0170***		4.5554***		2.5401***		0.1298***		-0.1306***		0.0066***	
SRNE	-0.0003		0.3135***		-0.6793***		0.0245**		-0.0172		0.0000	
STPK	-0.0075***		-0.4037***		-1.0584***		-0.0774***		-0.0218***		-0.0004***	
TGC	-0.0150***		-0.0602***		2.2833***						-0.0015***	
TR	-0.0026	-0.0015	1.7791***	1.2413***	1.0216***	0.5035***	0.2873***	0.2118***	-0.0769***	-0.0829***	0.0003	0.0001
UONE		-0.0002		-0.0023		0.4060***						-0.0001
VIR		-0.0016		-0.5963***		-0.5675***		0.2773***		0.0303		-0.0001
WKHS	0.0019		-0.6377***		-0.5153**		0.2421***		-0.0235***		0.0002***	
ZOM	0.0064***		-0.0602***		-1.7276***						-0.0035***	
F-M Estimate	-0.0033***	-0.0023***	0.7682***	-0.0152	0.1766	-0.0332	0.1207***	0.1777***	-0.0410***	0.0095	0.0002	-0.0002**
Pooled	-0.0060***	-0.0052***	0.6077***	-0.4058***	0.3896**	-0.3758**	0.2451***	0.2686***	-0.0337***	0.0150	0.0003	-0.0007**
# of Sig. Positive	3	0	17***	5	12	8	20***	11***	2	5**	10**	1
# of Positive	8**	0***	20***	7	16	9	20***	11***	2**	8	16**	4**
# of Sig. Negative	10	0	6***	7**	9	6	5	1*	22***	3	10	4
# of Negative	21**	15***	9***	8	13	6	5	2**	24***	5	13**	11**

Table 10: Options Open Interest

This table reports the estimates for the impact of a brokerage restriction on the options open interest in log contracts. Observations are the log open interest in a given firm on a given trading day. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted*_{S1} (*Restricted*_{S2}) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Data are from Cboe LiveVol DataShop. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	(1)	(2)	(3)	(4)
<i>Restricted</i>	0.3930** (0.1676)			
<i>Restricted</i> _{S1}		0.4590*** (0.1259)		0.3261*** (0.0867)
<i>Restricted</i> _{S2}			0.3735** (0.1636)	0.3094** (0.1564)
N	97,744	97,744	97,744	97,744
R^2_{adj}	0.968	0.968	0.968	0.968
Pr(S1 = S2)	–	–	–	0.917

Table 11: Options Delta

This table reports the estimates for the impact of a brokerage restriction on the absolute value of delta for traded options. Observations are the volume-weighted absolute value of delta for traded options in a given firm aggregated over the day or 15-minute interval within trading hours. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted_{S1}* (*Restricted_{S2}*) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Data are from Cboe LiveVol DataShop. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	-0.0583*** (0.0150)				-0.0557*** (0.0125)			
<i>Restricted_{S1}</i>		-0.0535* (0.0297)		-0.0288 (0.0243)		-0.0559*** (0.0190)		-0.0358** (0.0140)
<i>Restricted_{S2}</i>			-0.0631*** (0.0151)	-0.0575*** (0.0135)			-0.0604*** (0.0136)	-0.0531*** (0.0122)
N	88,285	88,285	88,285	88,285	1,285,043	1,285,043	1,285,043	1,285,043
R^2_{adj}	0.196	0.196	0.196	0.196	0.112	0.112	0.112	0.112
Pr($S1 = S2$)	-	-	-	0.327	-	-	-	0.417

Table 12: Exempt Short Sale Volume

This table reports the estimates for the impact of a brokerage restriction on exempt short sale volume. In Panel A, the dependent variable is the log exempt short sale volume. In Panel B, the dependent variable is the ratio of exempt short sale volume to total short sale volume. *Restricted* is a binary variable equal to one if the firm is subject to a brokerage restriction at any point during the observation and zero otherwise. *Restricted*_{S1} (*Restricted*_{S2}) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the observation and zero otherwise. Data are from publicly available Monthly Short Sale Transaction Files. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and time (either day or 15-minute interval depending on the panel). *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Panel A: Exempt Short Sale Volume

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	0.7499 (0.5910)				1.0730** (0.4188)			
<i>Restricted</i> _{S1}		1.4140*** (0.4322)		1.2533*** (0.4419)		1.7736*** (0.2383)		1.5353*** (0.2316)
<i>Restricted</i> _{S2}			0.6170 (0.6132)	0.3549 (0.6228)			0.9076** (0.4531)	0.6037 (0.4331)
N	133,891	133,891	133,891	133,891	3,481,201	3,481,201	3,481,201	3,481,201
R^2_{adj}	0.562	0.562	0.562	0.562	0.309	0.309	0.309	0.309
Pr(S1 = S2)	–	–	–	0.310	–	–	–	0.090

Panel B: Percentage Exempt Short Sale Volume

	Daily Panel				15-minute Interval Panel			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Restricted</i>	0.0105*** (0.0040)				0.0106** (0.0041)			
<i>Restricted</i> _{S1}		0.0161*** (0.0033)		0.0134*** (0.0032)		0.0147*** (0.0032)		0.0122*** (0.0030)
<i>Restricted</i> _{S2}			0.0087** (0.0041)	0.0059 (0.0041)			0.0086** (0.0040)	0.0062 (0.0039)
N	131,674	131,674	131,674	131,674	3,202,599	3,202,599	3,202,599	3,202,599
R^2_{adj}	0.123	0.123	0.123	0.123	0.036	0.036	0.036	0.036
Pr(S1 = S2)	–	–	–	0.232	–	–	–	0.285

Table 13: Effects of Restrictions - Alternative Window Definition

This table presents the coefficient estimates for the two-way fixed effects panel regressions using an alternative window definition for identification. Unlike our main tests which identify the effects of restrictions using pre-restriction observations, these tests drop all pre-restriction observations for a given restricted firm and identify the effects of restrictions using observations after the restrictions have been removed. *Ret* is the excess 15-minute return. *Options (Equity) Volume* is the excess trading volume in log contracts (shares). *Options (Equity) Bid-Ask Spread* is the excess volume-weighted percentage bid-ask spread for a round-trip trade. *IV-RV* is the excess volume-weighted implied volatility minus the realized volatility calculated using five-minute returns. To be included in this aggregation, an option must have days to maturity in the interval (7,30] and have log moneyness in the interval (-.2,2). The estimates presented are the coefficients of a regression containing both our *Restricted_{S1}* and *Restricted_{S2}* variables jointly. *Restricted_{S1}* (*Restricted_{S2}*) is a binary variable equal to one if the firm is subject to a Set 1 (Set 2) brokerage restriction at any point during the 15-minute interval and zero otherwise. Options data are from Cboe LiveVol DataShop, and equity data are from TAQ. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and 15-minute interval. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	Ret	Options Volume	Equity Volume	IV-RV	Options Bid-Ask Spread	Equity Bid-ask Spread
<i>Restricted_{S1}</i>	-0.0051*** (0.0009)	1.0613*** (0.2478)	0.9498*** (0.1233)	0.2399*** (0.0229)	-0.0548*** (0.0156)	0.0011** (0.0005)
<i>Restricted_{S2}</i>	-0.0013*** (0.0004)	0.1643 (0.1824)	0.1891 (0.1593)	0.1050* (0.0553)	0.0017 (0.0129)	-0.0000 (0.0001)
N	3,451,861	3,502,994	3,502,994	881,713	1,303,489	3,351,263
R^2_{adj}	0.081	0.748	0.794	0.605	0.283	0.357
Pr($S1 = S2$)	0.000	0.005	0.001	0.019	0.012	0.034

Internet Appendix for Does the Game Stop?

1. Relative size of US brokerages

In order to gauge the impact of various brokerage restrictions on the marginal investor, it is useful to understand not only the proportion of retail and institutional trades within the set of restricted firms, but also the size of the brokerages which restricted trading behavior relative to other retail-oriented brokerages which did not restrict trading. While we lack specific data on the volume of trades placed at these brokerages, the SEC requires broker-dealers to publish quarterly reports of their routing practices. These Rule 606 disclosures report the venues to which trades were routed and net payments paid or received by these venues for that order flow. Since many brokerages, such as E-Trade, TD Ameritrade, and Charles Schwab, have recently eliminated most brokerage fees and commissions in response to Robinhood's rapid growth, these payments likely provide some information on the relative volume handled by specific brokerages over our sample period.

Table A.1 reports net payments for NMS equity and options orders for a set of retail-oriented US brokerages for the period December 2020 to March 2021. In each of these months, Robinhood received the largest payments for both equity and options trades of the set of brokerages we report. On average, Robinhood received \$41.8m per month for equity trades and \$63.7m per month for options trades. To put these numbers in perspective, Robinhood received roughly 3.8 (4.4) times the payments received by Charles Schwab for equity (options) orders on average over this sample period. TD Ameritrade also received large payments for equity (options) order routing over this period averaging \$21.4m (\$44.1m) per month. Over this period, TD Ameritrade received on average 1.9 (3.0) times the payments received by Charles Schwab. Broadly, we take these values as evidence of the importance (in terms of trading volume handled) of the brokerages which implemented trading restrictions within the landscape of retail trading over our sample period. However,

we note that payments received for order flow may vary across brokerages for a variety of reasons beyond simply trading volume, such as the type of trader (informed versus liquidity), the type of order (market versus other types of trades), the securities that each brokerage focuses on, the specific payment arrangements made by each broker, and more generally, the revenue and business model pursued by each brokerage.

2. Details of brokerage restrictions

While our main tests are concerned with the impact of the presence of trading restrictions, there is heterogeneity in both the size and scope of trading restrictions across firms and through time. In this section, we provide additional details about the trading restrictions studied in our paper.

2.1. Robinhood restrictions

Table A.2 reports the timeline of the Robinhood restrictions. Based on the snapshots from the Wayback Machine, restrictions in equities and options changed 16 times over our sample period and affected a total of 29 firms in our sample. In Panel A, we report the maximum allowable holding in equity shares reported by Robinhood. When securities are classified as “position-close only,” we code the maximum allowable holding as zero shares, but we also note that Robinhood did not force liquidation of shares provided that margin requirements were met. Once Robinhood removed the “position-close only” classification and moved to limiting maximum holdings to a strictly positive number of shares, we report the maximum number of shares an investor can hold in the security in the table. For example, Tootsie Roll (TR) was classified as “position-close only” on Thursday, January 28, 2021 at 10:50:20 EST. Before trading began on Friday, January 29, 2021, restrictions in TR were relaxed, and investors could hold a maximum position of 25 shares of TR long in their Robinhood account. Restrictions of some amount stayed in place for TR through trading hours on January 29 and had been lifted by the time the market opened on Monday, February 1. Panel B reports the maximum allowable holding in options contracts.

2.2. TD Ameritrade restrictions

Rather than simply limiting the number of long equity shares or long options contracts that could be held in an account, TD Ameritrade implemented a set of broad restrictions limiting several facets of trading such as more stringent margin requirements for equity trades or limitations on the types of option spreads that could be traded. We classify these restrictions into four broad categories listed below with an example of each type:

1. Restrictions on Equity Margin Requirements

- “Stocks - 100% holding requirement (not marginable)”

2. Restrictions on Short Selling

- “Short selling is not allowed at this time.”

3. Restrictions on Short Options Positions

- “Opening orders on short individual options are not allowed with the exception of cash-secured puts or covered calls, which must be placed through a broker.”

4. Restrictions on Custom (Non-standard) Spread Orders

- “Custom spreads are not allowed, but standard spread orders are. Spread orders allowed include: Verticals, Back/Ratio, Calendar, Diagonal, Straddle, Strangle, Covered Stock, Collar, Butterfly, Combo, Condor, Iron Condor, Vertical Roll, Collar with Stock, Double Diagonal and Double Calendar.”

Table A.3 reports the timeline of the TD Ameritrade restrictions. Based on the snapshots from the Way-back Machine, restrictions in equities and options changed six times over our sample period and affected a total of 15 firms in our sample. All restrictions were removed at the time of the snapshot taken after market close on February 24, 2021. Restrictions were put in place for GME for a second time at market close on

February 25, 2021. The restrictions on GME and RKT put in place on March 4, 2021 were still in place when our sample ends on March 12, 2021.

3. Additional implied volatility results

In investigating the impact of brokerage restrictions on options implied volatility, we face a tradeoff in aggregating options trades to a panel of 15-minute interval implied volatilities between maximizing the number of trades included in our aggregation and over-weighting options that are far from the money which may be thinly traded or may reflect changes in the shape of the volatility smile rather than a parallel shift up or down in implied volatility. Table A.4 presents results from alternative definitions of implied volatility based on varying the options included in our aggregation based on days to maturity or moneyness. The results in Table 6 include options with days to maturity in the interval $(7, 30]$ days and with log moneyness in the interval $[-.2, .2]$. These results include on average 43.3% of option trades by volume and 86.7% of near-term options volume, where near-term options are options with days to maturity in the interval $(7, 30]$. Our expanded results expand the options included in our implied volatility calculation to include options with days to maturity up to 90 days and log moneyness in the interval $[-.4, .4]$ at its widest. These loosened restrictions cover up to 71.2% of options volume and 96.0% of near-term volume. We find similar effects of brokerage restrictions on options implied volatilities as we increase the number of options trades included in our calculation of implied volatilities. The point estimates of $Restricted_{S1}$ are both statistically and economically significant across specifications and indicate an increase in implied volatility from an annualized 18.44% to 19.22%. Similarly, the point estimates of $Restricted_{S2}$ are statistically insignificant in each specification.

4. Rule 605 Volume

In this section, we introduce a new measure of retail trading volume calculated from Rule 605 disclosures. While this measure is available at lower frequencies than the retail trading volume identified using the subpenny algorithm of Boehmer et al. (2021), it has two distinct advantages. First, the subpenny algorithm of Boehmer et al. (2021) only captures off-exchange trading volume while Rule 605 volume includes trades both on- and off-exchange. Second, Rule 605 volume can be combined with Rule 606 disclosures to create a measure of trading volume at the brokerage-firm-month level.¹

Rule 605 disclosures report the monthly number of orders and number of shares filled by a particular market center or venue v in a given stock i in a given month t . Information is categorized by order size and order type, market vs. limit. We define

$$\text{Rule 605 Volume}_{i,t} = \sum_{v \in V} \text{Filled Volume}_{v,i,t} \quad (\text{A.1})$$

where *Filled Volume* is the total number of shares traded in orders filled by venue v in firm i in month t . To better capture only retail volume, our set of venues, V , is restricted to venues listed in Rule 606 disclosures by the set of brokerages in Table A.1 and excludes venues that are also major exchanges.² We also rescale *Rule 605 Volume* such that the ratio of *Rule 605 Volume* to total trading volume on TAQ is winsorized at the 95th percentile.

Panel A of Table A.5 reports summary statistics on the percentage of retail trading volume identified by Rule 605 disclosures and the subpenny algorithm of Boehmer et al. (2021) (BJZZ) for the sample period January 2020 to June 2021. On average, *Rule 605 Volume* comprises roughly 20% of total trading volume

¹We thank an anonymous referee for this helpful suggestion.

²Specifically, we exclude the following venues: CBOE BYX Exchange (BYXX), CBOE BZX Exchange (BATS), CBOE EDGX Exchange (EDGK), CBOE EDGA Exchange (EDGA), Nasdaq Stock Market (Q), New York Stock Exchange (XNYS), NYSE Arca (ARCA), IEX (V), and NYSE American (XASE).

while *BJZZ Volume* comprises roughly 9% of total trading volume. Consistent with *BJZZ Volume* capturing at most only the retail trades occurring off-exchange, *Rule 605 Volume* is on average 2.5 times *BJZZ Volume*.

In Panel B of Table A.5, we explore the correlations between these various measures of trading volume. Notably, *Rule 605 Volume* is highly correlated with *BJZZ Volume* when using either raw number of shares or when retail trading volume is scaled by total volume. Our tests involving these data in the main text utilize lagged % *Rule 605 Volume* data to mitigate look-ahead bias in our data. We explore the autocorrelation in % *Rule 605 Volume* by examining correlations between *Rule 605 Volume* and the implied level of Rule 605 volume. This *Impl. Rule 605 Volume* is calculated by taking the product of % *Rule 605 Volume* for firm i in month $t - 1$ and *Total Volume* for firm i in month t . Panel C reports the correlations between these measures of trading volume after transforming the raw variables into percentiles in each cross-section (month).

Our discussion of Rule 605 volume to this point has focused on aggregate Rule 605 volume rather than brokerage-specific Rule 605 volume to facilitate the comparison of retail trading volume identified through Rule 605 disclosures versus retail trading volume identified by the BJZZ algorithm. We next define

$$Rule\ 605\ Volume_{b,i,t} = \sum_{v \in V} \left(Filled\ Volume_{v,i,t} \cdot \frac{Order\ Payments_{b,v,t}}{\sum_{b \in B} Order\ Payments_{b,v,t}} \right) \quad (A.2)$$

where *Rule 605 Volume* $_{b,i,t}$ is the total number of shares traded in orders at brokerage b in firm i in month t . We split Rule 605 volume between brokerages using information in Rule 606 disclosures on net payments for NMS orders between venues and brokerages. Specifically, we scale volume filled by venue v in firm i in month t by the ratio of payments for order flow (*Order Payments*) made by venue v to brokerage b and the total payments for order flow made by venue v in month t . Again, our set of brokerages, B , is the set of brokerages in Table A.1. We note that payment for order flow is not reported at the brokerage-venue-firm-month level and is instead aggregated across all firms. Thus, our proxy assumes that payments for order

flow are similar both across firms and across brokerages.

While we lack specific data on order flow attributable to a given brokerage, we can speak somewhat to the validity of our measure by comparing this brokerage-specific volume measure for Robinhood to data on the number of accounts holding a given stock at a specific point in time at Robinhood from Robintrack. We note that the overlap in the sample between Rule 605/606 disclosure data and Robintrack data is relatively short, January 2020 through August 2020, and that brokerage-specific volume is a flow variable while number of accounts holding a given stock is a stock variable. However, untabulated correlations between the average number of accounts holding a given stock over the month and retail volume attributable to Robinhood investors is relatively high after transforming the raw variables into percentiles in each cross-section (month). The pooled correlation is 0.838, while the mean (median) correlation by date is 0.838 (0.838). The interquartile range of the by date correlations is 0.832 to 0.843.

Table A.1: Net Payments for NMS Orders for a Set of Retail-oriented US Brokerages

This table presents monthly net payments for NMS orders for a set of retail-oriented US brokerages from December 2020 to March 2021. Amounts are in USD and are obtained from Rule 606 disclosures. Net payments are calculated by summing net payments received across venues for market orders, marketable limit orders, non-marketable limit orders, and other orders across. Panel A reports net payments made for equity orders and includes both S&P 500 and non-S&P 500 equities. Panel B reports net payments made for options orders.

Panel A: Equity Orders

	12/2020	1/2021	2/2021	3/2021
Ally Invest	558,738.99	643,072.41	685,462.34	514,508.88
Charles Schwab	10,084,462.62	10,964,868.51	11,588,689.84	11,208,689.98
E-Trade	16,133,199.63	20,094,023.65	22,332,831.75	18,943,127.71
Fidelity	4,434,970.00	5,168,596.00	6,019,343.00	4,998,334.00
Interactive Brokers	1,684,507.00	2,034,961.00	4,921,415.00	4,299,375.00
Robinhood	34,139,033.95	47,538,138.26	51,116,636.86	34,478,377.95
TD Ameritrade	19,174,104.00	23,606,664.00	23,583,405.00	19,161,502.00
TradeStation	2,760,169.45	3,393,783.80	4,262,280.38	3,673,684.48
Webull	5,961,929.74	7,339,618.80	8,813,149.92	8,808,484.47
ZacksTrade	611.00	-186.33	1,092.91	1,322.27

Panel B: Options Orders

	12/2020	1/2021	2/2021	3/2021
Ally Invest	860,154.27	868,733.05	938,259.26	911,929.34
Charles Schwab	13,771,875.51	14,059,229.23	14,677,673.35	15,582,003.16
E-Trade	23,412,947.76	25,347,460.71	25,408,029.46	27,277,613.80
Fidelity	8,733,398.00	10,187,712.00	11,087,157.00	11,697,869.00
Interactive Brokers	7,266,828.00	8,649,888.00	10,310,542.00	10,904,934.00
Robinhood	57,233,255.96	65,842,998.00	69,685,264.74	62,200,836.87
TD Ameritrade	40,374,486.00	42,592,755.00	46,833,208.00	46,621,830.00
TradeStation	1,874,190.00	1,844,478.75	1,831,688.00	2,137,981.00
Webull	5,267,099.30	5,614,856.67	7,043,026.10	8,402,482.00
ZacksTrade	3,876.05	2,779.45	2,986.65	2,650.11

Table A.2: Summary of Robinhood Restrictions

This table presents a timeline of restrictions put in place by Robinhood during late January and early February 2021. During this period, Robinhood reported these restrictions on two public-facing websites: <https://robinhood.com/us/en/support/articles/changes-due-to-recent-market-volatility> and <https://blog.robinhood.com/news/2021/1/28/keeping-customers-informed-through-market-volatility>. We recover snapshots of these webpages through time using the Internet Archive Wayback Machine. The reported timestamps are in Eastern Standard Time. Panel A reports the maximum allowable holding in equity shares of a given firm at the reported date and time. Panel B reports the maximum allowable holding in options contracts written on a given firm's equity at the reported date and time. Robinhood did not force the liquidation of contracts in excess of the maximum allowable holding. As an example, investors could hold a maximum position of 150 shares long in GTE in a Robinhood account as of 14:59:17 on January 29, 2021. This restriction was tightened to a maximum position of 5 shares long as of 15:35:11 on January 29, 2021. All restrictions in GTE were then lifted on 4:37:20 on January 31, 2021.

Panel A: Maximum Allowable Holding in Equity Shares (No Forced Liquidation)

	1/28 9:03:57	1/28 10:50:20	1/28 11:42:34	1/29 1:46:41	1/29 12:38:12	1/29 13:52:03	1/29 14:59:17	1/29 15:35:11	1/29 16:06:53	1/31 4:37:20	2/1 12:37:17	2/1 14:06:40	2/2 11:42:52	2/2 20:44:35	2/4 6:14:09	2/5 0:22:00
AAL		0	0	55	55	55	5	1	1							
AMC	0	0	0	115	25	25	10	1	1	10	75	350	1250	1250	5500	
AMD							1	1	1							
BBBY	0	0	0	30	30	30	2	1	1							
BBY		0														
BYND								1	1							
CCIV								1	1							
CRIS							1	1	1							
EXPR	0	0	0	200	200	200	5	5	5	20	200	1000	3000			
GM							1	1	1							
GME	0	0	0	5	2	2	1	1	1	1	4	20	100	100	500	
GNUS										600	5000	5000				
GTE							150	5	5							
INO								1	1							
JAGX							30	5	5							
KOSS	0	0	0	25	10	10	1	1	1	2	25	150				
MRNA							1	1	1							
MUX								5	5							
NVAX								1	1							
OPEN								1	1							
RKT								1	1							
SBUX								1	1							
SIEB								1	1							
SRNE								1	1							
STPK								1	1							
TGC								5	5							
TR		0	0	25	25	25	25	1	1							
TRXC									5							
WKHS							3	1	1							
ZOM								5	5							

Table A.2: Summary of Robinhood Restrictions (cont.)

Panel B: Maximum Allowable Holding in Options Contracts (No Forced Liquidation)

	1/28 9:03:57	1/28 10:50:20	1/28 11:42:34	1/29 1:46:41	1/29 12:38:12	1/29 13:52:03	1/29 14:59:17	1/29 15:35:11	1/29 16:06:53	1/31 4:37:20	2/1 12:37:17	2/1 14:06:40	2/2 11:42:52	2/2 20:44:35	2/4 6:14:09	2/5 0:22:00
AAL		0	0	50	50	25	10	10	10							
AMC	0	0	0	100	100	50	10	10	10	10	75	350	1250	1250	5000	
AMD																
BBBY	0	0	0	50	50	25	10	10	10							
BBY		0														
BYND																
CCIV																
CRIS																
EXPR	0	0	0	100	100	50	10	10	10	20	200	1000	3000			
GM																
GME	0	0	0	10	10	5	5	5	5	5	5	20	100	100	500	
GNUS										600	1000	1000				
GTE																
INO																
JAGX																
KOSS	0	0	0													
MRNA																
MUX																
NVAX																
OPEN																
RKT																
SBUX																
SIEB																
SRNE																
STPK																
TGC																
TR		0	0	50	50	25	10	10	10							
TRXC																
WKHS																
ZOM																

Table A.3: Summary of TD Ameritrade Restrictions

This table presents a timeline of restrictions put in place by TD Ameritrade from January 28, 2021 through March 12, 2021. During this period, TD Ameritrade reported these restrictions on the following website: <https://tdameritrade.com/td-ameritrade-trading-restrictions-stocks>. We recover snapshots of these webpages through time using the Internet Archive Wayback Machine. The reported timestamps are in Eastern Standard Time. Restrictions are classified as: 1) restrictions on equity margin requirements, 2) restrictions on short selling, 3) restrictions on short options positions, and 4) restrictions on custom (non-standard) spread orders. Further details on the classification of these restrictions can be found in Section 2.2 of the Internet Appendix.

	1/28 16:00:00	2/8 9:00:00	2/24 19:13:45	2/25 16:00:00	2/26 22:39:22	3/4 16:30:00
AMC	1,3,4	1,3			1,3	
BBBY	1,3,4					
CVM	1,3,4	1,3			1,3	
DDS	1,3,4	1,3			1,3	
EXPR	1,3,4	1,3			1,3	
FIZZ	1,3,4					
FOSL	1,3,4					
GME	1,3,4	1,3		1,2,3	1,3	1,2,3
IRBT	1,3,4					
KOSS	1,3,4					
NCMI	1,3,4	1,3			1,3	
RKT						1,2,3
TR	1,3,4					
UONE	1,3,4					
VIR	1,3,4	1,3			1,3	

Table A.4: Impact of Brokerage Restrictions on Implied Volatilities

This table reports the estimates for the impact of a brokerage restriction on implied volatilities for traded options. Observations are the volume-weighted implied volatilities for traded options in a given firm aggregated over 15-minute intervals within trading hours. The units are annualized standard deviations. To be included in this aggregation, an option must have days to maturity and log moneyness in the reported intervals. We also report the fraction of daily volume and daily near-term volume included in the volume-weighted implied volatility calculation, where near-term options are options with days to maturity in the interval (7, 30]. $Restricted_{S1}$ is a binary variable equal to one if the firm is subject to a brokerage restriction by a brokerage in Set 1 at any point during the 15-minute interval and zero otherwise. Similarly, $Restricted_{S2}$ is a binary variable equal to one if the firm is subject to a brokerage restriction by a brokerage in Set 2 at any point during the 15-minute interval and zero otherwise. Options data are from Cboe LiveVol DataShop. Standard errors are clustered at the firm-level. Fixed effects are included to control for firm and 15-minute interval. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Maturity (in days)	(7, 30]	(7, 30]	(7, 30]	(7, 60]	(7, 60]	(7, 60]	(7, 90]	(7, 90]	(7, 90]
Moneyiness Range (log)	[-.2, .2]	[-.3, .3]	[-.4, .4]	[-.2, .2]	[-.3, .3]	[-.4, .4]	[-.2, .2]	[-.3, .3]	[-.4, .4]
Daily Volume Covered	0.433	0.466	0.481	0.593	0.644	0.668	0.628	0.684	0.712
Near-term Options Only	0.867	0.930	0.960	–	–	–	–	–	–
$Restricted_{S1}$	0.1902* (0.0981)	0.1877** (0.0954)	0.1863* (0.0955)	0.1844** (0.0896)	0.1863** (0.0888)	0.1836** (0.0879)	0.1896** (0.0881)	0.1922** (0.0872)	0.1903** (0.0864)
$Restricted_{S2}$	0.0749 (0.0828)	0.0790 (0.0860)	0.0880 (0.0870)	0.0625 (0.0810)	0.0674 (0.0817)	0.0741 (0.0828)	0.0586 (0.0795)	0.0605 (0.0800)	0.0663 (0.0812)
N	866,389	900,673	915,754	1,032,386	1,077,964	1,098,532	1,055,612	1,103,907	1,126,151
R^2_{adj}	0.895	0.886	0.877	0.908	0.902	0.895	0.910	0.904	0.898
Pr($S1 = S2$)	0.479	0.508	0.552	0.431	0.443	0.481	0.390	0.386	0.417

Table A.5: Rule 605 Volume Summary Stats

This table reports summary statistics and correlations for several measures of trading volume. Observations are firm-months for the sample period between January 2020 and June 2021. *Rule 605 Volume* is the trading volume in shares summed across venues as reported in the venue’s Rule 605 disclosure. We restrict our attention to venues listed on the Rule 606 disclosures of the brokerages in Table A.1 and exclude venues that are major exchanges. *BJZZ Volume* is the trading volume in shares of trades identified as retail using the subpenny algorithm of Boehmer et al. (2021). *Total Volume* is the trading volume in shares from TAQ. *% Rule 605 Volume* is the ratio of *Rule 605 Volume* to *Total Volume*. *% Rule 605 Volume* is winsorized at the 95th percentile and *Rule 605 Volume* is rescaled to be consistent with this winsorization. *emph% BJZZ Volume* is the ratio of *BJZZ Volume* to *Total Volume*. *Impl. Rule 605 Volume* is the implied level of Rule 605 volume calculated by taking the product of *% Rule 605 Volume* for firm *i* in month *t* – 1 and *Total Volume* for firm *i* in month *t*. Percentile variables in Panel C are computed for each cross-section (month).

Panel A: Summary Statistics

	Mean	Std Dev	<i>p</i> 5	<i>p</i> 10	<i>p</i> 25	<i>p</i> 50	<i>p</i> 75	<i>p</i> 90	<i>p</i> 95
<i>% Rule 605 Volume</i>	0.2008	0.1552	0.0466	0.0562	0.0785	0.1354	0.2990	0.4711	0.5460
<i>% BJZZ Volume</i>	0.0919	0.0846	0.0185	0.0231	0.0325	0.0550	0.1280	0.2223	0.2695
<i>Rule 605 Volume</i> / <i>BJZZ Volume</i>	2.5110	1.0965	1.4264	1.6717	1.9770	2.3168	2.7516	3.3724	4.0341

Panel B: Correlations of Raw Variables

	Pooled	By Firm			By Date				
		Mean	<i>p</i> 25	<i>p</i> 50	<i>p</i> 75	Mean	<i>p</i> 25	<i>p</i> 50	<i>p</i> 75
$\rho(\textit{Rule 605 Volume}, \textit{Total Volume})$	0.9209	0.8479	0.8030	0.9105	0.9754	0.9218	0.9072	0.9220	0.9336
$\rho(\textit{BJZZ Volume}, \textit{Total Volume})$	0.9084	0.8181	0.7598	0.8908	0.9673	0.9036	0.8889	0.9108	0.9223
$\rho(\textit{Rule 605 Volume}, \textit{BJZZ Volume})$	0.9246	0.9206	0.9281	0.9727	0.9916	0.9247	0.8921	0.9391	0.9591
$\rho(\% \textit{Rule 605 Volume}, \% \textit{BJZZ Volume})$	0.8664	0.7239	0.6462	0.8370	0.9242	0.8709	0.8522	0.8670	0.8975
$\rho(\textit{Rule 605 Volume}, \textit{Impl. Rule 605 Volume})$	0.9848	0.8056	0.7435	0.8759	0.9598	0.9869	0.9844	0.9891	0.9901

Panel C: Correlations of Percentile Variables

	Pooled	By Firm			By Date				
		Mean	<i>p</i> 25	<i>p</i> 50	<i>p</i> 75	Mean	<i>p</i> 25	<i>p</i> 50	<i>p</i> 75
$\rho(\textit{Rule 605 Volume}, \textit{Total Volume})$	0.9109	0.8406	0.8042	0.8966	0.9518	0.9110	0.9065	0.9106	0.9158
$\rho(\textit{BJZZ Volume}, \textit{Total Volume})$	0.9110	0.8047	0.7641	0.8766	0.9412	0.9108	0.9042	0.9125	0.9154
$\rho(\textit{Rule 605 Volume}, \textit{BJZZ Volume})$	0.9891	0.9083	0.9096	0.9609	0.9847	0.9891	0.9879	0.9896	0.9904
$\rho(\% \textit{Rule 605 Volume}, \% \textit{BJZZ Volume})$	0.9114	0.7093	0.6321	0.8169	0.9150	0.9121	0.9096	0.9194	0.9213
$\rho(\textit{Rule 605 Volume}, \textit{Impl. Rule 605 Volume})$	0.9870	0.8163	0.7670	0.8798	0.9531	0.9870	0.9858	0.9875	0.9891