Retail Trading in Options and the Rise of the Big Three Wholesalers

Svetlana Bryzgalova,* Anna Pavlova,† and Taisiya Sikorskaya‡

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Abstract

We document rapid increases in (i) retail trading in options and (ii) payment for order flow (PFOF), received by the U.S. retail brokerages from the so-called wholesalers in exchange for routing orders to them. Nearly 90% of PFOF comes from three wholesalers. Exploiting new flags in transaction-level data, we isolate wholesaler trades and build a novel measure of retail options trading. Our measure comoves positively with other proxies for retail investor popularity and drops significantly during platform outages experienced by large U.S. brokerages. We document that retail investors prefer cheaper, lottery-like weekly options, with the average bid-ask spread of a whopping 12.6%. They lose money on average, primarily because of high trading costs, and participate in frenzies.

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*London Business School and CEPR, sbryzgalova@london.edu

†London Business School and CEPR, apavlova@london.edu

‡London Business School, tsikorskaya@london.edu

1 Introduction

The advent of zero-commission trading in stocks and options has revolutionized retail brokerage services in the United States. Since their market entry in 2015, smartphone investing app Robinhood and other commission-free brokerages have attracted an unprecedented inflow of retail customers, mainly young and tech-savvy, yet inexperienced, investors. At the peak of its popularity in late 2021, Robinhood alone has amassed 21.3 million monthly active users, as reported in their quarterly statements.

One concern frequently brought up in the context of the recent retail trading boom is related to the controversial practice of payment for order flow (PFOF). Retail brokerages route clients' orders to financial intermediaries known as wholesalers for execution and receive PFOF in return. In equities, wholesalers cross this order flow on their private trading platforms, away from national exchanges, and other market makers cannot compete for these orders. This is known as *internalization*. PFOF is a divisive practice because such order flow fragmentation may lead to wider bid-ask spreads on exchanges and because it incentivizes retail brokerages to encourage investors to trade more. In June 2022, Gary Gensler, chair of the U.S. Securities and Exchange Commission (SEC), has publicly criticized PFOF and order execution quality for retail investors.[1] However, the Commission's attention has been focused solely on equities; in fact, Gensler gave the options market as an example of superior retail order execution. Unlike equities, all options in the U.S. trade on exchanges, which mechanically should expose them to competition from other market makers. It is therefore thought that problems arising from internalization are specific to equities.

In this paper, we argue that much of the retail order flow in options is also effectively internalized. We identify a friction that may hinder competition from other market makers on options exchanges. Specifically, wholesalers execute retail orders through so-called *price improvement mechanisms*, which, as we show, often amounts to internalization. This allows us to isolate wholesaler trades and build a proxy for retail trading in options by exploiting a recently introduced flag for price improvement mechanisms in transaction-level data. We find that our measure of retail trading grew 104% in our sample of one and a half years, in line with the growth in PFOF for options.[2] Retail traders prefer cheaper, weekly options, the average quoted bid-ask spread for which is as high as 12.6%, and lose money on average. A large fraction of retail order flow is serviced by very few wholesalers: The share in PFOF of the top three has grown to nearly 90% as of the second quarter of 2021.

[1] See https://www.bloomberg.com/news/articles/2022-06-08/sec-chief-takes-aim-at-payment-for-order-flow-in-sweeping-plans.

[2] We consider the combined PFOF from the largest U.S. retail brokerages reports under SEC Rule 606 (routing of orders). See Section 2.1 for the list of brokerages in our sample.

We start by documenting a stylized fact that, although only a fraction of investors trade options, most of the PFOF received by retail brokerages comes from options, not equities. For example, in 2021, U.S. brokerages received $2.4 billion in PFOF for options and only $1.3 billion for equities. The lion's share of PFOF for options came from only three wholesalers: Citadel, Susquehanna, and Wolverine.

Retail brokers in the U.S. are required to provide the best execution to their clients, and so they have an agreement with a wholesaler to provide price improvement relative to the best available bid and ask prices.[3] To do so, they would often use an options exchange process known as a price improvement auction or mechanism. Exploiting a flag for price improvement mechanisms, introduced by the Options Price Reporting Authority (OPRA) in November 2019 for transaction-level data, we are able to identify wholesaler trades and build a novel measure of retail trading in options. In our dataset, these are trades executed through a single-leg price improvement mechanism, which we abbreviate as SLIM.[4] The monthly dollar trading volume in SLIM transactions grew by 104% from January 2020 to July 2021, alongside the PFOF in options (158%).

We show that our measure picks up recent retail investor frenzies in GameStop and other "meme" stocks, as measured by mentions in `WallStreetBets`, an investing forum popular with new retail investors. Furthermore, it is strongly correlated with an alternative retail investor trading measure – small trades in options (up to 10 contracts) – commonly used in the media and industry,[5] as well as with Robinhood user popularity provided by Robintrack, and the retail frenzies measure of Barber, Huang, Odean, and Schwartz (2022). We also construct a novel retail popularity measure based on the internalized volume in equities and exchange-traded funds (ETFs) and show that it comoves with SLIM trades in the corresponding options.

We provide several further tests to argue that our measure indeed represents retail trades. First, SLIM trading in options on tickers popular with retail investors drops significantly during outages on large U.S. retail brokerage platforms, namely TD Ameritrade, Charles Schwab, and Robinhood. For example, when comparing SLIM trading in the options on the same ticker during the times when all these platforms experience an outage versus normal operation, we find that SLIM trading in options on popular stocks goes down by almost one percentage point. Broker platform outages are plausibly exogenous to retail

[3]Most of order flow in options received by retail brokerages in our sample is routed to wholesalers. The fraction of orders routed directly to exchanges is small; see Table A1 in the Appendix.

[4]Specifically, we use OPRA type "SLAN," which stands for single-leg non-ISO price improvement mechanisms. See Appendix A.2 for a description.

[5]For instance, Bloomberg relies on small trades to proxy retail participation in options; see https://www.bloomberg.com/professional/blog/gamestop-highlights-importance-of-option-related-equity-flows/.

trading in options on a particular ticker. Second, we also run a similar test on tickers that were subject to trading restrictions imposed by large retail brokerages in 2021. We find that SLIM trading in those tickers drops significantly, by over 6 percentage points when both TD Ameritrade/ Charles Schwab and Robinhood restrict trading. Finally, Section 4 presents more evidence supporting SLIM as a measure of retail trading in options.

The new generation of retail investors is more tech-savvy and participates in investment forums, but they are still financial novices. It is quite striking that they are so active in options markets, despite much higher bid-ask spreads on options relative to stocks.[6] For example, 50% of retail trades in our sample are in ultra short-term options, weeklys (i.e., options with less than a week to expiration), with an average quoted bid-ask spread of 12.6%. However, the true trading costs for options may be obfuscated by the zero commissions; an opportunity to trade options is displayed prominently on gamified investing apps used by the new generation of investors.[7] These investors may be attracted by a cheap way of achieving leverage that these options provide. Embedded leverage in weekly options is very high, often exceeding 50 (see Table A4 in the Appendix). Moreover, on some investing platforms, for example, Robinhood, weekly options are presented as a default choice to an options trader.

Retail investors in our sample strongly prefer call options to puts: The volume share in calls is 69%. They trade mostly at-the-money (72% of trades) or slightly-out-of-the-money (24% of trades) options. The latter involve higher trading costs, with the average quoted bid-ask spread of 28%. 14% of retail trades have a "micro" size of up to $250, and their average quoted bid-ask spread is 23.6%. We document that retail investors prefer options on larger companies, those with lower share prices, and higher recent trading volume (e.g., attention-grabbing tickers). This is consistent with the literature on retail participation in equities. We view these cross-sectional relationships as evidence of speculative rather than hedging motives behind retail trades. Finally, we document significant increases in both call and put net purchases during retail investor frenzies, especially in trades of a smaller size.

Are retail options trades profitable? To answer this question, we analyze the performance of SLIM trades at the one-, two-, five-, 10-day horizons, and until expiration. On aggregate, these trades lose money for all horizons. For example, assuming a holding horizon of 10 days, we estimate that the aggregate portfolio of retail investors lost $2.2 billion from November 2019 until June 2021. The losses are concentrated primarily in short-term call

[6] Muravyev and Pearson (2020) report that the average quoted bid-ask spread of options on stocks in the S&P 500 is as high as 17.2%. For comparison, for the S&P 500 stocks, this number is 3.55bps (as reported in Hagströmer (2021)). Higher aggregate PFOF for options relative to that for stocks (see Table A3 in the Appendix) indicates that executing order flow in options is a very lucrative business for wholesalers.

[7] Chapkovski, Khapko, and Zoican (2021) show that gamification induces risk-taking in novice traders, while Kalda, Loos, Previtero, and Hackethal (2021) find that trading on smartphones induces investors to purchase riskier and lottery-type assets.

options and driven by the indirect costs of trading. The aggregate trading costs, measured as a distance from an actual trade price to midquote for all SLIM trades in our sample, amount to a staggering $6.5 billion. This number is much higher than direct trading costs (about $950 million), computed using commissions of retail brokerages in our sample.[8]

We argue that our retail trading measure is less noisy than the industry alternative, small trades. Using the new OPRA trade flags, we identify many institutional transactions (broken down into multiple transactions of small sizes) in the small trades measure.

Finally, we perform a back-of-the-envelope calculation to assess how SLIM trading volume compares to the retail trading volume that can be inferred from the recently revised SEC Rule-606 forms filed by brokerages in the U.S. We find that SLIM reflects over 70% of inferred trading volume from market and marketable limit orders and over 30% of the total inferred retail trading volume. To make up for the remaining retail trading, we propose alternatives to SLIM that are noisier but are capable of capturing a larger fraction or the majority of the retail trading volume in options. Specifically, we consider another way in which wholesalers can internalize transactions of up to 5 contracts, and use the new OPRA trade flags to isolate such trades. We then add to those trades a refined subset of small trades (of up to 10 contracts), again using OPRA flags to define the subset, and finally also include trades of small dollar values (up to $5,000). We show that these measures are similar to SLIM in terms of observables. Like SLIM, these measures comove positively with proxies for retail investor popularity, drop significantly during outages experienced by large U.S. retail brokerages, as well as during trading restrictions imposed by these brokerages, and are not statistically different from SLIM in terms of their profitability. This helps us conclude that, while the SLIM methodology does not capture the entire retail volume, SLIM trades are comparable to our broader measures of retail trading.

Our paper is related to the emerging literature exploring retail investor trading in the age of Robinhood. Welch (2022), Barber, Huang, Odean, and Schwartz (2022), Boehmer, Jones, Zhang, and Zhang (2021), Eaton, Green, Roseman, and Wu (2022b), and Fedyk (2021) focus on retail investor equity holdings and trading and argue that the new generation of investors differs from retail investors previously examined in the literature (most notably, by Barber and Odean (2001)) along several important dimensions. Although the counts of retail investor equity positions are available from Robintrack, data on their trading in options is not available to researchers. To our knowledge, we are the first to document retail investor preferences and market participation in options, which we infer from transaction-level data that includes newly introduced OPRA trade types.

We are aware of the following papers on retail trading in options. Using account-

[8]Robinhood does not charge commissions for options trades, but many other brokerages still do.

level data from a brokerage, Bauer, Cosemans, and Eichholtz (2009) document that retail investors' motives for trading appear to be gambling and entertainment and that they incur substantial losses on their options investments. Lakonishok, Lee, Pearson, and Poteshman (2006) argue that speculation is the key driver of retail investors' trading in options and that during the dot-com bubble they favored options on growth stocks. Our paper uses transaction-level data for the entire U.S. options market to document the trading patterns of the new generation of retail investors. We confirm the findings of Lakonishok, Lee, Pearson, and Poteshman that retail investors have a strong preference for call options and that, on average, they write more options than they buy. We document additionally that they opt for ultra short-term (weekly) options (consistent with preferences for skewness discussed in Barberis and Huang (2008) and Boyer and Vorkink (2014)), participate in trading frenzies, and incur large trading costs (possibly masked by zero-commission offers).

Also related to our work are papers on options market structure and liquidity, for example, Battalio, Griffith, and Van Ness (2021), Ramachandran and Tayal (2021), Muravyev and Pearson (2020), Christoffersen, Goyenko, Jacobs, and Karoui (2018), Battalio, Shkilko, and Van Ness (2016), Muravyev (2016), and Mayhew (2002). None of these papers, however, constructs measures of retail investor trading and, more generally, examines retail investors. In independent contemporaneous work, Ernst and Spatt (2022) and Hendershott, Khan, and Riordan (2022) propose the same method as ours to identify wholesaler trades in the options market. Their main focus is on the price improvement (relative to the best prevailing quotes) achieved by wholesalers. Our focus is on the behavior of retail investors in the options market and their performance during the recent retail trading boom. In another recent paper, Eaton, Green, Roseman, and Wu (2022a) use retail brokerage outages to document that options on stocks popular with retail investors experience demand pressures that affect their implied volatilities.

Our findings are related to the literature on investor protection (e.g., Barbu (2022), Bhattacharya, Illanes, and Padi (2019), Egan (2019), and Campbell, Jackson, Madrian, and Tufano (2011)). We show how retail brokers and wholesalers benefit from the growth of retail trading in the options market, potentially more so than from retail trading in equities. Furthermore, retail investors' tendencies to trade options contracts with relatively larger spreads and to forgo profits from early exercise directly translate into larger gains for intermediaries and arbitrageurs. The complexity of options contracts from the viewpoint of an average retail investor and the potentially misaligned incentives of intermediaries call for more research and potential enhancements to investor protection on trading platforms.

The rest of the paper is organized as follows. Section 2 documents PFOF patterns, introduces our measure of retail trading in options, examines retail investor behavior, and

provides a number of validation exercises for our measure. Section 3 explores performance of retail investors' trades. Section 4 provides further supportive evidence that SLIM is a measure of retail trading in options, and Section 5 concludes. The Appendix provides technical details, additional evidence, and robustness checks.

2 PFOF and rise of retail trading in options market

In this section, we document novel facts about retail trading in the U.S. options market. Leveraging several granular datasets and regulatory filings, we characterize a recent increase in the concentration of retail brokerage markets. We propose a new measure of retail activity in the options market based on transaction-level data, describe its composition and performance, and show how it relates to the existing stock-level retail activity measures and other stock characteristics.

2.1 Data

We use option transaction-level data from OPRA LiveVol provided by CBOE. This data covers all trades on 16 U.S. exchanges in index, ETF, and equity options. In our analysis, we focus on ETF and equity options and exclude index options.[9] Our sample covers November 4, 2019 to June 30, 2021.

Following the literature, we remove canceled trades, trades with nonpositive size or price, with a negative spread (difference between best ask and best bid), and only keep trades for which trade price is above the best bid minus spread and below the best ask plus spread. We aggregate trades of the same contract with the same quote time, exchange ID, trade price, and trade condition ID into one line. We do not exclude open or close trades from our analysis, yet we confirm that excluding trades before 9:45 a.m. and after 3:50 p.m. does not change our results. We winsorize trade prices, sizes, and spreads at 99.5^{th} percentile daily. To compute trade imbalances, we follow the method described in Muravyev (2016), whereby trades with prices above (below) the midpoint are classified as "buy" ("sell") trades and trades at midpoint are classified according to the quote rule on the exchange where the trade took place. We also confirm that our results hold when using a so-called quote rule, that is, when midpoint trades are excluded (shown to have strong performance for options data by Savickas and Wilson (2003)), and Lee and Ready (1991) algorithm (or tick rule to classify trades at midpoint instead of excluding them).[10]

[9] Our sample also includes some ADRs. For brevity, we refer to underlying assets as "stocks and ETFs" in the text that follows.

[10] The resulting ticker-level imbalances have a correlation over 99% between the quote and Lee-Ready (1991)

We use daily option price, volume, and open interest data from OptionMetrics. It comes at a contract level for the period between January 4, 1996, and June 30, 2021. We lag open interest for all the data after November 28, 2000, to have a series of consistent open interest as of the end of day.[11] We exclude contracts with a non-standard settlement.

All stock-level data comes from the Center for Research in Security Prices (CRSP). This includes dividend history, stock prices and returns, and outstanding shares. To link with OptionMetrics, we rely on the SecId-PERMNO crosswalk provided by WRDS.

Our data on retail investor popularity is as follows. We download all comments submitted by users to "Daily Discussion" (DD) and "What Are Your Moves Tomorrow" (MT), most popular daily threads on `WallStreetBets` subreddit of `reddit.com`. The sample spans October 1, 2019 to June 30, 2021, and is collected via PRAW, which is a Python API toolkit to access `reddit.com`. In particular, we download all the comments (original posts and reactions to them) for each daily DD or MT thread.[12] To count ticker mentions in the downloaded comments, we start from the list of unique historical tickers from CRSP and search for them in all the comments, and then simply sum by date. We search only for capitalized tickers, as it is typical for the reddit audience to use those. Since we might omit any lower-case mentions, and we do not cover other threads of the forum (such as occasional megathreads), our measure provides a lower bound for ticker popularity. For Robinhood breadth of ownership, we use Robintrack data, which is provided in intraday snapshots and covers May 5, 2018, to August 13, 2020. We use the number of users holding a stock as of the last intraday snapshot.

In addition, we rely on FINRA OTC Transparency data to get stock trading volumes executed off lit exchanges, that is, automated trading system (ATS), typically referred to as "dark pools," and non-ATS OTC trades. Pursuant to FINRA's Regulatory Notice 15-48, these are available from April 2016, by security and venue.[13]

Recently revised Rule 606[14] requires broker-dealers to report the aggregate data on PFOF in stocks and options, along with its composition across a number of categories. We download these forms for the largest brokers in the United States directly from their websites. We consider all the leading retail brokerages that rely on wholesalers for PFOF in servicing retail flow. The list of brokers, largest venues, and their corresponding payments for order flow is reported in Table A3 in the Appendix. We consider PFOF and PFOF-implied

methods, while the correlation of both of them with the Muravyev (2016) method is 94%.

[11] The lag is due to the change in the reporting format of OptionMetrics. This implies that end-of-day open interest is measured after option exercises.

[12] Few dates are missing due to retrieval limitations on `reddit.com`.

[13] Details are on the website of FINRA: https://otctransparency.finra.org/otctransparency/AtsIssueData. For details on the rule, see: https://www.finra.org/rules-guidance/notices/15-48.

[14] For details, see https://www.sec.gov/rules/final/2018/34-84528.pdf

volume for each reporting broker. However, in tests with broker platform outages and trading restrictions, we merge TD Ameritrade and Charles Schwab from October 2020 because that is when Charles Schwab completed its acquisition of TD Ameritrade. Details on our samples of outages and restrictions are reported in Appendices A.17 and A.18, respectively.

2.2 Zero commissions, PFOF, and market structure

The global retail brokerage industry has changed drastically in recent years. More platforms are offering zero-commission trading in equities, and commissions in other asset classes have been reduced as well. Elimination of commissions has fueled a retail participation boom in financial markets, rise in day trading, and gamification of investing.[15] The success of the zero-commission business model relies on PFOF received from intermediaries in exchange for routing retail orders to them for execution. In response to the changing industry landscape and to promote transparency, the SEC introduced new reporting requirements for brokers. In this section, we use the forms filed in compliance with the new rule (Rule 606 reports) to describe the market for PFOF.

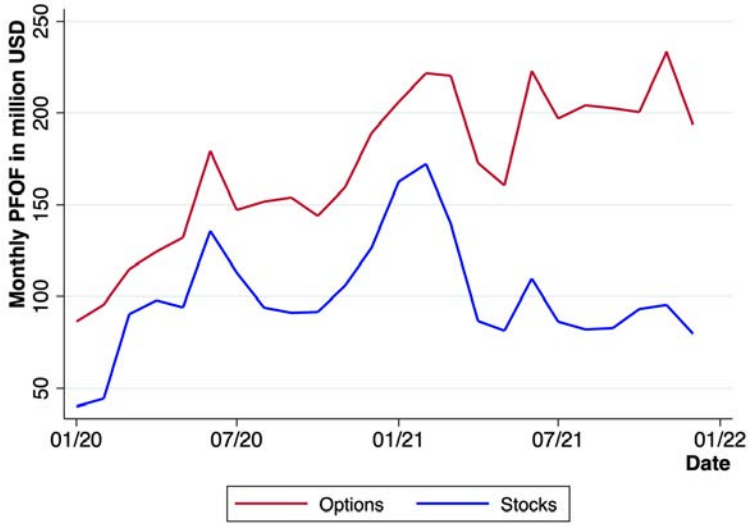
Figure 1 plots monthly PFOF received by the U.S. retail brokerages in our sample since the more detailed reporting of PFOF was made compulsory by the SEC. Although only a fraction of retail investors trade options, the amount of PFOF from options exceeds that from stocks by about 100%, in each month in our sample. In 2021, the annual PFOF from options was $2.4 billion, compared to $1.3 billion from equities. Our results below help understand why wholesalers offer so much PFOF for options.

Despite recent growth in retail trading and the commercial success of the zero-commission model, the wholesaler market remains quite concentrated, with top five PFOF providers accounting for over 95% of the total PFOF received by U.S. brokerages (see Figure 2). Also apparent from Figure 2 is the high concentration of PFOF providers in options, with the share of the top three providers – Citadel, Susquehanna, and Wolverine – increasing from 73% at the start of our sample and reaching an average value of about 85%. It peaked at nearly 90% in the second quarter of 2021. We hereafter refer to Citadel, Susquehanna, and Wolverine as *the Big Three wholesalers* in options.

PFOF also tends to be concentrated in a handful of brokerages, as we show in Appendix A.5. This is, however, to a large extent a reflection of their preferred business model. For example, Interactive Brokers do not rely on the wholesaler-based PFOF model and send retail orders directly to the exchanges. We therefore exclude them from our sample. On the other hand, TD Ameritrade is by far the largest receiver of payment for order flow in both

[15] See, e.g., the interview with the SEC chair: https://www.cnbc.com/amp/2022/01/19/secs-gensler-warns-investors-about-frequent-trades-on-brokerage-apps.html.

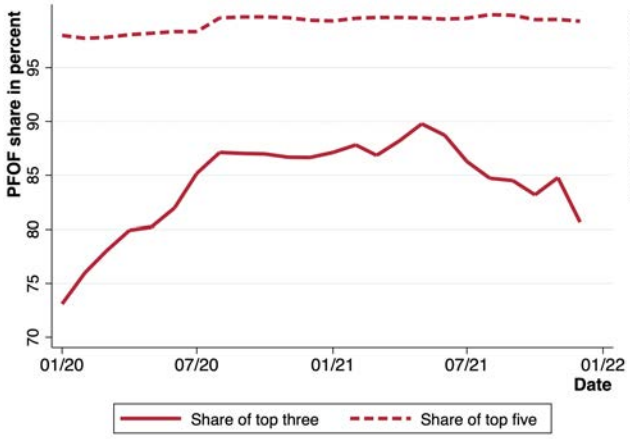
Figure 1: Payment for order flow: Options vs stocks



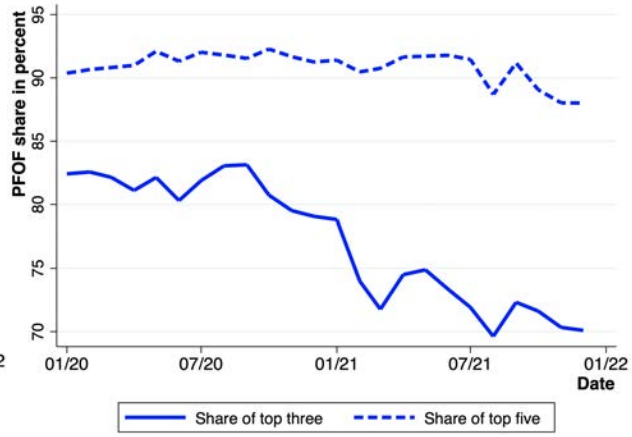
This figure plots aggregate monthly payments for order flow received by U.S. retail brokerages.

Figure 2: Market concentration in PFOF: Options vs. stocks

(a) Options



(b) Stocks



This figure plots the share of PFOF received by U.S. retail brokerages from the top three and top five wholesalers. The top three wholesalers in options are Citadel, Susquehanna, and Wolverine while the top three wholesalers in stocks are Citadel, Virtu, and Susquehanna.

stocks and options. Interestingly, Robinhood's share of PFOF in options has been steadily increasing from 15% in January 2020, likely due to the attractiveness of the zero-commission trading in options, provided by the company. It peaked at above 30% in January 2021, before stabilizing at about 25% by the end of the year.

2.3 SLIM: A measure of retail trading in options

In this section we propose a new measure of retail trading in options. While recent literature on the ongoing retail investor boom has come up with a number of new retail trading measures, all of them have been focused on equities. These stock-level measures include retail trading imbalances (Boehmer, Jones, Zhang, and Zhang (2021)), breadth of Robinhood user ownership (Welch (2022) and Eaton, Green, Roseman, and Wu (2022b)), and counts of `WallStreetBets` ticker mentions (also Eaton, Green, Roseman, and Wu (2022b)).[16] Even though these measures are not for options, retail investor frenzies in options and underlying equities are likely to occur at the same time, so we find it useful to include measures of retail investor activity in equities in our dataset.[17]

We add one more measure of retail equity trading to the list: internalized volume, which is the share of non-ATS OTC weekly trading volume in total volume, at a stock level, based on FINRA and CRSP data.[18] FINRA makes public the identities of the largest market makers executing non-ATS OTC transactions. Internalized trades for stocks are executed off lit exchanges, yet not in "dark pools" (which are classified as ATS transactions). The non-ATS OTC transactions consist primarily of internalized order flow from retail and institutional customers of wholesalers. Table A5 in the Appendix ranks market makers by their non-ATS OTC volume share.[19] This ranking closely resembles the one in which we sort wholesalers by their share in PFOF. To the best of our knowledge, this measure has not been used in the extant literature to date. For more details, see Appendix A.7.

The debate on the adverse consequences of internalization by both policy makers and academics so far has focused exclusively on equities. We now argue that, despite the different market structures, the patterns are similar, if not more acute, in options.

A highly publicized advantage to investors for having their orders routed to a wholesaler by a retail brokerage in exchange for PFOF, is that the wholesaler promises a price improvement to the customers, that is, the execution price that is at least as good as or better than the best quoted price, known as National Best Bid and Offer, or NBBO. To meet this commitment, wholesalers execute retail orders through *price improvement auctions/mechanisms,* offered by most options exchanges in the U.S.

Here is how it works. A retail investor sends an order, which the broker routes to a

[16] This list is based on the most recent measures with wider coverage, and it omits papers using proprietary data, such as NASDAQ TRF data.

[17] We include the latter two measures because we do not have Trade and Quote (TAQ) data required for constructing the measure of Boehmer, Jones, Zhang, and Zhang (2021).

[18] Not all of these trades originate from retail brokerages (FINRA defines it as "non-ATS electronic trading systems and internalized trades"). Yet, our results suggest that a significant fraction of these trades do.

[19] Our list of wholesalers/internalizers is very close to that documented in Eaton, Green, Roseman, and Wu (2022b) based on NASDAQ data.

wholesaler in exchange for PFOF and price improvement. Unlike a stock order, which can be internalized by a wholesaler on its own private trading platform, all options orders in the United States must be executed on exchanges. The wholesaler therefore engages its affiliated market maker to bring a paired order (with the affiliated market maker taking the other side) to a price improvement auction on an exchange. Market participants ("responders") have a window of time to respond (by sending a "contra" offer) with a better price (hence, the name "price improvement mechanism"), which could lead to the wholesaler losing the trade. In practice, the fees set by exchanges are stacked against responders, and it is prohibitively expensive to break up many of these paired trades.[20] These responder fees are so high because exchanges also compete for the order flow and incentivize wholesalers to bring orders to them.[21]

Our novel measure of retail trading activity in options is based on trades that went through price improvement auctions. To construct it, we use a dataset from OPRA that includes all options transactions in the U.S. We take advantage of a unique feature of our dataset: the new trade type flags introduced by OPRA on November 4, 2019. This classification is significantly more detailed than its predecessors, and hence we can construct our measure starting only from November 4, 2019. Specifically, we use the OPRA transaction code SLAN, which stands for a single-leg price improvement mechanism; we use an acronym SLIM to refer to these trades.[22] In our analysis below, we primarily focus on *SLIM Share*, which could be computed as a frequency share and as a trading volume share. We adopt the latter definition, as it would be more relevant for assessing the influence of retail traders on the market. We compute it daily and aggregate to a ticker level using traded volumes.[23]

Price improvement auctions were first introduced to improve trade execution for institutional investors, but a specific type of them that we use, single-leg non-ISO price improvement actions (OPRA trade type "SLAN"), are now used by wholesalers primarily for executing retail orders. ISO stands for "Intermarket Sweep Orders," which is a type of market orders, developed for large institutional trades, that take all available liquidity at the

[20] On most exchanges, order execution by a wholesaler-affiliated market maker gets charged the fee of just $0.05 per contract. In contrast, it would cost another market maker $0.50 to break up/respond to one of these already paired orders during an auction. In the latter case, the wholesaler receives a net rebate of $0.30 per contract just for bringing the order to the exchange. Appendix A.8 contains a detailed description of the fee structure pertaining to price improvement mechanisms on U.S. options exchanges and also highlights the fee advantages enjoyed by affiliated market makers.

[21] To some extent, this is natural, since markets benefit from the presence of largely uninformed retail flow and wholesalers are therefore compensated for delivering these orders. However, the structure and size of the fees associated with servicing retail order flow, that would lead to the optimal level of competition among market makers and efficient order execution, are still an open question.

[22] See Appendix A.2 for a description.

[23] We discuss other measures constructed using SLIM trades, e.g., SLIM Imbalances, later in this section.

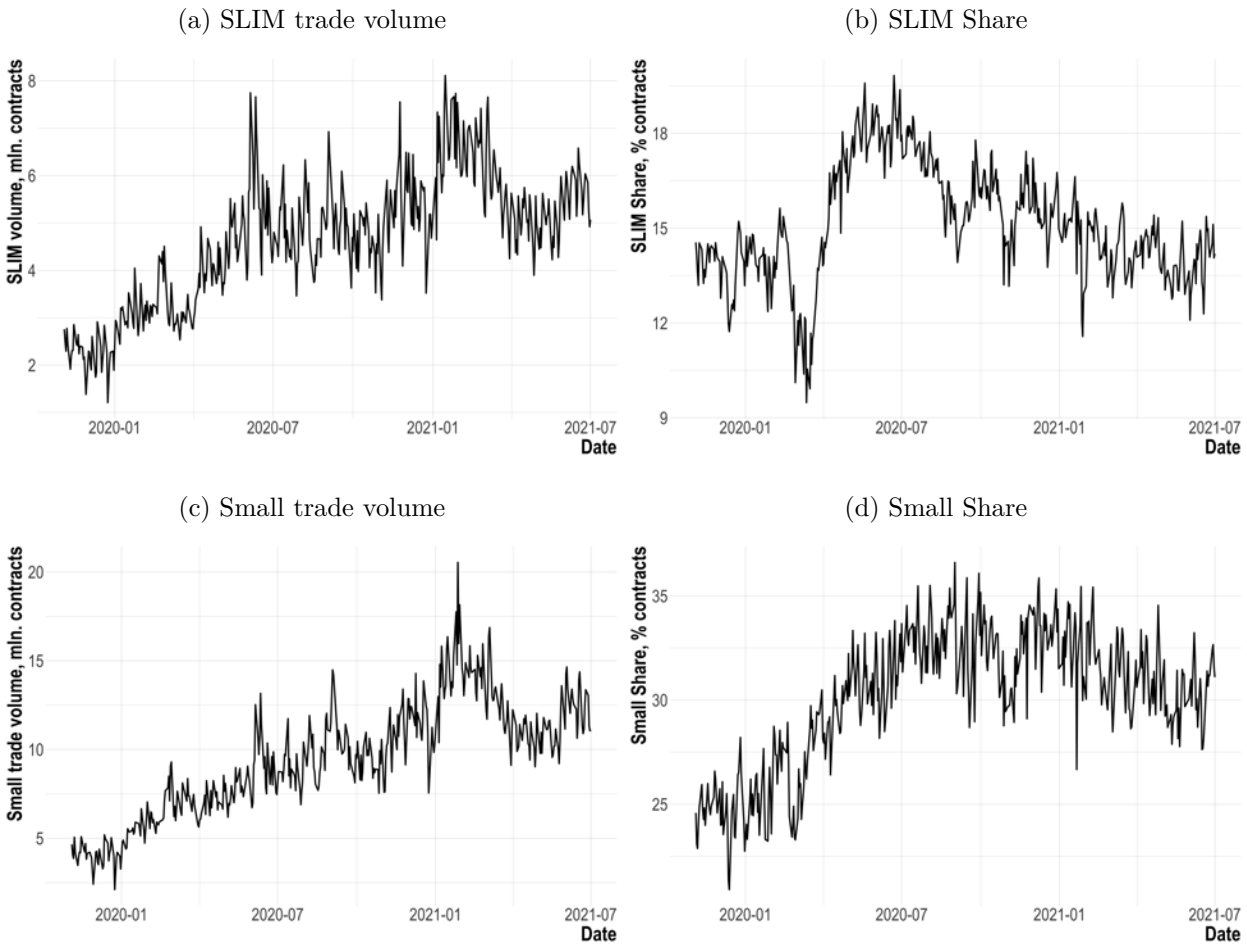
best price, then all liquidity at the next best price, and so on, until the order is filled. Trades that are executed in ISO price improvement auctions have a very different profile than SLIM trades – these are large institutional trades. There are also Multi-leg Price Improvement Auctions, Stock Options Auction, etc. (see Appendix A.2 for more details), which may have have some retail investor transactions, but they are a much noisier measure of retail trading and we therefore restrict our measure to single-leg non-ISO price improvement auctions.

For comparison, we also report a measure of retail trading in options, often used in the media and industry: *Small Share*, the volume share of trades of up to 10 contracts, and the corresponding trading volume in small trades. The frequency share of small trades is 87% in our sample, which overestimates retail investor activity in options. This measure is noisier than SLIM because in addition to retail trades it contains transactions of proprietary trading firms (e.g., Simplex Trading) or ISO orders of large institutional investors, which were broken into smaller trades by order execution algorithms. For example, ISO transactions are reported by OPRA as a collection of separate small transactions for the same contract but at different prices and different exchanges. In our sample, the Small trades measure picks up 16.8% of ISO trades. Using the OPRA flag for ISOs, we can reconstruct the original order by bunching together trades in the same contract at virtually the same time on multiple exchanges – we term them "bunched" ISO trades. In the original sample, the volume share of trades above $20,000 is only 17.6%, while in the bunched sample this share reaches 43.7%. In Section 2.4, we propose a refinement of the Small trades measure based on the new OPRA trade flags, which is a more accurate measure of retail trading.

In Figure 3, we plot our retail trading measure in options, SLIM Share, alongside Small Share. We also plot the total volume of SLIM and small trades. Panels (a) and (c) reveal significant growth of and comovement between SLIM and small trading volumes: Retail investor trading shows a marked increase in our sample. For example, the dollar trading volume in SLIM and small transactions has grown by 104% and 139%, respectively, from January 2020 to July 2021. This is in line with the growth of PFOF for options, which is 158% over the same period, based on monthly data. The growth in retail trading is especially high from January 2020 until March 2021. This period includes several well-publicized retail investor frenzies in equities and a meteoric rise in the number of Robinhood's active users. This increased participation is also reflected in higher average shares, especially in summer 2020, when the average SLIM Share was almost as high as 20%.

Table 1 presents various features of SLIM trades and compares them to non-SLIM trades in the options market. To formally test the differences between them, we compute the average daily characteristics for SLIM and non-SLIM trades across each of the dimensions reported in Table 1. Values in bold correspond to the features of the SLIM trades that are

Figure 3: Retail investor trading in options



This figure characterizes retail investor trading in the U.S. options market between November 2019 and June 2021. Panels (a) and (c) plot total daily trading volumes in SLIM and small trades, respectively. Panels (b) and (d) plot daily SLIM and Small Shares, respectively, averaged across all stocks and ETFs in our sample.

statistically different from those of non-SLIM trades at 1% at a daily frequency. We report the daily averages and test their differences to those of non-SLIM trades in Tables A7 and A8 in the Appendix.

One striking fact is that retail investors prefer to trade options with the shortest maturities: 50.3% of SLIM trades (in terms of their volume share) are in weekly options, compared with 42.8% for the non-SLIM trades. This difference is highly significant, both statistically and economically. The average bid-ask spread in options with less than a week to expiration is a whopping 12.6%. (The effective spread is lower, 6.6%, but it is still orders of magnitude higher than that in equities).

Why do retail investors opt for ultra short-term options? One possible explanation is

that options with the shortest maturity are listed as default on trading apps (e.g., they are a default choice on Robinhood).[24] Another explanation is investor preferences for lotteries or gambling. This explanation is consistent with preferences for skewness discussed in Barberis and Huang (2008) and Boyer and Vorkink (2014) and a number of other behavioral biases (e.g., overconfidence, sensation-seeking, and preferences for gambling), summarized in Table 1 of Liu, Peng, Xiong, and Xiong (2022).[25] Finally, retail investors may simply be cash-constrained. Indeed, weekly options have the lowest prices relative to otherwise identical contracts with longer maturities, so retail investors could opt for the cheapest alternative. At a 12.6% quoted bid-ask spread, the cheapest alternative, however, is by no means cheap to trade. Lured by recent low- or zero-commission offers, retail investors possibly underestimate the indirect trading costs in the options market.[26]

Our analysis reveals that the average quoted bid-ask spread of retail trades across all the maturity buckets is 13.7%, compared to 11.5% for the non-SLIM trades. The former is higher because of the composition of retail trades, which are skewed toward tickers and contracts with higher bid-ask spreads.

Table 1 also reveals that retail investors strongly prefer calls to puts: The volume share in calls is 69%. We further find that written options are more popular with retail investors than purchased options. Retail brokerages in our sample place various restrictions on naked options positions, as detailed in FINRA (2021b). Therefore, while written puts may simply be covered with cash, written calls (that do not simply close a pre-existing long position in the same contract) are most likely part of a covered call strategy. All these findings confirm the results of Lakonishok, Lee, Pearson, and Poteshman (2006), who use account-level data to document the same behavior for customers of a discount brokerage and a full-service one. Finally, Muravyev and Pearson (2020) document that there is a 3.4% sell imbalance in OPRA data for options on S&P 500 stocks.

We observe from Table 1 that retail investors trade mostly at-the-money (72% of trades) or slightly-out-of-the-money (24%) options. The latter involves higher trading costs, with average quoted bid-ask spread of 28.7%. Furthermore, 14.2% of retail trades have a "micro" size of up to $250, compared to 12.4% for non-SLIM trades, and their average

[24] Default options often have a significant impact on financial decision-making; see Madrian and Shea (2001), Choi, Laibson, Madrian, and Metrick (2004), Beshears, Choi, Laibson, and Madrian (2009), and Beshears, Choi, Laibson, Madrian, and Skimmyhorn (2022), among others.

[25] Weekly at-the-money options, favored by retail investors, often have an implied leverage of 58-73. Table A4 in the Appendix reports implied leverage for various option groups. For evidence that the new generation of retail traders in options are cash-constrained, see FINRA (2021a) and Appendix A.32.

[26] The PFOF model and its implications for execution quality and cost transparency have been under scrutiny of regulators for years. See, e.g., the 2021 U.S. Congressional hearing on Robinhood named "Game Stopped? Who Wins and Loses When Short Sellers, Social Media, and Retail Investors Collide.": https://www.nytimes.com/2021/02/19/business/dealbook/robinhood-hearing-congress.html.

Table 1: Composition of SLIM and non-SLIM trades

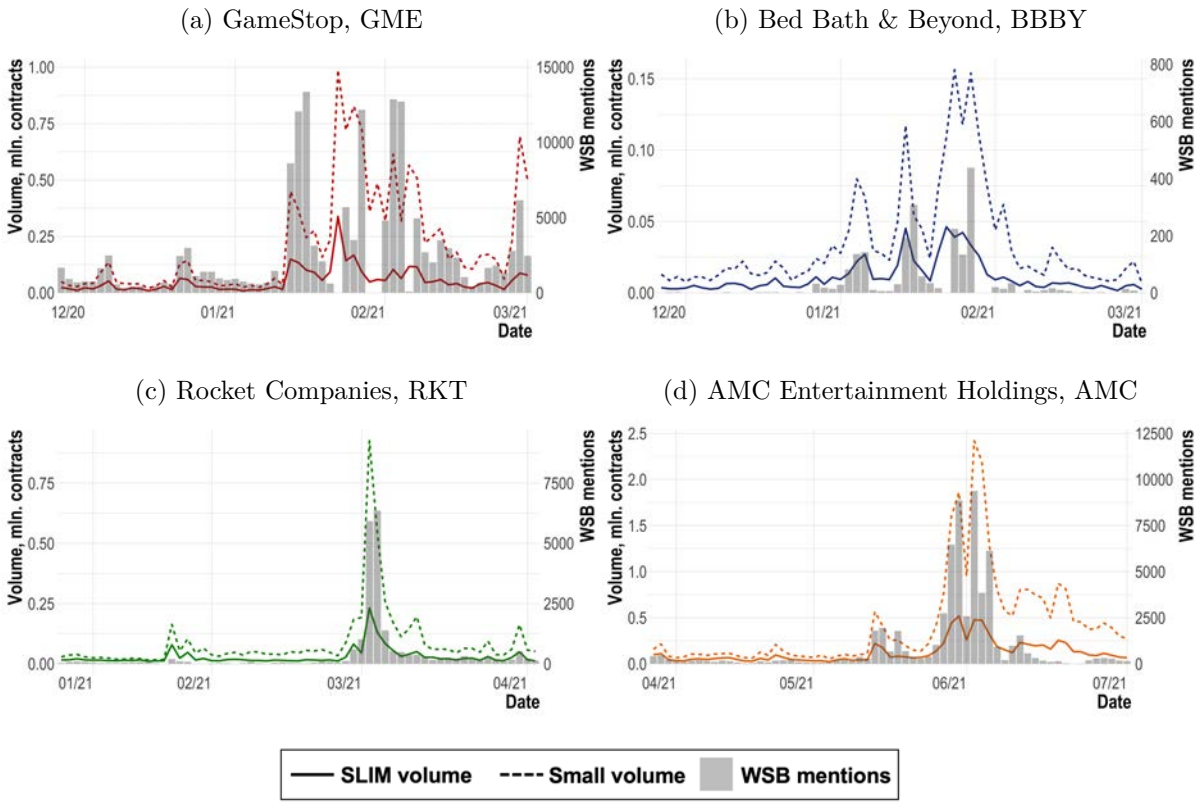
Characteristic	Category	SLIM trades				Non-SLIM trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	**71.5**	**69.3**	**13.5**	**6.6**	64.2	61.4	10.9	8.4
	Put	**28.5**	**30.7**	**14.0**	**6.9**	35.8	38.6	12.6	8.7
Trade size (contracts)	1	**45.6**	**6.2**	**13.9**	**6.4**	43.0	5.3	11.3	8.2
	2-5	31.0	**13.2**	**12.7**	**6.2**	31.7	12.3	11.3	8.3
	6-10	**11.8**	**14.2**	**14.1**	**7.2**	11.6	12.3	12.2	9.2
	11-100	**11.0**	**52.6**	**15.0**	**8.4**	12.6	47.6	12.3	9.8
	Above 100	**0.6**	**13.8**	**15.0**	**12.0**	1.1	22.5	12.8	10.6
Trade size (dollars)	Below 250	**41.2**	**14.2**	**23.6**	**11.7**	36.9	12.4	20.5	15.1
	250-500	**15.5**	**8.9**	**8.7**	**3.9**	14.9	7.5	8.4	5.6
	500-1,000	**13.7**	**11.3**	**7.4**	**3.2**	14.3	9.9	7.0	4.6
	1,000-2,500	**13.8**	**17.3**	**6.2**	**2.6**	15.3	16.0	5.9	3.9
	2,500-5,000	**7.0**	**13.5**	**5.2**	**2.1**	8.1	13.3	5.0	3.3
	5,000-10,000	**4.5**	**13.1**	**4.5**	**1.9**	5.0	12.3	4.3	2.9
	10,000-20,000	**2.5**	10.1	**3.9**	**3.2**	2.8	10.3	3.8	5.4
	20,000-50,000	**1.3**	**7.7**	**3.5**	**6.6**	1.8	9.5	3.3	10.8
	Above 50,000	**0.5**	**4.0**	**3.2**	**11.9**	0.9	8.8	3.0	17.5
Trade direction	Sell	**50.1**	**49.8**	**14.0**	**7.1**	49.3	48.7	10.4	8.0
	Buy	**47.0**	**47.8**	**13.0**	**6.6**	48.0	49.0	12.5	9.6
	Midpoint	**2.9**	2.4	**20.2**	0.0	2.6	2.3	15.5	0.0
Time to expiry	Less than a week	**48.3**	**50.3**	12.6	**6.6**	42.5	42.8	13.1	10.1
	1-2 weeks	**13.9**	**13.0**	**12.4**	**6.0**	14.6	13.4	9.9	7.2
	2-4 weeks	**15.9**	**15.1**	**15.2**	**7.1**	17.1	16.6	11.1	7.6
	1-3 months	**13.3**	**13.4**	**14.0**	**6.2**	15.4	16.0	9.7	6.6
	3-12 months	**7.3**	**7.1**	**18.4**	7.8	8.4	9.3	10.1	7.9
	Over a year	**1.3**	**1.2**	**17.7**	**9.4**	1.9	1.9	12.6	11.9
Moneyness	Below -2	0.3	**0.2**	54.1	**28.4**	0.3	0.3	47.4	32.2
	-2 to -1	0.3	0.4	**50.8**	**25.6**	0.4	0.4	43.9	27.4
	-1 to -0.1	**23.4**	**23.9**	**28.7**	**13.9**	24.0	24.9	21.1	15.0
	At the money	**71.7**	**71.8**	**8.7**	**4.2**	70.1	69.6	8.3	6.2
	0.1 to 1	**4.0**	**3.5**	**8.6**	**4.8**	4.9	4.4	5.8	7.0
	1 to 2	**0.2**	**0.1**	**9.0**	**7.7**	0.2	0.2	6.5	15.1
	Above 2	**0.1**	**0.1**	**16.8**	**11.6**	0.1	0.1	12.0	27.0
Trade direction and type	Sell - Call	**35.5**	**34.3**	**13.7**	**7.0**	31.6	29.8	9.8	7.8
	Sell - Put	**14.5**	**15.5**	**14.6**	**7.5**	17.7	18.9	11.5	8.1
	Buy - Call	**33.9**	**33.4**	**12.9**	**6.6**	31.0	30.3	12.0	9.5
	Buy - Put	**13.1**	**14.4**	13.0	**6.6**	17.0	18.7	13.4	9.9
	Midpoint - Call	**2.1**	**1.6**	**20.8**	0.0	1.6	1.4	14.6	0.0
	Midpoint - Put	**0.9**	**0.8**	**18.6**	0.0	1.0	0.9	17.0	0.0
ETF	No	81.3	**72.4**	**14.9**	**7.2**	81.6	70.6	12.1	9.0
	Yes	18.7	**27.6**	**8.4**	**4.4**	18.4	29.4	8.9	6.7
Total		100	100	13.7	6.7	100	100	11.5	8.6

This table reports characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. The last raw reports frequency-weighted average for the full sample. Here we report the full-sample aggregates, yet SLIM values are reported in bold when they are statistically different from the respective values for non-SLIM trades with the p-value below 1% at a daily frequency (using Newey-West standard errors with the optimal number of lags, which, on average, turns out to be 15 days, see details in Tables A7 and A8 in the Appendix).

quoted bid-ask spread is 23.6%. These observations suggest that retail investors are entering the options market with an intent to speculate rather than hedge – a point made also in Lakonishok, Lee, Pearson, and Poteshman and Bauer, Cosemans, and Eichholtz (2009). All these results are very similar if we use the quote rule to classify trades and exclude open and close trades, as shown in Table A10 in the Appendix.

We note that 11.7% of SLIM trades in Table 1 are above $20,000. The literature on

Figure 4: "Meme" stocks retail trading and `WallStreetBets` mentions in 2021



This figure plots daily `WallStreetBets` (WSB) mentions (gray bars) and daily volume of SLIM and Small trades.

retail trading in equities typically considers such large trades to be institutional (starting from Lee and Radhakrishna (2000)). Throughout the Appendix, we show the robustness of all of our subsequent results to using SLIM trades below $20,000 as our proxy for retail trades. Table A11 in the Appendix shows the descriptive statistics of trades below $20,000, which are very similar to those without the size filter. Table A12 reports the correlations of SLIM trades below $20,000 with equity-based measures of retail popularity. We further discuss potential limitations of our measure of retail trading in options in Section 2.4.

A natural question to ask is how our measures of retail trading in options behave during retail investor frenzies. To illustrate, Figure 4 plots SLIM and small trade volumes alongside counts of `WallStreetBets` mentions for four "meme" stocks: GameStop, Bed Bath & Beyond, Rocket Companies, and AMC. We should note that our measure of `WallStreetBets` mentions has some missing dates due to the retrieval limitations on `reddit.com`, which appear as gaps in the figure.[27] It is apparent from Figure 4 that both measures adequately capture peaks of `WallStreetBets` mentions of these tickers. In Ta-

[27]These limitations can be circumvented only with real-time scraping of `reddit.com` data.

ble 2 below, we establish the cross-sectional relationship between our measure and stock-level retail activity measures formally in a regression framework, for the entire sample.

Having defined our measure of retail activity in the options market, we explore its relationship with the characteristics of both options contracts and their underlying. To do that, we first run the following panel regression, separately for call and put options:[28]

$$SLIM\ Trading_{i,t} = \boldsymbol{\gamma}' X_{i,t} + \boldsymbol{\delta}' C_{i,t} + \alpha_i + \mu_t + \varepsilon_{i,t}. \tag{1}$$

For call or put contracts of each ticker i on date t separately, we consider two measures for $SLIM\ Trading_{i,t}$. The first one is $SLIM\ Share_{i,t}$, the volume share of SLIM trades among all the options transactions in ticker i on date t, which reflects the general presence of retail investors. The second measure is $SLIM\ Imbalance_{i,t}$, in both calls and puts, which is the volume difference in buy and sell SLIM trades scaled by the total volume of SLIM trades, corresponding to a buy or sell tilt in retail investor trades.

Our vector of characteristics $X_{i,t}$ includes the following ticker-level variables: log dollar trading volume in options on $t-1$, log price on $t-1$, log total trading volume (lit, ATS, and non-ATS OTC) in the underlying stock or ETF over the previous week, relative spread in the underlying averaged over the previous week, volatility of the underlying returns over the previous week, and log market capitalization value as of $t-1$. Our vector of contract characteristics $C_{i,t}$, equal-weighted at ticker i level, includes quoted spread, options moneyness, their time to expiration in months, and leverage.[29] We include ticker and date fixed effects, α_i and μ_t. Finally, we report descriptive statistics for all these variables in Table A13 in the Appendix.

Table 2 presents the results of estimating equation (1). A notable feature of SLIM trades is that retail investor share and order imbalance are higher in the options on the underlying with a larger market capitalization and a higher trading volume in the previous week. The latter is consistent with higher retail participation in attention-grabbing securities. Furthermore, retail investors tend to prefer tickers with lower underlying price (and hence, cheaper options as well). In addition, retail trading is more prevalent in the options on more liquid stocks and ETFs. Earlier studies have documented similar relationships for the stock-level imbalances (see Boehmer, Jones, Zhang, and Zhang (2021) and Welch (2022)).[30]

[28] Splitting the contracts allows us to document differential relationship with the past return on the underlying stock or ETF. All the other results remain similar if we pool both types of contracts together.

[29] Results are not sensitive to whether we use equal-weighting or volume-weighting for contract characteristics at a ticker level. Furthermore, our results are robust to including implied volatility, trade size, delta, and other option Greeks, such as theta, vega, and gamma, into the list of contract-level controls.

[30] Both SLIM Share and Imbalance are also correlated with a quasi-Robinhood portfolio, designed to reflect retail-popular tickers. Portfolio weights are based on the previous total trading volume, following the general procedure of Welch (2022). See Table A14 in the Appendix.

Table 2: Retail trading in options and underlying characteristics

	SLIM Share		**SLIM Imbalance**	
	Call	Put	Call	Put
	(1)	(2)	(3)	(4)
Option volume, lagged log	-0.020***	-0.043***	0.040***	0.029***
	(-6.68)	(-17.31)	(13.28)	(9.28)
Underlying price, log	-0.257***	-0.207***	-0.036***	-0.057***
	(-15.42)	(-14.02)	(-3.18)	(-5.55)
Underlying return, past week	-0.005***	0.013***	-0.004***	0.005***
	(-3.87)	(9.84)	(-2.71)	(3.21)
Total volume in underlying, past week log	0.050***	0.042***	0.014***	0.035***
	(8.73)	(8.35)	(2.94)	(6.58)
Underlying spread	-0.028***	-0.012***	-0.017***	-0.013***
	(-7.14)	(-3.19)	(-4.85)	(-3.46)
Underlying volatility, past week	0.000	-0.000	-0.005**	-0.004*
	(0.16)	(-0.02)	(-2.21)	(-1.70)
Market cap, lagged log	0.062**	0.039*	-0.075***	-0.001
	(2.57)	(1.94)	(-4.71)	(-0.08)
Option time to expiration	-0.008***	-0.012***	0.002	-0.001
	(-5.59)	(-9.66)	(1.52)	(-0.86)
Option moneyness	-0.016***	-0.014***	-0.002	0.001
	(-8.70)	(-7.78)	(-1.07)	(0.81)
Option spread	-0.023***	-0.026***	-0.009***	-0.010***
	(-11.76)	(-13.33)	(-3.45)	(-3.68)
Option leverage	0.004**	0.002	0.001	0.001
	(2.04)	(0.88)	(0.30)	(0.46)
Observations	1,436,457	1,248,002	1,106,430	838,604
Adjusted R-squared	0.102	0.077	0.021	0.023

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. SLIM Share is the ticker-level volume shares of SLIM trades. SLIM Imbalance is the ticker-level volume imbalance for SLIM trades. Underlying price (log) is as of the day before. Underlying return is the total return over the last week. Underlying spread is averaged over the previous week. Underlying volatility is return volatility over the previous week. Option spread is the contract quoted relative spread. Option time to expiration (in months), moneyness, spread, and leverage are equal-weighted across trades at a ticker level. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Notably, we see that SLIM Imbalance in calls is likely to be higher in smaller stocks. However, we also see that our chosen set of characteristics has smaller overall explanatory power for imbalances. It suggests that most of the potential price pressure originated from retail investors in the options market seems to be unrelated to fundamentals. This is consistent with the retail flow being fairly balanced and, hence, attractive to market makers.

How are SLIM Share and SLIM Imbalance related to other measures of retail activity?

To answer this question, we run a panel regression similar to that in equation (1) but in addition, consider other measures of retail activity:

$$SLIM\ Trading_{i,t} = \beta Retail_{i,t} + \boldsymbol{\gamma}' X_{i,t} + \boldsymbol{\delta}' C_{i,t} + \alpha_i + \mu_t + \varepsilon_{i,t}, \tag{2}$$

where $Retail_{i,t}$ is one of the following measures of retail activity at a ticker level, $share^{small}$ is the volume share of trades up to 10 contracts for ticker i on date t (within call and put options), *Internalized volume in underlying*$_{i,t}$ is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume of ticker i in the week of date t, *Robinhood ownership breadth,* $log_{i,t}$, is the logarithm of the number of Robinhood users holding the ticker i at the end of date t, and *WSB mentions,* $log_{i,t}$, is the logarithm of the number of times ticker i was mentioned on `WallStreetBets` forum on date t. We use the same set of controls for options contracts ($C_{i,t}$) and their underlying ($X_{i,t}$) as in equation (1).

Table 3 presents the results of estimating equation (2). Our first observation is that the measures of retail trading are positively correlated with both SLIM Share and SLIM Imbalance in the cross-section. This provides further validation of our measure of retail trading in options, with additional supporting evidence presented in Section 4. However, along with the ticker-level X and C characteristics and fixed effects, they explain only 7%–11% of the total variation in SLIM Share, showing very limited improvement over the explanatory power documented in Table 2.

We note that only `WallStreetBets` mentions seem to exhibit no correlation with SLIM Share, albeit they have a very strong relationship with SLIM Imbalance suggesting that ticker popularity on the investor forum is indeed related to the overall buying pressure in both calls and puts, even after conditioning on all the contract and underlying characteristics. The relationship between both SLIM Share and SLIM Imbalance with `WallStreetBets` mentions becomes particularly evident and highly statistically significant if we restrict the sample to micro-trades (of $250 or less), as we show in Appendix A.15. This suggests that micro-trades in options are particularly good in representing the universe of `WallStreetBets` users.

Given that the trading volume in the U.S. options market is highly skewed, one might be concerned that our results hold only for very thinly traded contracts. In Table A16 in the Appendix, we estimate equation (2) for the 341 tickers that constitute the top decile by the total dollar trading volume in our sample. The estimation results are similar to what we document in this section.

Table 3: Retail trading in options and other measures of retail activity

	Retail trading in calls				Retail trading in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: SLIM Share								
Small Share	0.057***				0.053***			
	(23.92)				(25.16)			
Internalized volume in underlying		0.025***				0.019***		
		(8.84)				(6.98)		
Robinhood ownership breadth, log			0.032***				0.061***	
			(3.23)				(6.05)	
WSB mentions, log				-0.002				0.002
				(-0.88)				(1.61)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.104	0.102	0.096	0.113	0.079	0.077	0.071	0.084
Panel B: SLIM Imbalance								
Small Imbalance	0.517***				0.516***			
	(258.12)				(226.56)			
Internalized volume in underlying		0.015***				0.004		
		(5.09)				(1.33)		
Robinhood ownership breadth, log			0.042***				0.031***	
			(4.20)				(3.40)	
WSB mentions, log				0.012***				0.009***
				(9.78)				(6.53)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,102,700	1,106,430	436,475	953,691	834,037	838,604	340,258	751,965
Adjusted R-squared	0.184	0.021	0.026	0.020	0.179	0.023	0.025	0.022

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. SLIM and Small Share are the ticker-level volume shares of SLIM and small trades, respectively. SLIM and Small Imbalance are the ticker-level volume imbalance for SLIM and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

2.3.1 SLIM trading during broker platform outages and trading restrictions

In this section, we exploit trading restrictions on retail platforms to validate our measure of retail trading. We use both aggregate (time series) and stock-level (panel) trading restrictions, already introduced in the literature. First, we follow Eaton, Green, Roseman, and Wu (2022b) and Barber, Huang, Odean, and Schwartz (2022) to show that the retail trading share, as measured by SLIM volume share, significantly goes down when retail broker platforms experience outages. Second, we follow Jones, Reed, and Waller (2021) to show that trading restrictions on particular tickers are also associated with a lower SLIM share in those tickers. Combining two types of restrictions allows us to use both time-series and cross-sectional variation to validate SLIM, and mitigate concerns related to our measurment

of restrictions.

Eaton, Green, Roseman, and Wu (2022b) and Barber, Huang, Odean, and Schwartz (2022) use the data on outages from DownDetector.com[31] and Robinhood incident history, respectively, to study the effects of retail trading in stock markets. The data of Eaton, Green, Roseman, and Wu covers more brokers but it is not public. However, DownDetector.com reports the largest outages for each broker in our sample on its Twitter account. We hand-collect that data and construct a sample of outages covering large brokers from public sources. Details on how we construct this sample are presented in Appendix A.17. We study the effects of outages on retail trading in a sample of the top 100 most mentioned tickers on `WallStreetBets` during our full sample period.

The unprecendented volatility in certain stocks resulted in many retail brokers restricting trading in January 2021. Jones, Reed, and Waller (2021) study the effect of those restrictions on the overall stock and options trading activity. We identify the timing of restrictions in two ways. First, we precisely follow the timings reported in Table 1 of Jones, Reed, and Waller, that cover the restrictions introduced by Robinhood and TD Ameritrade and are based on the snapshots from the Internet Archive Wayback Machine. Second, since the snapshots from the Wayback Machine are infrequent, we refine the list of restrictions by manually searching for online posts on Twitter and reddit.com related to the restrictions. This allows us to make the starting and ending time more precise and to add more tickers to the sample. Further details and the table with the resultant restrictions for the second approach are reported in Appendix A.18.

To identify the effect of restrictions on the retail trading share, we estimate the following panel regression:

$$SLIM\ Share_{i,t} = \sum_j \beta_j D(Broker\ j\ restricted)_{j,i,t} + \boldsymbol{\gamma}' X_{i,t} + \alpha_{i,d} + \mu_{tod} + \varepsilon_{i,t}. \qquad (3)$$

In equation above, $SLIM\ Share_{i,t}$ is the share of SLIM volume in the total volume of trading in options on stock i in minute t. $D(Broker\ j\ restricted)_{j,i,t}$ is a dummy variable equal to 1 if broker j had a trading restriction on stock i in minute t. Since outages affect trading in all stocks on a broker platform, $D(Broker\ j\ restricted)_{j,i,t} = 1$ for all i if broker j experiences an outage in minute t. $X_{i,t}$ is a set of additional stock-level controls such as the logarithm of total trading volume and the logarithm of stock price two days before minute t, as well as the change in log volume and log price from one day before minute t to minute $t-1$. $\alpha_{i,d}$ are ticker by date fixed effects, and μ_{tod} are time-of-the-day fixed effects.[32] We cluster standard

[31] DownDetector.com is the largest consolidator of outage data.

[32] When using ticker-level restrictions, we are only able to include α_i with α_d, or ticker and date fixed effects,

errors by ticker and minute. We report estimation results with and without controls $X_{i,t}$, and our results are not sensitive to the exact definition of these controls. Because outages occurred throughout our main sample, we include all days when estimating regression (3). In contrast, ticker-specific restrictions concentrated in January-March 2021, so we restrict the sample to 30 days before the start of the first restriction and 30 days after the end of the last restriction, although the results do not change if we consider narrower estimation windows.

Table 4 reports the estimation results. Consistent with SLIM picking up retail trades, we find that SLIM Share in a ticker is significantly lower in the minute when broker restrictions are in place, both statistically and economically. Columns (1)-(2) reveal that when the largest retail brokers in options experience outages, SLIM Share is almost 1 percentage point lower in stocks most popular with retail investors. When ticker-level restrictions are considered, the magnitudes are even larger. Columns (3)-(4) show that SLIM Share is up to 4.5 percentage points lower when Robinhood restricts trading, over 2 percentage points lower when TD Ameritrade or Charles Schwab restrict trading, and over 6 percentage points lower when trading is restricted for all of them. Volume and price controls do not significantly change the estimates.[33] The magnitudes are also similar in columns (5)-(6), in which we use our refined sample of restrictions, yet the estimates are more precise, as expected.

Given our data sources, it is unlikely that we measure the timing of both outages and ticker-level restrictions in a precise way. Nevertheless, we expect any measurement error in the restrictions to attenuate the estimates, making it harder for us to find the relationship between SLIM Share and restrictions.

For ticker-level restrictions, our baseline is the sample of restricted stocks augmented with the sample of stocks with the top 100 number of mentions on `WallStreetBets` during the sample period. In Appendix Table A19, we also report the results for two alternative samples: the sample of restricted stocks only and the baseline sample augmented with stocks with at least two retail herding events (frenzies) in the data of as defined by Barber, Huang, Odean, and Schwartz (2022).[34] We deem stocks in the baseline sample to be most comparable to each other, though the estimates are stable across the samples.

because of very limited intraday variation in the restrictions imposed by TD Ameritrade. Furthermore, using minute fixed effects instead of time-of-the-day fixed effects for ticker-level restrictions produces very similar results.

[33] Ticker-level restrictions and especially outages are likely to be exogenous to ticker-level retail trading shares. We include the recent stock price and trading volume changes as well as their lagged values to make sure that the estimates are stable.

[34] We thank Brad Barber for kindly sharing data on herding events.

Table 4: Trading restrictions and retail trading in options

	SLIM Share					
	Outages		Restrictions of Jones, Reed, and Waller (2021)		Refined restrictions	
	(1)	(2)	(3)	(4)	(5)	(6)
D(RH restricted)	0.072	0.190	-4.440**	-4.075*	-3.078***	-2.794
	(0.47)	(1.19)	(-2.03)	(-1.67)	(-2.67)	(-1.59)
D(TD restricted)	-0.223**	-0.153	-2.021**	-2.421**	-2.195***	-1.905***
	(-2.17)	(-1.48)	(-2.58)	(-2.57)	(-3.41)	(-3.31)
D(Both restricted)	-0.996***	-0.730***	-6.156***	-3.398**	-6.329***	-4.304***
	(-3.52)	(-2.78)	(-3.07)	(-2.27)	(-3.83)	(-3.23)
Lagged log volume, 2-day		-0.003		-0.151**		-0.116*
		(-0.24)		(-2.30)		(-1.93)
Lagged log price, 2-day		1.317		-3.739***		-3.591***
		(1.27)		(-3.88)		(-5.14)
Log volume change, one day		-0.378***		-0.464***		-0.454***
		(-16.64)		(-15.98)		(-16.32)
Log price change, one day		1.712		-4.401***		-3.832***
		(1.59)		(-3.63)		(-4.47)
Observations	3,793,278	3,237,765	2,340,612	1,952,774	3,009,692	2,489,629
Adjusted R-squared	0.100	0.100	0.110	0.119	0.104	0.110
Fixed effects	Ticker*Date and Time of day		Ticker, Date, Time of day			
Sample	100 WSB		Restricted + 100 WSB			

This table reports the results of estimating (3) in a minute-ticker panel. Columns (1)-(2) use outages as restrictions, columns (3)-(4) use ticker-level restrictions from Jones, Reed, and Waller (2021), and columns (5)-(6) use ticker-level restrictions from our sample. $D(RH\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by Robinhood in minute t, and 0 otherwise. $D(TD\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by TD Ameritrade or Charles Schwab (from October 2020) in minute t, and 0 otherwise. $D(Both\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by both Robinhood and TD Ameritrade/Charles Schwab in minute t, and 0 otherwise. SLIM Share is the ticker-level volume share of SLIM trades. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. In columns (1)-(2), the sample includes the top 100 most mentioned tickers on `WallStreetBets` (100 WSB). In columns (3)-(6), we augment that with the restricted tickers. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

2.4 Alternative measures of retail trading in options

Our measure of retail trading has a few limitations. First, 11.7% of the SLIM volume is concentrated in transactions with over $20,000 in value (see Table 1), which is considered a cutoff for retail trades in the related literature on equities (see, e.g., Lee and Radhakrishna (2000)). We therefore exclude trades above this size in our robustness checks. Table A12 in the Appendix confirms that the results are virtually the same. We also do not see a small fraction of retail trades that do not go through a wholesaler and instead are sent directly to exchanges, e.g., those originated by semi-professional traders on Interactive Brokers.

Second, and more importantly, our measure omits some retail trades executed through trade types other than SLIM. These other trades may include non-marketable limit orders. Furthermore, depending on the order attractiveness, some trades may be routed by a wholesaler to an affiliated or other specialist on an exchange, instead of running it through a price improvement mechanism. We attempt to capture these trades in our alternative measures of retail trading presented below.

Third, our measure omits complex strategies, such as bull spreads, straddles, or butterfly spreads. Complex strategies typically require multi-leg transactions, and, therefore, wholesalers looking for price improvement would usually execute them via multi-leg price improvement auctions, as opposed to single-leg ones. In the OPRA data, these transactions appear as a trade type "MLAN" (multi-leg non-ISO price improvement mechanism) and we refer to them as "MLIM" for consistency. These MLIM trades correspond to about 4% of the total market volume, and they are composed primarily of trades of 'protail' investors – small professional investors and hedge funds – albeit some may be those of retail investors. We have also computed mentions of multi-leg strategies on `WallStreetBets` in our sample period and found that those constitute a very small number relative to the mentions of individual tickers and comments overall. In addition, in Appendix A.20, we report descriptive statistics and cross-sectional correlations of MLIM with the equity-based measures of retail activity. It further demonstrates that these trades are clearly quite different in nature to those going through single-leg actions. Since we want to capture trading of the new generation of retail investors, we are hesitant to include MLIM trades in our analysis.[35]

Despite all these limitations, our measure provides the first comprehensive classification of retail trades in the options market. We are not aware of a reliable approach to estimate type 1/type 2 errors of our method. Nevertheless, we believe that the majority of the trades we capture originated from retail investors, and they can be used as a representative sample to study investor preferences and behavior in the options market. It is

[35]Tables A22 and A23 in the Appendix demonstrate that all multi-leg trades taken together and trades above $50,000 are also clearly different from SLIM trades.

reassuring that in independent contemporaneous work, Ernst and Spatt (2022) and Hendershott, Khan, and Riordan (2022) rely on the same empirical strategy to classify retail trades in the options market. (Their findings are complementary to ours, as they focus on the order execution quality and market microstructure.) In Section 4, we provide more evidence that our measure reflects retail trading in the U.S. options market.

We now propose several alternative measures of retail trading in options. The first measure, also proposed by Ernst and Spatt (2022), takes advantage of another way to "internalize" retail orders, facilitated by exchanges. If an order is routed to a market maker who is a Designated/Primary market maker (formerly a specialist) in a ticker and it currently quotes at the NBBO, this market maker has priority to execute, at NBBO, any order of 5 contracts or fewer in full.[36] That is, the Designated market maker can effectively internalize these orders. There are 16 options exchanges in the U.S., and for most tickers, a wholesaler can route a retail order of up to 5 contracts to an exchange in which it is a Designated market maker in that ticker. Our empirical proxy for these trades is single-leg electronic trades (OPRA trade type "AUTO") of 5 contracts or fewer, priced at NBBO. Together with SLIM, these trades form our *All Internalized* measure.

What fraction of retail trading volume do SLIM and All Internalized measures capture? To answer this question, we present a back-of-the-envelope calculation of the wholesaler-intermediated trading volume using Rule 606 (PFOF) disclosures from the brokers in our sample. Specifically, we divide the total monthly dollar PFOF from Rule 606 reports for each order category – market, marketable limit, non-marketable limit, and other orders – by an average PFOF per contract in that category, which yields the PFOF-implied trading volume.[37] The estimates of the Rule-606 implied trading volume and their splits by order type are presented in Table 5. When assessing these figures, one should keep in mind the fact that the trading volume implied from the Rule 606 reports is an overstatement of the actual retail trading volume in our sample. This is because some retail orders are executed against other retail orders (e.g., a market buy order against a sell order resting in the limit order book): Such transactions receive PFOF for both the buy and the sell order from wholesalers but are counted as one transaction in the OPRA data. Nonetheless, the total Rule-606 implied trading volume computed in Column (1) of Table 5 establishes a useful upper bound on the volume of the wholesaler-intermediated retail transactions.

By contrasting Columns (2) and (6) of Table 5, we conclude that the SLIM method-

[36] See e.g., https://www.sec.gov/rules/sro/cboeedgx/2018/34-84697-ex5.pdf, paragraph (g)(2), or https://www.federalregister.gov/documents/2021/05/20/2021-10579/self-regulatory-organizations-box-exchange-llc-notice-of-filing-and-immediate-effectiveness-of-a#citation-17-p27492, Rule 7135(c)(2)(iii).

[37] We thank the anonymous referee for suggesting this calculation to us.

Table 5: Trading volume implied by Rule 606 reports and by our measures of retail trading

Month	Rule 606 reports: Implied 606 volume	Market and market. limit orders	Non-market. limit orders	Other orders	OPRA market volume	Retail volume as % of Implied 606 volume: SLIM	SLIM + ≤ 5 Single-Leg Electronic at NBBO	SLIM + Small Single-Leg Electronic	SLIM + Small+Cheap Single-Leg Electronic	Implied 606 volume as % of market volume
	(1)	(2)	(3)	(4)	(5)	(6)	All Internalized	All Retail	All Retail	(1)/(5)
01/20	195.5	41.7%	35.8%	22.5%	449.7	31.9%	50.1%	66.0%	117.8%	43.5%
02/20	213.8	38.3%	37.6%	24.1%	485.3	30.5%	50.0%	66.6%	113.0%	44.1%
03/20	248.0	30.3%	52.0%	17.7%	548.1	26.4%	46.3%	66.0%	103.2%	45.3%
04/20	260.2	41.8%	42.9%	15.3%	500.7	31.0%	50.4%	65.8%	104.5%	52.0%
05/20	268.6	44.5%	39.4%	16.1%	500.5	33.6%	52.0%	67.3%	103.8%	53.7%
06/20	345.1	44.8%	41.0%	14.2%	647.8	33.9%	53.0%	69.0%	105.2%	53.3%
07/20	297.9	45.9%	39.1%	15.0%	578.5	34.1%	55.8%	71.8%	108.3%	51.5%
08/20	300.7	46.0%	38.2%	15.9%	602.3	32.7%	55.0%	71.5%	109.3%	49.9%
09/20	311.4	44.4%	39.5%	16.0%	676.8	33.7%	57.6%	75.5%	116.0%	46.0%
10/20	288.1	44.5%	38.7%	16.7%	629.8	34.7%	57.8%	75.1%	116.6%	45.8%
11/20	302.4	45.6%	39.5%	14.9%	582.7	29.6%	50.7%	66.3%	103.6%	51.9%
12/20	352.9	46.9%	37.6%	15.4%	744.9	32.9%	57.1%	74.8%	116.7%	47.4%
01/21	395.1	45.0%	39.9%	15.2%	865.2	31.8%	56.0%	74.2%	115.1%	45.7%
02/21	408.6	45.1%	39.5%	15.4%	848.3	30.1%	52.5%	69.6%	109.2%	48.2%
03/21	427.2	45.1%	39.6%	15.3%	918.1	30.3%	53.6%	71.3%	114.4%	46.5%
04/21	345.7	46.2%	37.5%	16.3%	716.5	29.9%	52.0%	68.3%	111.7%	48.2%
05/21	325.9	44.0%	37.6%	18.4%	724.1	29.9%	52.5%	69.8%	116.3%	45.0%
06/21	426.2	46.1%	37.3%	16.6%	892.8	29.0%	50.9%	68.0%	113.4%	47.7%
Average	**317.4**	**43.7%**	**39.6%**	**16.7%**	**661.8**	**31.5%**	**53.0%**	**69.8%**	**111.0%**	**48.1%**

This table compares the monthly trading volumes across several measures. Column (1) reports the total trading volume implied by the Rule 606 reports (million contracts). This volume is computed as the payment for order flow divided by the average payment per contract aggregated over the four reported order types (market, marketable limit, non-marketable limit, and other orders). Columns (2)-(4) report the weight of individual order types in the total implied volume. Column (5) reports the total OPRA trading volume (million contracts). "SLIM + ≤ 5 Single-Leg Electronic at NBBO" combines SLIM trading volume with that in trades sized up to 5 contracts that go through trade type "AUTO" (single-leg electronic) and are executed at the best bid or best ask price. "SLIM + Small Single-Leg Electronic at NBBO" combines SLIM trading volume with that in trades sized up to 10 contracts that go through trade type "AUTO" (single-leg electronic). "SLIM + Small + Cheap Single-Leg Electronic at NBBO" combines SLIM trading volume with that in trades sized up to 10 contracts and in trades with dollar value up to $5,000 that go through trade type "AUTO" (single-leg electronic). The data are from SEC Rule 606 reports in columns (1)-(5) and from OPRA otherwise.

ology identifies between 63% (June 2021) and 87% (March 2020) of trading volume from market and marketable limit orders reported in Rule 606 disclosures. To capture the remaining market and marketable limit orders, we next consider the expanded measure, or All Internalized trades. Table 5 reveals that the All Internalized trading volume exceeds Rule-606 implied volume originating from market and marketable limit orders. We view this as evidence that the internalized trading volume includes some volume from non-marketable limit orders. Barardehi, Bernhardt, Da, and Warachka (2021) argue that in equity markets wholesalers find it profitable to internalize a fraction of non-marketable orders. Since quoted spreads in equities are much tighter than in options, and moreover since quoted spreads in options are so wide – the average quoted and effective spreads for SLIM transactions are 13.7% and 6.7%, respectively (see Table 1) – we expect that a fraction of non-marketable limit orders in options does get internalized through SLIM.

It is evident from Table 5, however, that the SLIM or All Internalized methodologies do not pick up all retail trades. The omitted trades are primarily non-marketable limit orders that wholesalers send to the limit order book on an exchange. We therefore attempt

to construct an All Retail measure, which captures additionally transactions originating from non-marketable orders that are not captured by SLIM. The literature to date has not offered a reliable method to classify such trades in the OPRA data, and we therefore propose our own. We start from the measure of retail trading used in the industry, Small trades (i.e., transactions of up to 10 contracts). As we have discussed in Section 2.3, the Small trades measure overstates retail presence, and we therefore attempt to reduce the number of false positives. In our *All Retail (small)* measure, we include only a fraction of Small trades, namely, single-leg electronic trades under 10 contracts. The latter are our proxy for non-marketable retail orders sent to the limit order book. We note that we can identify single-leg electronic trades accurately using the new OPRA trade flags. By construction, All Retail (small) measure includes all of All Internalized transactions.

The new generation of retail options investors is likely to be cash constrained. FINRA (2021a) reports that more than twice as many new investors who opened brokerage accounts in 2020 held account balances less than $500 (33%) when compared to experienced entrants (16%), and more than five times as many when compared to existing account owners (6%). In our *All Retail (small + cheap)* measure, we therefore broaden our All Retail (small) measure by additionally including "cheap" trades, defined as single-leg electronic transactions of up to $5,000. Table 5 shows that All Retail (small) captures 70% of the Rule-606 implied trading volume, while All Retail (small + cheap) slightly overshoots it, exceeding it by 11%.

To establish that SLIM transactions are similar to those constituting our broader measures of retail trading, we first compare their descriptive statistics. In Appendix A.23, we provide the descriptive statistics for All Internalized and All Retail measures and show that they are generally in line with those for SLIM trades, reported in Table 1 (see also Tables A7 and A8 in the Appendix).

We next conduct validation tests, described in Section 2.3.1, in which we seek to check whether All Internalized and both All Retail measures drop during outages experienced by the two largest U.S. retail brokerages. Table A30 in the Appendix confirms that it is indeed the case. The results are strong for All Internalized measure. They weaken for our broader measures, All Retail (small) and All Retail (small + cheap). This is to be expected. As we expand the retail trading measures by including more transactions, we inevitably make them noisier. The significance of the coefficients reported in Table 4 therefore reduces. Yet, the coefficients on the dummy variables for TD Ameritrade/ Charles Schwab and Both outages remain consistently negative, even for our broadest measures. Similarly to SLIM, they all fall by around 1 percentage point.

We obtain similar results for a validation test involving trading restrictions imposed by retail brokerages on a number of tickers that are popular with retail investors. Specifically,

we estimate regression (3) using our broader measures of retail trading in options instead of SLIM. Table A31 in the Appendix reports the results. Similarly to SLIM, all the measures of retail trading are more than 6 percentage points lower when broker restrictions are in place. We find mostly negative but insignificant reductions in retail share under TD restrictions, though the coefficients on D(TD restricted) are not significantly different from those for SLIM. The results are similar irrespective of the chosen sample of tickers (see Tables A32 and A33 in the Appendix).

Finally, we look at comovement of our All Internalized and All Retail measures with established retail investor popularity indicators. Tables A34, A35, and A36 in the Appendix, which are the analogs of Table 3 for SLIM, report the results. As evident from Panel A of the tables, our broader broader measures are positively correlated with measures of retail activity, such as Small share, internalized volume in equities, Robinhood breadth of ownership, and `WallStreetBets` mentions. As evident from Panel B, imbalances in our All Internalized and All Retail measures, for the most part, are also positively correlated with the measures of retail activity. We attribute the weakening of these results relative to their analogs for SLIM to the fact that our broader proxies for retail trading – All Internalized, All Retail (small), and All Retail (small + cheap) – are noisier measures of retail trading than SLIM.

Overall, our alternative measures of retail trading are consistent with what we find for SLIM. Yet, the evidence in favor of them representing a clean cross-section of retail orders is weaker. To this day, there is no reliable identification method for non-marketable retail orders submitted to the limit order book. Our main concern with the All Retail measures we propose above are the false positives that they contain. In the analysis that follows, we therefore stick to our SLIM methodology for identifying retail transactions.

3 Aggregate performance of retail investors in the U.S. options market

We compute dollar performance of each retail trade j over the horizon of h days:

$$\$Perf_{hj} = Direction_j \times Size_j \times 100 \times (Price_{j,t+h} - Price_{j,t}), \tag{4}$$

where $Size_j$ is the size of the trade in contracts,[38] $Price_{j,t+h}$ is the price of the traded contract at $t+h$, $Price_{j,t}$ is the price of the traded contract at t, and $Direction_j$ is the trade direction sign: 1 for buy trades and -1 for sell trades. We consider horizons h of one, two,

[38] We winsorize trade sizes as in our earlier analysis at 99.50^{th} percentile each day. Results are not sensitive to the winsorization.

five, and 10 days, as well as until the contract expiration.[39] We also report the intraday performance, which is till the close of the trade day.

We evaluate the contribution of gross performance and transaction costs separately. To compute the gross performance, we use midpoint prices: $Trade\,midquote_{j,t}$, or the bid-ask midquote at the time of the trade, for $Price_{j,t}$ and $Close\,midquote_{j,t+h}$, or the close midquote of the traded contract on day $t+h$ as reported by OptionMetrics, for $Price_{j,t+h}$. To compute the net performance, we assume that all transaction costs are paid when the trade is open, so we use the actual trade price for $Price_{j,t}$ and $Close\,midquote_{j,t+h}$ for $Price_{j,t+h}$. We do not explicitly consider trading costs paid as investors close their positions because some of them are held to expiration. In Section 2, we have shown that retail investors in our sample prefer ultra short-term options, and therefore it is likely that many of them are held to expiration. By ignoring trading costs at the end of the performance evaluation horizon, we are providing an upper bound for investor net performance.

We aggregate the trade-level performance defined in (4) into the total retail portfolio and report its daily average dollar performance in Table 6 (panel A). We also compute the performance of the buy and sell portfolios separately (panel B) by summing up the dollar performance of trades with the implied buy and sell direction, correspondingly. These calculations are consistent with the buy, sell, and buy minus sell portfolio performance calculations in Barber, Lee, Liu, and Odean (2008). We also report performance of trades aggregated over several dimensions specific to options such as contract type (call retail portfolio versus put retail portfolio), moneyness, and time to expiration.

Table 6 summarizes the daily mean performance of retail investor options trades. Even though performance before transaction costs of the buy minus sell portfolio in panel A is positive across horizons, ranging from \$8.2 to \$11.6 million per day, adding the observed transaction costs makes it significantly negative, between -\$3.8 and -\$6.2 million per day.

Curiously, the average performance of the sell portfolio is positive net of the observed transaction costs and, with the exception of intraday and one-day performance, not statistically different from zero. On the other hand, the buy portfolio incurs losses on average, even on a gross basis. Furthermore, net retail investor losses are concentrated in at-the-money calls with a very short time to expiration (less than a week).

Table A37 in the Appendix reports the aggregate performance between November 2019 and June 2021. Under the assumption of a 10-day holding period, retail investors lost \$2.22 billion on their options trades. Similar to the mean daily results in Table 6, the aggregate losses were concentrated in buy trades on at-the-money calls with less than a week

[39] We are using the last available price when the data for a certain horizon is not available. Note that at the time of writing, the OptionMetrics data covered the time period only up to December 31, 2021.

Table 6: SLIM daily performance, by trade direction and contract characteristics

	Gross performance, $ mln.						Net performance, $ mln.					
Horizon h	Intra-day	1 day	2 days	5 days	10 days	Expi-ration	Intra-day	1 day	2 days	5 days	10 days	Expi-ration
Panel A: All contracts												
	10.22	11.64	10.60	10.41	10.12	8.18	-5.22	-3.80	-4.83	-5.02	-5.32	-6.18
	(14.07)	(13.35)	(9.36)	(5.80)	(5.65)	(3.29)	(-11.37)	(-5.97)	(-4.19)	(-2.72)	(-2.80)	(-2.21)
Panel B: By trade direction												
Sell	12.88	18.99	23.25	21.22	16.05	-28.24	3.89	10.01	14.26	12.24	7.07	-36.63
	(7.25)	(2.85)	(2.17)	(1.13)	(0.66)	(-0.92)	(2.35)	(1.50)	(1.34)	(0.66)	(0.29)	(-1.20)
Buy	-2.66	-7.35	-12.64	-10.81	-5.93	36.42	-9.11	-13.80	-19.10	-17.26	-12.39	30.45
	(-1.59)	(-1.10)	(-1.22)	(-0.59)	(-0.24)	(1.21)	(-5.25)	(-2.07)	(-1.83)	(-0.94)	(-0.51)	(1.01)
Panel C: By contract type												
Call	7.32	8.16	6.99	6.50	5.83	4.22	-3.68	-2.83	-4.00	-4.50	-5.16	-5.91
	(13.08)	(10.93)	(6.36)	(3.62)	(3.25)	(2.03)	(-10.91)	(-4.19)	(-3.42)	(-2.36)	(-2.62)	(-2.54)
Put	2.90	3.48	3.61	3.92	4.29	3.96	-1.54	-0.97	-0.83	-0.53	-0.16	-0.27
	(15.06)	(10.15)	(8.81)	(6.66)	(6.18)	(3.12)	(-8.21)	(-3.78)	(-2.37)	(-0.96)	(-0.24)	(-0.20)
Panel D: By moneyness												
Below -2	0.06	0.06	0.06	0.06	0.07	0.07	-0.03	-0.03	-0.02	-0.03	-0.02	0.01
	(5.30)	(6.04)	(6.04)	(3.98)	(4.25)	(4.32)	(-6.42)	(-4.33)	(-3.99)	(-2.81)	(-1.77)	(0.79)
-2 to -1	0.06	0.06	0.06	0.06	0.07	0.05	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03
	(8.29)	(7.96)	(6.58)	(4.77)	(3.50)	(1.87)	(-11.32)	(-6.81)	(-5.39)	(-3.35)	(-1.52)	(-1.56)
-1 to -0.1	2.70	3.27	3.27	3.87	4.05	3.34	-1.21	-0.64	-0.64	-0.04	0.13	-0.09
	(12.31)	(13.18)	(11.55)	(10.51)	(8.24)	(4.66)	(-8.72)	(-3.89)	(-2.49)	(-0.16)	(0.30)	(-0.12)
At the	6.56	7.20	6.23	5.60	5.27	4.98	-3.35	-2.71	-3.67	-4.30	-4.64	-4.61
money	(13.54)	(11.23)	(6.58)	(3.47)	(3.26)	(2.37)	(-10.83)	(-4.15)	(-3.84)	(-2.61)	(-2.77)	(-2.04)
0.1 to 1	0.91	1.13	1.03	0.91	0.83	-0.03	-0.41	-0.19	-0.29	-0.41	-0.49	-1.15
	(11.24)	(8.80)	(7.47)	(3.96)	(2.91)	(-0.07)	(-6.67)	(-1.74)	(-2.02)	(-1.69)	(-1.58)	(-2.63)
1 to 2	0.04	0.03	0.09	0.02	-0.02	-0.00	-0.04	-0.04	0.01	-0.05	-0.09	-0.05
	(1.94)	(0.90)	(1.52)	(0.51)	(-0.34)	(-0.04)	(-1.67)	(-1.39)	(0.25)	(-1.69)	(-1.71)	(-0.53)
Above 2	-0.11	-0.11	-0.14	-0.11	-0.15	-0.22	-0.14	-0.15	-0.18	-0.15	-0.18	-0.24
	(-3.09)	(-3.12)	(-2.30)	(-1.87)	(-2.22)	(-3.25)	(-3.72)	(-3.92)	(-2.64)	(-2.33)	(-2.62)	(-3.56)
Panel E: By time to expiration												
Less than	3.95	4.20	3.51	3.09	3.09	3.08	-2.28	-2.03	-2.72	-3.14	-3.14	-3.14
a week	(12.29)	(7.80)	(4.73)	(3.38)	(3.38)	(3.36)	(-9.83)	(-4.56)	(-3.54)	(-3.14)	(-3.14)	(-3.13)
1-2 weeks	1.31	1.35	1.11	0.70	0.49	0.49	-0.48	-0.44	-0.67	-1.08	-1.30	-1.28
	(11.53)	(6.95)	(4.22)	(0.96)	(0.68)	(0.69)	(-7.78)	(-2.55)	(-2.50)	(-1.44)	(-1.79)	(-1.77)
2-4 weeks	1.76	2.03	1.88	1.86	1.62	1.36	-0.67	-0.40	-0.55	-0.56	-0.81	-1.04
	(12.52)	(10.83)	(8.84)	(5.16)	(3.67)	(1.79)	(-8.42)	(-3.28)	(-3.09)	(-1.70)	(-1.89)	(-1.41)
1-3 months	1.64	2.01	1.96	2.23	2.35	2.78	-0.74	-0.36	-0.41	-0.15	-0.02	0.46
	(15.38)	(14.65)	(14.15)	(11.12)	(8.87)	(4.48)	(-8.73)	(-3.40)	(-3.64)	(-0.77)	(-0.09)	(0.67)
3-12 months	1.16	1.47	1.54	1.86	1.95	-0.55	-0.73	-0.42	-0.36	-0.03	0.06	-2.13
	(10.98)	(9.89)	(9.48)	(6.27)	(3.99)	(-0.45)	(-8.52)	(-5.39)	(-2.93)	(-0.17)	(0.13)	(-1.62)
Over a year	0.41	0.57	0.61	0.67	0.62	1.02	-0.32	-0.15	-0.12	-0.06	-0.10	0.95
	(16.86)	(14.02)	(11.04)	(7.75)	(4.24)	(3.37)	(-10.71)	(-4.27)	(-2.30)	(-0.65)	(-0.66)	(3.22)

This table reports the mean daily performance of SLIM trades from November 2019 to June 2021. Gross and net performance of each type is computed as explained in Section 3. t-statistics based on Newey-West standard errors with the optimal number of lags are in parentheses.

to expiration.

In Table A38 in the Appendix, we report the overall trade performance by month and day of the week. Retail investor losses are not concentrated in any particular month, while, at the same time, January-February 2021 and February 2020 are the worst months in our sample, corresponding to losses of $650, $362, and $213 million respectively (using

net performance at a 10-day horizon). The same table reveals that, on average, investor performance seems to be lower when the holding period includes weekends.

Table A39 in the Appendix reveals the top and bottom 10 tickers, based on the aggregate net performance of trades originated by retail customers and those of the whole market. Similar to the latter, retail investors realized a gain on such large-cap names as Nvidia (NVDA), Alibaba (BABA), and Moderna (MRNA). Interestingly, however, in contrast to the market, they lost on trading in "meme" stocks, such as GameStop (GME) and AMC Entertainment (AMC), and on the United States Oil Fund (USO).

The dollar performance measure, considered so far, is our preferred performance indicator because it reveals where the aggregate retail losses come from and also allows us to compare performance in the types of contracts SLIM investors prefer trading, or in other words, where most of SLIM trading volume is.

To compare profitability of SLIM trades relative to that of our broader proxies for retail trading, All Internalized and All Retail, which include more trades, we need to appropriately scale the dollar performance measure. We therefore compute per dollar performance of retail trades, that is, investor returns or profitability of their trades. As noted in Barber, Lee, Liu, and Odean (2008), such measure would be artificially high if high dollar performance was earned on days with low trading volume. We proceed with this caveat in mind, and compute two measures of mean daily profitability: with and without leverage. Our measure of profitability with leverage ignores any collateral/margin requirements that investors may face on the options they write, i.e., it is as options textbooks would define it. Short positions can be netted against long. Formally, *the daily gross/net profitability with leverage* is computed as the daily gross/net performance of a portfolio at a given horizon divided by the absolute value of the net position of that portfolio (total purchased minus total sold). Our measure without leverage follows that in Barber, Lee, Liu, and Odean and assumes that each short position requires investor to deposit the entire proceeds from shorting as collateral, which earns zero interest. Under this definition, no netting is allowed and even a fully hedged short option position requires the same collateral as a naked one. Formally, *the daily gross/net profitability without leverage* is computed as the daily gross/net performance of a portfolio at a given horizon divided by the absolute value of daily dollar trading volume in that portfolio.

We view the above definitions of profitability as two extremes. It is clearly not possible for a retail investor's portfolio to have unlimited leverage, which the first definition implicitly permits. At the same time, the second definition could be too conservative. For example, covered calls are common retail investor strategies, which were already popular in the 1990s (see Lakonishok, Lee, Pearson, and Poteshman (2006)), and are viewed by the

new generation of retail investors as a way to earn extra income for a user who is "holding the underlying anyway" (see Appendix A.27 for more evidence from investor forums). Retail brokers would net the option position from the position in the underlying and deposit the proceeds from selling a covered call option at the time of the sale.

Tables A41–A40 in the Appendix present retail trades profitability under both definitions. Under the first definition that permits leverage, investors returns over any horizon are hugely volatile and large in absolute value (Table A40). The magnitudes of mean daily returns range from 111% to 124% for gross profitability and from -179% to 224% for net profitability over the same return horizons that we have assumed for dollar performance. These return patterns are consistent with the literature. For example, Broadie, Chernov, and Johannes (2009) argue that because options embed leverage and have highly nonlinear payoffs, standard statistics applied to options portfolios look rather extreme. Gross profitability is positive and significant for the horizons of up to 2 days and beyond 2 days, it is statistically indistinguishable from zero. On the other hand, net profitability is highly negative and significant for horizons of up to 2 days and then becomes indistinguishable from zero.

Under the assumption of no leverage, SLIM investors lose between 23 and 41 cents per 100 dollars of trading over the same return horizons that we have assumed for dollar performance (Tables A41). If we consider portfolios by trade and contract features, net profitability is mostly indistinguishable from zero. A notable exception is the portfolio of contracts with less than a week to expiration, which incurs significant losses at all holding periods.

The differences between the results delivered by the two definitions are quite drastic. It seems to us that the definition without leverage is perhaps too conservative for an options portfolio and actual investor portfolio returns are closer to those in the definition with leverage (although they would not be so extreme, given that in reality retail brokerage platforms do impose some margin/collateral requirements).

How does profitability of SLIM trades compare to that of broder measures of retail trading that we introduced in Section 2.4? To compare profitability of SLIM trades to that of All Internalized and All Retail ones, we adopt the profitability definition that involves leverage, as it delivers options returns that are more consistent with the literature. Table A42 in the Appendix reports the results of the difference in means tests of daily profitability of each of our broader measures and that of SLIM. It is clear from the tables that profitability of All Internalized and both All Retail trades is not statistically different from that of SLIM trades at the 1% level. This piece of evidence lends additional support to the claim that SLIM trades are representative of retail trades.

Our analysis thus far has not taken *direct* transaction costs into account. Some of the brokerages in our sample, such as Robinhood, offer commission-free options trading. However, the majority of brokerages still charge around \$0.65 per contract.[40] Using the fraction of PFOF in options paid to Robinhood as the upper bound of their share in the retail options trading (the share based on the Rule-606 implied trading volume is very similar), we can therefore estimate the aggregate *direct* transaction costs paid by retail investors. Using 1.93 million contracts as the aggregate SLIM volume and 25% as Robinhood's average share in PFOF for options, the direct transaction costs of retail trades in our sample period amount to $\$0.65 \times 1.93 \times 10^6 \times 0.75 \approx \$941$ million.

Even though *indirect* transaction costs are already included into the net performance figures we report, we find it useful to highlight their total value in our sample. It is computed by summing up the products of effective half-spread and trade size across all SLIM trades, resulting in around \$6.5 billion.[41] These costs are not as transparent as brokerage fees and are likely to be overlooked by retail investors. Furthermore, they become revenue for market makers and exchanges executing retail orders (rather than for retail brokerages). These costs are economically large, being almost seven times the direct costs of retail trading. Our calculation approach captures the actual gains and losses of retail trading and does not require any assumptions regarding their opportunity costs.

One limitation of our data is that some trades might come from multi-leg strategies involving options as well as underlying equities (e.g., a covered call), and we do not observe equity legs of these transactions. However, since the retail investor boom in our sample is largely driven by novice investors, we believe that only a small fraction of them use such sophisticated strategies. Therefore, it should have little impact on our aggregate retail performance estimates.

Results presented in Table A38 in the Appendix also allow us to study whether retail investor performance in the later parts of the sample is better than in the earlier ones, consistent with the research of Seru, Shumway, and Stoffman (2009) and Linnainmaa (2011) on investor learning. We find that, on the contrary, retail investors lost *more* money in the later subsample, especially in January and February of 2021, around the GameStop frenzy. This could happen if retail investors do not learn from their trading experience.[42] A more

[40] As of March 2022, TD Ameritrade, Charles Schwab, E*TRADE, and Fidelity all charge \$0.65 per contract, according to their websites. Some of the brokers provide commission discounts for frequent traders or for large transactions. However, given the stylized features of retail trading highlighted in Table 1, these discounts are unlikely to have a material impact on our estimates.

[41] To put this number into perspective, the total PFOF in options in our sample is around \$2.8 billion.

[42] Prior studies also suggest that investors learn worse after experiencing financial losses, in active trading (relative to observing other people decisions) and when they are emotionally involved in the decision-making. See Kuhnen (2015) and references therein. It would be interesting to extend our data and test

likely explanation, however, is the changing composition of the investor base. While some of the poor-performing early investors could have exited the sample, it seems that their attrition was more than compensated by the entry of new retail investors in the later months. After all, just in 2021 alone, the account base of Robinhood almost doubled, increasing from 11.7 to 21.3 million.

4 Additional support for SLIM as a measure of retail trading

In this section, we offer additional suggestive evidence that our measure captures *retail* trading in the U.S. options market.

4.1 SLIM trading on option expiration days

First, we exploit the fact that some U.S. retail brokerages handle expiring options on their clients' accounts in a rule-based manner. For example, Robinhood attempts to exercise in-the-money options (if the account has enough buying power) or sells the contract approximately one hour before the market close (if it does not).[43] This gives us a testable prediction for our measure of retail trading in contracts on their expiration day: We expect to see an imbalance in the direction of sell trades in the last one or two trading hours of the day. To test this prediction, we study volume share of buy and sell trades in each trading hour on option expiration day.

On expiration days, as Table A43 in the Appendix reports, there is a significantly larger sell volume share in SLIM trades in the last two hours of the trading day. Notably, this pattern does not emerge on non-expiration days. These features of SLIM trades are consistent with retail brokerages taking an automated action to close retail positions prior to the option's expiration. At the same time, there is no pattern like this for MLIM trades and other multi-leg trades, which are more likely to be institutional. We test these differences more formally in Table A44 and find them to be highly statistically significant.

4.2 SLIM trading during Robinhood herding events

Second, we study directional order imbalances across trade types during the Robinhood herding events (frenzies) uncovered in Barber, Huang, Odean, and Schwartz (2022).

these potential mechanisms for the performance of the new generation of retail investors.

[43] See Robinhood's rules here: https://robinhood.com/us/en/support/articles/expiration-exercise-and-assignment/, accessed on March 21, 2022.

In particular, we estimate equation (2) using a dummy for the Robinhood herding event in ticker i on date t instead of $Retail_{i,t}$. This analysis is performed on a subsample of our data (Novermber 4, 2019 to August 10, 2020) due to availability of Robintrack data with which the investor frenzies are identified.

Table A45 in the Appendix documents higher SLIM Imbalance during Robinhood herding events. We also find that the correlation is the highest for SLIM trades sized below $5,000. Importantly, imbalances in MLIM, all multi-leg, and large trades are not positively related to frenzies. Our results even show negative correlations, suggesting that other types of investors, most likely professional traders or institutions, trade against the retail investors during such events. Overall, we document that during the well-publicized investor frenzies there were directional order imbalances in retail trading in options as well.

4.3 SLIM trading around stock splits

As we have discussed earlier, the new generation of retail options investors is also more likely to be cash constrained. Micro SLIM trades (below $250) should therefore reflect the activity of cash-constrained investors, and we expect to see large changes in trading volume in these transactions around stock splits.[44] Note that stock splits should have no effect on investor positions in the underlying, because trading fractional shares is permitted on most popular investment platforms. However, they may still affect retail options investors because trading fractional options contracts is not permitted during our sample period. We perform a simple event study, reported in Appendix A.32, where we focus on two companies popular with retail investors, Apple (AAPL) and Tesla (TSLA), that executed stock splits on the same day, August 28, 2020. We find that SLIM trading volume on these two names went up significantly relative to a control group of companies popular with retail investors that did not go through a stock split. This formally confirms that SLIM trades, especially of micro sizes, are likely to be originated by cash-constrained investors.

4.4 Suboptimal exercise by SLIM investors

In our last validation exercise, we show that SLIM investors are less likely to exercise their options optimally.[45]

[44] We thank Yang Liu for suggesting this test.

[45] It has been previously documented that not all American options are exercised rationally (e.g., Poteshman and Serbin (2003)). Battalio, Figlewski, and Neal (2020), Cosma, Galluccio, Pederzoli, and Scaillet (2020), Jensen and Pedersen (2016), and Barraclough and Whaley (2012) focus on early exercise decisions and show in more recent data that a fraction of investors still fail to exercise their options optimally.

We rely on the Black-Scholes-Merton option pricing formula to determine whether it is optimal to exercise a call option early. Denote the expected ex-dividend price of an option by c_{ex}, its strike by K, and the current (cum-dividend) underlying stock price by S. The expected option ex-dividend price represents the expected time value of the option. *Early exercise value (EEV)* is therefore the difference between the current stock price, strike, and this expected time value of the option: $S - K - c_{ex}$. (This formula is equivalent to $Dividend - c_{ex} + S_{ex} - K$.) The details of the computation of c_{ex} are in Appendix A.33.

In the following analyses, we restrict our sample to call option contracts that are optimal to exercise on cum-dates and refer to it as the *early exercise sample*. The details of its construction are provided in Appendix A.34, and Table A47 in the Appendix presents the descriptive statistics.

Let $t-1$ denote the day before the cum-dividend date and let OI_{t-1} be open interest on that date (measured after all trades, exercises, and assignments on that date). To test the hypothesis that retail investor presence increases the fraction of open interest (OI) remaining (suboptimally) unexercised, we run the following regression:

$$f_{c,t} = \beta \, share_{c,t}^{SLIM} + \boldsymbol{\gamma}' X_{c,t} + \alpha_{i,t} + \varepsilon_{c,t}, \tag{5}$$

where $f_t \equiv OI_t / OI_{t-1}$ is the fraction of OI remaining unexercised, $share_{c,t}^{SLIM}$ is the average dollar volume share of SLIM trades over one trading week before the cum-dividend date t, which captures interest of retail investors. In some specifications, we also use Small Share ($share_{c,t}^{small}$) and ticker-level measures of retail investor popularity such as *Internalized volume in underlying* and *WSB mentions, log*, all computed over one trading week before the cum-dividend date t.[46] These measures are defined underneath equation (2). Our vector of controls $X_{c,t}$ is standard and it includes the following contract-level variables: log OI, EEV, log dollar trading volume, relative spread, implied volatility, moneyness, and days to expiration. Finally, our specification also includes the ticker by date fixed effects $\alpha_{i,t}$ as we aim to compare contracts within the same ticker yet different SLIM Share.

Table 7 reports the results of the regression in (5). We find that there is a strong positive relationship between retail investor trading, as measured by SLIM Share, and the fraction of options that were suboptimally not exercised on the cum-dividend day. This effect is highly significant regardless of whether we also include other measures of retail trading such as Small Share, internalized volume in the underlying, or WSB mentions into the model or not. A one standard deviation increase in the share of SLIM trades in the contract in the week preceding the cum-date raises the fraction unexercised by about one percentage point,

[46] We have also explored an alternative specification, in which we measure retail trading over two weeks preceding a cum-dividend date. Our results are quantitatively similar.

Table 7: Suboptimal exercise and retail investor popularity

	Fraction of OI not exercised				
	(1)	(2)	(3)	(4)	(5)
SLIM Share	4.561***	4.515***	5.155***	4.718***	4.918***
	(5.40)	(5.36)	(3.84)	(5.58)	(5.52)
Small Share		2.867***			
		(2.87)			
Internalized volume in underlying					27.631***
					(3.11)
WSB mentions, log					0.399**
					(2.33)
Observations	41,737	41,737	13,759	41,737	40,252
Adjusted R-squared	0.206	0.206	0.286	0.183	0.183
Sample	All	All	Top EEV tercile	All	All
FE	Ticker*Date	Ticker*Date	Ticker*Date	Ticker and Date	Ticker and Date
Contract controls	Y	Y	Y	Y	Y
Ticker controls	N	N	N	Y	Y

This table reports estimates of equation (5) in our early exercise sample. SLIM Share and Small Share are the contract-level volume shares of SLIM and small trades, respectively, averaged over one trading week before the cum-dividend date. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF, averaged over one trading week before the cum-dividend date. WSB mentions, log, is the logarithm of total mentions of the ticker on `WallStreetBets` forum. Contract controls include log dollar trading volume, relative spread, IV, moneyness, days to expiration, log OI, and EEV. Ticker controls include: underlying price, underlying volatility, underlying relative bid-ask spread, and underlying market cap. Since specification (5) includes ticker-level variables, in Column (5) we use ticker and date fixed effects, as opposed to ticker by date. S.E. are clustered by ticker and date. Robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

depending on the specification. This result is robust, and the magnitudes of the coefficients of interest do not significantly change as we relax the specification of fixed effects and switch on ticker-level controls instead (see Columns (4)–(5)).

In sum, we conclude that a higher SLIM Share is associated with a higher fraction of open interest left suboptimally unexercised by the ex-dividend date. We also see that there is no such association for other trade types such as MLIM, all multi-leg, and large trades. Table A48 in the Appendix summarizes these results.

5 Concluding Remarks

This paper focuses on the recent boom in retail investor trading in options. The new generation of retail investors are young and tech-savvy, yet amateur investors. Exploiting a new OPRA reporting requirement, we develop a novel measure of retail investor trading in options and document a rapid rise in retail investor trading in our sample. We argue that

retail investors enter the options market for speculative reasons. They prefer options with very short maturities, primarily calls. These contracts have high relative bid-ask spreads, making the options business a very lucrative one for wholesalers that execute retail order flow. This is further supported by the ballooning PFOF for options received by retail brokerages.

Our paper calls for more transparency in reporting wholesaler activities in the options market, consistent with the current requirement by FINRA in equities. In particular, it would be useful to know how often market makers affiliated with wholesalers get order allocations through price improvement auctions. The current highly concentrated market is likely to favor leading wholesalers and calls into question the extent of price improvement of retail orders. One particularly fruitful avenue for future research is uncovering the barriers to entry in this market and characterizing the optimal market structure.

We would not be the first ones calling for more transparency in trading costs in zero-commission offers of retail brokerages.[47] However, most prior calls were related to equities. Trading costs in options are orders of magnitude higher, so a regulatory requirement to disclose these costs to investors would be a welcome first step.

Frequent trading produces large order flow and revenue from PFOF for retail investing platforms. Trading less liquid assets, such as options, enhances these profits further. This may create an incentive for retail brokerages to encourage more trading in less liquid asset classes or securities. It would be interesting to explore this issue in follow-up work.

The new generation of investors, while tech-savvy and active on investing forums, could still be lacking in financial education that is required to successfully trade options. For example, retail investors trade options frequently, opting for contracts with very short maturities. This behavior is associated with significant trading costs, which are masked by zero-commission option trading offers by investing platforms (e.g., Robinhood). Another example of retail investor mistakes is that they fail to exercise their options when it is optimal to do so. The question of optimal options exercise requires knowledge of option pricing models, which retail investors are likely to be lacking. One possibility would be to require retail brokerages to report options' early exercise values to investors. The early exercise value could be computed from the Black-Scholes model. Another possibility is to make *automatic* early exercise of calls on cum-dividend dates (when it is optimal to do so) a default option for investors, from which they can opt out if they wish.

Naturally, to better understand retail investor strategies, their potential pitfalls, or

[47] Regulators have long been interested in various aspects of the system of payment for order flow and, in particular, whether internalization of orders really provides price improvement for the clients. In 2017 SEC found that some of the algorithms used by Citadel Securities to route retail orders, did not seek to obtain the best price on the marketplace, leading to a settlement fee of $22.6 mln (see https://www.sec.gov/news/pressrelease/2017-11.html).

discuss investor protection policies, it would be ideal to couple our analysis with account-level data from retail brokerages.

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A Internet Appendix

A.1 Share of non-directed orders, by broker

Table A1: Share of non-directed orders by broker

Broker	Options	Stocks	
		SP500	Other
Ally	100.0	100.0	100.0
Apex	97.7	80.7	77.4
Charles Schwab	100.0	99.7	99.4
E*TRADE	99.9	99.5	99.1
Fidelity	88.5	8.1	7.3
Robinhood	99.9	100.0	100.0
TD Ameritrade	99.5	100.0	99.9
Tradestation	99.4	98.2	98.8
Vanguard	100.0	.	.
Virtu	.	95.6	96.4
Webull	100.0	100.0	100.0
tastyworks	100.0	100.0	100.0
Average	**98.6**	**89.2**	**88.9**

This table reports the share of non-directed orders in all orders for each broker in Q1/2020–Q4/2021. Non-directed orders are orders routed to wholesalers and/or exchanges listed in Table A3. All data is from SEC Rule 606 reports.

A.2 OPRA trade types

The table below presents OPRA trade types, together with their descriptions, implemented on November 4, 2019. We also include the corresponding Trade Condition IDs from LiveVol, our data provider.

Table A2: OPRA trade types for transactions in U.S. options exchanges

OPRA Type Description	**OPRA Message Type**	**LiveVol Trade Condition ID**	**OPRA Condition Description**
AUTO		18	Transaction was executed electronically. Prefix appears solely for information; process as a regular transaction.
CANC		40	Transaction previously reported (other than as the last or opening report for the particular option contract) is now to be cancelled.
CBMO	Multi Leg Floor Trade of Proprietary Products	133	Transaction represents execution of a proprietary product non-electronic multi leg order with at least 3 legs. The trade price may be outside the current NBBO.
CNCL		41	Transaction is the last reported for the particular option contract and is now cancelled.
CNCO		42	Transaction was the first one (opening) reported this day for the particular option contract. Although later transactions have been reported, this transaction is now to be cancelled.
CNOL		43	Transaction was the only one reported this day for the particular option contract and is now to be cancelled.
ISOI		95	Transaction was the execution of an order identified as an Intermarket Sweep Order. Process like normal transaction.
LATE		13	Transaction is being reported late, but is in the correct sequence; i.e., no later transactions have been reported for the particular option contract.
MASL	Multi Leg Auction against single leg(s)	125	Transaction was the execution of an electronic multi leg order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period and trades against single leg orders/ quotes. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Solicitation Mechanism.
MESL	Multi Leg auto-electronic trade against single leg(s)	123	Transaction represents an electronic execution of a multi Leg order traded against single leg orders/ quotes.
MLAT	Multi Leg Auction	120	Transaction was the execution of an electronic multi leg order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period in a complex order book. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Solicitation Mechanism.
MLET	Multi Leg auto-electronic trade	119	Transaction represents an electronic execution of a multi leg order traded in a complex order book.
MLFT	Multi Leg floor trade	122	Transaction represents a non-electronic multi leg order trade executed against other multi-leg order(s) on a trading floor. Execution of Paired and Non-Paired Auctions and Cross orders on an exchange floor are also included in this category.

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Table A2: OPRA trade types for transactions in U.S. options exchanges (*cont.*)

MLCT	Multi Leg Cross	121	Transaction was the execution of an electronic multi leg order which was "stopped" at a price and traded in a two sided crossing mechanism that does not go through an exposure period. Such crossing mechanisms include and not limited to Customer to Customer Cross and QCC with two or more options legs.
MSFL	Multi Leg floor trade against single leg(s)	126	Transaction represents a non-electronic multi leg order trade executed on a trading floor against single leg orders/ quotes. Execution of Paired and Non-Paired Auctions on an exchange floor are also included in this category.
OPEN		6	Transaction is a late report of the opening trade and is out of sequence; i.e., other transactions have been reported for the particular option contract.
OPNL		7	Transaction is a late report of the opening trade, but is in the correct sequence; i.e., no other transactions have been reported for the particular option contract.
OSEQ		2	Transaction is being reported late and is out of sequence; i.e., later transactions have been reported for the particular option contract.
REOP		21	Transaction is a reopening of an option contract in which trading has been previously halted. Prefix appears solely for information; process as a regular transaction.
SCLI	Single Leg Cross ISO	117	Transaction was the execution of an Intermarket Sweep electronic order which was "stopped" at a price and traded in a two sided crossing mechanism that does not go through an exposure period. Such crossing mechanisms include and not limited to Customer to Customer Cross.
SLAI	Single Leg Auction ISO	115	Transaction was the execution of an Intermarket Sweep electronic order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Solicitation Mechanism marked as ISO.
SLAN	Single Leg Auction Non ISO	114	Transaction was the execution of an electronic order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Soliciation Mechanism.
SLCN	Single Leg Cross Non ISO	116	Transaction was the execution of an electronic order which was "stopped" at a price and traded in a two sided crossing mechanism that does not go through an exposure period. Such crossing mechanisms include and not limited to Customer to Customer Cross and QCC with a single option leg.
SLFT	Single Leg Floor Trade	118	Transaction represents a non-electronic trade executed on a trading floor. Execution of Paired and Non-Paired Auctions and Cross orders on an exchange floor are also included in this category.

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Table A2: OPRA trade types for transactions in U.S. options exchanges (*cont.*)

MLCT	Multi Leg Cross	121	Transaction was the execution of an electronic multi leg order which was "stopped" at a price and traded in a two sided crossing mechanism that does not go through an exposure period. Such crossing mechanisms include and not limited to Customer to Customer Cross and QCC with two or more options legs.
TASL	Stock Options Auction against single leg(s)	131	Transaction was the execution of an electronic multi leg stock/options order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period and trades against single leg orders/ quotes. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Solicitation Mechanism.
TESL	Stock Options auto-electronic trade against single leg(s)	130	Transaction represents an electronic execution of a multi Leg stock/options order traded against single leg orders/ quotes.
TFSL	Stock Options floor trade against single leg(s)	132	Transaction represents a non-electronic multi leg stock/options order trade executed on a trading floor against single leg orders/ quotes. Execution of Paired and Non-Paired Auctions on an exchange floor are also included in this category.
TLAT	Stock Options Auction	124	Transaction was the execution of an electronic multi leg stock/options order which was "stopped" at a price and traded in a two sided auction mechanism that goes through an exposure period in a complex order book. Such auctions mechanisms include and not limited to Price Improvement, Facilitation or Solicitation Mechanism.
TLCT	Stock Options Cross	128	Transaction was the execution of an electronic multi leg stock/options order which was "stopped" at a price and traded in a two sided crossing mechanism that does not go through an exposure period. Such crossing mechanisms include and not limited to Customer to Customer Cross.
TLET	Stock Options auto-electronic trade	127	Transaction represents an electronic execution of a multi leg stock/options order traded in a complex order book.
TLFT	Stock Options floor trade	129	Transaction represents a non-electronic multi leg order stock/options trade executed on a trading floor in a Complex order book. Execution of Paired and Non-Paired Auctions and Cross orders on an exchange floor are also included in this category.

This table reports OPRA trade types and their descriptions. The type of each transaction in U.S. options exchanges has to be classified using a type description from the table and reported to OPRA. This reporting requirement was implemented on November 4, 2019.

A.3 Payment for order flow, by broker and firm

Table A3: Payment for order flow: Data description

Firms	Broker											Total paid, $ mln.	Total paid, %
	TD Ameritrade	Robinhood	E*TRADE	Charles Schwab	Webull	Fidelity	tastyworks	Tradestation	Apex	Ally	Vanguard		
Panel A: Stocks													
CITADEL	388.1	215.3	115.2	71.4	56.8	0	1	9.6	10.5	4.8		**872.7**	36.4
SUSQUEHANNA	121.9	81.9	67.5	42.7		0	0.5	0	3.6	3.2		**321.3**	13.4
VIRTU	299.5	140.4	94.9	58.6	22.5	-0.4		22	9.8	3		**650.3**	27.1
WOLVERINE		29.3	0				0			0.1		**29.4**	1.2
DASH					0				0			**0.0**	0.0
MORGAN STANLEY						-0.5						**-0.5**	0.0
TWO SIGMA	94.8	65.5	16.2	8.2	7.1	0		6.8	1			**199.6**	8.3
NASDAQ		0	6.3	0.9	0.1	43.1		0		0		**50.4**	2.1
UBS	80.6		15.7	32.6		-0.1		6.2				**135.0**	5.6
CBOE			11.7	0.4	0	48.2		1.1				**61.4**	2.6
OTHER	8.6	0	6.1	2.4	31.3	-0.7		12.8	15.5	0		**76.0**	3.2
Total received, $ mln.	**993.5**	**532.4**	**333.6**	**217.2**	**117.8**	**89.6**	**1.5**	**58.5**	**40.4**	**11.1**	**0.0**	**2395.6**	
Total received, %	41.5	22.2	13.9	9.1	4.9	3.7	0.1	2.4	1.7	0.5	0.0		
Panel B: Options													
CITADEL	713.4	507.6	185.9	101.6	64.6	93	45	10.3	1.7	6.7	2.6	**1732.4**	42.1
SUSQUEHANNA	516.8	298.9	134.4	100.3	45.2	36.2	21.5	0.6	4.5	6.7	0.6	**1165.7**	28.3
VIRTU												**0.0**	0.0
WOLVERINE	142.6	238.7	69.4	73.4	6.6	44.3	0	9.6	3.7	4.6	0.3	**593.2**	14.4
DASH	125.3		89.2	36.6	37.8	15.4	30	11.7	5.5			**351.5**	8.5
MORGAN STANLEY	76.1	83.7	36.9	26.8		9		8.4				**240.9**	5.9
TWO SIGMA			5.1		0.3				0			**5.4**	0.1
NASDAQ						0						**0.0**	0.0
UBS												**0.0**	0.0
CBOE						0						**0.0**	0.0
OTHER	2.1		0.9	3.4	0	6.6	7.4	0.9	2.4	0	0.6	**24.3**	0.6
Total received, $ mln.	**1576.3**	**1128.9**	**521.8**	**342.1**	**154.5**	**204.5**	**103.9**	**41.5**	**17.8**	**18.0**	**4.1**	**4113.4**	
Total received, %	38.3	27.4	12.7	8.3	3.8	5.0	2.5	1.0	0.4	0.4	0.1		

This table reports the total payment for order flow in stocks (Panel A) and options (Panel B) for each broker-firm pair in Q1/2020–Q4/2021. Relationships with missing values do not exist. PFOFs with zero values are rounded to zero. Negative values indicate fees paid. All data is from SEC Rule 606 reports. NASDAQ and CBOE represent exchanges within NASDAQ and CBOE groups, respectively.

A.4 Embedded leverage in options trades

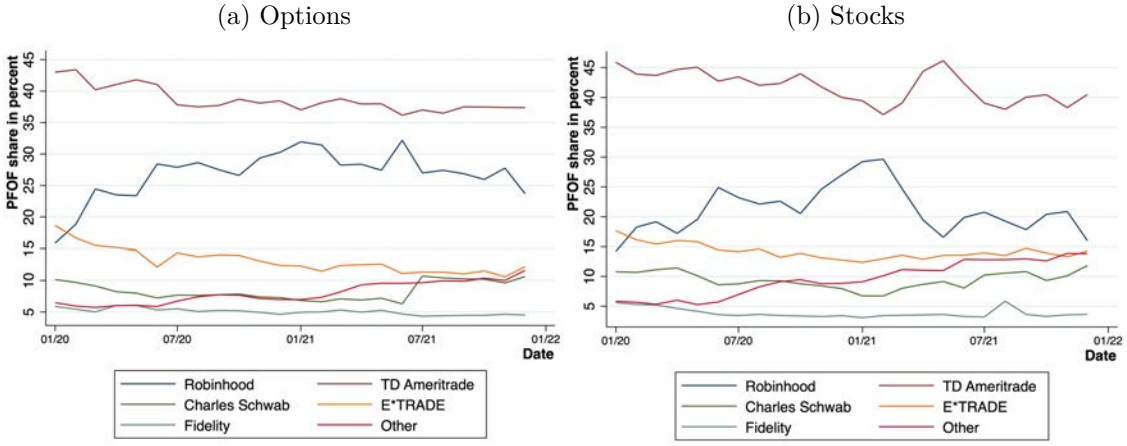
Table A4: Embedded leverage by moneyness and maturity bin

Moneyness	Frequency-weighted within a bin: Time to expiration					Volume-weighted within a bin: Time to expiration				
	Less than a week	1-2 weeks	2-4 weeks	1-3 months	Above 3 months	Less than a week	1-2 weeks	2-4 weeks	1-3 months	Above 3 months
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: SLIM trades										
Below -2	12.0	4.8	3.3	3.3	2.9	36.3	8.5	3.7	3.8	2.9
-2 to -1	6.4	5.6	4.9	5.1	3.8	7.0	6.3	6.2	6.2	4.2
-1 to -0.1	19.8	13.4	10.2	8.6	6.2	23.1	15.3	11.6	9.6	6.3
At the money	57.9	22.4	15.6	11.0	5.8	83.4	25.5	17.8	12.7	6.7
0.1 to 1	5.5	4.5	3.9	3.6	2.5	5.5	4.3	3.7	3.4	2.7
1 to 2	2.0	2.1	2.8	2.1	2.4	2.4	5.1	9.8	2.8	5.5
Above 2	25.8	20.2	13.5	14.0	13.6	60.5	58.7	32.4	31.6	34.0
Panel B: SLIM trades below $250										
Below -2	12.9	5.0	3.5	3.6	3.1	41.0	9.4	3.8	4.1	3.0
-2 to -1	7.0	6.1	5.3	5.5	4.3	7.5	6.8	6.7	6.6	4.7
-1 to -0.1	21.5	14.2	10.9	9.2	7.6	24.8	16.0	12.2	10.1	7.3
At the money	71.5	25.1	17.7	13.3	7.6	93.2	28.3	20.4	15.6	10.3
0.1 to 1	5.3	3.9	3.3	2.6	1.5	5.4	3.9	3.4	2.8	3.9
1 to 2	2.3	2.9	5.4	3.3	6.7	3.4	12.5	30.5	6.2	29.4
Above 2	69.4	41.9	36.9	46.2	60.1	153.1	110.2	81.4	95.7	134.4
Panel C: All trades										
Below -2	11.3	4.5	3.3	2.8	2.3	15.8	5.8	3.6	3.3	2.4
-2 to -1	6.3	5.3	4.6	4.5	3.3	7.0	6.0	5.7	5.5	3.8
-1 to -0.1	21.0	14.7	11.7	9.3	5.4	24.0	16.7	13.3	10.4	5.9
At the money	62.8	23.3	16.8	11.8	6.0	93.2	27.5	20.2	14.1	7.7
0.1 to 1	5.6	4.7	4.1	3.7	2.7	5.6	4.6	4.0	3.7	2.8
1 to 2	2.7	2.8	2.7	2.5	3.8	3.7	10.8	5.2	3.8	10.6
Above 2	27.8	24.1	14.6	17.6	14.5	53.5	61.3	29.2	45.9	38.1

This table reports the average embedded leverage of options by their moneyness and maturity bin at the time of the trade. Panel A reports averages for SLIM trades only, Panel B – for SLIM trades below $250 in value, and Panel C – for all options trades. Leverage is computed as $|\Delta \times S/p|$, where Δ is the option's delta at the time of the trade, S is the underlying midpoint price at the time of the trade, and p is the option's trade price. All the values are first wighted either by frequency (Columns (1)–(5)) or trading volume (Columns (6)–(10)) within a corresponding bin and then frequency-weighted across time. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

A.5 PFOF trends, by broker

Figure A1: Share in the payment for order flow: Options versus stocks, by brokerage



This figure plots the share in monthly payments for order flow of the largest U.S. retail brokerages.

A.6 OTC trading volume, by venue

Table A5: Top 15 internalizers in the United States

Firm	**OTC volume, billion shares**	**Venue share in total volume, %**	**Cumulative share, %**
CITADEL SECURITIES	477.82	44.31	44.31
VIRTU	357.61	33.16	77.47
SUSQUEHANNA	119.10	11.04	88.52
TWO SIGMA	48.50	4.50	93.01
JANE STREET CAPITAL	28.49	2.64	95.66
UBS	25.35	2.35	98.01
WOLVERINE	7.29	0.68	98.68
COMHAR CAPITAL MARKETS	3.84	0.36	99.04
HRT EXECUTION SERVICES	3.46	0.32	99.36
LEK SECURITIES CORPORATION	2.27	0.21	99.57
GOLDMAN	2.20	0.20	99.77
ACS EXECUTION SERVICES	0.44	0.04	99.81
IMC	0.32	0.03	99.84
MORGAN STANLEY	0.29	0.03	99.87
COWEN	0.28	0.03	99.90

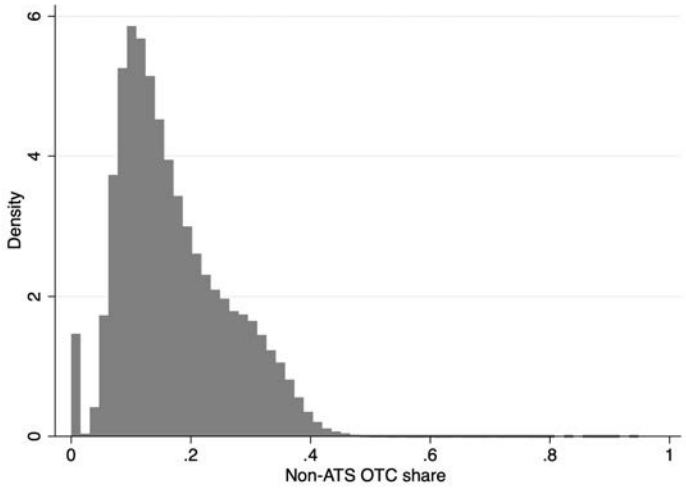
This table reports the top 15 firms in terms of their total OTC non-ATS (i.e., internalized) stock volume between November 2019 and June 2021. It us based on FINRA OTC Transparency data.

A.7 A measure of internalized volume in equities

Figure A2 plots a histogram of weekly non-ATS OTC trading volume (internalized volume) as a share of the total weekly stock trading volume. The average share of internalized

volume in the total one is 17% in our sample, and it is trending upwards.

Figure A2: Histogram of non-ATS OTC share



This figure plots the share of non-ATS OTC volume in the total trading volume for all equities and ETFs with options traded in the U.S. between November 2019 and June 2021.

A.8 Price improvement mechanism fees, by exchange

In this section, we summarize fees related to price improvement mechanisms across the U.S. exchanges. In particular, we consider two scenarios. The first one is when a customer order is paired in an auction and the wholesaler-affiliated market maker trades gets the full allocation (i.e., the auction not broken). In the second scenario, a customer order is paired in an auction and an unaffiliated market maker trades in full (i.e., the auction is broken as an unaffiliated market maker provides a better price).

Table A6: PIM-related exchange fees across the U.S. exchanges

				1. Customer order is paired in an auction and wholesaler trades in full					**2. Customer order is paired in an auction and unaffiliated market maker trades in full**				
Exchange Code	Full Name	PIM Name	SLAN trade volume share, %	Customer Exchange Fee/Rebate	Break-up credit	Affiliated market maker	Non-affiliated market maker (responder fee)	Exchange	Customer Exchange Fee/Rebate	Break-up credit	Affiliated market maker	Non-affiliated market maker (responder fee)	Exchange
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Panel A: Penny program securities													
PHLX	Philadelphia Stock Exch.	PIXL	31.00	(0.17)	NA	0.05	NA	0.12	(0.17)	(0.25)†	NA	0.25	(0.08)
CBOE	Chicago Board Options Exch.	AIM / C-AIM	21.70	(0.14)	NA	0.07	NA	0.07	(0.14)	(0.25)	NA	0.50	(0.11)
AMEX	American Stock Exch.	CUBE	15.50	(0.12)	NA	0.05	NA	0.07	(0.12)	(0.30)	NA	0.50	(0.08)
MIAX	MIAX Options Exch.	MIAX PRIME	12.00	(0.11)	NA	0.05	NA	0.06	(0.11)	(0.25)	NA	0.50	(0.14)
BOX	Boston Stock Exch.	PIP	6.80	(0.11)	NA	0.05	NA	0.06	(0.11)	(0.34)	NA	0.50	(0.05)
EDGX	Direct Edge X	AIM	5.10	(0.06)	NA	0.05	NA	0.01	(0.06)	(0.25)	NA	0.50	(0.19)
MRX	ISE Mercury	PIM	4.10	-	NA	0.02	NA	(0.02)	-	(0.25)	NA	0.50	(0.25)
ISE	International Securities Exch.	PIM	2.60	(0.02)	NA	0.10	NA	(0.08)	(0.02)	(0.15)	NA	0.50	(0.33)
GEMX	ISE Gemini	PIM	1.10	-	NA	0.05	NA	(0.05)	-	-	NA	0.05	(0.05)
NASDBX	NASDAQ OMX BX Options	PRISM	0.06	-	NA	0.05	NA	(0.05)	-	(0.35)	NA	0.49	(0.14)
EMLD	MIAX Emerald Options Exch.	Emerald PRIME	0.05	(0.10)	NA	0.05	NA	0.05	(0.10)	(0.53)	NA	0.55	0.08
Panel B: Non-penny program securities													
PHLX	Philadelphia Stock Exch.	PIXL	31.00	(0.17)	NA	0.05	NA	0.12	(0.17)	(0.70)	NA	0.40	(0.23)
CBOE	Chicago Board Options Exch.	AIM / C-AIM	21.70	(0.14)	NA	0.07	NA	0.07	(0.14)	(0.60)	NA	1.05	(0.31)
AMEX	American Stock Exch.	CUBE	15.50	(0.12)	NA	0.05	NA	0.07	(0.12)	(0.70)	NA	1.05	(0.23)
MIAX	MIAX Options Exch.	MIAX PRIME	12.00	(0.11)	NA	0.05	NA	0.06	(0.11)	(0.60)	NA	1.10	(0.39)
BOX	Boston Stock Exch.	PIP	6.80	(0.11)	NA	0.05	NA	0.06	(0.11)	(0.81)	NA	1.15	(0.23)
EDGX	Direct Edge X	AIM	5.10	(0.06)	NA	0.05	NA	0.01	(0.06)	(0.60)	NA	1.05	(0.39)
MRX	ISE Mercury	PIM	4.10	-	NA	0.02	NA	(0.02)	-	(0.60)	NA	1.10	(0.50)
ISE	International Securities Exch.	PIM	2.60	(0.02)	NA	0.10	NA	(0.08)	(0.02)	(0.15)	NA	1.10	(0.93)
GEMX	ISE Gemini	PIM	1.10	-	NA	0.05	NA	(0.05)	-	-	NA	0.05	(0.05)
NASDBX	NASDAQ OMX BX Options	PRISM	0.06	-	NA	0.05	NA	(0.05)	-	(0.70)	NA	0.94	(0.24)
EMLD	MIAX Emerald Options Exch.	Emerald PRIME	0.05	(0.10)	NA	0.05	NA	0.05	(0.10)	(1.05)	NA	1.10	0.05

This table reports the exchange fees related to price improvement mechanisms (PIM) on all U.S. options exchanges where this mechanisms are used, as of May 10, 2022. Panel A reports fees for securities in the penny program, and Panel B for those not in the penny program. Columns (5)–(9) report fees in a scenario when customer order is paired in an auction and the wholesaler trades in full. Columns (10)–(14) report fees in a scenario when customer order is paired in an auction and an unaffiliated market maker trades in full. Negative values indicate rebates. Rebates typically vary by volume tier, and we report the highest rebate. These fees and rebates are for the majority of underlying securities (they do not include securities with special fees such as SPY). All values are in $ per contract. † signifies break-up credit fees that we could not locate within the corresponding exchange fee schedule, yet its value has been reported by an active market maker participating in PIM.

Table A7: Composition of SLIM and non-SLIM trades

Characteristic	Category	SLIM trades				Non-SLIM trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	70.2	68.3	14.1	3.4	63.2	60.7	11.4	4.3
	Put	29.8	31.7	14.3	3.5	36.8	39.3	12.5	4.3
Trade size (contracts)	1	44.4	5.9	14.1	3.2	42.4	5.2	11.4	4.1
	2-5	31.2	12.9	12.9	3.1	31.7	12.1	11.4	4.1
	6-10	12.2	14.2	14.4	3.6	11.8	12.2	12.3	4.6
	11-100	11.5	52.8	15.2	4.2	12.9	47.6	12.4	4.9
	Above 100	0.7	14.1	15.3	6.1	1.2	22.8	12.8	5.3
Trade size (dollars)	Below 250	40.6	14.0	24.3	6.0	36.8	12.3	20.8	7.6
	250-500	15.5	8.8	9.0	2.0	14.9	7.5	8.5	2.8
	500-1,000	13.8	11.3	7.6	1.6	14.3	9.9	7.0	2.3
	1,000-2,500	14.0	17.4	6.3	1.3	15.3	16.1	5.9	1.9
	2,500-5,000	7.1	13.6	5.2	1.1	8.1	13.3	5.0	1.6
	5,000-10,000	4.6	13.1	4.5	1.0	5.0	12.3	4.3	1.5
	10,000-20,000	2.5	10.1	3.9	1.7	2.8	10.3	3.7	2.8
	20,000-50,000	1.3	7.7	3.5	3.3	1.7	9.5	3.2	5.4
	Above 50,000	0.5	4.1	3.2	5.9	0.9	8.8	2.9	8.9
Trade direction	Sell	50.1	49.8	14.2	3.6	49.3	48.6	10.5	4.0
	Buy	46.9	47.8	13.2	3.3	48.0	49.0	12.6	4.8
	Midpoint	3.0	2.4	20.5	0.0	2.7	2.4	15.9	0.0
Time to expiry	Less than a week	47.6	49.6	12.7	3.3	42.1	42.2	12.8	4.9
	1-2 weeks	14.0	13.0	11.6	2.7	14.6	13.4	9.5	3.4
	2-4 weeks	16.0	15.3	14.9	3.4	17.2	16.8	11.2	3.7
	1-3 months	13.7	13.6	14.1	3.1	15.7	16.3	9.8	3.3
	3-12 months	7.3	7.2	18.5	3.9	8.4	9.3	10.2	3.9
	Over a year	1.4	1.3	17.9	4.8	2.0	1.9	13.3	6.1
Moneyness	Below -2	0.2	0.2	63.3	16.2	0.2	0.3	63.7	20.7
	-2 to -1	0.3	0.4	54.8	13.7	0.4	0.4	49.8	15.3
	-1 to -0.1	22.4	23.4	30.5	7.3	23.1	24.3	22.4	7.8
	At the money	72.8	72.3	9.0	2.1	71.3	70.4	8.4	3.1
	0.1 to 1	3.9	3.4	8.6	2.5	4.7	4.3	5.8	3.7
	1 to 2	0.1	0.1	10.5	5.2	0.2	0.2	7.4	9.9
	Above 2	0.1	0.1	20.3	7.3	0.1	0.1	14.2	17.0
Trade direction and type	Sell - Call	34.9	33.8	14.2	3.6	31.1	29.4	10.1	4.0
	Sell - Put	15.2	16.0	14.9	3.8	18.2	19.3	11.4	4.0
	Buy - Call	33.2	32.9	13.4	3.4	30.5	30.0	12.4	4.9
	Buy - Put	13.7	14.9	13.3	3.4	17.5	19.0	13.4	4.9
	Midpoint - Call	2.1	1.6	21.5	0.0	1.6	1.4	15.5	0.0
	Midpoint - Put	0.9	0.8	18.9	0.0	1.1	1.0	17.0	0.0
ETF	No	80.8	71.9	15.4	3.7	80.8	69.8	12.4	4.5
	Yes	19.2	28.1	8.6	2.3	19.2	30.2	8.9	3.4

This table reports daily average characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

Table A8: Differences between SLIM and non-SLIM trades

		SLIM minus non-SLIM			
Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	6.99	7.59	2.70	-0.92
		(17.80)	(21.87)	(20.75)	(-20.02)
	Put	-6.99	-7.59	1.74	-0.85
		(-17.80)	(-21.87)	(10.73)	(-20.86)
Trade size (contracts)	1	2.05	0.69	2.66	-0.89
		(4.93)	(7.42)	(14.81)	(-18.29)
	2-5	0.34	1.95	2.04	-0.96
		(2.63)	(19.79)	(17.07)	(-25.60)
	6-10	-1.37	5.25	2.78	-0.62
		(-13.40)	(16.31)	(14.63)	(-16.91)
	11-100	-0.52	-8.74	2.50	0.77
		(-22.20)	(-25.06)	(9.28)	(9.08)
	Above 100	-0.50	0.84	1.52	-1.04
		(-2.28)	(10.43)	(15.88)	(-35.71)
Trade size (dollars)	Below 250	3.79	1.68	3.45	-1.61
		(7.40)	(11.12)	(16.29)	(-19.95)
	250-500	0.59	1.32	0.56	-0.80
		(10.61)	(18.04)	(4.38)	(-14.88)
	500-1,000	-0.49	1.44	0.52	-0.68
		(-4.72)	(18.88)	(5.92)	(-17.27)
	1,000-2,500	-1.31	1.31	0.37	-0.61
		(-7.82)	(14.95)	(5.39)	(-20.40)
	2,500-5,000	-0.99	0.21	0.28	-0.54
		(-8.65)	(3.04)	(5.10)	(-22.50)
	5,000-10,000	-0.40	0.77	0.20	-0.51
		(-5.31)	(11.31)	(4.37)	(-19.42)
	10,000-20,000	-0.34	-0.20	0.21	-1.14
		(-7.12)	(-2.46)	(4.66)	(-16.65)
	20,000-50,000	-0.40	-1.81	0.26	-2.09
		(-12.67)	(-21.49)	(5.65)	(-15.84)
	Above 50,000	-0.45	-4.73	0.23	-2.95
		(-20.72)	(-24.76)	(3.37)	(-8.65)
Trade direction	Sell	0.81	1.17	3.70	-0.37
		(8.60)	(10.56)	(29.43)	(-12.81)
	Buy	-1.11	-1.20	0.58	-1.51
		(-10.20)	(-9.81)	(5.19)	(-27.04)
	Midpoint	0.29	0.03	4.56	NA
		(4.95)	(0.67)	(21.84)	(NA)
Time to expiry	Less than a week	5.56	7.36	-0.14	-1.59
		(18.87)	(30.87)	(-1.02)	(-47.20)
	1-2 weeks	-0.69	-0.41	2.02	-0.65
		(-9.21)	(-4.23)	(14.10)	(-19.89)
	2-4 weeks	-1.23	-1.59	3.63	-0.39
		(-10.36)	(-10.67)	(21.29)	(-6.07)
	1-3 months	-2.03	-2.64	4.31	-0.21
		(-19.81)	(-21.09)	(14.48)	(-3.34)
	3-12 months	-1.06	-2.11	8.32	-0.03
		(-6.97)	(-15.84)	(9.66)	(-0.15)
	Over a year	-0.55	-0.62	4.58	-1.33
		(-10.81)	(-10.34)	(6.40)	(-6.40)
Moneyness	Below -2	0.01	-0.06	-0.41	-4.51
		(0.49)	(-2.63)	(-0.21)	(-12.40)
	-2 to -1	-0.02	-0.04	5.06	-1.58
		(-1.20)	(-2.15)	(4.64)	(-6.17)
	-1 to -0.1	-0.64	-0.87	8.07	-0.54
		(-4.34)	(-4.52)	(22.81)	(-7.24)
	At the money	1.52	1.95	0.59	-0.94
		(8.67)	(9.10)	(6.33)	(-35.66)
	0.1 to 1	-0.80	-0.86	2.75	-1.20
		(-8.62)	(-12.89)	(10.79)	(-13.54)
	1 to 2	-0.03	-0.06	3.02	-4.73
		(-6.67)	(-8.11)	(11.64)	(-9.87)
	Above 2	-0.03	-0.06	6.14	-9.69
		(-6.21)	(-8.69)	(7.17)	(-11.42)
Trade direction and type	Sell - Call	3.86	4.44	4.11	-0.39
		(18.41)	(23.35)	(21.89)	(-11.40)
	Sell - Put	-3.05	-3.27	3.42	-0.23
		(-18.78)	(-20.81)	(19.40)	(-5.17)
	Buy - Call	2.68	2.96	0.99	-1.50
		(15.05)	(17.17)	(6.30)	(-16.62)
	Buy - Put	-3.78	-4.16	-0.10	-1.55
		(-17.11)	(-20.93)	(-0.66)	(-34.28)
	Midpoint - Call	0.45	0.20	5.98	NA
		(9.62)	(5.66)	(20.31)	(NA)
	Midpoint - Put	-0.15	-0.17	1.90	NA
		(-6.48)	(-10.78)	(7.08)	(NA)
ETF	No	-0.05	2.09	2.95	-0.87
		(-0.17)	(4.30)	(23.13)	(-20.54)
	Yes	0.05	-2.09	-0.34	-1.10
		(0.17)	(-4.30)	(-3.51)	(-25.97)

This table reports mean differences between daily characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. In parentheses are t-statistics based on Newey-West standard errors with the optimal number of lags.

A.9 Additional descriptive statistics on SLIM trades

Table A9: Composition of SLIM trades, additional statistics

Characteristic	**Category**	Dollar volume share, %	Dollar spread, $	Implied volatility	Trade price, $
Type	Call	70.25	0.22	0.85	4.87
	Put	29.75	0.21	0.80	4.48
Trade size	1	13.32	0.25	0.85	5.62
(contracts)	2-5	22.31	0.21	0.83	4.70
	6-10	18.37	0.17	0.83	3.66
	11-100	39.71	0.13	0.81	2.75
	Above 100	6.28	0.06	0.68	1.31
Trade size	Below 250	2.03	0.08	0.94	0.74
(dollars)	250-500	2.76	0.15	0.81	2.29
	500-1,000	4.84	0.21	0.79	3.71
	1,000-2,500	10.78	0.30	0.76	6.47
	2,500-5,000	12.16	0.44	0.73	11.47
	5,000-10,000	15.67	0.54	0.71	16.68
	10,000-20,000	16.75	0.66	0.69	22.78
	20,000-50,000	19.53	0.82	0.68	29.18
	Above 50,000	15.47	1.13	0.68	42.10
Trade direction	Sell	51.11	0.23	0.83	4.96
	Buy	46.97	0.20	0.85	4.67
	Midpoint	1.92	0.15	0.69	2.74
Time to expiration	Less than a week	40.39	0.17	0.89	4.06
	1-2 weeks	12.29	0.18	0.84	4.41
	2-4 weeks	14.39	0.21	0.85	4.26
	1-3 months	16.60	0.25	0.73	5.63
	3-12 months	12.43	0.40	0.69	7.84
	Over a year	3.89	0.85	0.60	14.16
Moneyness	Below -2	0.06	0.21	2.48	0.93
	-2 to -1	0.11	0.27	1.92	1.40
	-1 to -0.1	10.90	0.18	1.25	2.08
	At the money	77.19	0.20	0.67	5.16
	0.1 to 1	10.90	0.55	1.17	12.96
	1 to 2	0.57	0.80	1.51	18.25
	Above 2	0.28	0.87	1.61	17.99
Trade direction	Sell - Call	35.95	0.23	0.84	5.11
and type	Sell - Put	15.16	0.22	0.80	4.60
	Buy - Call	32.95	0.21	0.87	4.74
	Buy - Put	14.02	0.19	0.81	4.50
	Midpoint - Call	1.35	0.16	0.70	2.85
	Midpoint - Put	0.57	0.13	0.68	2.46
ETF	No	79.02	0.24	0.92	5.18
	Yes	20.98	0.09	0.46	2.91

This table reports characteristics of trades by category. Our sample is from November 2019 to June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Dollar spread, $ is the spread between the best bid and best ask on the contract (across all exchanges) in U.S. dollars at the time of the trade. Implied volatility is trade-implied volatility reported by OPRA. For all measures, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

A.10 Descriptive statistics on SLIM trades, without open and close trades

Table A10: Composition of option trades

Characteristic	Category	SLIM trades				All trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	71.2	69.0	13.3	6.5	65.0	62.3	10.8	7.7
	Put	28.8	31.0	13.7	6.7	35.0	37.7	11.9	8.0
Trade size (contracts)	1	45.6	6.2	13.7	6.3	44.4	6.0	10.9	7.4
	2-5	30.9	13.3	12.4	6.1	31.6	13.3	10.8	7.5
	6-10	11.8	14.5	13.8	7.1	11.4	13.3	12.0	8.4
	11-100	11.0	53.1	14.6	8.2	11.6	48.7	12.3	9.1
	Above 100	0.6	12.9	14.6	11.6	0.9	18.8	12.6	10.2
Trade size (dollars)	Below 250	41.4	14.3	23.4	11.6	37.9	13.3	19.9	13.7
	250-500	15.4	8.9	8.3	3.7	15.0	8.0	7.7	4.8
	500-1,000	13.6	11.3	7.0	3.0	14.2	10.3	6.5	4.0
	1,000-2,500	13.8	17.3	5.9	2.5	15.0	16.4	5.5	3.3
	2,500-5,000	7.0	13.5	4.9	2.0	7.8	13.3	4.6	2.8
	5,000-10,000	4.6	13.1	4.2	1.8	4.9	12.2	4.0	2.5
	10,000-20,000	2.5	10.1	3.7	2.9	2.7	10.0	3.5	4.8
	20,000-50,000	1.3	7.6	3.3	6.2	1.6	8.9	3.1	10.4
	Above 50,000	0.5	3.9	3.0	11.4	0.8	7.7	2.9	17.6
Trade direction	Sell	46.2	46.4	13.6	7.6	47.5	47.2	10.1	7.6
	Buy	43.4	44.8	13.0	7.1	45.8	46.9	12.0	9.1
	Midpoint	10.4	8.8	14.2	0.0	6.7	6.0	13.3	0.0
Time to expiration	Less than a week	47.2	49.6	12.3	6.5	42.4	42.8	12.5	9.1
	1-2 weeks	13.8	12.8	12.2	6.0	14.4	13.2	9.7	6.6
	2-4 weeks	16.0	15.2	14.9	7.0	17.1	16.5	10.8	7.0
	1-3 months	13.6	13.6	13.7	6.1	15.4	15.9	9.5	6.0
	3-12 months	7.6	7.3	18.3	7.7	8.6	9.4	10.5	7.3
	Over a year	1.4	1.3	17.4	9.1	1.9	1.9	12.2	10.9
Moneyness	Below -2	0.3	0.3	53.3	27.9	0.3	0.3	46.2	30.1
	-2 to -1	0.4	0.4	50.2	25.3	0.4	0.4	42.8	25.7
	-1 to -0.1	23.8	24.1	28.4	13.7	24.2	25.2	21.1	14.0
	At the money	71.2	71.5	8.4	4.1	70.0	69.4	7.8	5.5
	0.1 to 1	4.1	3.6	8.2	4.6	4.8	4.4	5.7	6.4
	1 to 2	0.2	0.1	8.6	7.4	0.2	0.2	6.3	13.8
	Above 2	0.1	0.1	16.3	11.2	0.1	0.1	11.6	24.8
Trade direction and type	Sell - Call	32.7	31.8	13.4	7.4	30.8	29.3	9.6	7.5
	Sell - Put	13.5	14.5	14.3	8.0	16.7	17.9	10.9	7.8
	Buy - Call	31.2	31.2	13.0	7.1	29.9	29.4	11.6	8.9
	Buy - Put	12.2	13.6	13.1	7.1	15.9	17.5	12.7	9.3
	Midpoint - Call	7.3	6.0	14.5	0.0	4.2	3.6	12.9	0.0
	Midpoint - Put	3.1	2.9	13.4	0.0	2.5	2.3	14.0	0.0
ETF	No	81.4	72.4	14.6	7.1	81.6	71.3	11.8	8.2
	Yes	18.6	27.6	8.3	4.4	18.4	28.7	8.4	6.0

This table reports characteristics of trades by category. Our sample is from November 2019 to June 202. It is limited to trades after 9:45 a.m. and before 3:50 p.m., and trades are classified using the quote method. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. The overwhelming majority of the reported values for SLIM trades are different from those for non-SLIM trades with the p-value below 1%.

A.11 Descriptive statistics on SLIM trades below $20,000 by category

Table A11: Composition of SLIM trades below $20,000 in size

Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	71.5	70.0	13.7	6.5
	Put	28.5	30.0	14.2	6.9
Trade size	1	46.4	7.0	13.9	6.3
(contracts)	2-5	31.3	14.8	12.7	6.1
	6-10	11.7	15.7	14.4	7.3
	11-100	10.2	52.4	16.1	9.1
	Above 100	0.4	10.2	20.2	16.6
Trade size	Below 250	42.0	16.0	23.6	11.7
(dollars)	250-500	15.8	10.0	8.7	3.9
	500-1,000	14.0	12.8	7.4	3.2
	1,000-2,500	14.1	19.6	6.2	2.6
	2,500-5,000	7.1	15.3	5.2	2.1
	5,000-10,000	4.6	14.8	4.5	1.9
	10,000-20,000	2.5	11.4	3.9	3.2
	20,000-50,000				
	Above 50,000				
Trade direction	Sell	50.0	49.8	14.2	7.0
	Buy	47.0	47.8	13.1	6.7
	Midpoint	3.0	2.4	20.3	0.0
Time to expiration	Less than a week	48.5	51.7	12.8	6.7
	1-2 weeks	14.0	13.1	12.6	6.1
	2-4 weeks	15.9	15.1	15.4	7.1
	1-3 months	13.2	12.8	14.2	6.1
	3-12 months	7.2	6.5	19.0	7.5
	Over a year	1.3	1.0	18.7	7.9
Moneyness	Below -2	0.3	0.3	54.1	28.4
	-2 to -1	0.4	0.4	51.0	25.7
	-1 to -0.1	23.7	25.7	28.8	13.9
	At the money	71.6	70.7	8.9	4.2
	0.1 to 1	3.8	2.8	8.9	3.8
	1 to 2	0.1	0.1	9.6	4.5
	Above 2	0.1	0.1	18.1	8.0
Trade direction	Sell - Call	35.5	34.6	13.9	6.8
and type	Sell - Put	14.5	15.2	14.9	7.5
	Buy - Call	33.9	33.8	13.1	6.7
	Buy - Put	13.1	14.0	13.2	6.7
	Midpoint - Call	2.1	1.6	21.0	0.0
	Midpoint - Put	0.9	0.8	18.8	0.0
ETF	No	81.4	74.0	15.1	7.1
	Yes	18.6	26.0	8.5	4.5

This table reports characteristics of SLIM trades (single-leg price improvement auctions) that are smaller than $20,000 in size by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

A.12 SLIM trades below $20,000 and other measures of retail activity

Table A12: Share of SLIM option trades below $20,000 in size and other measures of retail activity

	SLIM < $20k trades in calls				**SLIM < $20k trades in puts**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: SLIM < $20k Share								
Small Share	0.080***				0.072***			
	(32.77)				(34.16)			
Internalized volume in underlying		0.023***				0.019***		
		(8.35)				(7.25)		
Robinhood ownership breadth, log			0.027***				0.061***	
			(2.69)				(6.01)	
WSB mentions, log				-0.002				0.003*
				(-1.16)				(1.77)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.115	0.110	0.102	0.124	0.085	0.082	0.077	0.090
Panel B: SLIM < $20k Imbalance								
Small Imbalance	0.522***				0.521***			
	(262.74)				(227.77)			
Internalized volume in underlying		0.015***				0.004		
		(5.10)				(1.42)		
Robinhood ownership breadth, log			0.042***				0.029***	
			(4.20)				(3.24)	
WSB mentions, log				0.012***				0.010***
				(9.91)				(6.91)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,101,380	1,105,025	435,904	952,614	832,607	837,046	339,427	750,667
Adjusted R-squared	0.187	0.021	0.027	0.020	0.182	0.023	0.025	0.022

This table reports the results of estimating (1) on daily data from November 2019 to June 2021. SLIM < $20k and Small Share are the ticker-level volume shares of SLIM (below $20,000) and small trades, respectively. SLIM < $20k and Small Imbalance are the ticker-level volume imbalance for SLIM (below $20,000) and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.13 Descriptive statistics for the ticker-level sample

Table A13: Descriptive statistics for the ticker-level variables

	Call options					Put options				
	Mean	Median	St. Dev.	p1	p99	Mean	Median	St. Dev.	p1	p99
SLIM Share	0.20	0.13	0.23	0.00	1.00	0.16	0.06	0.24	0.00	1.00
SLIM < \$250 Share	0.06	0.01	0.15	0.00	1.00	0.06	0.01	0.16	0.00	1.00
SLIM < \$5k Share	0.17	0.09	0.22	0.00	1.00	0.14	0.04	0.23	0.00	1.00
SLIM < \$20k Share	0.19	0.12	0.23	0.00	1.00	0.15	0.06	0.24	0.00	1.00
SLIM > \$20k Share	0.01	0.00	0.04	0.00	0.16	0.00	0.00	0.04	0.00	0.12
Small Share	0.59	0.53	0.34	0.00	1.00	0.63	0.63	0.36	0.00	1.00
MLIM Share	0.02	0.00	0.08	0.00	0.44	0.04	0.00	0.11	0.00	0.67
Complex Share	0.11	0.02	0.20	0.00	0.97	0.16	0.03	0.25	0.00	1.00
Large Share	0.06	0.00	0.15	0.00	0.72	0.06	0.00	0.15	0.00	0.79
> \$50k Share	0.02	0.00	0.08	0.00	0.43	0.02	0.00	0.08	0.00	0.44
SLIM Imbalance	-0.11	-0.11	0.65	-1.00	1.00	-0.17	-0.23	0.70	-1.00	1.00
SLIM < \$250 Imbalance	-0.17	-0.19	0.65	-1.00	1.00	-0.22	-0.31	0.70	-1.00	1.00
SLIM < \$5k Imbalance	-0.12	-0.12	0.64	-1.00	1.00	-0.18	-0.23	0.70	-1.00	1.00
SLIM < \$20k Imbalance	-0.11	-0.11	0.64	-1.00	1.00	-0.18	-0.23	0.70	-1.00	1.00
SLIM > \$20k Imbalance	-0.04	-0.04	0.80	-1.00	1.00	-0.08	-0.13	0.83	-1.00	1.00
Small Imbalance	-0.05	-0.04	0.52	-1.00	1.00	-0.03	-0.02	0.58	-1.00	1.00
MLIM Imbalance	-0.08	0.00	0.51	-1.00	1.00	-0.11	-0.03	0.54	-1.00	1.00
Complex Imbalance	-0.04	0.00	0.47	-1.00	1.00	-0.06	0.00	0.51	-1.00	1.00
Large Imbalance	-0.03	0.00	0.73	-1.00	1.00	-0.05	-0.01	0.75	-1.00	1.00
> \$50k Imbalance	-0.01	0.00	0.74	-1.00	1.00	-0.05	-0.04	0.77	-1.00	1.00
Internalized volume in underlying	0.17	0.15	0.09	0.00	0.39	0.17	0.15	0.08	0.00	0.38
Robinhood ownership breadth, log	6.90	6.80	1.76	3.30	11.78	7.02	6.91	1.78	3.33	11.93
WSB mentions, log	0.18	0.00	0.56	0.00	3.22	0.19	0.00	0.58	0.00	3.26
Option trading volume, lagged log	5.41	5.30	2.89	0.19	12.38	4.90	4.70	2.85	0.18	11.84
Underlying price, log	3.30	3.37	1.29	0.33	6.03	3.39	3.45	1.26	0.44	6.10
Underlying return, past week	0.01	0.00	0.09	-0.24	0.32	0.01	0.00	0.09	-0.25	0.33
Total volume in underlying, log	15.43	15.39	1.50	11.89	19.18	15.60	15.56	1.46	12.15	19.27
Underlying spread	0.04	0.04	0.03	0.00	0.18	0.05	0.04	0.03	0.00	0.18
Underlying volatility	0.48	0.36	0.42	0.04	2.39	0.49	0.36	0.43	0.04	2.45
Market cap, log	7.57	7.57	1.94	3.24	12.13	7.76	7.76	1.90	3.46	12.21
D(is ETF)	0.15	0.00	0.35	0.00	1.00	0.14	0.00	0.35	0.00	1.00
Option spread	0.49	0.36	0.41	0.05	2.00	0.48	0.34	0.42	0.05	2.00
Option moneyness	-0.05	-0.04	0.13	-0.47	0.43	-0.10	-0.07	0.18	-0.94	0.37
Option time to expiration	0.08	0.06	0.06	0.00	0.27	0.07	0.05	0.06	0.00	0.30
Option leverage	14.51	10.64	12.65	2.38	75.02	13.61	10.05	12.35	0.97	71.17
Option delta	0.42	0.42	0.14	0.11	0.83	-0.35	-0.33	0.15	-0.82	-0.06
Option gamma	0.12	0.08	0.15	0.01	0.66	0.12	0.07	0.16	0.00	0.71
Option vega	6.64	3.37	10.50	0.19	47.13	6.31	3.16	9.99	0.15	44.84
Option theta	-18.88	-7.67	52.77	-172.61	-0.45	-20.49	-8.68	54.33	-180.76	-0.47

This table reports the descriptive statistics for the daily ticker-level sample from November 2019 till June 20211, separately for call and put options. The sample includes all stock and ETF tickers with lagged price above \$1. SLIM and Small Share are the ticker-level volume shares of SLIM and small trades, respectively. SLIM and Small Imbalance are the ticker-level volume imbalance for SLIM and small trades, respectively. Share and imbalance are constructed similarly for SLIM < \$250, SLIM < \$5,000, SLIM < \$20,000, SLIM \$5,000 − 20,000, MLIM, complex (all multi-leg), large (above 100 contracts) trades and trades above \$50,000. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying price (log) is as of the day before. Underlying return is the total return over the last week. Total volume in underlying, log, is the logarithm of the total trading volume (lit, ATS and non-ATS OTC) in underlying ticker over the previous week. Underlying spread is averaged over the previous week. Underlying volatility is return volatility over the previous week. Option spread is the contract quoted relative spread. Option time to expiration (in months), moneyness, spread, and leverage are equal-weighted across trades at a ticker level. Option Greeks are from OptionMetrics (not winsorized, equal-weighted across trades at a ticker level). WSB mentions, Robinhood ownership breadth, underlying volatility, and spread as well as option spread, time to expiration, and lambda are winsorized at 99^{th} percentile. Underlying return and option moneyness are winsorized at 0.5^{th} and 99.5^{th} percentiles.

A.14 SLIM volume and quasi-Robinhood portfolio

Table A14: SLIM trading and quasi-Robinhood portfolio

	SLIM Share		**SLIM Imbalance**	
	Call	Put	Call	Put
	(1)	(2)	(3)	(4)
QRH weight	0.017***	0.023***	-0.003	0.034***
	(3.04)	(4.25)	(-0.59)	(6.81)
Observations	1,430,765	1,242,849	1,101,529	834,658
Adjusted R-squared	0.102	0.077	0.021	0.023

This table reports the results of estimating (1) on daily data from November 4, 2019 till August 10, 2020, separately for call and put options. The sample includes all stock and ETF tickers with lagged price above $1. As a dependent variable, we use SLIM Share or SLIM Imbalance. SLIM is a single-leg price improvement auction, through which we measure retail activity. QRH weight is a log weight of the ticker in a quasi-Robinhood portfolio suggested in Welch (2022), using a three-month lag instead of a 12-month lag. All regressions include X and C controls, as described in Section 2.3, as well as date and ticker fixed effects. t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.15 SLIM trades below $250 and other measures of retail activity

Table A15: Share of SLIM option trades below $250 in size and other measures of retail activity

	SLIM < $250 trades in calls				**SLIM < $250 trades in puts**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: SLIM < $250 Share								
Small Share	0.227***				0.206***			
	(74.54)				(72.49)			
Internalized volume in underlying		0.010***				0.009***		
		(3.44)				(3.29)		
Robinhood ownership breadth, log			0.007				0.027***	
			(0.70)				(3.01)	
WSB mentions, log				0.006***				0.004***
				(4.41)				(3.46)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.149	0.114	0.102	0.127	0.102	0.070	0.068	0.076
Panel B: SLIM < $250 Imbalance								
Small Imbalance	0.481***				0.474***			
	(205.67)				(160.60)			
Internalized volume in underlying		0.017***				0.013***		
		(5.80)				(3.81)		
Robinhood ownership breadth, log			0.042***				0.028***	
			(3.71)				(2.69)	
WSB mentions, log				0.018***				0.013***
				(13.51)				(9.40)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	938,895	939,586	366,203	823,682	686,300	686,847	271,801	623,959
Adjusted R-squared	0.147	0.029	0.038	0.029	0.140	0.030	0.032	0.029

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. SLIM < $250 and Small Share are the ticker-level volume shares of SLIM (below $250) and small trades, respectively. SLIM < $250 and Small Imbalance are the ticker-level volume imbalance for SLIM (below $250) and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.16 SLIM trades and other measures of retail activity, most traded tickers only

Table A16: Retail trading in options and other measures of retail activity, most traded tickers only

	Retail trading in calls				Retail trading in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: SLIM Share								
Small Share	0.311***				0.209***			
	(17.12)				(16.97)			
Internalized volume in underlying		0.092***				0.067***		
		(3.60)				(4.10)		
Robinhood ownership breadth, log			0.049				0.019	
			(0.95)				(0.46)	
WSB mentions, log				-0.014				0.021**
				(-1.31)				(2.54)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	135,444	135,444	57,838	126,756	135,159	135,159	57,617	126,471
Adjusted R-squared	0.413	0.380	0.358	0.375	0.346	0.328	0.286	0.326
Panel B: SLIM Imbalance								
Small Imbalance	0.282***				0.212***			
	(40.24)				(34.12)			
Internalized volume in underlying		0.033***				0.001		
		(3.30)				(0.13)		
Robinhood ownership breadth, log			0.069***				0.061**	
			(2.64)				(2.49)	
WSB mentions, log				0.048***				0.022***
				(8.93)				(4.15)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	134,974	134,980	57,489	126,292	134,182	134,194	56,850	125,506
Adjusted R-squared	0.112	0.045	0.044	0.045	0.095	0.057	0.053	0.056

This table reports the results of estimating (1) on daily data for the underlying securities in the top decile by their total option dollar traded volume from November 2019 to June 2021 (355 tickers). SLIM and Small Share are the ticker-level volume shares of SLIM and small trades, respectively. SLIM and Small Imbalance are the ticker-level volume imbalance for SLIM and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.17 Constructing the sample of broker outages

Our sample of outages is manually constructed from several public sources.

For outages on Robinhood, we follow Barber, Huang, Odean, and Schwartz (2022) and use incident history from Robinhood's website.[48] Incident history includes the exact time when an outage started and ended, as well as the services that were affected.

For all other brokers, we mainly rely on Twitter. The start time of an outage is typically reported in posts from DownDetector.com. Such posts typically include the name of the broker whose platform is experiencing an outage and the time when the outage started (according to the data of DownDetector.com, which is based on user reports to the website and posts on Twitter). Users frequenty comment on such posts stipulating the range of actions that they are not able to perform. See, for example, a tweet reporting TD Ameritrade's outage on November 19, 2019: https://twitter.com/downdetector/status/1270712032665337856. The end time of an outage is typically reported by the retail broker itself. For the same TD Ameritrade's outage on November 19, 2019: https://twitter.com/TDAmeritrade/status/1270726116710313991. We also include outages reported by ordinary users on Twitter, yet we always require two tweets to identify an outage (from Twitter users, DownDetector.com, or the retail broker itself). We believe that our approach may miss smaller outages but should pick up all major ones. Comments on Twitter also allow us to document the affected service for all outages.

Our final list of outages only includes incidents that may significantly affect trading in options. In other words, we exlcude certain types of outages, such as those related to cryptoassets, trading fractional shares, and loading of charts. The resultant number of outages by broker from November 2019 to July 2021 is reported in Table A17 below.

Table A17: Number of outages by broker

Broker	No. outages
TD Ameritrade	35
Robinhood	33
Charles Schwab	29
E*TRADE	27
Fidelity	21
Ally	21
Vanguard	16
Webull	11
Tradestation	5
tastyworks	2

[48] Accessed in August 2022 via https://status.robinhood.com/history?page=1.

A.18 Refined sample of broker restrictions in 2021

We start from Table 1 in Jones, Reed, and Waller (2021) and construct the sample of refined timings of broker restrictions using the Wayback Machine, Twitter, and reddit.com. We cannot fully separate TD Ameritrade and Charles Schwab because Charles Schwab completed its acquisition of TD Ameritrade in October 2020 and TD referred customers to the official statements issued by Charles Schwab at the time of restrictions. Furthermore, we do not include smaller brokerages separately due to their market share and because their (less frequent) restrictions coincide with times when both Robinhood and TD Ameritrade / Charles Schwab had restrictions in place. Such brokerages include Ally, Apex, E*TRADE, tastyworks, Tradestation, and Webull. Finally, we could not find evidence of restrictions by some brokerages in our sample, such as Fidelity.

A handful of tickers remained restricted even in summer 2021, with little evidence on the exact end date of restrictions. In those cases, we set the end date to March 19, 2021, when most restrictions ceased. This end date also allows us to keep the overall sample comparable to that in Jones, Reed, and Waller (2021).

Table A18: Broker restrictions and retail trading in options, smaller sample

Ticker	Broker	Start date	Start time	End date	End time
AAL	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
ACB	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
AG	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
AMC	Robinhood	28/01/2021	08:15:00	04/02/2021	21:56:00
AMC	TD Ameritrade or Charles Schwab	27/01/2021	13:15:00	19/03/2021	16:30:00
AMD	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
BB	Robinhood	28/01/2021	08:15:00	02/02/2021	11:08:00
BB	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
BBBY	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
BBBY	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
BYDDY	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
BYND	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
CCIV	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
CLOV	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
CRIS	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
CTRM	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
CVM	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
DDS	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
EXPR	Robinhood	28/01/2021	08:15:00	02/02/2021	20:44:00
EXPR	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
EZGO	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
FIZZ	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
FOSL	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
GM	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
GME	Robinhood	28/01/2021	08:15:00	04/02/2021	21:56:00
GME	TD Ameritrade or Charles Schwab	25/01/2021	00:00:00	19/03/2021	16:30:00
GNUS	Robinhood	31/01/2021	01:44:00	02/02/2021	11:08:00
GSX	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
GTE	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
HIMS	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
INO	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
IPOE	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
IPOF	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
IRBT	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
JAGX	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
KOSS	Robinhood	28/01/2021	08:15:00	02/02/2021	11:08:00
KOSS	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
LLIT	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
MRNA	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
MUX	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
NAK	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
NAKD	Robinhood	28/01/2021	08:15:00	02/02/2021	20:44:00
NAKD	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
NCITY	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
NCMI	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
NOK	Robinhood	28/01/2021	08:15:00	02/02/2021	20:44:00
NOK	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
NVAX	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
OPEN	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
RKT	TD Ameritrade or Charles Schwab	04/03/2021	16:30:00	19/03/2021	16:30:00
RKT	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
RLX	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
RYCEY	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
SBUX	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
SHLS	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
SIEB	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
SLV	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
SNDL	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
SOXL	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
SRNE	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
STPK	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
TGC	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
TIRX	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
TR	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
TR	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
TRVG	Robinhood	28/01/2021	08:15:00	31/01/2021	01:44:00
TRXC	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00
UONE	TD Ameritrade or Charles Schwab	28/01/2021	16:00:00	08/02/2021	09:00:00
VIR	TD Ameritrade or Charles Schwab	28/01/2021	10:21:00	04/03/2021	17:18:00
WKHS	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
XM	Robinhood	29/01/2021	14:00:00	31/01/2021	01:44:00
ZOM	Robinhood	29/01/2021	14:57:00	31/01/2021	01:44:00

A.19 Ticker-level restrictions: Alternative samples

Table A19: Ticker-level restrictions and retail trading in options, alternative samples

	SLIM Share			
Sample	Restricted only		Restricted+WSB+Frenzy	
	(1)	(2)	(3)	(4)
Panel A: Jones, Reed, and Waller (2021) sample				
D(RH restricted)	-2.580	-2.885	-4.417**	-3.968*
	(-1.14)	(-1.16)	(-2.05)	(-1.66)
D(TD restricted)	-1.482*	-2.205**	-1.862**	-2.225**
	(-1.76)	(-2.41)	(-2.43)	(-2.43)
D(Both restricted)	-5.391**	-3.585**	-5.950***	-2.903*
	(-2.53)	(-2.58)	(-2.96)	(-1.89)
Lagged log volume, 2-day		-0.378**		-0.133**
		(-2.33)		(-2.57)
Lagged log price, 2-day		-3.326***		-4.197***
		(-3.14)		(-4.87)
Log volume change, one day		-0.498***		-0.429***
		(-11.31)		(-18.24)
Log price change, one day		-4.460***		-4.396***
		(-4.29)		(-4.20)
Observations	625,629	490,548	3,908,566	2,489,593
Adjusted R-squared	0.131	0.125	0.101	0.117
Panel B: Refined sample				
D(RH restricted)	-2.054*	-2.676	-2.911***	-2.617
	(-1.68)	(-1.50)	(-2.62)	(-1.53)
D(TD restricted)	-1.728**	-1.781***	-2.162***	-1.808***
	(-2.57)	(-3.21)	(-3.43)	(-3.12)
D(Both restricted)	-5.338***	-4.239***	-6.264***	-4.116***
	(-3.07)	(-2.99)	(-3.79)	(-3.06)
Lagged log volume, 2-day		-0.232**		-0.108**
		(-2.10)		(-2.12)
Lagged log price, 2-day		-3.438***		-3.710***
		(-4.20)		(-5.58)
Log volume change, one day		-0.517***		-0.424***
		(-12.04)		(-18.43)
Log price change, one day		-4.603***		-3.558***
		(-4.91)		(-4.22)
Observations	1,120,301	883,456	4,785,974	3,093,337
Adjusted R-squared	0.120	0.124	0.097	0.111

This table reports the results of estimating (3) in a minute-ticker panel. Sample in columns (3)-(4) includes only tickers that have ever been restricted, while the one in columns (5)-(6) includes the baseline and tickers that experienced at least two retail frenzies in the sample of Barber, Huang, Odean, and Schwartz (2022). $D(RH\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by Robinhood in minute t, and 0 otherwise. $D(TD\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by TD Ameritrade or Charles Schwab in minute t, and 0 otherwise. $D(Both\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by both Robinhood and TD Ameritrade/Charles Schwab in minute t, and 0 otherwise. SLIM Share is the ticker-level volume share of SLIM trades. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. All regressions include time of the day, date, and ticker fixed effects. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.20 Characteristics of MLIM trades

In this section, we describe trades that are multi-leg and that went through price improvement auctions. These trades are on average larger than SLIM trades, more balanced by option type, and negatively correlated with equity-based measures of retail activity. Furthermore, a larger fraction of these trades is executed at midpoint.

Table A20: MLIM trades in options and other measures of retail activity

	MLIM trades in calls				**MLIM trades in puts**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: MLIM Share								
Small Share	0.048***				0.045***			
	(16.42)				(22.09)			
Internalized volume in underlying		-0.004				0.006**		
		(-1.44)				(2.23)		
Robinhood ownership breadth, log			0.008				0.012	
			(1.12)				(1.36)	
WSB mentions, log				-0.008***				-0.002
				(-5.62)				(-1.35)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.060	0.058	0.043	0.061	0.048	0.047	0.041	0.049
Panel B: MLIM Imbalance								
Small Imbalance	0.281***				0.373***			
	(59.75)				(75.38)			
Internalized volume in underlying		-0.000				0.000		
		(-0.10)				(0.03)		
Robinhood ownership breadth, log			-0.024*				-0.016	
			(-1.88)				(-1.04)	
WSB mentions, log				-0.001				-0.005***
				(-0.81)				(-3.43)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	542,812	543,022	198,014	502,477	457,425	457,960	174,656	427,021
Adjusted R-squared	0.033	0.014	0.016	0.013	0.058	0.021	0.023	0.019

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. MLIM and Small Share are the ticker-level volume shares of MLIM and small trades, respectively. MLIM and Small Imbalance are the ticker-level volume imbalance for MLIM and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A21: Composition of MLIM trades

Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	54.1	53.5	15.4	7.0
	Put	45.9	46.5	18.2	8.5
Trade size	1	54.4	10.3	17.6	8.6
(contracts)	2-5	28.6	16.9	15.4	6.5
	6-10	9.8	16.6	16.2	6.8
	11-100	6.7	40.1	16.1	7.3
	Above 100	0.5	16.2	14.6	7.7
Trade size	Below 250	40.6	15.4	29.9	14.9
(dollars)	250-500	14.6	8.1	10.0	2.9
	500-1,000	13.9	10.1	8.3	2.2
	1,000-2,500	14.3	15.4	7.2	1.8
	2,500-5,000	7.2	11.9	6.2	1.5
	5,000-10,000	4.5	10.8	5.4	1.4
	10,000-20,000	2.5	9.1	4.8	5.3
	20,000-50,000	1.5	8.8	4.2	12.8
	Above 50,000	0.8	10.4	3.7	19.3
Trade direction	Sell	54.3	53.4	13.9	6.1
	Buy	39.6	41.0	20.1	11.0
	Midpoint	6.0	5.6	19.7	0.0
Time to expiration	Less than a week	36.1	40.4	23.1	12.7
	1-2 weeks	14.9	14.7	14.8	6.2
	2-4 weeks	21.8	19.0	13.8	4.5
	1-3 months	20.3	17.5	10.3	3.2
	3-12 months	5.7	6.9	15.3	7.4
	Over a year	1.1	1.5	14.8	9.8
Moneyness	Below -2	0.1	0.3	79.8	37.4
	-2 to -1	0.2	0.3	68.5	24.7
	-1 to -0.1	25.0	22.9	32.8	14.8
	At the money	69.8	71.2	11.4	5.2
	0.1 to 1	4.8	5.1	5.9	5.3
	1 to 2	0.1	0.1	6.7	16.2
	Above 2	0.0	0.1	12.2	23.3
Trade direction	Sell - Call	29.0	28.3	13.0	5.8
and type	Sell - Put	25.3	25.1	14.9	6.5
	Buy - Call	22.0	22.3	18.2	9.7
	Buy - Put	17.6	18.7	22.4	12.7
	Midpoint - Call	3.1	2.9	18.2	0.0
	Midpoint - Put	2.9	2.7	21.3	0.0
ETF	No	74.6	70.6	17.7	7.2
	Yes	25.4	29.4	13.9	9.2

This table reports characteristics of MLIM trades (multi-leg price improvement auctions) by category. Our sample is from November 2019 to June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

A.21 Complex strategy trades and measures of retail activity

Table A22: Complex strategy trades in options and measures of retail activity

	Trades in calls				Trades in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Complex Share								
Small Share	-0.008***				0.020***			
	(-3.01)				(7.62)			
Internalized volume in underlying		-0.006**				0.000		
		(-2.08)				(0.08)		
Robinhood ownership breadth, log			-0.012				0.003	
			(-1.25)				(0.23)	
WSB mentions, log				-0.011***				-0.002
				(-5.89)				(-0.99)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.126	0.126	0.122	0.135	0.108	0.107	0.101	0.114
Panel B: Complex Imbalance								
Small Imbalance	0.403***				0.514***			
	(105.45)				(127.45)			
Internalized volume in underlying		0.000				0.003		
		(0.10)				(1.03)		
Robinhood ownership breadth, log			-0.018*				-0.002	
			(-1.90)				(-0.17)	
WSB mentions, log				-0.003**				-0.003**
				(-2.17)				(-2.56)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	809,093	810,180	307,652	725,746	706,819	709,103	277,897	641,913
Adjusted R-squared	0.067	0.009	0.012	0.008	0.120	0.012	0.015	0.010

This table reports the results of estimating (1) on daily data from November 2019 to June 2021. Complex and Small Share are the ticker-level volume shares of all multi-leg strategy and small trades, respectively. Complex and Small Imbalance are the ticker-level volume imbalance for all multi-leg and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.22 Trades above $50,000 and measures of retail activity

Table A23: Trades in size above $50,000 in options and measures of retail activity

	Trades in calls				Trades in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Share of trades sized above $50,000								
Small Share	-0.209***				-0.193***			
	(-33.84)				(-28.99)			
Internalized volume in underlying		0.017***				-0.005*		
		(7.40)				(-1.77)		
Robinhood ownership breadth, log			0.044***				-0.009	
			(4.25)				(-0.67)	
WSB mentions, log				0.011***				0.003
				(4.54)				(1.12)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.155	0.125	0.120	0.126	0.132	0.104	0.107	0.105
Panel B: Imbalance in trades sized above $50,000								
Small Imbalance	0.248***				0.238***			
	(30.38)				(25.80)			
Internalized volume in underlying		-0.001				0.010		
		(-0.19)				(1.10)		
Robinhood ownership breadth, log			-0.053**				-0.021	
			(-2.26)				(-0.84)	
WSB mentions, log				0.005**				0.006***
				(2.37)				(2.60)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	181,716	181,931	65,258	169,372	132,775	133,173	55,581	123,645
Adjusted R-squared	0.024	0.016	0.020	0.014	0.029	0.021	0.026	0.020

This table reports the results of estimating (1) on daily data from November 2019 to June 2021. Small Share is the ticker-level volume share of small trades. Small Imbalance is the ticker-level volume imbalance for small trades. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.23 Alternative measures of retail trading: More details

In this appendix we present additional tables supporting the alternative measures presented in Section 2.4 in the main text.

Table A24: Composition of All Internalized trades

Characteristic	Category	All Internalized trades				Not All Internalized trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	67.6	67.1	10.3	4.0	60.7	58.0	13.7	4.0
	Put	32.4	32.9	10.4	4.1	39.3	42.0	15.0	4.0
Trade size (contracts)	1	52.0	13.4	10.0	3.9	32.6	2.0	15.3	3.2
	2-5	40.5	32.5	9.7	4.0	22.1	4.1	15.6	3.5
	6-10	3.7	8.5	14.4	3.6	20.7	10.7	12.3	4.5
	11-100	3.5	31.6	15.2	4.2	22.6	41.6	12.4	4.8
	Above 100	0.2	14.0	15.3	6.0	2.0	41.6	12.8	5.2
Trade size (dollars)	Below 250	44.7	21.8	16.8	6.7	29.6	7.3	29.1	8.3
	250-500	16.6	11.3	6.2	2.4	13.2	5.1	11.9	3.1
	500-1,000	14.4	12.6	5.2	1.9	14.1	7.3	9.4	2.5
	1,000-2,500	13.1	16.0	4.4	1.6	17.3	13.1	7.4	2.0
	2,500-5,000	5.8	10.8	3.7	1.3	10.3	11.7	5.9	1.7
	5,000-10,000	3.1	9.4	3.3	1.0	7.0	11.4	4.9	1.4
	10,000-20,000	1.4	7.1	3.0	0.9	4.2	10.3	4.2	1.2
	20,000-50,000	0.7	5.7	2.8	0.7	2.8	10.8	3.5	1.0
	Above 50,000	0.2	5.3	2.6	0.6	1.5	23.0	3.2	0.9
Trade direction	Sell	49.6	49.6	9.5	3.6	48.7	48.4	13.0	3.5
	Buy	49.4	48.9	10.7	4.4	46.5	48.9	14.9	4.8
	Midpoint	0.9	1.5	20.5	0.0	4.8	2.7	15.9	0.0
Time to expiry	Less than a week	45.2	47.2	10.6	4.3	40.5	38.7	15.5	4.9
	1-2 weeks	14.9	13.6	8.3	3.3	14.2	12.7	11.6	3.1
	2-4 weeks	16.4	15.8	10.1	3.8	17.7	17.6	13.6	3.3
	1-3 months	14.0	14.2	9.1	3.3	16.9	18.5	11.7	2.8
	3-12 months	7.8	7.6	10.4	3.6	8.7	10.3	12.5	3.1
	Over a year	1.7	1.5	11.1	4.1	2.1	2.1	17.0	3.5
Moneyness	Below -2	0.2	0.3	52.3	19.9	0.2	0.3	74.1	19.9
	-2 to -1	0.3	0.4	41.5	15.8	0.4	0.5	58.6	14.5
	-1 to -0.1	22.1	23.2	20.8	7.9	24.0	25.2	26.6	7.5
	At the money	72.8	72.3	7.2	2.8	70.2	69.0	10.0	2.8
	0.1 to 1	4.3	3.7	5.8	2.1	4.9	4.6	6.9	1.5
	1 to 2	0.2	0.1	7.3	2.8	0.2	0.2	8.9	2.1
	Above 2	0.1	0.1	14.4	5.7	0.1	0.1	16.6	4.7
Trade direction and type	Sell - Call	33.6	33.2	9.5	3.6	29.2	27.9	12.6	3.5
	Sell - Put	16.1	16.4	9.8	3.8	19.4	20.5	14.0	3.6
	Buy - Call	33.4	32.9	10.9	4.5	28.5	28.5	14.6	4.8
	Buy - Put	16.0	16.0	10.8	4.5	18.0	20.4	15.8	4.9
	Midpoint - Call	0.6	1.0	21.5	0.0	2.9	1.5	15.5	0.0
	Midpoint - Put	0.3	0.5	18.9	0.0	1.9	1.1	17.0	0.0
ETF	No	83.3	74.6	10.9	4.2	78.1	62.9	15.3	4.2
	Yes	16.7	25.4	7.3	2.9	21.9	37.1	10.2	3.4

This table reports daily average characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

Table A25: Differences between All Internalized and not All Internalized trades

		All Internalized minus not All Internalized			
Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	6.96	9.12	-3.36	0.02
		(17.71)	(27.87)	(-24.18)	(0.24)
	Put	-6.96	-9.12	-4.58	0.11
		(-17.71)	(-27.87)	(-27.08)	(1.76)
Trade size (contracts)	1	19.44	11.43	-5.35	0.69
		(75.97)	(32.03)	(-39.06)	(7.06)
	2-5	-16.99	-2.24	2.02	-0.90
		(-146.43)	(-10.79)	(16.92)	(-23.40)
	6-10	-19.02	-9.97	2.77	-0.58
		(-113.59)	(-12.82)	(14.50)	(-15.98)
	11-100	-1.85	-27.56	2.49	0.82
		(-40.98)	(-62.76)	(9.20)	(9.71)
	Above 100	18.43	28.34	-5.89	0.55
		(65.78)	(66.09)	(-54.68)	(6.09)
Trade size (dollars)	Below 250	15.08	14.56	-12.32	-1.67
		(65.09)	(52.37)	(-48.13)	(-12.71)
	250-500	3.44	6.19	-5.76	-0.71
		(42.37)	(96.66)	(-28.76)	(-27.10)
	500-1,000	0.22	5.25	-4.20	-0.52
		(1.66)	(54.85)	(-25.55)	(-27.47)
	1,000-2,500	-4.19	2.98	-2.95	-0.43
		(-28.94)	(15.10)	(-20.84)	(-20.77)
	2,500-5,000	-4.50	-0.92	-2.20	-0.44
		(-80.89)	(-6.20)	(-20.34)	(-21.99)
	5,000-10,000	-3.85	-2.02	-1.64	-0.42
		(-60.33)	(-23.18)	(-20.15)	(-23.21)
	10,000-20,000	-2.80	-3.23	-1.16	-0.38
		(-38.94)	(-44.67)	(-17.70)	(-21.13)
	20,000-50,000	-2.09	-5.11	-0.79	-0.33
		(-28.55)	(-52.19)	(-12.81)	(-19.77)
	Above 50,000	-1.33	-17.70	-0.57	-0.24
		(-22.42)	(-44.44)	(-6.53)	(-13.26)
Trade direction	Sell	0.97	1.21	-3.56	0.07
		(10.24)	(11.38)	(-32.02)	(1.57)
	Buy	2.90	-0.03	-4.16	-0.37
		(31.88)	(-0.29)	(-49.21)	(-4.17)
	Midpoint	-3.87	-1.18	4.56	NA
		(-35.77)	(-30.00)	(21.90)	(NA)
Time to expiry	Less than a week	4.72	8.45	-4.88	-0.55
		(20.44)	(41.75)	(-58.45)	(-7.56)
	1-2 weeks	0.71	0.91	-3.28	0.18
		(11.01)	(7.75)	(-35.90)	(3.00)
	2-4 weeks	-1.28	-1.74	-3.44	0.52
		(-13.12)	(-9.00)	(-29.59)	(7.86)
	1-3 months	-2.88	-4.30	-2.61	0.49
		(-30.18)	(-24.14)	(-13.71)	(7.71)
	3-12 months	-0.82	-2.70	-2.11	0.42
		(-6.62)	(-18.91)	(-6.82)	(4.38)
	Over a year	-0.44	-0.63	-5.91	0.61
		(-10.23)	(-10.27)	(-16.46)	(6.83)
Moneyness	Below -2	-0.03	-0.10	-21.78	-0.01
		(-5.24)	(-5.45)	(-11.21)	(-0.03)
	-2 to -1	-0.09	-0.09	-17.13	1.25
		(-8.74)	(-7.82)	(-16.67)	(4.94)
	-1 to -0.1	-1.90	-2.06	-5.71	0.37
		(-12.34)	(-9.92)	(-24.89)	(3.13)
	At the money	2.61	3.24	-2.81	0.03
		(16.00)	(13.43)	(-67.78)	(0.66)
	0.1 to 1	-0.58	-0.88	-1.12	0.61
		(-8.18)	(-6.13)	(-14.98)	(16.40)
	1 to 2	-0.00	-0.06	-1.61	0.66
		(-0.71)	(-5.22)	(-7.02)	(9.26)
	Above 2	-0.00	-0.05	-2.19	0.94
		(-1.46)	(-7.96)	(-3.69)	(4.14)
Trade direction and type	Sell - Call	4.33	5.30	-3.10	0.07
		(18.35)	(30.67)	(-16.89)	(1.58)
	Sell - Put	-3.36	-4.09	-4.21	0.17
		(-14.90)	(-24.05)	(-29.46)	(3.45)
	Buy - Call	4.88	4.38	-3.69	-0.36
		(23.44)	(24.45)	(-37.85)	(-4.06)
	Buy - Put	-1.97	-4.40	-4.97	-0.33
		(-11.26)	(-25.95)	(-22.22)	(-3.37)
	Midpoint - Call	-2.24	-0.55	5.99	NA
		(-31.41)	(-18.87)	(20.35)	(NA)
	Midpoint - Put	-1.63	-0.63	1.89	NA
		(-36.62)	(-40.79)	(7.00)	(NA)
ETF	No	5.14	11.64	-4.39	0.07
		(45.59)	(25.62)	(-38.80)	(1.17)
	Yes	-5.14	-11.64	-2.89	-0.47
		(-45.59)	(-25.62)	(-19.88)	(-5.11)

This table reports mean differences between daily characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. In parentheses are t-statistics based on Newey-West standard errors with the optimal number of lags.

Table A26: Composition of All Retail (small) trades

Characteristic	Category	All Retail (small) trades				Not All Retail (small) trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	67.1	66.9	11.0	4.0	58.4	59.3	13.9	4.5
	Put	32.9	33.1	11.1	4.2	41.6	40.7	15.4	4.3
Trade size	1	47.6	12.1	10.7	3.9	32.4	2.0	15.4	4.0
(contracts)	2-5	36.0	28.4	10.4	3.9	22.6	4.2	15.5	4.0
	6-10	13.5	29.1	11.6	4.4	8.5	4.3	15.9	4.4
	11-100	2.7	24.0	15.2	4.2	33.5	60.6	12.4	4.9
	Above 100	0.2	6.4	15.3	6.1	3.0	28.9	12.8	5.3
Trade size	Below 250	41.4	22.3	18.6	6.7	29.3	7.7	29.5	8.8
(dollars)	250-500	16.4	12.3	7.1	2.4	12.1	5.5	12.7	3.3
	500-1,000	14.9	14.3	5.8	2.0	12.9	8.0	10.2	2.6
	1,000-2,500	14.5	18.6	4.8	1.6	16.4	15.2	8.2	2.2
	2,500-5,000	6.7	11.6	3.9	1.3	10.5	14.3	6.4	1.8
	5,000-10,000	3.6	8.9	3.3	1.2	7.8	14.2	5.3	1.6
	10,000-20,000	1.6	5.9	2.9	3.3	5.2	12.4	4.3	2.3
	20,000-50,000	0.8	4.1	2.5	8.7	3.6	11.7	3.6	3.6
	Above 50,000	0.2	2.0	2.2	20.0	2.1	11.1	3.1	6.1
Trade direction	Sell	49.0	49.0	10.3	3.9	50.3	48.7	12.7	3.9
	Buy	48.6	48.7	11.2	4.3	46.1	48.9	15.8	5.2
	Midpoint	2.4	2.3	14.7	0.0	3.5	2.4	19.5	0.0
Time to expiry	Less than a week	44.5	46.3	11.1	4.2	39.8	41.9	16.7	5.5
	1-2 weeks	14.8	13.9	9.0	3.3	13.9	13.1	11.7	3.3
	2-4 weeks	16.5	15.9	11.0	3.8	18.1	16.9	13.3	3.3
	1-3 months	14.3	14.2	9.9	3.5	17.6	16.7	11.3	2.9
	3-12 months	8.1	8.0	11.1	4.0	8.5	9.4	12.0	3.8
	Over a year	1.8	1.6	12.0	5.9	2.2	2.0	17.2	6.2
Moneyness	Below -2	0.2	0.2	55.2	19.8	0.3	0.3	75.8	20.1
	-2 to -1	0.3	0.4	43.8	15.6	0.4	0.5	59.9	14.3
	-1 to -0.1	22.0	22.8	22.0	7.8	25.0	24.8	26.6	7.7
	At the money	72.8	72.3	7.7	2.8	69.1	69.8	10.2	3.1
	0.1 to 1	4.4	4.0	6.3	3.5	5.0	4.3	6.2	3.5
	1 to 2	0.2	0.1	8.0	7.6	0.2	0.2	7.7	12.4
	Above 2	0.1	0.1	15.5	12.1	0.1	0.1	14.9	21.7
Trade direction	Sell - Call	32.9	32.7	10.3	3.9	29.2	28.7	12.1	4.0
and type	Sell - Put	16.1	16.3	10.7	4.1	21.1	20.0	13.8	3.8
	Buy - Call	32.6	32.7	11.4	4.3	27.3	29.2	15.5	5.3
	Buy - Put	15.9	16.0	11.3	4.4	18.8	19.6	16.8	5.2
	Midpoint - Call	1.6	1.5	15.3	0.0	1.9	1.4	18.9	0.0
	Midpoint - Put	0.8	0.8	14.0	0.0	1.6	1.0	20.7	0.0
ETF	No	83.1	77.2	11.6	4.3	76.0	66.6	15.7	4.6
	Yes	16.9	22.8	7.7	2.9	24.0	33.4	10.6	3.7

This table reports daily average characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

Table A27: Differences between All Retail (small) and not All Retail (small) trades

		All Retail (small) minus not All Retail (small)			
Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	8.71	7.58	-2.90	-0.46
		(17.41)	(26.87)	(-16.48)	(-5.10)
	Put	-8.71	-7.58	-4.29	-0.14
		(-17.41)	(-26.87)	(-17.02)	(-1.67)
Trade size (contracts)	1	15.17	10.11	-4.67	-0.06
		(65.46)	(40.47)	(-19.61)	(-0.44)
	2-5	5.07	24.78	-4.22	0.02
		(19.81)	(98.69)	(-20.86)	(0.15)
	6-10	-30.74	-36.56	2.78	-0.62
		(-74.91)	(-55.73)	(14.63)	(-16.91)
	11-100	-2.89	-22.50	2.50	0.77
		(-34.72)	(-47.49)	(9.28)	(9.08)
	Above 100	13.39	24.17	-5.06	-0.10
		(47.49)	(110.01)	(-26.76)	(-0.96)
Trade size (dollars)	Below 250	12.03	14.64	-10.92	-2.08
		(47.00)	(80.36)	(-36.24)	(-13.92)
	250-500	4.24	6.80	-5.63	-0.82
		(56.62)	(146.21)	(-29.76)	(-18.44)
	500-1,000	1.92	6.29	-4.41	-0.63
		(17.71)	(75.44)	(-29.47)	(-18.00)
	1,000-2,500	-1.88	3.43	-3.37	-0.54
		(-14.21)	(14.49)	(-24.09)	(-18.30)
	2,500-5,000	-3.84	-2.67	-2.51	-0.48
		(-57.33)	(-11.41)	(-19.04)	(-16.23)
	5,000-10,000	-4.21	-5.30	-1.95	-0.36
		(-63.04)	(-41.01)	(-19.76)	(-10.54)
	10,000-20,000	-3.51	-6.48	-1.45	1.07
		(-33.74)	(-98.17)	(-21.11)	(7.65)
	20,000-50,000	-2.84	-7.65	-1.09	5.11
		(-23.01)	(-42.76)	(-21.03)	(24.51)
	Above 50,000	-1.92	-9.08	-0.96	13.91
		(-18.22)	(-23.89)	(-13.45)	(19.32)
Trade direction	Sell	-1.34	0.36	-2.38	0.02
		(-11.39)	(4.45)	(-13.74)	(0.28)
	Buy	2.42	-0.19	-4.57	-0.93
		(23.95)	(-1.78)	(-23.82)	(-9.15)
	Midpoint	-1.08	-0.17	-4.88	NA
		(-13.23)	(-4.58)	(-18.81)	(NA)
Time to expiry	Less than a week	4.71	4.49	-5.58	-1.29
		(15.25)	(21.34)	(-30.20)	(-13.43)
	1-2 weeks	0.87	0.77	-2.73	-0.03
		(9.08)	(8.12)	(-17.59)	(-0.35)
	2-4 weeks	-1.56	-0.99	-2.27	0.50
		(-11.74)	(-7.27)	(-11.56)	(5.34)
	1-3 months	-3.30	-2.51	-1.34	0.55
		(-24.53)	(-20.22)	(-5.21)	(6.59)
	3-12 months	-0.32	-1.44	-0.85	0.18
		(-1.98)	(-12.72)	(-2.54)	(1.32)
	Over a year	-0.41	-0.33	-5.20	-0.28
		(-8.31)	(-7.32)	(-12.61)	(-1.28)
Moneyness	Below -2	-0.05	-0.09	-20.58	-0.29
		(-5.94)	(-6.99)	(-8.87)	(-0.72)
	-2 to -1	-0.12	-0.09	-16.05	1.32
		(-8.43)	(-8.99)	(-12.03)	(4.35)
	-1 to -0.1	-2.99	-2.02	-4.64	0.04
		(-13.30)	(-12.58)	(-13.55)	(0.27)
	At the money	3.68	2.50	-2.51	-0.26
		(16.00)	(12.94)	(-24.86)	(-4.58)
	0.1 to 1	-0.54	-0.24	0.03	0.04
		(-4.84)	(-2.79)	(0.37)	(0.43)
	1 to 2	0.01	-0.03	0.26	-4.84
		(1.48)	(-3.72)	(1.09)	(-5.28)
	Above 2	0.01	-0.03	0.58	-9.60
		(1.04)	(-5.95)	(0.84)	(-7.35)
Trade direction and type	Sell - Call	3.67	4.06	-1.77	-0.09
		(13.93)	(28.16)	(-10.60)	(-0.91)
	Sell - Put	-5.01	-3.70	-3.07	0.29
		(-20.41)	(-25.76)	(-13.64)	(4.20)
	Buy - Call	5.34	3.45	-4.02	-0.98
		(20.20)	(22.29)	(-21.77)	(-10.31)
	Buy - Put	-2.92	-3.63	-5.42	-0.80
		(-12.97)	(-25.94)	(-16.95)	(-6.57)
	Midpoint - Call	-0.30	0.08	-3.59	NA
		(-7.27)	(3.12)	(-6.98)	(NA)
	Midpoint - Put	-0.78	-0.25	-6.72	NA
		(-17.29)	(-13.77)	(-28.50)	(NA)
ETF	No	7.09	10.59	-4.10	-0.35
		(29.01)	(22.54)	(-27.61)	(-4.09)
	Yes	-7.09	-10.59	-2.89	-0.84
		(-29.01)	(-22.54)	(-14.52)	(-7.34)

This table reports mean differences between daily characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. In parentheses are t-statistics based on Newey-West standard errors with the optimal number of lags.

Table A28: Composition of All Retail (small + cheap) trades

Characteristic	Category	All Retail (small + cheap) trades				Not All Retail (small + cheap) trades			
		Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	67.0	66.0	11.3	4.2	57.1	57.2	13.4	3.9
	Put	33.0	34.0	11.5	4.4	42.9	42.8	15.3	3.9
Trade size (contracts)	1	44.1	7.6	10.7	3.9	38.9	2.8	15.4	4.0
	2-5	33.3	17.7	10.4	3.9	27.1	6.0	15.5	4.0
	6-10	12.5	18.1	11.6	4.4	10.2	6.2	15.9	4.4
	11-100	9.7	46.6	15.2	6.0	20.8	50.4	9.8	3.3
	Above 100	0.4	10.0	25.1	11.0	3.0	34.6	8.9	3.5
Trade size (dollars)	Below 250	39.3	17.8	19.4	7.1	32.6	6.5	27.9	7.7
	250-500	16.0	11.2	7.8	2.8	12.4	3.8	11.2	2.3
	500-1,000	15.0	14.7	6.5	2.3	12.1	4.9	9.3	1.8
	1,000-2,500	15.8	23.7	5.4	1.9	13.3	7.9	7.7	1.5
	2,500-5,000	8.2	19.5	4.5	1.6	7.2	6.5	6.5	1.2
	5,000-10,000	3.3	5.5	3.3	1.2	9.4	20.3	5.3	1.6
	10,000-20,000	1.5	3.7	2.9	3.3	6.2	17.7	4.3	2.3
	20,000-50,000	0.7	2.6	2.5	8.7	4.3	16.7	3.6	3.6
	Above 50,000	0.2	1.3	2.2	20.0	2.6	15.7	3.1	6.1
Trade direction	Sell	48.9	48.4	10.5	4.1	50.9	49.2	12.4	3.5
	Buy	48.7	49.3	11.7	4.6	45.3	48.2	15.5	4.6
	Midpoint	2.4	2.2	15.1	0.0	3.8	2.6	19.3	0.0
Time to expiry	Less than a week	44.8	48.4	11.5	4.4	37.8	37.6	17.0	5.1
	1-2 weeks	14.7	13.7	9.3	3.4	14.0	12.9	11.4	2.8
	2-4 weeks	16.5	15.8	11.3	4.0	18.5	17.5	12.9	2.8
	1-3 months	14.2	13.5	10.3	3.7	18.5	18.6	10.7	2.5
	3-12 months	8.0	7.2	11.5	4.2	8.8	10.9	11.3	3.4
	Over a year	1.7	1.3	12.4	6.0	2.4	2.4	16.9	5.9
Moneyness	Below -2	0.2	0.3	55.7	20.5	0.2	0.2	80.7	18.4
	-2 to -1	0.3	0.5	44.2	16.2	0.4	0.4	62.9	12.8
	-1 to -0.1	22.6	26.2	22.4	8.1	24.0	21.9	26.7	6.9
	At the money	72.4	69.9	7.9	3.0	69.4	71.6	10.0	2.8
	0.1 to 1	4.2	2.9	6.4	3.6	5.7	5.6	6.0	3.5
	1 to 2	0.2	0.1	8.3	7.6	0.2	0.2	6.8	12.4
	Above 2	0.1	0.1	17.0	12.5	0.1	0.1	11.0	21.2
Trade direction and type	Sell - Call	32.7	31.8	10.5	4.0	28.9	28.0	11.7	3.6
	Sell - Put	16.2	16.6	11.0	4.3	22.0	21.2	13.7	3.5
	Buy - Call	32.7	32.7	11.9	4.6	26.2	27.7	14.9	4.7
	Buy - Put	16.0	16.6	11.8	4.7	19.1	20.5	16.7	4.8
	Midpoint - Call	1.6	1.4	15.8	0.0	2.0	1.4	18.3	0.0
	Midpoint - Put	0.8	0.8	14.4	0.0	1.8	1.1	20.8	0.0
ETF	No	82.5	75.1	12.0	4.5	76.1	64.4	15.4	4.1
	Yes	17.5	24.9	8.1	3.1	23.9	35.6	10.3	3.4

This table reports daily average characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts.

Table A29: Differences between All Retail (small + cheap) and not All Retail (small + cheap) trades

		All Retail (small + cheap) minus not All Retail (small + cheap)			
Characteristic	**Category**	Frequency share, %	Volume share, %	Quoted spread, %	Effective spread, %
Type	Call	9.87	8.82	-2.08	0.28
		(19.71)	(31.22)	(-8.97)	(2.04)
	Put	-9.87	-8.82	-3.86	0.49
		(-19.71)	(-31.22)	(-12.88)	(4.92)
Trade size (contracts)	1	5.18	4.76	-4.67	-0.06
		(15.25)	(26.59)	(-19.61)	(-0.44)
	2-5	2.34	11.93	-4.22	0.02
		(12.88)	(49.17)	(-20.86)	(0.15)
	6-10	-11.04	-3.78	5.43	2.63
		(-26.36)	(-4.55)	(12.36)	(16.91)
	11-100	-2.64	-24.61	16.21	7.53
		(-33.41)	(-56.35)	(31.86)	(40.11)
	Above 100	6.16	11.70	-5.06	-0.10
		(31.01)	(44.67)	(-26.76)	(-0.96)
Trade size (dollars)	Below 250	6.66	11.26	-8.51	-0.58
		(16.87)	(75.67)	(-25.49)	(-3.12)
	250-500	3.60	7.44	-3.44	0.52
		(44.22)	(137.67)	(-16.63)	(7.24)
	500-1,000	2.87	9.83	-2.78	0.54
		(27.74)	(107.17)	(-16.19)	(9.02)
	1,000-2,500	2.52	15.81	-2.34	0.49
		(15.56)	(71.37)	(-15.76)	(9.71)
	2,500-5,000	1.03	13.02	-1.99	0.43
		(9.89)	(53.93)	(-16.56)	(10.92)
	5,000-10,000	-6.04	-14.73	-1.95	-0.36
		(-59.04)	(-63.44)	(-19.76)	(-10.54)
	10,000-20,000	-4.66	-14.01	-1.45	1.07
		(-35.37)	(-134.48)	(-21.11)	(7.65)
	20,000-50,000	-3.61	-14.16	-1.09	5.11
		(-24.26)	(-65.31)	(-21.03)	(24.51)
	Above 50,000	-2.36	-14.49	-0.96	13.91
		(-19.09)	(-29.95)	(-13.45)	(19.32)
Trade direction	Sell	-2.01	-0.79	-1.90	0.55
		(-13.93)	(-8.59)	(-8.64)	(5.24)
	Buy	3.40	1.14	-3.78	-0.07
		(30.65)	(12.38)	(-13.26)	(-0.45)
	Midpoint	-1.39	-0.34	-4.16	NA
		(-14.66)	(-6.96)	(-17.93)	(NA)
Time to expiry	Less than a week	7.06	10.82	-5.54	-0.71
		(20.45)	(55.29)	(-20.82)	(-5.27)
	1-2 weeks	0.79	0.79	-2.14	0.60
		(7.73)	(8.89)	(-10.77)	(6.24)
	2-4 weeks	-2.03	-1.75	-1.59	1.19
		(-13.91)	(-13.17)	(-6.22)	(9.97)
	1-3 months	-4.29	-5.09	-0.42	1.20
		(-26.52)	(-36.54)	(-1.33)	(10.83)
	3-12 months	-0.81	-3.66	0.23	0.79
		(-5.27)	(-28.00)	(0.55)	(4.31)
	Over a year	-0.73	-1.11	-4.49	0.06
		(-10.64)	(-11.81)	(-9.62)	(0.22)
Moneyness	Below -2	-0.01	0.12	-24.94	2.11
		(-0.98)	(4.05)	(-9.93)	(4.56)
	-2 to -1	-0.08	0.11	-18.61	3.42
		(-3.74)	(3.63)	(-13.70)	(8.94)
	-1 to -0.1	-1.48	4.36	-4.33	1.26
		(-4.13)	(10.64)	(-10.69)	(6.31)
	At the money	3.05	-1.70	-2.15	0.18
		(9.18)	(-3.81)	(-15.95)	(2.75)
	0.1 to 1	-1.45	-2.69	0.35	0.08
		(-10.80)	(-20.58)	(3.05)	(0.84)
	1 to 2	-0.02	-0.14	1.53	-4.76
		(-3.54)	(-10.52)	(5.43)	(-4.96)
	Above 2	-0.01	-0.06	6.00	-8.64
		(-1.07)	(-5.72)	(7.83)	(-5.74)
Trade direction and type	Sell - Call	3.81	3.83	-1.16	0.46
		(13.65)	(21.66)	(-5.51)	(3.54)
	Sell - Put	-5.82	-4.63	-2.74	0.80
		(-24.53)	(-31.07)	(-10.91)	(10.76)
	Buy - Call	6.51	4.99	-3.02	-0.04
		(24.26)	(37.64)	(-11.63)	(-0.27)
	Buy - Put	-3.11	-3.85	-4.86	-0.04
		(-13.61)	(-29.41)	(-12.53)	(-0.27)
	Midpoint - Call	-0.45	-0.00	-2.50	NA
		(-9.76)	(-0.06)	(-5.07)	(NA)
	Midpoint - Put	-0.95	-0.34	-6.44	NA
		(-17.89)	(-12.44)	(-24.53)	(NA)
ETF	No	6.34	10.72	-3.42	0.39
		(22.97)	(21.75)	(-15.87)	(3.15)
	Yes	-6.34	-10.72	-2.21	-0.26
		(-22.97)	(-21.75)	(-8.99)	(-1.84)

This table reports mean differences between daily characteristics of trades by category. Our sample is from November 2019 till June 2021. (Implied) Trade direction is based on whether the trade price is above (buy), below (sell), or at the midpoint. Quoted spread is the spread between the best bid and best ask on the contract (across all exchanges) relative to the midpoint price at the time of the trade. Effective spread is an absolute percentage deviation of the trade price from the midpoint price at the time of the trade, multiplied by 2. For both spreads, we report frequency-weighted averages. Moneyness for calls is measured as $(MidpointPrice - Strike)/Strike$, with the opposite sign for puts. In parentheses are t-statistics based on Newey-West standard errors with the optimal number of lags.

Table A30: Outages and retail trading in options

	All Internalized Share		All Retail (small) Share		All Retail (small+cheap) Share	
	(1)	(2)	(3)	(4)	(5)	(6)
D(RH outage)	-0.163	-0.011	-0.120	-0.001	-0.009	-0.086
	(-0.94)	(-0.06)	(-0.64)	(-0.00)	(-0.05)	(-0.47)
D(TD outage)	-0.250*	-0.201	-0.272*	-0.210	-0.151	-0.159
	(-1.90)	(-1.58)	(-1.95)	(-1.52)	(-1.25)	(-1.31)
D(Both outage)	-1.381***	-0.820**	-0.762**	-0.133	-0.845**	-0.605*
	(-3.86)	(-2.22)	(-2.07)	(-0.35)	(-2.41)	(-1.66)
Lagged log volume, 2-day		-0.013		-0.026		-0.015
		(-0.73)		(-1.43)		(-0.94)
Lagged log price, 2-day		2.247*		1.595		2.099**
		(1.82)		(1.18)		(2.06)
Log volume change, one day		-1.019***		-1.246***		-0.707***
		(-34.44)		(-37.54)		(-23.97)
Log price change, one day		0.073		-0.628		-4.285***
		(0.07)		(-0.65)		(-4.39)
Observations	3,793,278	3,237,765	3,793,278	3,237,765	3,793,278	3,237,765
Adjusted R-squared	0.151	0.138	0.186	0.166	0.178	0.172

This table reports the results of estimating (3) in a minute-ticker panel. $D(RH\,outage)_{i,t} = 1$ if Robinhood experienced an outage in minute t, and 0 otherwise. $D(TD\,outage)_{i,t} = 1$ if TD Ameritrade or Charles Schwab (from October 2020) experienced an outage in minute t, and 0 otherwise. $D(Both\,outage)_{i,t} = 1$ if both Robinhood and TD Ameritrade/Charles Schwab experienced an outage in minute t, and 0 otherwise. The dependent variables is the ticker-level volume share of the respective measure of retail trading. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. The sample includes the top 100 most mentioned tickers on `WallStreetBets`. All regressions include ticker, date, and time of the day fixed effects. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A31: Broker restrictions and retail trading in options

	All Internalized Share		All Retail Share (small)		All Retail Share (small+cheap)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Jones, Reed, and Waller (2021) sample						
D(RH restricted)	-7.931***	-7.327***	-7.646***	-7.536***	-7.777***	-8.346**
	(-3.43)	(-2.98)	(-3.50)	(-3.18)	(-2.69)	(-2.25)
D(TD restricted)	-0.629	-1.338	-0.553	-1.659	1.288*	1.136*
	(-0.46)	(-0.76)	(-0.35)	(-0.92)	(1.74)	(1.74)
D(Both restricted)	-4.962**	-2.892**	-3.324**	-2.176*	-4.742*	-1.464
	(-2.53)	(-2.20)	(-2.15)	(-1.81)	(-1.74)	(-0.58)
Lagged log volume, 2-day		-0.674***		-0.805***		-0.472***
		(-8.39)		(-8.73)		(-7.56)
Lagged log price, 2-day		-2.404***		-2.056***		-5.722***
		(-3.02)		(-2.73)		(-7.85)
Log volume change, one day		-1.321***		-1.557***		-0.975***
		(-34.17)		(-34.28)		(-18.92)
Log price change, one day		-6.631***		-6.914***		-11.677***
		(-4.86)		(-4.94)		(-7.19)
Observations	2,340,612	1,952,774	2,340,612	1,952,774	2,340,612	1,952,774
Adjusted R-squared	0.144	0.140	0.174	0.158	0.150	0.151
Panel B: Refined sample						
D(RH restricted)	-6.387***	-5.397***	-6.479***	-6.106***	-5.187***	-5.331***
	(-4.83)	(-3.61)	(-4.42)	(-3.84)	(-2.91)	(-2.88)
D(TD restricted)	-1.308	-0.967	-1.172	-0.973	0.468	1.369
	(-1.03)	(-0.83)	(-0.75)	(-0.70)	(0.48)	(1.48)
D(Both restricted)	-6.871***	-4.848***	-6.023***	-4.385***	-6.065***	-3.740*
	(-3.92)	(-3.29)	(-3.84)	(-3.16)	(-2.86)	(-1.71)
Lagged log volume, 2-day		-0.697***		-0.828***		-0.469***
		(-8.22)		(-8.23)		(-8.00)
Lagged log price, 2-day		-1.097		-0.603		-4.258***
		(-1.38)		(-1.04)		(-6.07)
Log volume change, one day		-1.312***		-1.560***		-0.962***
		(-35.30)		(-36.25)		(-19.35)
Log price change, one day		-4.776***		-4.973***		-9.523***
		(-3.73)		(-4.02)		(-6.65)
Observations	3,009,692	2,489,629	3,009,692	2,489,629	3,009,692	2,489,629
Adjusted R-squared	0.134	0.128	0.160	0.143	0.136	0.137

This table reports the results of estimating (3) in a minute-ticker panel. The sample includes tickers that have ever been restricted and the top 100 most mentioned tickers on `WallStreetBets`. $D(RH\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by Robinhood in minute t, and 0 otherwise. $D(TD\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by TD Ameritrade or Charles Schwab in minute t, and 0 otherwise. $D(Both\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by both Robinhood and TD Ameritrade/Charles Schwab in minute t, and 0 otherwise. All Internalized Share is the ticker-level volume share of SLIM trades and single-leg electronic trades below size 5 executed at NBBO. All Retail Share (small) is the ticker-level volume share of SLIM trades and single-leg electronic trades up to size 10. All Retail Share (small+cheap) is the ticker-level volume share of SLIM trades and single-leg electronic trades with size up to 10 and dollar values up to $5,000. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. All regressions include ticker, date, and time of the day fixed effects. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A32: Broker restrictions and retail trading in options, smaller sample

	All Internalized Share		All Retail Share (small)		All Retail Share (small+cheap)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Jones, Reed, and Waller (2021) sample						
D(RH restricted)	-4.698*	-4.966*	-4.374*	-5.317**	-5.748*	-6.319*
	(-1.83)	(-1.90)	(-1.78)	(-2.05)	(-1.99)	(-1.76)
D(TD restricted)	-0.403	-1.373	-0.696	-2.028	1.120	0.796
	(-0.27)	(-0.76)	(-0.42)	(-1.07)	(1.28)	(0.93)
D(Both restricted)	-3.415	-2.160	-2.149	-1.857	-3.888	-1.882
	(-1.66)	(-1.65)	(-1.27)	(-1.54)	(-1.35)	(-0.72)
Lagged log volume, 2-day		-0.803***		-0.833***		-0.462***
		(-5.17)		(-5.82)		(-4.10)
Lagged log price, 2-day		-2.239**		-2.081**		-4.829***
		(-2.08)		(-2.06)		(-5.23)
Log volume change, one day		-1.432***		-1.585***		-0.885***
		(-28.67)		(-23.20)		(-11.04)
Log price change, one day		-6.172***		-6.548***		-9.961***
		(-3.73)		(-3.63)		(-4.48)
Observations	625,629	490,548	625,629	490,548	625,629	490,548
Adjusted R-squared	0.117	0.111	0.131	0.116	0.095	0.092
Panel B: Refined sample						
D(RH restricted)	-4.107***	-3.882**	-4.231**	-4.744***	-3.305*	-3.950**
	(-2.78)	(-2.50)	(-2.66)	(-2.87)	(-1.85)	(-2.17)
D(TD restricted)	-0.654	-0.568	-0.889	-0.831	0.455	1.044
	(-0.49)	(-0.48)	(-0.57)	(-0.61)	(0.44)	(1.12)
D(Both restricted)	-4.489**	-3.418**	-3.992**	-3.258**	-4.430*	-2.938
	(-2.37)	(-2.18)	(-2.45)	(-2.26)	(-1.98)	(-1.29)
Lagged log volume, 2-day		-0.836***		-0.938***		-0.557***
		(-7.15)		(-7.52)		(-6.43)
Lagged log price, 2-day		-0.377		-0.040		-3.326***
		(-0.43)		(-0.06)		(-5.11)
Log volume change, one day		-1.404***		-1.615***		-0.867***
		(-27.52)		(-27.18)		(-11.08)
Log price change, one day		-4.716***		-5.232***		-8.299***
		(-3.04)		(-3.42)		(-5.03)
Observations	1,120,301	883,456	1,120,301	883,456	1,120,301	883,456
Adjusted R-squared	0.117	0.112	0.134	0.121	0.084	0.084

This table reports the results of estimating (3) in a minute-ticker panel. The sample includes only the tickers that have ever been restricted. $D(RH\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by Robinhood in minute t, and 0 otherwise. $D(TD\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by TD Ameritrade or Charles Schwab in minute t, and 0 otherwise. $D(Both\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by both Robinhood and TD Ameritrade/Charles Schwab in minute t, and 0 otherwise. All Internalized Share is the ticker-level volume share of SLIM trades and single-leg electronic trades below size 5 executed at NBBO. All Retail Share (small) is the ticker-level volume share of SLIM trades and single-leg electronic trades up to size 10. All Retail Share (small+cheap) is the ticker-level volume share of SLIM trades and single-leg electronic trades with size up to 10 and dollar values up to $5,000. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. All regressions include ticker, date, and time of the day fixed effects. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A33: Broker restrictions and retail trading in options, larger sample

	All Internalized Share		All Retail Share (small)		All Retail Share (small+cheap)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Jones, Reed, and Waller (2021) sample						
D(RH restricted)	-8.616***	-7.710***	-8.597***	-8.170***	-8.808***	-8.730**
	(-3.76)	(-3.11)	(-3.94)	(-3.37)	(-3.06)	(-2.40)
D(TD restricted)	-0.826	-1.409	-0.911	-1.807	0.720	0.945
	(-0.61)	(-0.81)	(-0.58)	(-1.00)	(1.02)	(1.49)
D(Both restricted)	-5.377***	-2.872**	-3.908**	-2.536**	-5.666**	-2.016
	(-2.72)	(-2.14)	(-2.58)	(-2.16)	(-2.10)	(-0.80)
Lagged log volume, 2-day		-0.634***		-0.751***		-0.439***
		(-9.54)		(-9.66)		(-8.16)
Lagged log price, 2-day		-2.943***		-2.290***		-5.457***
		(-3.91)		(-3.21)		(-8.78)
Log volume change, one day		-1.312***		-1.514***		-0.910***
		(-40.38)		(-39.12)		(-20.65)
Log price change, one day		-7.801***		-8.171***		-11.422***
		(-6.27)		(-6.33)		(-8.65)
Observations	3,908,566	2,489,593	3,908,566	2,489,593	3,908,566	2,489,593
Adjusted R-squared	0.144	0.149	0.181	0.171	0.155	0.157
Panel B: Refined sample						
D(RH restricted)	-6.876***	-5.542***	-7.334***	-6.545***	-6.242***	-5.771***
	(-5.29)	(-3.79)	(-5.02)	(-4.12)	(-3.50)	(-3.13)
D(TD restricted)	-1.442	-0.857	-1.401	-0.930	0.012	1.252
	(-1.15)	(-0.73)	(-0.91)	(-0.67)	(0.01)	(1.41)
D(Both restricted)	-7.275***	-4.930***	-6.586***	-4.755***	-7.088***	-4.281**
	(-4.14)	(-3.24)	(-4.21)	(-3.35)	(-3.37)	(-1.97)
Lagged log volume, 2-day		-0.664***		-0.772***		-0.426***
		(-8.93)		(-9.03)		(-8.52)
Lagged log price, 2-day		-1.490*		-0.893		-4.192***
		(-1.86)		(-1.57)		(-6.88)
Log volume change, one day		-1.298***		-1.511***		-0.894***
		(-42.64)		(-42.75)		(-21.95)
Log price change, one day		-5.918***		-6.303***		-9.743***
		(-4.81)		(-5.45)		(-8.08)
Observations	4,785,974	3,093,337	4,785,974	3,093,337	4,785,974	3,093,337
Adjusted R-squared	0.138	0.139	0.172	0.158	0.144	0.144

This table reports the results of estimating (3) in a minute-ticker panel. The sample includes tickers that have ever been restricted, the top 100 most mentioned tickers on `WallStreetBets`, and tickers that experienced at least two retail frenzies in the sample of Barber, Huang, Odean, and Schwartz (2022). $D(RH\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by Robinhood in minute t, and 0 otherwise. $D(TD\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by TD Ameritrade or Charles Schwab in minute t, and 0 otherwise. $D(Both\,restricted)_{i,t} = 1$ if trading in the stock i was restricted by both Robinhood and TD Ameritrade/Charles Schwab in minute t, and 0 otherwise. All Internalized Share is the ticker-level volume share of SLIM trades and single-leg electronic trades below size 5 executed at NBBO. All Retail Share (small) is the ticker-level volume share of SLIM trades and single-leg electronic trades up to size 10. All Retail Share (small+cheap) is the ticker-level volume share of SLIM trades and single-leg electronic trades with size up to 10 and dollar values up to $5,000. Option volume, lagged, is the 2-day lag of the logarithm of the total options volume. Underlying price, lagged, is the 2-day lag of the logarithm of underlying price in dollars. Option volume change is the change in log total options volume from one day before minute t to minute $t-1$. Underlying price change is the change in log underlying price from one day before minute t to minute $t-1$. All regressions include ticker, date, and time of the day fixed effects. t-statistics are based on standard errors clustered by ticker and minute (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A34: Retail trading in options and other measures of retail activity

	All Internalized trading in calls				All Internalized trading in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: All Internalized Share								
Small Share	0.431***				0.402***			
	(162.81)				(169.51)			
Internalized volume in underlying		0.020***				0.012***		
		(7.36)				(4.61)		
Robinhood ownership breadth, log			0.028***				0.012	
			(2.71)				(1.13)	
WSB mentions, log				0.013***				0.010***
				(8.66)				(7.03)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.231	0.103	0.101	0.109	0.222	0.103	0.100	0.109
Panel B: All Internalized Imbalance								
Small Imbalance	0.715***				0.732***			
	(461.82)				(469.46)			
Internalized volume in underlying		-0.003				0.008***		
		(-1.15)				(2.78)		
Robinhood ownership breadth, log			0.004				-0.015	
			(0.40)				(-1.62)	
WSB mentions, log				0.010***				0.005***
				(8.76)				(4.43)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,323,515	1,327,247	535,544	1,103,685	1,098,223	1,102,788	449,921	952,960
Adjusted R-squared	0.454	0.016	0.018	0.016	0.478	0.023	0.022	0.022

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. All Internalized and Small Share are the ticker-level volume shares of All Internalized and small trades, respectively. All Internalized and Small Imbalance are the ticker-level volume imbalance for All Internalized and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A35: Retail trading in options and other measures of retail activity

	All Retail (small) trading in calls				All Retail (small) trading in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: All Retail (small) Share								
Small Share	0.735***				0.686***			
	(325.38)				(289.64)			
Internalized volume in underlying		0.016***				0.010***		
		(6.51)				(3.90)		
Robinhood ownership breadth, log			0.006				-0.005	
			(0.59)				(-0.46)	
WSB mentions, log				0.016***				0.008***
				(9.76)				(4.69)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.565	0.193	0.194	0.197	0.532	0.186	0.188	0.191
Panel B: All Retail (small) Imbalance								
Small Imbalance	0.874***				0.881***			
	(800.70)				(937.72)			
Internalized volume in underlying		-0.001				0.007***		
		(-0.57)				(2.67)		
Robinhood ownership breadth, log			0.009				-0.015	
			(0.98)				(-1.59)	
WSB mentions, log				0.008***				0.004***
				(7.43)				(3.27)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,396,844	1,400,576	569,831	1,148,199	1,186,671	1,191,238	489,986	1,013,481
Adjusted R-squared	0.758	0.017	0.020	0.017	0.773	0.024	0.023	0.022

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. All Retail (small) and Small Share are the ticker-level volume shares of All Retail (small) and small trades, respectively. All Retail (small) and Small Imbalance are the ticker-level volume imbalance for All Retail (small) and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

Table A36: Retail trading in options and other measures of retail activity

	All Retail (small + cheap) trading in calls				All Retail (small + cheap) trading in puts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: All Retail (small + cheap) Share								
Small Share	0.347***				0.317***			
	(83.49)				(75.04)			
Internalized volume in underlying		0.006**				0.010***		
		(2.46)				(3.73)		
Robinhood ownership breadth, log			-0.007				-0.000	
			(-0.70)				(-0.02)	
WSB mentions, log				0.005***				0.002
				(2.77)				(0.93)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,436,457	1,436,457	587,030	1,169,587	1,248,002	1,248,002	514,122	1,051,468
Adjusted R-squared	0.269	0.186	0.184	0.196	0.239	0.165	0.162	0.172
Panel B: All Retail (small + cheap) Imbalance								
Small Imbalance	0.782***				0.794***			
	(467.52)				(526.45)			
Internalized volume in underlying		-0.002				0.009***		
		(-0.88)				(3.46)		
Robinhood ownership breadth, log			0.008				-0.021**	
			(0.95)				(-2.22)	
WSB mentions, log				0.006***				0.001
				(5.36)				(0.44)
Underlying controls X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contract controls C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,398,109	1,410,569	575,114	1,154,084	1,188,688	1,205,555	496,424	1,022,923
Adjusted R-squared	0.618	0.017	0.020	0.017	0.642	0.024	0.023	0.023

This table reports the results of estimating (1) on daily data from November 2019 till June 2021. All Retail (small + cheap) and Small Share are the ticker-level volume shares of All Retail (small + cheap) and small trades, respectively. All Retail (small + cheap) and Small Imbalance are the ticker-level volume imbalance for All Retail (small + cheap) and small trades, respectively. Internalized volume in underlying is the share of non-ATS OTC (i.e., internalized) volume in the total trading volume in the underlying stock or ETF. Robinhood ownership breadth, log, is the logarithm of the total number of Robinhood users holding the ticker at the end of each day. WSB mentions, log, is the logarithm of the number of mentions a ticker gets on `WallStreetBets` during the day. Underlying controls X and contract controls C are described in Section 2.3. All regressions include date and ticker fixed effects. All variables are standardized within the contract type (call or put). t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.24 Aggregate SLIM performance

Table A37: SLIM aggregate performance

	Gross performance, $ bln.						Net performance, $ bln.					
Horizon h	Intra-day	1 day	2 days	5 days	10 days	Expi-ration	Intra-day	1 day	2 days	5 days	10 days	Expi-ration
Panel A: All contracts												
	4.26	4.85	4.42	4.34	4.22	3.41	-2.18	-1.58	-2.02	-2.10	-2.22	-2.58
Panel B: By trade direction												
Sell	5.37	7.92	9.69	8.85	6.69	-11.77	1.62	4.17	5.95	5.10	2.95	-15.27
Buy	-1.11	-3.06	-5.27	-4.51	-2.47	15.19	-3.80	-5.76	-7.96	-7.20	-5.17	12.70
Panel C: By contract type												
Call	3.05	3.40	2.92	2.71	2.43	1.76	-1.53	-1.18	-1.67	-1.88	-2.15	-2.46
Put	1.21	1.45	1.51	1.63	1.79	1.65	-0.64	-0.40	-0.35	-0.22	-0.07	-0.11
Panel D: By moneyness												
Below -2	0.02	0.02	0.02	0.02	0.03	0.03	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
-2 to -1	0.03	0.03	0.03	0.02	0.03	0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01
-1 to -0.1	1.13	1.36	1.37	1.61	1.69	1.39	-0.51	-0.27	-0.27	-0.02	0.06	-0.04
At the money	2.74	3.00	2.60	2.34	2.20	2.08	-1.40	-1.13	-1.53	-1.79	-1.94	-1.92
0.1 to 1	0.38	0.47	0.43	0.38	0.35	-0.01	-0.17	-0.08	-0.12	-0.17	-0.20	-0.48
1 to 2	0.02	0.01	0.04	0.01	-0.01	0.00	-0.01	-0.02	0.01	-0.02	-0.04	-0.02
Above 2	-0.04	-0.05	-0.06	-0.05	-0.06	-0.09	-0.06	-0.06	-0.07	-0.06	-0.08	-0.10
Panel E: By time to expiration												
Less than a week	1.65	1.75	1.46	1.29	1.29	1.28	-0.95	-0.84	-1.13	-1.31	-1.31	-1.31
1-2 weeks	0.54	0.56	0.46	0.29	0.20	0.21	-0.20	-0.18	-0.28	-0.45	-0.54	-0.53
2-4 weeks	0.73	0.85	0.78	0.78	0.67	0.57	-0.28	-0.17	-0.23	-0.24	-0.34	-0.43
1-3 months	0.68	0.84	0.82	0.93	0.98	1.16	-0.31	-0.15	-0.17	-0.06	-0.01	0.19
3-12 months	0.48	0.61	0.64	0.78	0.81	-0.23	-0.31	-0.18	-0.15	-0.01	0.02	-0.89
Over a year	0.17	0.24	0.25	0.28	0.26	0.42	-0.13	-0.06	-0.05	-0.02	-0.04	0.40

This table reports the aggregate performance of SLIM trades from November 2019 till June 2021. Gross and net performance is computed as explained in Section 3.

A.25 Aggregate SLIM performance, by month and weekday

Table A38: SLIM aggregate performance, by month and weekday

	Gross performance, $ bln.						Net performance, $ bln.					
Horizon h	Intra-day	1 day	2 days	5 days	10 days	Expi-ration	Intra-day	1 day	2 days	5 days	10 days	Expi-ration
Panel A: By month												
Nov-19	0.069	0.072	0.082	0.084	0.079	0.234	-0.031	-0.027	-0.017	-0.016	-0.020	0.139
Dec-19	0.068	0.086	0.084	0.082	0.089	0.236	-0.037	-0.018	-0.021	-0.022	-0.015	0.136
Jan-20	0.103	0.125	0.123	0.173	0.275	0.497	-0.051	-0.029	-0.031	0.019	0.121	0.351
Feb-20	0.119	0.133	0.048	-0.049	0.016	-0.275	-0.109	-0.096	-0.180	-0.277	-0.213	-0.491
Mar-20	0.190	0.287	0.313	0.361	0.400	-0.236	-0.237	-0.140	-0.114	-0.066	-0.027	-0.632
Apr-20	0.214	0.252	0.255	0.259	0.142	0.050	-0.095	-0.057	-0.054	-0.050	-0.167	-0.240
May-20	0.234	0.279	0.296	0.311	0.288	0.296	-0.059	-0.013	0.003	0.018	-0.005	0.018
Jun-20	0.239	0.280	0.210	0.402	0.362	0.441	-0.151	-0.110	-0.180	0.012	-0.028	0.071
Jul-20	0.318	0.403	0.425	0.488	0.521	0.428	-0.050	0.036	0.058	0.121	0.154	0.081
Aug-20	0.277	0.357	0.386	0.305	0.281	0.245	-0.071	0.009	0.038	-0.043	-0.067	-0.077
Sep-20	0.238	0.256	0.235	0.260	0.260	0.283	-0.145	-0.127	-0.148	-0.123	-0.124	-0.082
Oct-20	0.178	0.195	0.153	0.158	0.205	0.130	-0.134	-0.117	-0.159	-0.154	-0.108	-0.167
Nov-20	0.207	0.202	0.179	0.209	0.253	0.229	-0.128	-0.133	-0.157	-0.127	-0.083	-0.084
Dec-20	0.296	0.384	0.387	0.093	0.041	0.062	-0.077	0.011	0.013	-0.281	-0.333	-0.284
Jan-21	0.259	0.202	-0.062	-0.196	-0.182	-0.240	-0.209	-0.266	-0.530	-0.664	-0.650	-0.669
Feb-21	0.380	0.394	0.279	0.218	0.123	0.130	-0.104	-0.090	-0.205	-0.266	-0.362	-0.314
Mar-21	0.301	0.300	0.344	0.365	0.316	0.356	-0.141	-0.142	-0.098	-0.077	-0.125	-0.046
Apr-21	0.152	0.213	0.207	0.220	0.195	0.199	-0.146	-0.085	-0.091	-0.078	-0.103	-0.073
May-21	0.199	0.210	0.264	0.284	0.272	0.227	-0.070	-0.059	-0.005	0.016	0.003	-0.014
Jun-21	0.220	0.222	0.213	0.315	0.284	0.117	-0.132	-0.130	-0.139	-0.036	-0.068	-0.200
Panel B: By weekday												
Mon	0.869	1.062	0.835	0.906	0.886	0.933	-0.308	-0.114	-0.341	-0.271	-0.291	-0.150
Tue	0.842	1.093	0.891	0.872	0.938	0.678	-0.397	-0.147	-0.348	-0.368	-0.302	-0.470
Wed	0.892	0.820	0.783	0.851	0.775	0.562	-0.401	-0.473	-0.510	-0.442	-0.518	-0.640
Thu	0.784	0.801	0.775	0.637	0.757	0.593	-0.563	-0.546	-0.573	-0.711	-0.591	-0.664
Fri	0.874	1.078	1.138	1.077	0.864	0.644	-0.507	-0.303	-0.243	-0.304	-0.518	-0.651

This table reports the aggregate performance of SLIM trades by month and weekday in November 2019 to June 2021. Gross and net performance is computed as explained in Section 3.

A.26 Aggregate performance, best and worst tickers

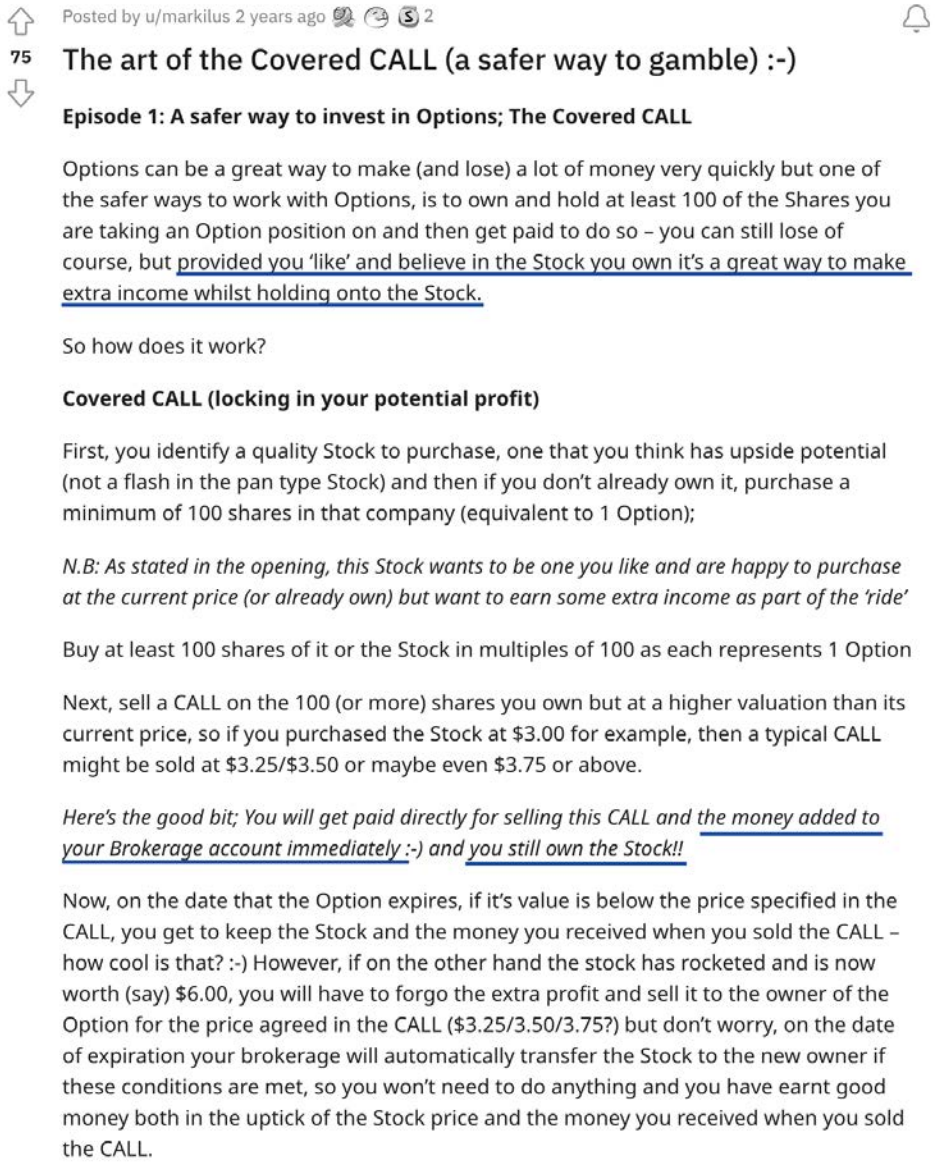
Table A39: Best and worst performing tickers

	Top 10 tickers – Net performance, $ mln.							Bottom 10 tickers – Net performance, $ mln.					
Ticker	Intraday	1 day	2 days	5 days	10 days	Expiration	Ticker	Intraday	1 day	2 days	5 days	10 days	Expiration
Panel A: SLIM trades													
AAPL	-79.2	-30.9	-13.0	48.8	117.1	128.1	SPY	-317.6	-298.5	-494.0	-528.0	-477.3	-333.9
NVDA	-14.7	20.0	58.3	88.5	98.9	58.2	TSLA	-123.8	3.7	-182.2	-454.3	-462.5	-34.6
MRNA	-5.6	3.1	11.8	21.3	22.5	37.5	QQQ	-61.1	-67.3	-127.1	-128.6	-184.6	-235.0
GOOGL	-3.9	-6.3	12.4	39.1	19.0	-18.6	USO	-36.2	-35.9	-37.3	-55.1	-152.6	-252.7
BABA	-10.3	10.4	23.6	33.6	14.9	0.8	AMC	-23.6	-65.9	-102.0	-107.6	-104.5	-114.9
DIS	-8.5	-9.8	-5.7	-1.4	12.3	-41.2	AMZN	-70.7	-36.5	-15.5	-40.1	-69.7	-427.8
GS	-4.6	-6.5	-3.8	3.6	12.1	-2.1	GME	-13.6	14.5	-73.7	-60.7	-62.0	-64.4
CRWD	-4.1	1.5	3.3	9.0	11.4	35.3	RIOT	-6.0	-12.0	-12.1	-29.4	-47.8	-95.0
ZM	-29.7	-31.9	-23.4	-2.8	10.9	10.7	NIO	-19.0	-16.5	-15.5	-14.9	-39.5	-66.8
TWLO	-3.5	0.6	2.9	3.1	10.8	18.0	MARA	-3.8	-6.1	-7.6	-11.0	-36.4	-45.5
Panel B: All trades													
TSLA	-380.0	699.5	394.8	1161.2	1494.5	3412.9	SPY	-827.3	-934.8	-1447.5	-2076.7	-1962.5	-1066.3
AMZN	-199.3	132.0	483.6	946.5	1130.0	497.7	QQQ	18.1	-121.7	-141.1	-248.5	-273.3	-1019.4
IDEX	-568.2	110.5	109.8	561.0	937.0	1007.8	IWM	-83.1	-92.5	-87.5	-100.3	-243.3	-4.9
GME	7.0	1108.4	318.6	788.4	884.4	409.1	NKLA	-54.2	-24.9	-142.9	-161.7	-220.4	-258.7
AMC	-572.3	-92.9	-5.8	536.2	593.9	499.2	RKT	131.0	-7.2	-68.3	-118.5	-141.0	-33.5
USO	150.9	180.0	180.1	119.5	286.3	461.1	DIA	2.3	-60.5	-22.3	-54.4	-137.6	-191.2
NVDA	-58.6	2.7	156.1	110.2	243.9	-380.9	FB	-33.0	57.5	6.1	11.7	-108.5	-164.6
BABA	-79.7	-54.2	-48.5	-73.5	136.8	815.4	FUBO	-2.2	-19.5	-63.5	-96.8	-95.7	-57.8
HYG	-13.3	-3.6	23.9	70.3	135.1	93.9	NFLX	-25.4	-174.5	-142.4	-177.8	-92.1	-22.2
MRNA	-47.8	-26.2	-25.8	122.1	131.5	132.9	V	-26.9	-34.3	-32.2	-41.8	-90.3	-58.1

This table reports the aggregate performance of top 10 and bottom 10 tickers from November 2019 to June 2021. In panel A, the ranking is based on trades originated by SLIM investors. In panel B, the ranking is based on all OPRA trades. To rank tickers, we use a 10-day holding period. Net performance at each horizon is computed as explained in Section 3.

A.27 Retail investor views on covered calls

Figure A3: Discussion of covered calls on reddit.com/r/options



Posted by u/markilus 2 years ago 2

75

The art of the Covered CALL (a safer way to gamble) :-)

Episode 1: A safer way to invest in Options; The Covered CALL

Options can be a great way to make (and lose) a lot of money very quickly but one of the safer ways to work with Options, is to own and hold at least 100 of the Shares you are taking an Option position on and then get paid to do so – you can still lose of course, but provided you 'like' and believe in the Stock you own it's a great way to make extra income whilst holding onto the Stock.

So how does it work?

Covered CALL (locking in your potential profit)

First, you identify a quality Stock to purchase, one that you think has upside potential (not a flash in the pan type Stock) and then if you don't already own it, purchase a minimum of 100 shares in that company (equivalent to 1 Option);

N.B: As stated in the opening, this Stock wants to be one you like and are happy to purchase at the current price (or already own) but want to earn some extra income as part of the 'ride'

Buy at least 100 shares of it or the Stock in multiples of 100 as each represents 1 Option

Next, sell a CALL on the 100 (or more) shares you own but at a higher valuation than its current price, so if you purchased the Stock at $3.00 for example, then a typical CALL might be sold at $3.25/$3.50 or maybe even $3.75 or above.

Here's the good bit; You will get paid directly for selling this CALL and the money added to your Brokerage account immediately :-) and you still own the Stock!!

Now, on the date that the Option expires, if it's value is below the price specified in the CALL, you get to keep the Stock and the money you received when you sold the CALL – how cool is that? :-) However, if on the other hand the stock has rocketed and is now worth (say) $6.00, you will have to forgo the extra profit and sell it to the owner of the Option for the price agreed in the CALL ($3.25/3.50/3.75?) but don't worry, on the date of expiration your brokerage will automatically transfer the Stock to the new owner if these conditions are met, so you won't need to do anything and you have earnt good money both in the uptick of the Stock price and the money you received when you sold the CALL.

Excerpt as of August 2022 from https://www.reddit.com/r/options/comments/l66izy/the_art_of_the_covered_call_a_safer_way_to_gamble/. Underlinings are ours.

A.28 SLIM trade profitability

Table A40: SLIM daily per dollar performance, with leverage

	Gross profitability, %						Net profitability, %					
Horizon h	Intra-day	1 day	2 days	5 days	10 days	Expi-ration	Intra-day	1 day	2 days	5 days	10 days	Expi-ration
Panel A: All contracts												
	142.83	133.45	116.54	110.90	123.59	121.46	-178.58	-132.66	-186.73	-72.21	-23.20	224.17
	(5.81)	(5.84)	(1.99)	(1.45)	(1.55)	(1.33)	(-2.24)	(-2.66)	(-2.32)	(-0.69)	(-0.16)	(0.58)
Panel B: By trade direction												
Sell	2.06	2.55	2.85	1.75	-0.12	-11.61	0.70	1.21	1.50	0.39	-1.50	-13.07
	(8.81)	(2.84)	(2.01)	(0.67)	(-0.03)	(-2.09)	(2.94)	(1.33)	(1.05)	(0.15)	(-0.41)	(-2.32)
Buy	-0.57	-0.88	-1.25	-0.12	1.85	13.83	-1.56	-1.87	-2.23	-1.12	0.84	12.76
	(-2.37)	(-0.95)	(-0.86)	(-0.05)	(0.50)	(2.36)	(-6.65)	(-2.04)	(-1.56)	(-0.43)	(0.23)	(2.20)
Panel C: By contract type												
Call	266.36	299.85	234.98	465.46	476.48	668.43	-99.06	-83.62	-46.15	-65.93	-97.41	-167.36
	(2.23)	(2.12)	(2.73)	(1.57)	(1.62)	(2.46)	(-3.57)	(-2.66)	(-0.95)	(-1.92)	(-2.26)	(-1.55)
Put	76.80	76.23	-22.70	-51.48	72.47	-12.39	-63.08	-76.01	-80.33	-71.15	-79.41	100.81
	(2.85)	(3.09)	(-0.34)	(-0.57)	(1.96)	(-0.09)	(-3.69)	(-3.27)	(-2.91)	(-2.83)	(-2.07)	(0.86)
Panel D: By moneyness												
Below -2	116.48	110.67	124.62	123.28	120.25	59.59	-132.64	-88.22	-76.39	-275.14	103.66	-135.60
	(4.55)	(5.33)	(4.04)	(4.31)	(4.38)	(2.67)	(-0.90)	(-0.39)	(-0.39)	(-2.21)	(0.40)	(-0.99)
-2 to -1	151.13	177.65	175.39	181.79	195.51	195.56	-72.58	-72.33	-79.34	-67.03	-57.02	-130.37
	(2.79)	(2.64)	(2.61)	(2.90)	(2.54)	(1.10)	(-6.66)	(-6.20)	(-5.63)	(-4.11)	(-3.08)	(-2.21)
-1 to -0.1	156.43	177.92	221.46	218.48	261.24	281.45	-112.00	-65.63	-46.60	46.98	122.36	209.50
	(2.92)	(4.18)	(2.86)	(3.54)	(3.50)	(4.20)	(-6.46)	(-3.30)	(-2.16)	(1.00)	(1.34)	(0.94)
At the money	264.06	289.19	120.19	163.92	205.17	13.35	-185.83	-123.49	-78.11	-54.82	122.11	135.20
	(2.86)	(2.73)	(0.87)	(0.92)	(1.37)	(0.05)	(-2.72)	(-1.69)	(-1.08)	(-0.64)	(0.86)	(0.67)
0.1 to 1	41.14	52.37	126.01	147.45	194.11	-902.59	-11.33	-12.44	-12.80	-8.93	0.88	-1.70
	(2.71)	(1.02)	(1.41)	(1.84)	(1.58)	(-1.05)	(-6.05)	(-2.38)	(-2.70)	(-1.69)	(0.11)	(-0.08)
1 to 2	4.83	10.54	11.36	18.41	10.66	27.60	-29.08	-36.20	-28.31	-38.35	-21.30	56.90
	(2.45)	(2.19)	(2.24)	(2.38)	(2.12)	(1.29)	(-2.16)	(-2.16)	(-2.20)	(-1.77)	(-0.81)	(0.68)
Above 2	-1.64	-22.87	-14.70	-7.72	-6.69	-13.71	-18.31	-27.92	-26.31	-20.87	-25.40	-14.00
	(-0.08)	(-0.70)	(-0.52)	(-0.38)	(-0.31)	(-0.57)	(-0.93)	(-1.42)	(-1.36)	(-1.01)	(-1.14)	(-0.59)
Panel E: By time to expiration												
Less than a week	70.44	150.51	320.07	277.22	277.17	276.60	-211.45	-130.79	-37.43	-262.40	-263.13	-261.91
	(0.74)	(1.43)	(1.69)	(1.91)	(1.91)	(1.90)	(-2.78)	(-1.38)	(-0.33)	(-2.41)	(-2.41)	(-2.40)
1-2 weeks	112.94	170.24	170.58	162.13	278.57	278.39	-111.93	-13.36	1.06	98.00	124.84	139.30
	(4.39)	(1.96)	(2.04)	(1.13)	(0.99)	(0.99)	(-1.81)	(-0.36)	(0.01)	(0.48)	(0.51)	(0.56)
2-4 weeks	107.18	155.82	164.35	124.80	205.37	205.72	-29.64	-9.26	-12.78	1.77	35.29	27.46
	(2.98)	(2.02)	(1.80)	(2.80)	(2.01)	(1.85)	(-7.00)	(-1.04)	(-1.18)	(0.08)	(0.88)	(0.73)
1-3 months	187.97	211.12	195.41	233.83	307.07	766.93	-29.39	-31.31	-47.36	0.99	36.74	20.05
	(3.01)	(3.40)	(4.15)	(3.17)	(2.34)	(1.99)	(-4.86)	(-2.18)	(-1.67)	(0.05)	(1.28)	(0.16)
3-12 months	54.03	154.47	195.98	273.38	275.85	575.66	-62.24	-44.38	-10.34	33.59	30.60	148.19
	(3.25)	(1.55)	(1.47)	(1.45)	(1.39)	(0.99)	(-3.05)	(-2.36)	(-0.76)	(0.84)	(0.76)	(0.59)
Over a year	28.68	39.88	44.63	42.11	71.38	-116.28	-43.71	-25.20	-12.50	-24.10	-4.42	-49.90
	(7.15)	(6.20)	(6.07)	(6.82)	(2.54)	(-0.44)	(-3.07)	(-1.94)	(-0.57)	(-0.64)	(-0.10)	(-0.26)

This table reports the mean daily profitability of SLIM trades from November 2019 to June 2021. Gross and net profitability is computed taking trade leverage into account, as explained in Section 3. t-statistics based on Newey-West standard errors with the optimal number of lags are in parentheses.

Table A41: SLIM daily per dollar performance, without leverage

	Gross profitability, %						Net profitability, %					
Horizon h	Intra-day	1 day	2 days	5 days	10 days	Expi-ration	Intra-day	1 day	2 days	5 days	10 days	Expi-ration
Panel A: All contracts												
	0.78	0.90	0.85	0.86	0.88	0.88	-0.41	-0.29	-0.34	-0.33	-0.31	-0.23
	(30.25)	(21.12)	(12.08)	(7.19)	(6.79)	(3.56)	(-15.03)	(-6.10)	(-4.88)	(-2.83)	(-2.42)	(-0.91)
Panel B: By trade direction												
Sell	2.06	2.55	2.85	1.75	-0.12	-11.61	0.70	1.21	1.50	0.39	-1.50	-13.07
	(8.81)	(2.84)	(2.01)	(0.67)	(-0.03)	(-2.09)	(2.94)	(1.33)	(1.05)	(0.15)	(-0.41)	(-2.32)
Buy	-0.57	-0.88	-1.25	-0.12	1.85	13.83	-1.56	-1.87	-2.23	-1.12	0.84	12.76
	(-2.37)	(-0.95)	(-0.86)	(-0.05)	(0.50)	(2.36)	(-6.65)	(-2.04)	(-1.56)	(-0.43)	(0.23)	(2.20)
Panel C: By contract type												
Call	0.80	0.92	0.86	0.86	0.82	0.75	-0.42	-0.30	-0.36	-0.36	-0.40	-0.38
	(25.06)	(14.59)	(8.90)	(5.23)	(4.80)	(2.72)	(-11.79)	(-5.21)	(-3.94)	(-2.30)	(-2.40)	(-1.31)
Put	0.77	0.90	0.92	0.99	1.11	1.18	-0.43	-0.30	-0.28	-0.21	-0.09	0.04
	(27.03)	(14.41)	(11.22)	(7.21)	(6.13)	(2.98)	(-13.89)	(-4.83)	(-3.22)	(-1.49)	(-0.48)	(0.11)
Panel D: By moneyness												
Below -2	10.34	10.58	11.01	10.68	12.66	11.52	-5.52	-5.36	-4.75	-5.03	-2.90	0.42
	(14.97)	(14.99)	(15.95)	(6.79)	(6.78)	(8.46)	(-14.07)	(-12.20)	(-11.08)	(-3.39)	(-1.56)	(0.32)
-2 to -1	5.04	5.35	5.08	5.25	6.41	3.10	-3.27	-2.94	-3.23	-3.03	-1.84	-3.38
	(21.99)	(18.49)	(10.03)	(6.53)	(4.92)	(1.63)	(-18.65)	(-14.34)	(-6.88)	(-3.65)	(-1.44)	(-1.70)
-1 to -0.1	2.03	2.53	2.57	3.01	3.26	3.64	-0.95	-0.45	-0.40	0.04	0.30	1.04
	(42.59)	(18.11)	(24.59)	(16.08)	(8.91)	(4.56)	(-16.58)	(-3.30)	(-4.47)	(0.25)	(0.82)	(1.30)
At the money	0.67	0.75	0.68	0.63	0.63	0.75	-0.36	-0.28	-0.35	-0.39	-0.40	-0.25
	(22.03)	(12.95)	(8.09)	(4.40)	(4.25)	(3.04)	(-11.81)	(-4.87)	(-4.22)	(-2.78)	(-2.68)	(-1.02)
0.1 to 1	0.55	0.65	0.63	0.59	0.58	-0.02	-0.22	-0.12	-0.14	-0.18	-0.19	-0.67
	(21.72)	(12.94)	(9.61)	(4.98)	(3.66)	(-0.07)	(-9.03)	(-2.35)	(-2.08)	(-1.55)	(-1.21)	(-2.42)
1 to 2	0.32	0.40	0.51	0.50	0.33	-0.83	-0.37	-0.29	-0.18	-0.20	-0.37	-1.30
	(2.59)	(2.12)	(2.05)	(1.78)	(0.85)	(-1.12)	(-3.04)	(-1.58)	(-0.72)	(-0.78)	(-1.00)	(-1.77)
Above 2	-2.16	-2.35	-2.22	-2.05	-3.00	-4.60	-2.87	-3.06	-2.93	-2.77	-3.71	-5.04
	(-1.24)	(-1.37)	(-1.29)	(-1.16)	(-1.58)	(-1.62)	(-1.63)	(-1.78)	(-1.70)	(-1.56)	(-1.94)	(-1.76)
Panel E: By time to expiration												
Less than a week	0.80	0.82	0.72	0.66	0.66	0.66	-0.48	-0.46	-0.56	-0.62	-0.62	-0.62
	(17.93)	(9.71)	(5.58)	(4.00)	(4.00)	(3.98)	(-11.71)	(-5.61)	(-4.39)	(-3.79)	(-3.78)	(-3.78)
1-2 weeks	0.77	0.88	0.80	0.66	0.45	0.46	-0.33	-0.22	-0.30	-0.44	-0.65	-0.63
	(17.50)	(8.55)	(6.35)	(2.08)	(1.21)	(1.24)	(-7.84)	(-2.07)	(-2.08)	(-1.38)	(-1.75)	(-1.72)
2-4 weeks	0.92	1.08	1.04	1.11	1.04	0.82	-0.36	-0.19	-0.23	-0.16	-0.24	-0.44
	(26.97)	(17.15)	(11.46)	(6.53)	(4.50)	(2.20)	(-10.96)	(-2.95)	(-2.65)	(-0.96)	(-1.01)	(-1.18)
1-3 months	0.73	0.91	0.89	1.03	1.20	1.71	-0.34	-0.16	-0.17	-0.03	0.14	0.67
	(35.21)	(20.42)	(18.48)	(10.77)	(8.31)	(3.85)	(-13.33)	(-3.36)	(-3.54)	(-0.35)	(0.95)	(1.49)
3-12 months	0.65	0.83	0.89	1.04	1.08	0.39	-0.43	-0.25	-0.20	-0.04	-0.01	-0.55
	(22.94)	(14.71)	(13.18)	(7.96)	(4.26)	(0.50)	(-14.50)	(-5.98)	(-3.30)	(-0.37)	(-0.02)	(-0.66)
Over a year	0.70	1.01	1.07	1.19	1.20	2.38	-0.53	-0.22	-0.16	-0.04	-0.03	2.26
	(16.51)	(12.77)	(11.04)	(7.95)	(4.01)	(3.27)	(-16.05)	(-3.46)	(-1.83)	(-0.28)	(-0.11)	(3.22)

This table reports the mean daily profitability of SLIM trades from November 2019 to June 2021. Gross and net profitability is computed without taking trade leverage into account, as explained in Section 3. t-statistics based on Newey-West standard errors with the optimal number of lags are in parentheses.

A.29 Comparing SLIM trade profitability to other trade types

Table A42: Differences in profitability between SLIM and other trades

	Mean difference tests of SLIM daily profitability:								
	versus All Internalized			versus All Retail (small)			versus All Retail (small+cheap)		
Horizon h	Est., %	t-stat.	p-value, %	Est., %	t-stat.	p-value, %	Est., %	t-stat.	p-value, %
Panel A: Gross profitability									
Intraday	-224.98	-1.69	9.25	-483.50	-1.67	9.64	-341.54	-2.24	2.55
1 day	-402.60	-1.63	10.41	-416.74	-1.92	5.57	-374.14	-2.05	4.15
2 days	-517.73	-1.64	10.11	-538.78	-1.78	7.57	-505.69	-1.77	7.72
5 days	-587.22	-1.55	12.27	-657.54	-1.77	7.75	-477.39	-1.87	6.15
10 days	-638.03	-1.41	15.91	-605.71	-1.80	7.18	-494.67	-1.83	6.77
Expiration	-756.54	-1.26	20.75	-785.52	-1.72	8.56	-529.90	-1.59	11.18
Panel B: Net profitability									
Intraday	-144.44	-1.92	5.60	-129.51	-1.62	10.58	-120.39	-1.41	16.04
1 day	-108.15	-1.98	4.83	-93.94	-1.85	6.46	-87.49	-1.60	10.94
2 days	-208.00	-2.44	1.51	-154.56	-1.95	5.22	-30.46	-0.20	84.22
5 days	-213.67	-1.45	14.76	-66.41	-0.59	55.54	-126.84	-1.52	12.91
10 days	-127.10	-0.80	42.33	-32.91	-0.22	82.67	-61.55	-0.54	58.95
Expiration	170.38	0.38	70.31	280.56	0.72	47.30	407.62	0.96	33.63

This table reports the mean difference tests in daily profitability of SLIM trades and our alternative measures of retail trading. Gross and net profitability is computed with taking trade leverage into account, as explained in Section 3. t-statistics are based on Newey-West standard errors with the optimal number of lags.

A.30 Characteristics of SLIM and other trade types on option expiration day

To shed light on statistical significance of observations in Table A43 and Section 4 in general, we regress the daily series of differences between buy and sell shares onto dummies for each trading hour interacted with trade type. In particular, we estimate the following regression:

$$
\begin{aligned}
&Volume\,Share^{buy}_{i,h,t} - Volume\,Share^{sell}_{i,h,t} \\
&\qquad = \beta \sum_{j=1}^{7} D(End\,of\,day - j\,hour(s))_{i,h,t} * D(SLIM)_{i,h,t} \\
&\qquad + \delta \sum_{j=1}^{7} D(End\,of\,day - j\,hour(s))_{i,h,t} * D(MLIM)_{i,h,t} \\
&\qquad + \gamma \sum_{j=1}^{7} D(End\,of\,day - j\,hour(s))_{i,h,t} * D(Complex)_{i,h,t} + \varepsilon_{i,h,t}.
\end{aligned}
$$

Table A44 reports the results. SLIM trades exhibit a statistically significant intraday pattern compared to other trade types: On the option expiration days, there is a larger sell

Table A43: Composition of option trades on expiration day

Hour to expiration	Trade direction	SLIM		MLIM		Complex	
		Frequency share, %	Volume share, %	Frequency share, %	Volume share, %	Frequency share, %	Volume share, %
1	Sell	5.12	5.99	5.54	5.85	5.40	5.71
1	Buy	3.86	4.38	5.88	6.68	6.98	8.02
1	Midpoint	0.17	0.17	0.51	0.53	0.40	0.38
2	Sell	6.34	6.58	7.09	7.06	6.10	6.14
2	Buy	4.67	5.44	6.80	7.25	6.84	7.26
2	Midpoint	0.22	0.21	0.63	0.59	0.45	0.38
3	Sell	4.63	5.42	4.84	4.80	4.47	4.49
3	Buy	4.10	5.06	4.46	4.79	4.88	5.05
3	Midpoint	0.19	0.20	0.48	0.45	0.36	0.33
4	Sell	5.21	5.65	5.18	5.09	4.82	4.74
4	Buy	4.72	5.53	4.72	5.00	5.15	5.18
4	Midpoint	0.22	0.21	0.51	0.48	0.38	0.33
5	Sell	6.47	6.50	6.30	6.13	5.84	5.66
5	Buy	5.90	6.51	5.61	5.77	6.11	6.10
5	Midpoint	0.27	0.25	0.60	0.55	0.45	0.38
6	Sell	9.84	8.91	8.89	8.42	8.27	7.92
6	Buy	9.12	9.00	7.59	7.74	8.36	8.35
6	Midpoint	0.41	0.36	0.78	0.68	0.61	0.51
7	Sell	14.18	11.36	12.55	11.45	12.04	11.29
7	Buy	13.83	11.83	10.12	9.93	11.40	11.19
7	Midpoint	0.53	0.42	0.92	0.78	0.72	0.59

This table reports characteristics of trades by category for options on their expiration day. Our sample is from November 2019 till June 2021. SLIM (MLIM) stand for the trades that went through a single-leg (multi-leg) price improvement auction, while Complex trades correspond to all milti-leg trades in options. Trade direction is based on the classification method of Muravyev (2016), and 'Midpoint' refers to the trades we could not classify (for additional details, see Section 2.1).

volume share in the last two hours of the trading day. This is consistent with retail brokerages taking an automated action to close retail positions prior to the option's expiration. This pattern does not emerge if the estimation is done on non-expiration days.

Table A44: Intra-day buy-sell patterns on option expiration days

	Buy-sell volume share by trade type:					
	SLIM		MLIM		Complex	
Variable	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
	(1)	(2)	(3)	(4)	(5)	(6)
D(EOD -1 hour)	-0.242***	(-16.39)	-0.087*	(-1.91)	0.100**	(2.08)
D(EOD -2 hours)	-0.084***	(-5.65)	-0.034**	(-2.47)	0.025	(1.27)
D(EOD -3 hours)	0.002	(0.16)	-0.017***	(-5.50)	0.012	(0.80)
D(EOD -4 hours)	0.053***	(3.52)	-0.012**	(-2.71)	0.006	(0.37)
D(EOD -5 hours)	0.088***	(5.81)	-0.015*	(-1.87)	0.005	(0.31)
D(EOD -6 hours)	0.144***	(9.01)	-0.028	(-1.58)	0.010	(0.44)
D(EOD -7 hours)	0.278***	(16.76)	-0.037	(-0.93)	-0.003	(-0.07)
Test equality to SLIM -1 hour				10.58***		55.33***
Test equality to SLIM -2 hours				6.67**		52.55***

This table reports estimation results from a pooled regression of hourly volume share difference between buy and sell trades on hourly dummies interacted with trade types on option expiration days from November 2019 till June 2021. Total number of observations is 18,432. D(EOD -X hours) equals 1 for X^{th} hour to the end of the trading day (EOD) for the respective trade type: SLIM trades in Column (1), MLIM trades in Column (3), and all milti-leg trades in Column (5). Constant is excluded. t-statistics are based on standard errors double-clustered by date and trade type. The last two rows report results of a Wald test for the same buy-sell volume share in the last two trading hours of SLIM trades compared to MLIM and Complex trades (i.e., comparing the corresponding coefficients in front of D(EOD -1 hour) and D(EOD -2 hours) across different trade types). *** p<0.01, ** p<0.05, and * p<0.1.

A.31 SLIM volume and Robinhood herding events (frenzies)

Table A45: Options trade imbalances and herding events

	Imbalance in trades of type:							
	SLIM		**SLIM** < $250		**SLIM** < $5**k**		**SLIM** < $20**k**	
	Call	Put	Call	Put	Call	Put	Call	Put
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D(Robinhood frenzy)	0.073***	0.094***	0.128***	0.179***	0.088***	0.133***	0.075***	0.104***
	(3.09)	(3.01)	(5.28)	(5.60)	(3.66)	(4.39)	(3.16)	(3.40)
Observations	450,681	350,957	377,592	280,253	446,646	346,076	450,103	350,102
Adjusted R-squared	0.026	0.024	0.037	0.031	0.028	0.025	0.026	0.024
	MLIM		**All complex**		**All** > $50**k**		**All** > 100 **contracts**	
	Call	Put	Call	Put	Call	Put	Call	Put
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
D(Robinhood frenzy)	-0.115***	-0.019	-0.064*	-0.012	0.128	-0.126	-0.035	-0.006
	(-2.81)	(-0.30)	(-1.96)	(-0.37)	(1.55)	(-1.44)	(-0.92)	(-0.09)
Observations	204,043	179,808	317,816	286,963	67,277	57,106	130,141	98,373
Adjusted R-squared	0.015	0.023	0.012	0.015	0.020	0.026	0.021	0.030

This table reports the results of estimating (1) on daily data from November 4, 2019 August 10, 2020, separately for call and put options. The sample includes all stock and ETF tickers with lagged price above $1. As a dependent variable, we use imbalance of contract volume traded via the indicated trade type, aggregated at the ticker level. SLIM is a single-leg price improvement auction, through which we measure retail activity. SLIM < $250, < $5k, and < $20k correspond to SLIM trades of the respective dollar size. MLIM is a multi-leg price improvement auction. D(Robinhood frenzy) equals 1 if the ticker experienced a Robinhood herding event using the data of Barber, Huang, Odean, and Schwartz (2022). All regressions include X and C controls, as described in Section 2.3, as well as date and ticker fixed effects. t-statistics are based on standard errors clustered by ticker and date (in parentheses). *** p<0.01, ** p<0.05, and * p<0.1.

A.32 Are retail investors in the U.S. options market cash-constrained?

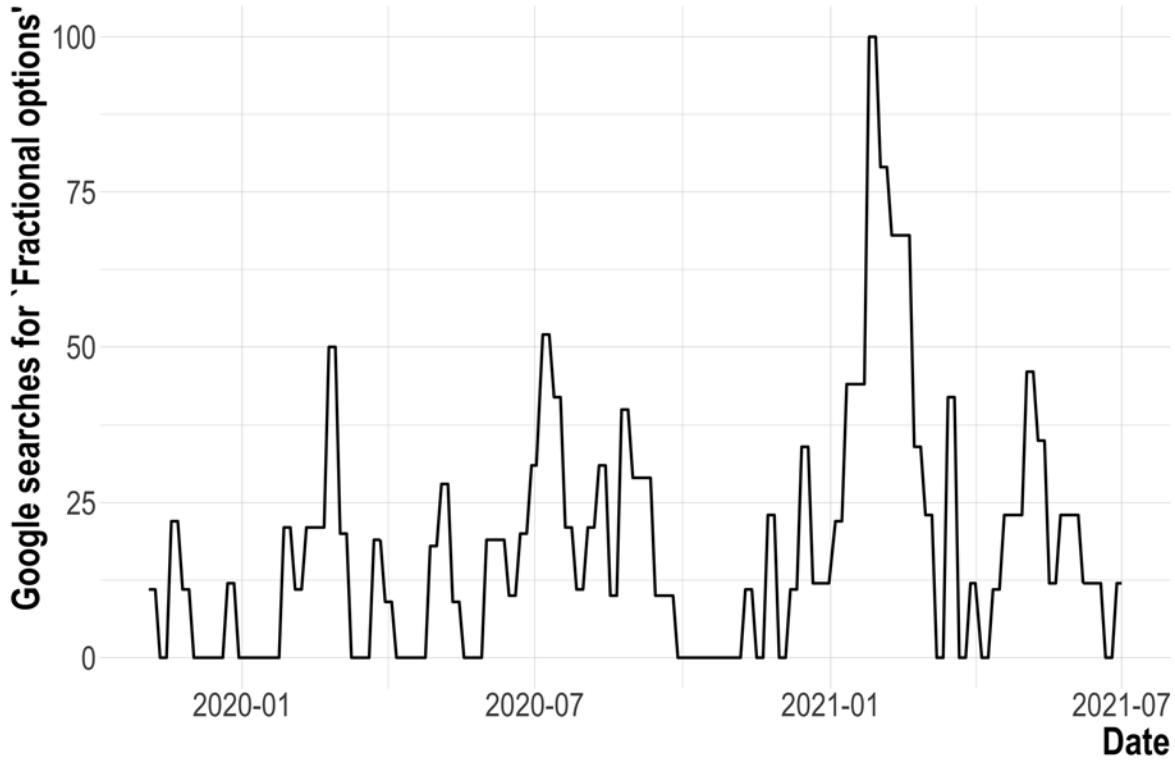
In this section, we present suggestive evidence for binding cash constraints for retail investors in the US options market.

First of all, we see that, during retail frenzies, Google users are more likely to search for "fractional options." Trading fractional options is not permitted in the U.S. in our sample, yet it could allow constrained investors to trade in contracts on an underlying with a high price. Figure A4 plots Google searches for fractional options in our sample. It demonstrates that people are more actively searching for this phrase during the periods of retail frenzies, that is, in June-July 2020 and January 2021.

Second, we see that stock splits on retail-popular yet expensive underlying stocks are associated with an increase in the retail trading volume in options. Figure A5 shows that the average daily volume in SLIM trades below \$250[49] in Apple (AAPL) and Tesla (TSLA)

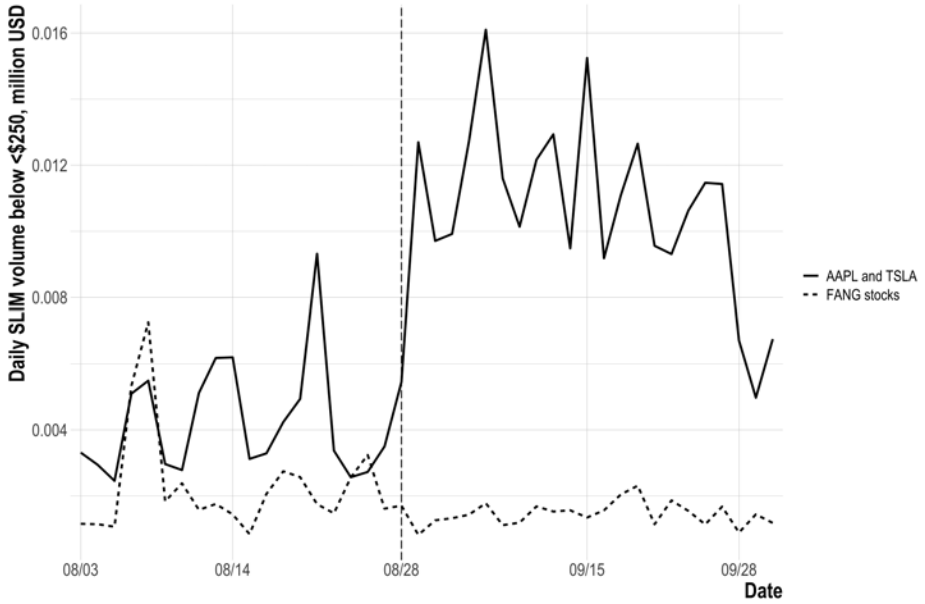
[49] We focus on SLIM trades below \$250 as this measure most likely reflects retail investors who are cash-constrained.

Figure A4: Google searches for fractional options



This figure plots weekly Google searches for fractional options between November 2019 and June 2021. Data source is Google Trends (see https://trends.google.com/trends/), accessed on May 8, 2022.

Figure A5: SLIM trading volume around stock splits



This figure plots the dollar volume in SLIM trades below $250 in size two months around August 28, 2020, when AAPL and TSLA had stock splits (4:1 and 5:1, respectively). The solid line is the average daily SLIM volume of AAPL and TSLA, while the dashed line is the average of FANG companies (Facebook, Amazon, Netflix, and Alphabet). The vertical dashed line indicates the day of the split.

has risen sharply right after their stock splits (both on August 28, 2020) while SLIM trading in FANG stocks, equally popular among retail investors, remained roughly the same.

Finally, we investigate whether a change in SLIM trading is related to stock splits for all underlying securities that had a split in our sample period. Specifically, we estimate the following cross-sectional regression:

$$Y_i = \beta \, Split\, ratio_i + \boldsymbol{\gamma}' X_i + \varepsilon_i. \tag{6}$$

Y_i is one of the following measures of trading activity change around the split of shares in company i: Δ *SLIM volume (contracts)* is a log difference between the daily average number of contracts in SLIM trades below $250 one month after the split and one month before the split, Δ *SLIM volume (USD)* is the same for the average daily dollar volume, Δ *SLIM freq. share* is the difference between the average daily frequency share of SLIM trades below $250 in the total options trading volume one month after the split and one month before the split, and *Internalized volume in equities* is the difference between the average share of non-ATS OTC volume in the total underlying volume one month after the split and one month before the split. X_i are controls related to the underlying stock or ETF, all averaged over one month

before the split: price, volatility, return, volume (log), and market capitalization (log).

If retail investors are cash-constrained, we expect their activity to increase more when the constraint is becoming less binding. Consistent with this hypothesis, Table A46 reveals that retail trading in options tends to increase more when the split ratio is higher. This is true for all the measures we consider: contract volume change, dollar volume change, or the change in the share in the total option trading volume for that underlying. Furthermore, this effect is large both statistically and economically, as the size of the split ratio explains 35%–40% of the variation in SLIM volume around the event date. Notably, the change in internalized volume in equities is not sensitive to the split ratio size, which is consistent with the availability of trading fractional shares the United States.

Table A46: SLIM trading activity and split ratio

	Δ SLIM volume (contracts)	Δ SLIM volume (USD)	Δ SLIM freq. share	Internalized volume in equities
	(1)	(2)	(3)	(4)
Panel A: Without controls				
Split ratio	0.214***	0.181***	0.008***	0.002
	(6.84)	(5.43)	(2.66)	(1.04)
Observations	75	75	75	75
Adjusted R-squared	0.390	0.351	0.130	0.005
Panel B: With controls				
Split ratio	0.198***	0.136***	0.008*	0.002
	(6.63)	(3.43)	(1.86)	(0.99)
Observations	75	75	75	75
Adjusted R-squared	0.399	0.428	0.144	-0.027

This table reports estimates of equation (6) on daily data from November 2019 till June 2021. Controls in Panel B include average underlying price, average underlying volatility, average underlying return, average underlying volume (log), and average underlying market capitalization (log), all computed over one month before the split. Heteroscedasticity-robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

A.33 Early exercise: Technical details

We compute the expected call option ex-dividend price using the Black-Scholes-Merton formula:

$$
\begin{aligned}
c_{ex} &= S_{ex}e^{-y(T-t)}N(d_1) - Ke^{-r(T-t)}N(d_2), \\
d_1 &= \frac{1}{\sigma\sqrt{T-t}} ln\left(\frac{S_{ex}}{K} + \left[r - y + \frac{\sigma^2}{2}\right](T-t)\right), \\
d_2 &= d_1 - \sigma\sqrt{T-t}, \\
y &= Dividend_{ex}/S_{ex},
\end{aligned}
$$

where S_{ex} is the expected price after the stock goes ex-dividend, that is the price at close on the cum-dividend day minus expected dividend, $T-t$ is time to maturity in years, that is difference in the expiration date and the current date in days divided by 360, K is the contract strike, σ^2 is the annualized implied volatility,[50] r is the interpolated maturity-specific interest rate provided by OptionMetrics (annualized %), and $Dividend_{ex}$ is the expected dividend after the ex-date.[51]

A.34 Early exercise sample: Data filters and calculated variables

We use our dataset described in 2.1 together with the following filters to arrive at the final early exercise sample. We include all call option contracts on dividend-paying stocks with $EEV > 0$. Furthermore, since our valuation might be imperfect, we add a market-based filter of the optimality of exercise: We only keep contracts with a decline in open interest on the cum-dividend date.[52] By implication, we only have contracts with non-missing open interest on the cum-dividend date and the date before that. We remove contracts with missing trading volume on cum-dividend date (either in OPRA or in OptionMetrics).

To measure arbitrageur activity, we use floor trading share, defined as the total volume in transactions of OPRA types SLFT and MLFT, divided by the total volume on the cum-dividend date.[53] For both SLIM and Small Share, we compute a one-week moving average (requiring a minimum of a one-day observation) and use its lagged value on the cum-dividend date. We use the same rolling measures for the retail activity variables described in the main text, as well as volume, spread, and implied volatility controls.

[50] We use the daily contract-level implied volatility from OptionMetrics. If it is missing, we interpolate it from the neighboring strikes.

[51] We assume that its size is equal to the current dividend if the stock pays one more dividend after the current dividend until the option expires and 0 otherwise.

[52] This is consitent with Hao, Kalay, and Mayhew (2010).

[53] In unreported tests, we confirm that using dollar-volume-based measures instead yields similar results.

Table A47: Early exercise sample descriptive statistics

	Mean	Median	St. Dev.	p1	p99
Fraction of OI not exercised, %	17.50	1.99	28.17	0.00	98.71
Floor trades volume share on cum-date	0.49	0.58	0.47	0.00	1.00
D(floor share > 0)	0.54	1.00	0.50	0.00	1.00
SLIM Share	0.14	0.06	0.18	0.00	0.81
Small Share	0.84	1.00	0.22	0.00	1.00
Internalized volume in equities	0.17	0.16	0.05	0.07	0.30
WSB mentions, log	-1.05	-0.89	3.20	-4.61	6.99
OI, log	4.28	4.19	2.21	0.00	9.60
Early exercise value (EEV), $	0.52	0.34	0.60	0.00	3.01
Market EEV, $	0.07	0.02	0.37	-0.57	1.07
Potential profit, $	4,466.65	53.66	48,262.21	0.00	70,017.45
Potential profit, log $	3.70	4.00	3.46	0.00	11.16
Dollar volume, log	1.85	1.55	1.39	0.00	6.61
Relative spread	0.09	0.05	0.13	0.00	0.65
Implied volatility, annualized	0.44	0.37	0.45	0.00	1.72
Moneyness	12.09	5.48	20.75	0.51	108.35
Days to expiration	50.14	14.00	108.12	1.00	603.00

This table reports descriptive statistics for all contracts in the early exercise sample (29,111 observations). SLIM and Small Share are the contract-level volume shares of SLIM and small trades, respectively, averaged over one trading week before the cum-dividend date. Internalized volume in equities is the ticker-level share of volume executed in the non-ATS OTC space relative to the total trading volume, averaged over one trading week before the cum-dividend date. WSB mentions is the number of underlying ticker mentions on `WallStreetBets` forum, averaged over one trading week before the cum-dividend date. Relative spread is options contract quoted spread at the time of the trade relative to the midpoint price. Implied volatility is as reported in LiveVol, interpolated using nearest strikes if missing. Moneyness of call options is measured as $(Midpoint\,Price - Strike)/Strike$.

As earlier, we compute relative spread quoted at the time of each option trade as $2(best\,ask - best\,bid)/(best\,ask + best\,bid)$ (relative to the midpoint price). We compute moneyness of a call option as $0.5(underlying\,bid + underlying\,ask)/strike - 1$.[54]

[54]In the absence of TAQ data, we use underlying bid-ask midpoint as a high-frequency price.

A.35 Fraction not exercised, and trade types

Table A48: Suboptimal exercise and trading via different trade types

	Fraction of OI not exercised, %			
	(1)	(2)	(3)	(4)
SLIM Share	4.561***			
	(5.40)			
MLIM Share		-0.729		
		(-0.53)		
Complex Share			-2.541***	
			(-3.91)	
Large Share				-3.384
				(-1.48)
Observations	41,737	41,737	41,737	41,737
Adjusted R-squared	0.206	0.205	0.206	0.205
Contract controls	Y	Y	Y	Y

This table reports estimates of equation (5) in our dividend play sample. SLIM Share is the contract-level volume shares of SLIM trades, averaged over one trading week before the cum-dividend date (similar for MLIM, complex, and large trades). MLIM trades are trades that went through multi-leg price improvement auctions. Complex trades are all multi-leg trades. Large trades are trades with lot size above 100. Contract controls include log dollar trading volume, relative spread, IV, moneyness, days to expiration, log OI, and EEV. All regressions include ticker by date fixed effects. S.E. are clustered by ticker and date. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.