Retail limit orders [*]

Amber Anand

Mehrdad Samadi

Jonathan Sokobin

Kumar Venkataraman

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[*] Anand (amanand@syr.edu) is at Syracuse University, Samadi (mehrdad.samadi@frb.gov) is at the Federal Reserve Board, Sokobin (Jonathan.Sokobin@finra.org) is at FINRA, and Venkataraman (kumar@mail.cox.smu.edu) is at the SMU Cox School of Business. For their comments, we thank Abby Kim, Heather Seidel, Yue Tang and seminar participants at FINRA. Anand, Samadi, and Venkataraman are adjunct researchers with the Office of Chief Economist, Regulatory Economics and Market Analysis, at FINRA. The views expressed in this paper are those of the authors and do not necessarily reflect the views of FINRA or the Federal Reserve Board or of the authors' colleagues on the staff of FINRA or the Federal Reserve Board.

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Abstract

We add to the academic and regulatory focus on retail market orders by studying the use of nonmarketable limit orders by US retail equity traders trading through 19 large retail brokerage firms. We find that retail limit order usage is substantial, accounting for 26% of retail orders and 30% of submitted share volume, in a stratified sample of stocks. Retail limit orders concentrate behind the best quotes but still exhibit substantially higher fill rates than previously documented in market-level statistics. Retail limit orders exhibit lower implementation shortfall costs than marketable orders; a result robust to controls for differences across stocks, order placement times, order sizes, trade direction and brokerages. Our results indicate that limit orders offer an attractive choice for retail investors to earn compensation for supplying liquidity in the current market structure.

1. Introduction

The increase in retail trading activity in the US equity markets has brought renewed academic attention to order handling and trading costs of retail orders. Retail traders do not typically have access to the same tools, order routing choices and information as institutional and professional traders. These limitations are the likely explanation for the prevalence of payment for order flow arrangements whereby market makers pay brokers to trade with retail marketable orders as they are perceived to be less informed.[1] Recent studies show that market makers provide substantial price improvement to retail marketable orders.[2]

The focus on marketable orders missed the potential use of nonmarketable limit orders by retail traders. A rich theoretical literature on order types describes tradeoffs between market and limit orders: the benefits of immediacy with a marketable order versus the risk of non-execution but also potentially execution at a better price with a limit order (see Handa and Schwartz (1996), Parlour (1998), among others). Empirical literature finds that limit orders are an important part of traders' toolkits. Using NYSE audit trail data from 1990-91, Harris and Hasbrouck (1996) find that limit orders placed at or better than the prevailing quote have lower trading costs than market orders.[3] While retail traders can submit limit orders through brokerages in practice, there is little understanding of retail traders' limit order usage, handling and execution quality outcomes in the literature. This lack of analysis is due to the difficulty in identifying retail limit orders in publicly available equity market trading data.[4]

The order choice of retail traders is particularly interesting because it is not clear whether a limit order is an attractive choice for retail investors in the current market structure. First, high frequency trading strategies are commonplace in the market. Hasbrouck and Saar (2009) document the phenomenon of

[1] For ease of exposition, we use "marketable orders" to refer to market orders and marketable limit orders, and "limit orders" to refer to nonmarketable limit orders in this paper. Nonmarketable limit orders are not executable at the time they are received by the broker based on the opposite National Best Bid or Offer quote, whereas marketable orders (including market and marketable limit) are executable at the time of order receipt.

[2] See, for example, Battalio and Jennings (2023), Brown, Johnson, Kothari and So (2024), Dyhrberg, Shkilko and Werner (2023) and Ernst and Spatt (2022).

[3] Biais, Hillion and Spatt (1995), Ranaldo (2004), and Griffiths, Smith, Turnbull and White (2000) provide important evidence on order choice from international markets.

[4] Methods used to track retail trading in publicly available data primarily capture a subset of marketable retail trading (Boehmer, Jones, Zhang, and Zhang (2021) and Barber, Huang, Jorion, Odean, and Schwarz (2023)).

fleeting limit orders that are cancelled within two seconds of placement. As Baruch and Glosten (2013) note, the trend of rapid placements and cancellations has only grown since. For example, the SEC's market data tool shows that approximately 95% of orders in large stocks are cancelled (fully or partially) within 30 seconds in Q4, 2023, and that the cancellation hazard rate peaks at 56 milliseconds.[5] Given the conventional wisdom that retail investors are likely to be less sophisticated traders, a limit order trading strategy, which requires the ability to monitor market conditions and respond quickly, could potentially be less suitable, particularly in markets characterized by the importance of speed. Second, Battalio, Corwin and Jennings (2016) highlight the concerns that retail traders do not appear to control the decision where to route limit orders, and the routing practices of some brokers may lower retail limit order execution probabilities. On the other hand, with appropriate order handling rules and intermarket linkages designed to protect limit orders, as are envisioned under the US regulatory framework, limit orders can offer a mechanism to earn compensation for liquidity provision and could potentially be an important tool for retail traders in implementing their trades.[6]

To better understand these tradeoffs, we examine regulatory data on orders and trades in a stratified sample of US exchange-listed stocks to provide a first look into how retail investors use limit orders, how retail limit orders are routed and executed, and, importantly, the execution quality outcomes of retail limit orders relative to marketable orders. Our data come from the FINRA Order Audit Trail System (OATS), which provided securities regulators with detailed information on orders received by brokers from their clients.[7] Our sample consists of over 27 million orders submitted by individual account holders of 19 active retail brokers in 300 stocks stratified to contain 100 large, medium and small stocks by market capitalization

[5] The SEC methodology counts partial as well as full cancellations. Details of the methodology are available at https://www.sec.gov/marketstructure/quote-life-report-methodology. Data visualizations are at: https://www.sec.gov/securities-topics/market-structure-analytics.

[6] Examples of limit order protections in the current regulatory system include FINRA Rule 5320, which prohibits market makers from trading ahead of customer orders; SEC Rule 604 and FINRA Rule 6460, which require display of quote matching and improving limit orders; and SEC Rule 611, which prohibits trade-throughs, protecting limit orders at the top of each exchange's limit order book.

[7] The OATS system has been replaced by the Consolidated Audit Trail (CAT).

in May 2020. We identify these brokers based on their overall activity and the proportion of their orders likely to be associated with retail customers.[8]

OATS links events associated with the order from the time of order receipt by the broker to the eventual execution or cancellation of the order, including venue-specific routing decisions and outcomes, such as executions, execution prices, and time stamps associated with each routing, modification, execution, or cancellation decision in an order's life cycle. FINRA member firms were required to report all activity in equities (orders, routes, cancellations and executions) to OATS; as a result, OATS did not suffer from attrition or sample selection bias issues that often affect data received from a subset of industry participants.[9]

We find that limit orders are a significant part of retail investors' order flow, comprising 30% of submitted shares, 26% of submitted orders and 18% of executed shares by retail traders in our sample. Limit order usage persists across stock size categories with a slightly higher proportion in small capitalization stocks. In our data, retail traders place limit orders across price aggressiveness levels, with a large concentration (more than 70% of retail limit orders) placed behind the best quotes (i.e., buy orders priced lower than the best bid price and sell orders priced higher than the best ask price).

Given the tradeoffs inherent in the use of limit orders by retail traders discussed above, we examine the role of limit orders in retail trading. The average fill rate, the proportion of shares in an order that receive an execution, for retail limit orders in our sample is 65%, which significantly exceeds those documented for the entire market.[10] Similar fill rates are observed in the cross section of stocks, with small stocks showing slightly lower fill rates around 60%. Notably, even the least aggressive orders that are placed far behind the best quotes receive average fill rates of 49%. A possible explanation for these fill rates lies in the order duration of retail limit orders. In contrast to very short order durations discussed earlier for the

[8] As described later, we use a combination of two characteristics for likely retail orders. These orders are marked as "individual" (in contrast to "institutional") in the data, and the orders are "held" orders (in contrast to "not-held" orders). SEC (2018) notes that institutional orders are more likely to be handled on a not-held basis. A "not-held" order provides the broker-dealer with price and time discretion in handling the order. We refer to the individual, held orders associated with our identified brokers as retail orders.

[9] Einav and Levin (2014) and Card et al. (2010) advocate for the use of such administrative data in economic analyses.

[10] For example, Li, Ye and Zheng (2023) find fill rates lower than 3% on the NYSE.

overall market, retail investors keep their limit orders open in the market for longer periods. Retail limit orders, on average, have an order duration of 1,200 seconds, and orders in the least aggressive category show an average duration longer than 3,000 seconds. Thus, order lifetimes are measured in minutes for retail limit orders rather than the typical milliseconds observed for the market. The higher fill rates observed for retail limit orders correspond to longer wait times.

We next study the execution quality of retail limit orders relative to retail marketable orders based on the implementation shortfall (IS) approach outlined in Perold (1988) and used by Harris and Hasbrouck (1996) and Griffiths, Smith, Turnbull and White (2000). Specifically, the IS cost is based on the trade execution prices for the filled portion of the order and the opportunity costs of non-execution for the unfilled portion of the order. The opportunity costs capture the scenarios where the market price moves away from the limit price of the order, forcing the trader to trade by placing a marketable order at the time of limit order cancellation. In other words, the trader pays the cost of the price drift over the order's lifetime as well as the bid-ask spread that exists at the time of cancellation for the unfilled portion of the order. We use retail marketable orders as the benchmark to assess limit order execution quality because recent studies show that retail marketable orders commonly receive price improvement from market makers (Battalio and Jennings (2023), Brown, Johnson, Kothari and So (2024), Dyhrberg, Shkilko and Werner (2023) and Ernst and Spatt (2022)), and because marketable and limit orders are common order types offered by retail brokerages.

We find evidence that retail limit orders receive better execution quality than marketable orders based on the IS cost measure. Our main regression specification includes stock-day fixed effects whereby the results correspond to retail marketable and limit order costs within the same stock-day. We also present results with broker fixed effects that account for potential differences across brokers, such as routing practices, clienteles and even information frictions that reduce limit order usage (e.g., web or app interface quality).[11] We also account for additional order characteristics and intraday market conditions by

[11] In unreported results, we include broker-stock-day fixed effects, comparing trading costs between limit and marketable orders within a brokerage firm for the same stock on the same day. Results are similar.

controlling for order size and the bid-ask spread at the time of order receipt by the retail broker. Finally, we examine specifications with stock-five-minute time interval-trade direction fixed effects to further compare trading costs for marketable and limit orders submitted under similar conditions (buy or sell orders in the same stock that are submitted within a 5-minute window). Across all specifications, we find that trading costs of limit orders are lower than those of market orders by ten basis points, a sizable differential relative to the average marketable order IS of 1.1 basis points. These results directly tie to the high fill rates documented above; that is, while the unfilled shares in limit orders bear an opportunity cost, these costs are smaller than the benefit of lower trading costs for executed shares due to the high fill rates. While limit orders require costly monitoring of market conditions, more order parameters to choose from, and patience relative to marketable orders, our results indicate that retail traders using limit orders receive compensation for supplying liquidity subject to these higher frictions.

We examine whether estimated differences in limit and marketable order outcomes are related to factors affecting the relative desirability of the two order types highlighted in the literature. We find that the trading costs differentials between limit and market orders are larger when quoted spreads are wider (consistent with Cohen, Maier, Schwartz and Whitcomb (1981)), and when realized volatility is higher (consistent with Handa and Schwartz (1996)). Across stocks, the advantage for limit orders is larger in smaller stocks, consistent with limit orders earning higher compensation for supplying liquidity in less liquid securities.

Finally, we study the trading mechanisms surrounding retail limit order handling. We find that the vast majority (89%) of retail limit orders are sent from the broker receiving the order to market makers and not directly to exchanges. Market makers can execute limit orders on a principal basis (taking the other side of the trade) or on a riskless principal basis (finding liquidity from another market participant, and then filling the order). We find that market makers fill about 31% of the executed shares on a principal basis while 64% of the executed shares are filled by simultaneously sourcing liquidity from other market

participants (riskless principal).[12] We also find that limit orders with higher proportion of principal fills by market makers have a statistically lower IS than those that are primarily executed on a riskless principal basis, but the economic magnitude of the difference is small. Notably, the handling of retail limit orders is markedly different than that of marketable orders. Brokers route nearly all retail marketable orders to market makers, and market makers execute marketable flow largely in a principal capacity.

Our analysis contributes to the existing literature by presenting novel evidence of the economic relevance and usage of limit orders by retail traders; and by showing that retail limit orders exhibit lower trading costs than retail marketable orders.[13] Differences in trading costs between retail limit and marketable orders behave in ways predicted by theory, with limit orders showing better performance at times of higher spreads and higher volatility, and in smaller stocks. Overall, we show limit orders are a feasible choice for retail traders and allow them to earn compensation for liquidity provision. The results on order duration, fill rates and IS indicate that the feasibility of limit orders exists, not in spite of retail traders being slow, but likely *because of* them being slow and not following the market trends of rapid placements and cancellations.

While much attention has been devoted to retail investor market participation, asset allocation, portfolio diversification and trading behavior (see Campbell (2016); and Gomes, Haliassos, and Ramadorai (2021) for surveys), attention has only recently turned to the implementation of retail trades. Several recent papers examine facets of retail marketable orders executions, including trading cost differentials across brokerages (Schwarz, Barber, Huang, Jorion, and Odean (2023)) and retail broker order routing to market makers (Dyhrberg, Shkilko and Werner (2023), Huang, Jorion, Lee, and Schwarz (2023), and Ernst,

[12] A small proportion of orders are executed on an agency basis by market makers.

[13] Order handling rules and trade-through rules in the current market structure protect customer limit orders. Our results may be indicative of these rules helping retail limit order execution quality. There are proposed changes that affect how retail marketable orders are handled. SEC (2022) proposes Rule 615, which would require retail marketable order internalization to occur in qualified auctions, with the goal of obtaining greater price improvement. Further, the recently adopted revisions to Rule 605 in SEC (2024) include extending the rule to broker-dealers to better understand execution quality of internalized retail marketable trades and enhance competition. These changes may improve the execution quality of marketable orders and affect our inferences.

Malenko, Spatt, and Sun (2024)). We extend this literature by examining trading costs of retail limit and marketable orders.

Two papers have previously examined retail limit orders in other contexts. Kelley and Tetlock (2013) show that retail limit orders provide liquidity to the market by trading against daily returns (while marketable orders trade with momentum and predict information in news announcements). The trading patterns in Kelley and Tetlock (2013) are suggestive of retail traders as sophisticated market participants. We analyze different dimensions of retail limit order trading activity, including order handling and execution quality. Battalio, Corwin and Jennings (2016) examine retail limit order handling by brokerages and show that some retail brokers route limit orders to exchanges that pay rebates for limit orders. Importantly, Battalio, Corwin and Jennings (2016) use a proprietary data set of institutional orders to show that limit orders routed to these exchanges have worse outcomes than orders routed to exchanges where executed limit orders pay a fee.

The focus of our analysis differs from that of Battalio, Corwin and Jennings (2016) in several ways: we examine all retail limit orders associated with our sample of brokers, including orders routed to market makers. We find that market markets receive the majority of limit orders in our sample and that a substantial minority of these orders are executed by the market makers in a proprietary capacity. We also find that retail limit order fill rates are large in absolute terms. Further, our data allow us to analyze both marketable and limit retail order flow received by our sample of brokers, allowing us to see how important limit orders are for retail traders relative to marketable orders. Finally, since we can track orders from when they are received by brokers, we examine the trading costs of limit orders relative to those of marketable orders. Our analysis indicates that limit orders are a viable option for retail traders, who are compensated for bearing execution uncertainty and frictions involved in submitting limit orders.

Our analysis is guided by the rich literature examining use of marketable and limit orders in equity markets more broadly. Many early theoretical models, including Demsetz (1968), Cohen et al. (1981) and Copeland and Galai (1983), describe the trade-offs between market and limit orders. Parlour and Seppi (2008) provide a comprehensive review of the various models of limit order markets. On the empirical side,

Harris and Hasbrouck (1996) examine the performance of orders submitted through the NYSE's electronic (SuperDOT) system over three months in 1990-91. Using the IS approach, they find that at-the-quote limit orders are the best performing (and the most frequently submitted) order type in their sample. Griffiths et al. (2000) find similar results on the Toronto Stock Exchange.

We add to this literature by focusing on retail traders' limit order performance (relative to marketable orders) and doing so in the current market structure where the speed of trading may disadvantage these traders. It is interesting to compare our results to older studies. We find that current fill rates for retail traders are of comparable magnitudes to those in Harris and Hasbrouck (1996), perhaps because these traders leave orders open for longer periods. In contrast to the findings in Harris and Hasbrouck (1996), we find that behind-the-quote orders exhibit the lowest IS and most frequent usage among the retail limit orders in our sample.

In the remainder of the paper, we describe the data and the sample, outline our empirical results and conclude.

2. Data and sample description

The primary dataset that we examine is the FINRA OATS database for the month of May 2020.[14] A large number of broker-dealers in the U.S. reported audit trail information on equity orders to FINRA.[15] For each broker-level order ("top order") received from a customer, OATS provides information detailing how the broker handled the top order. The dataset combines a unique broker identifier, the customer ("beneficiary owner") type, the submitted quantity, and the order type with the audit trail of routes, venues, executions, modifications, and cancellations associated with the order's lifecycle.

We examine 19 large retail brokerage firms in our sample. To arrive at this sample of brokerages, we use the beneficiary account owner type classification field to identify retail brokers. The beneficiary

[14] The OATS system has since been replaced by the Consolidated Audit Trail (CAT).

[15] FINRA was responsible for the regulation of 3,435 member firms in 2020 (https://www.finra.org/rules-guidance/guidance/reports-studies/2021-industry-snapshot/firm-data#firms1). The data are similar to those underlying the statistics created by FINRA for the tick size pilot program. More details are available at http://www.finra.org/industry/tick-size-pilot-program.

account owner type field indicates whether an order arises from an account representing institutional, individual, market maker, or proprietary interest. We restrict attention to orders marked as coming from individual customers.[16] We also use the "not-held" order handling code in constructing our sample. SEC (2018) notes that not-held orders are generally associated with institutional customers; thus, individual orders are more likely to be "held." Specifically, our selected brokers are required to have the following three characteristics: 1) the majority of customer orders are marked as individual; 2) at least 90% of orders marked as individual are held orders; 3) the broker handles at least 100,000 held top orders arising from individual accounts in our sample stocks during May 2020. These requirements leave us with 19 retail brokers.[17] The median brokerage firm in the sample has 99% of customer (individual plus institutional) orders marked as arising from individual accounts, and 100% of the individual account orders marked as held. Our analysis examines held, individual orders received by these 19 brokers.

Our data are unique in providing a detailed look at an order lifecycle and allowing us to examine retail orders. Recent studies have used both public and proprietary databases. The Rule 605 data used by Dyrhberg et al. (2023) provides execution quality statistics only for marketable orders. Both, Battalio and Jennings (2023) and Schwarz, Barber, Huang, Jorion and Odean (2023), use proprietary datasets of marketable orders. Relative to the datasets used in these studies, our sample includes all marketable and nonmarketable orders received by the largest 19 retail brokerages in our sample and traces the life of the order from order receipt by the broker to its eventual resolution.

Our stock sample consists of a size-stratified group of 300 exchange-listed stocks traded in May 2020.[18] We focus on common stocks (CRSP share codes 10 and 11) with a share price of at least $5 and

[16] FINRA rule 4512 (c) defines institutions as a "bank, savings and loan association, insurance company or registered investment company; an investment adviser registered either with the SEC under Section 203 of the Investment Advisers Act or with a state securities commission (or any agency or office performing like functions); or any other person (whether a natural person, corporation, partnership, trust or otherwise) with total assets of at least $50 million." Customer orders that do not meet the criteria of the rule are classified as individuals.

[17] To maintain the anonymity of regulatory data, our analyses are conducted across the entire sample of 19 firms, not at the level of the brokerage firm or a smaller subgroup of firms.

[18] May 2020 has the advantage of capturing a period after the increase in retail activity experienced during the pandemic of 2020. While volatility sharply rose in March 2020, it had declined substantially by May 2020.

less than $10,000. To select the 300 stocks, we form size terciles based on market capitalization in CRSP at the end of April 2020 and select the largest 100 stocks from each tercile that we can match with the OATS and TAQ databases. To construct NBBO quotes, we consider NBBO quotes from the TAQ NBBO and Quote files whose quote conditions are not equal to 'A','B','H','O','R','W'.[19] We additionally remove cancelled quotes, quotes without an associated price, quotes with non-positive share quantity, quotes corresponding to locked and crossed markets and quotes with percentage bid-ask spreads larger than 10%. We apply several data filters with the objectives of limiting the sample to: orders where trading costs can be easily measured (e.g., excluding orders where multiple top orders are merged or orders with cancel-replace instructions), orders which are representative of typical retail orders (e.g., restricting the sample to orders for less than 5,000 shares and orders with easily attributed routing to market makers or exchanges) and eliminating possible outliers and data errors (excluding orders with the absolute value of IS greater than 10%). Details of each filter and the surviving number of top orders after applying the filter are included in the Appendix.

Our final sample contains more than 27 million marketable and limit orders placed by individual account owners with brokers for more than four billion shares and accounting for more than 3.6 billion traded shares. In unreported results, we find that in contrast to the proliferation of order types documented in the broader equity market (Li, Ye, and Zheng, 2021), marketable and limit orders comprise approximately 90% of orders coming from retail traders in our sample. Figure 1 presents the proportion of limit orders in the sample, proportion of shares submitted via limit orders and the proportion of executed shares that trade via limit orders. Across the 300 stocks, approximately 26% of orders are limit orders, which are associated with 30% of shares submitted and 18% of shares traded. Figure 1 also shows that the proportions are consistent across large, medium and small stocks. Table 1 presents the corresponding numbers. Table 1, Panel A shows that order sizes are larger for limit orders than marketable orders, but the traded size is smaller due to the nonexecution risk of limit orders. Table 1, Panel B presents the statistics

[19] These quote conditions are associated with slow quotes or opening quotes.

by stock terciles. We find that the sample is highly skewed towards the 100 large stocks: approximately 93% of orders and 90% of shares are submitted in these stocks. Order and trade sizes are larger in smaller stocks.

In Figure 2, we present a disaggregation of limit orders by price aggressiveness categories. Table 1, Panel C presents the corresponding numbers. We separate limit orders into four categories similar to those of Biais, Hillion, and Spatt (1995): orders placed within the NBBO quotes, placed at the NBBO quotes (e.g., buy orders at the best bid), placed behind the quote but within five times the prevailing NBBO spread at time of order receipt by the broker, and those further behind. While Figure 2 shows that retail limit orders are placed across the price aggressiveness spectrum, an unexpected finding is that most limit orders are placed behind NBBO quotes. Approximately 40% of retail limit orders (39% of submitted shares) are placed behind the quotes within five times spread, and another 34% (29.5% of submitted shares) are placed even further behind. This order placement strategy differs from that documented on the NYSE in Harris and Hasbrouck (1996), who find that at-the-quote limit orders are most common. With fast moving markets, the less aggressive placement strategy we document may be a mechanism for retail traders to ensure that their orders aren't marketable upon arrival at the broker or venue. The result is also consistent with retail traders demanding a bigger premium for their patience and inability to rapidly cancel and replace limit orders.

3. Results

3.1. Outcomes, univariate results

Table 2, Panel A presents a comparison of outcomes for marketable and limit orders in our sample. The statistics are averaged across all orders within a particular category presented in the table. Marketable orders trade quickly with an average time to execution of three seconds. We present the fill rate, calculated as the filled quantity divided by the submitted quantity of a top order. Marketable orders almost always trade their intended quantity with an average fill rate of 99.8%. Limit orders have significantly longer durations. The average time to execution for a limit order is 951 seconds and the average order duration

(which includes cancellations in addition to executions) is 1,251 seconds. Retail trader patience seen in longer order durations appears to be rewarded in an average fill rate of 65% for limit orders. These fill rates are reminiscent of market-wide fill rates of 44% reported by Harris and Hasbrouck (1996).[20]

We next present *Effective spreads*, which are measured for a top order as:

$$\textit{Effective spread}_i = \frac{P_{1(i)} - P_{0(i)}}{P_{0(i)}} \times D_i, \qquad (1)$$

where $P_{1(i)}$ is the share volume-weighted execution price, $P_{0(i)}$ is the benchmark price, the NBBO bid-ask quote midpoint at the time when the broker receives the top order, and $D_{(i)}$ is a variable that equals 1 for buy orders and equals -1 for sell orders. As expected, Table 3, Panel A shows that executed limit orders have negative effective spreads, while marketable orders have positive effective spreads.

A common concern with limit orders is that the opportunity costs of non-execution can be high. That is, prices can move away from the order leading to the trader eventually filling the order at a worse price. In the IS approach, orders with fill rates below 100% incur an opportunity cost for the unfilled portion of an order (see Perold (1988), Wagner and Edwards (1993)). The approach assumes that the trader is precommitted to trading (Harris and Hasbrouck (1996), Griffiths et al. (2000)). We calculate IS for the order, including a cost for the unfilled portion of order, as follows:

$$\textit{Implementation Shortfall}_i = \left[f_i \times \frac{P_{1(i)} - P_{0(i)}}{P_{0(i)}} \times D_i\right] + \left[(1 - f_i) \times \frac{IP_{(i)} - P_{0(i)}}{P_{0(i)}} \times D_i\right], \qquad (2)$$

where f_i is the *fill rate* of the top order, $IP_{(i)}$ is the imputed price for unfilled portion of order, and other variables are as defined above. The literature has used different prices for $IP_{(i)}$ including the closing price (Keim and Madhavan (1997) and Conrad, Johnson and Wahal (2001)), a volume weighted average price after the order is cancelled (Jeria and Sofianos (2008)), and the opposite quote at the end of the life cycle (i.e., $IP_{(i)}$ is the ask (bid) quote for buy (sell) orders at the time of the last event in the order's life cycle). The opposite quote as the imputed price (used in Harris and Hasbrouck (1996) and Handa and Schwartz

[20] In an institutional context, Jeria and Sofianos (2008) reports fill rates for 43% for institutional orders in their sample. Using CAT data, SEC (2022), Table 5 reports fill rates close to 82% for at the midpoint and below the midpoint limit orders.

(1996)) applies the largest penalty for non-execution as it adds the drift during the order's lifecycle to the quoted spread as the trading cost of the unfilled portion of the order. Given our focus, we use the opposite quote at the time of cancellation in calculating IS since cancelling the limit order and replacing it with a marketable order is likely to be the easiest strategy for a retail trader.[21] Table 3, Panel A shows that accounting for opportunity costs raises the trading costs for limit orders, but the IS for limit orders remains approximately nine basis points lower than that for marketable orders, a sizable differential relative to the average marketable order IS of 1.1 basis points.

In Table 2, Panel B, we present statistics disaggregated by stock market capitalization terciles. Average order duration for limit orders is higher for smaller stocks indicating that traders are willing to be more patient in smaller stocks, which are typically less liquid. Fill rates are similar for the large and middle terciles at approximately 65%; they are smaller for the small stocks but remain reasonably high at 60%. We find that IS is smaller for limit orders than for marketable orders in each size tercile. The IS difference between marketable and limit orders is larger for small stocks. This result is consistent with limit orders earning larger spreads in smaller stocks, while not suffering from significantly lower fill rates.

We examine the outcomes for limit orders by aggressiveness category in Table 2, Panel C. As expected, fill rates are lower for less aggressive limit orders. Even so, fill rates remain high for behind the quote orders. Behind the quote orders within five times spreads fill 68.4% of the shares while orders further behind still show fill rates close to 50%. The time to execution is higher for less aggressive orders, rising to an average of 2,784 seconds (median of 882.3 seconds) for the least aggressive orders. The longer order durations and the higher fill rates are likely to be linked, but they also raise the question of whether the adverse price movements associated with longer durations overcome the benefit of higher fill rates for less aggressive orders. We find that IS is smaller for behind the quote orders, and especially so for retail limit

[21] Results are qualitatively similar when we impute alternative execution prices such as the closing price and a volume-weighted average trade price from the end of the order lifecycle to the close. As in Anand, Samadi, Sokobin, and Venkataraman (2021), the opportunity cost of non-execution tends to be smaller for these alternative prices.

orders far behind the quote. Thus, the benefits of patient trading outweigh the opportunity costs associated with limit orders.

3.2. Outcomes, regression analysis

The univariate results showing lower IS for limit orders do not control for differences in situations where marketable and limit orders are used, including the possibility that limit orders are used in different stocks (e.g., Figure 1 shows higher fraction of shares submitted via limit orders for smaller stocks). In this section, we use several tests to increase the granularity of the analysis to better compare marketable and limit order trading costs. We note the differing interpretations that can come from a more granular, controlled analysis in the regression framework. If we find that differential use (say, across stocks) drives the difference in outcomes, this would be consistent with retail traders choosing marketable and limit orders appropriately to suit the market conditions, such that the execution outcomes are similar when these conditions are accounted for. On the other hand, if differences persist even after controlling for differences in stocks and market conditions, it could indicate that some retail traders may benefit from being more patient with their trades.

The comparison between marketable and limit orders may be affected by differences in stocks traded, the trading day chosen for placing the orders, and the market conditions at the time of the trade. We account for these differences primarily through appropriate fixed effects in the following specification:

$$IS_i = \beta_1 Market_i + \beta' \mathbf{X} + FE + \epsilon_i, \qquad (3)$$

where IS_i is the implementation shortfall for order *i*. The variable of interest, *Market*, equals one if order *i* is a marketable order and zero if it is a limit order. **X** is a vector of control variables: log of order size, and the arrival percentage NBBO quoted spread. Order size accounts for the well-established result that order difficulty increases with order size. Arrival-time spreads account for variation in market conditions during the trading day. We use stock-day fixed effects in our main specification restricting the comparison to marketable and limit orders submitted in the same stock on the same day. To further refine the comparison,

we use a stock-day-buy/sell fixed effect to control for order direction. Separately, broker differences may influence the results if certain brokers have systems aligned towards marketable or limit orders, or if there are significant differences in the clienteles they serve. Further, Schwarz, Barber, Huang, Jorion and Odean (2023) show differences in execution quality of marketable orders across brokers. Accordingly, we add a broker fixed effect in addition to the other fixed effects discussed above.[22] Test statistics are based on standard errors clustered by stock and day.

Specifications (1) and (2) in Table 3, Panel A present the results with stock-day fixed effects, with and without the control variables. We find that marketable orders' implementation shortfalls are larger than those for limit orders by approximately nine basis points. The difference is highly statistically significant. Specification (3) further controls for trade direction with stock-day-buy/sell fixed effects; the results remain largely unchanged. Specifications (4), (5) and (6) use broker fixed effects in addition to fixed effects related to stock-days and order direction. All three specifications show that IS is approximately 10 basis points larger for marketable orders relative to limit orders. In our final specification (specification (7)), we further match marketable and limit orders such that their submission times are proximate. To implement this analysis, we divide each trading day into five-minute periods. We then construct a fixed effect that combines the stock, the day specific five-minute period and the buy/sell trade direction. The results show that, even with this level of granularity, marketable order IS is approximately nine basis points larger than limit order IS. Thus, results consistently indicate that retail traders earn a reward for being patient.[23]

Table 1 shows that our sample of orders is dominated by large stocks, raising the possibility that the results in Table 3, Panel A are driven by these large stocks. We separately examine the 200 stocks in the small and medium market capitalization categories in Table 3, Panel B. We present four specifications focused on stock-day and stock-day plus broker fixed effects, with and without control variables. The

[22] In another specification, we include broker-stock-day fixed effects (i.e., comparisons are limited to orders placed with the same broker in the same stock on the same day). The results are similar to those reported in Table 3.

[23] SEC (2022) suggests that market makers may treat limit orders placed between the opposite quote and the quote midpoint similar to marketable orders and trade with these orders. We note that within-quote limit orders are a small part of our sample. However, we repeat our analysis in Table 3 after removing limit orders placed between the quote midpoint and the opposite quote. Our inferences are unaffected by this filter. Results are available from the authors.

direction of the results is similar to that in Panel A. Marketable orders show statistically significantly larger IS, but the magnitudes are larger at approximately 20 basis points. These results are consistent with the univariate results in Table 2 showing that the limit order advantage is larger in smaller stocks.[24] We separately examine limit orders placed in each aggressiveness category with marketable orders in Table 4. We find that within-quotes orders show little difference in IS relative to marketable orders. The difference increases for less aggressive orders with the largest difference in the least aggressive orders. These results corroborate the univariate findings in Table 2 that the least aggressive orders do not suffer from very low fill rates, which makes the balance between opportunity costs and earning the spread fall in their favor.

3.3. Interaction Effects

We examine whether the difference between retail marketable and limit order trading costs is affected by other factors. In Table 5, we focus on two variables capturing market conditions shown to affect the relative attractiveness of marketable and limit orders: volatility and spread width. Handa and Schwartz (1996) and Ahn, Bae and Chan (2001) show that higher volatility increases the attractiveness of limit orders. Cohen et al. (1981) posit that the opposite quote exerts a "gravitational pull" which gets stronger as spreads narrow, thus increasing the likelihood of marketable orders when quoted spreads are small. Additionally, in the context of institutional orders, the results in Keim and Madhavan (1995, 1996) suggest that orders to buy may be more likely to be informationally motivated than orders to sell. The information motivation is potentially relevant for our analysis if more informed traders are more likely to choose marketable or limit orders. While we confirm in Table 3 that our results exist after controlling for order direction, the objective in this analysis is to check whether the trading cost difference between marketable and limit orders varies by the buy/sell order direction.

The analysis in Table 5 draws inferences from an estimation of the following model:

[24] In unreported results, we estimate a model for the overall sample where a small/medium stock dummy is interacted with the marketable order dummy. The specification shows that the difference between large and small/medium stocks is statistically significant.

$$IS_i = \beta_1 Market_i + \beta_2 C_i + \beta_3 Market_i * C_i + \beta' \mathbf{X} + FE + \epsilon_i, \quad (4)$$

where IS_i is the implementation shortfall for order *I*, and *Market*, equals one if order *i* is a marketable order and zero if it is a limit order. C_i is either: the arrival percentage NBBO quoted spread; the volatility of the stock for the day measured as the sum of five-minute squared quote-midpoint returns on a stock-day; or a buy/sell order direction indicator. The variable of interest is $Market_i * C_i$, which captures the interaction effect of the relevant factor on trading costs of marketable orders relative to limit orders. **X** is a vector of control variables: the log of order size, and, for the analysis of order direction and volatility, the arrival percentage NBBO quoted spread. We include stock-day fixed effects in the estimation. Since volatility is measured at the stock-day level, the estimation with volatility only includes the interaction of volatility and $Market_i$, and not the volatility variable by itself since it is subsumed by the fixed effects. Test statistics are based on standard errors clustered by stock and day.

Table 5 shows no statistically significant effects associated with the buy/sell order indicator; that is, the marketable and limit order differences are not statistically different between buy and sell orders. However, consistent with predictions from the literature, the limit order advantage in trading costs is higher at times of larger spreads and higher volatility. The coefficient on the interaction term with spreads indicates that a one standard deviation increase in quoted spreads increases the implementation shortfall of marketable orders, relative to limit orders, by a further 2.69 basis points. The corresponding increase is 1.8 basis points for a one standard deviation increase in volatility.

3.4. Additional Robustness

A possible explanation of our results is that among retail traders, limit orders are placed mostly by more sophisticated traders, while less sophisticated traders concentrate towards marketable orders. In this view, marketable orders represent a higher proportion of less sophisticated traders than limit orders. Further, for this explanation to affect our results, the trading costs would need to be lower for sophisticated traders,

which would then be reflected in our finding of lower IS for limit orders relative to marketable orders.[25] We previously control for variation in clientele sophistication across brokers by using broker fixed effects but trader heterogeneity may exist even within a broker clientele. In Table 3, we find that the differences between marketable and limit order implementation shortfalls exist even when we restrict the comparison to orders placed in the same five-minute period. We use the five-minute periods further to examine the possible differences in sophistication.

Specifically, since there are significantly more marketable than limit orders in our sample, there are five-minute periods with and without limit orders. If periods where we see limit orders, are particularly disadvantageous time periods for marketable orders, we may expect sophisticated traders to be more likely to use limit orders, while marketable orders during these periods are relatively more likely to come from less sophisticated traders. In contrast, in periods where we see only marketable orders, the orders likely represent a mix of more and less sophisticated traders. Following this argument, after controlling for other factors, we would then expect that marketable orders' IS is higher in periods with limit orders, than in periods without limit orders. In Table 6, we examine this possibility by comparing the trading costs of marketable orders that are submitted in five-minute periods that include limit orders with five-minute periods with no limit orders. We use stock-day and stock-day plus broker fixed effects and control for order size and arrival time spreads. Standard errors are clustered by stock and day. The results do not show a significant difference between marketable order IS in periods with and without limit orders, indicating that the mix of orders from more and less sophisticated traders, within marketable orders, is similar in the periods with and without limit orders.

Overall, our results are consistent with retail traders earning a compensation for bearing non-execution risk and for the cost of monitoring the market. The results also indicate that limit orders remain a feasible alternative for slower traders in the current market structure.

[25] We note that the directional prediction could also go in the opposite direction if sophistication is related to information with the expectation that informed traders incur larger costs of trading.

3.5. Retail limit order handling

While there is considerable attention paid in the literature to the handling of retail marketable orders, less is known about how limit orders are routed and executed.[26] We provide an analysis of the data as well as a discussion of the details surrounding limit order handling. Table 7, Panel A and Figure 3 present overall statistics on routing and execution of limit orders relative to marketable orders. The first set of bars in Figure 3 present the proportion of all submitted shares in our sample that are routed by brokers to market makers, separately for marketable and limit orders. Our sample is restricted to orders with market maker or exchange routes; hence, the remaining fraction (i.e., 100% minus the proportion routed to market makers) are routed directly by brokers to exchanges. Almost all (99.9%) of shares in marketable orders are routed by brokers to market makers. The proportion of limit orders is lower at 87%, implying that 13% are routed by brokers directly to exchanges. The second set of bars describes the proportion of executed shares – 99.9% of shares executed through marketable orders and 83% of shares executed through limit orders are executed at market makers.

The executions at market makers noted above include orders executed by market makers on a Principal or a Riskless Principal basis. Principal trades are ones where the market maker executes the trade as the counterparty taking the resulting traded shares into its own account. A Riskless Principal trade, in the retail equities context, occurs when a market maker executes an equivalent order with another market participant and upon execution of that order, executes the original order it received at the same price.[27] Market maker execution events are marked as Principal or Riskless Principal in the OATS data. We use these classifications in our analysis. The third set of bars in Figure 3 shows that of all marketable shares

[26] Battalio and Jennings (2023), Brown, Johnson, Kothari and So (2024), Dyhrberg, Shkilko and Werner (2023) and Ernst and Spatt (2022) examine price improvement offered to retail marketable orders by market makers. Schwarz, Barber, Huang, Jorion and Odean (2023), Huang, Jorion, Lee and Schwarz (2023) and Ernst, Malenko, Spatt and Sun (2024) focus on the broker monitoring of market maker price improvement.

[27] FINRA Notice to members 99-65 (https://www.finra.org/rules-guidance/notices/99-65) clarifies the use of Riskless Principal transactions. The guidance notes that, "Because Market Makers generally trade exclusively from a principal account, it is necessary to engage in two separate principal trades: one with the other market participant, and then another directly with the customer."

executed by market makers, approximately 90% are executed on a Principal basis (almost all of the remaining 10% execute as Riskless Principal). For retail limit orders executed by market makers, approximately 31% are executed with the market maker as Principal. The remaining executions occur mostly as Riskless Principal with 64% of shares executed on that basis.[28] Since 83% of shares in limit orders execute through market makers, these numbers imply that market makers execute as Principal approximately 26% of shares traded through limit orders by retail traders.[29] Thus, while market makers don't play as significant a role in executing limit orders as they do for marketable orders, they still execute as Principal a substantial proportion of limit orders.

We examine whether the proportion of limit order Principal executions varies by the aggressiveness of incoming limit orders. Table 7, Panel B, shows that Principal executions are more likely for within-quote (28.9% of shares for the average order) and at-the-quote orders (27.8%, on average) than for behind the quote orders (an average of 18.5% for orders within five times spread and 21.3% for orders further behind the quote). Given that fill rates and trading costs vary by order aggressiveness, we use a regression framework to examine whether the proportion of Principal execution for an order is associated with the order's IS.

Table 8 includes the regression results. This analysis is conducted within a sample of limit orders that receive an execution after being routed to a market maker. We note two shortcomings for this analysis. First, market makers can choose when to act as Principal and this endogeneity may manifest itself in a preference for easier trades (i.e., trades for which the cost of liquidity provision is lower). We try to account for the observable factors in our analysis. Second, as noted above, we are not able to attribute unfilled orders as Principal or Riskless Principal. If we assume that market makers have the choice of acting as Principal

[28] A small fraction of executed shares are handled on an agency basis by market makers. In our sample, agency trades are mostly restricted to limit orders contributing approximately 4% of all executed shares. For marketable orders, the corresponding proportion is 0.2%. Given the small magnitudes, we focus our attention on Principal and Riskless Principal executions in our analysis.

[29] We are unable to calculate similar statistics for order routes since our data only identify executions as Principal or Riskless Principal.

for orders they favor (for any reason), it is likely that orders routed out for a potential Riskless Principal execution would have lower fill rates and likely higher IS if opportunity costs are taken into account. In that scenario, we may be biasing the results towards Riskless Principal executions (the lower fill rate routes) since opportunity costs are underestimated for these routes. To the extent that fill rates and outcomes are related to order aggressiveness, we account for this possibility by comparing orders within aggressiveness categories. Specifically, we estimate the following model:

$$IS_i = \beta_1(\frac{P}{P+R})_i + \beta'\mathbf{X} + FE + \epsilon_i, \qquad (6)$$

where IS_i is the implementation shortfall for order *i*. The variable of interest, *P/(P+R)*, for an order *i* with an execution either on a Principal or a Riskless Principal basis, is the proportion of the execution that occurs with the market maker as Principal. **X** is a vector of control variables: log of order size, and the arrival percentage NBBO quoted spread. Since this model compares execution quality within limit orders only and outcomes are correlated with order aggressiveness, we use stock-day-aggressiveness fixed effects and stock-day-aggressiveness-buy/sell fixed effects to restrict the comparison within limit orders in the same aggressiveness category in the same stock on the same day. We find that limit orders with a higher proportion executed as Principal have lower IS. While the estimate is statistically significant, we note that the economic magnitude is small: going from 0% Principal execution to 100% Principal execution for an order is associated with a lower IS of approximately 0.8 basis points. This effect is smaller than the 9 to 10 basis point difference between the IS of marketable and limit orders documented in Table 3. We are unable to isolate the mechanism driving the difference. That is, market makers may improve IS by providing better execution, or market makers may choose easier orders. However, the analysis does allow two cautious statements: market makers acting as Principal does not appear to be associated with higher costs, and the market maker Principal versus Riskless Principal execution decision only makes a small difference to trading costs of limit orders.

4. Conclusion

We examine the handling and execution quality of retail limit orders, which, unlike retail marketable orders, have received little attention in the literature. We find that limit orders are a minority of orders placed by retail traders, but they form a significant proportion of retail orders accounting for 26% of orders and 30% of shares. We find that retail traders use limit orders across stock size categories. Retail limit orders span price aggressiveness categories, and, unlike the market-wide results in earlier literature, they concentrate behind the best quotes, with a substantial proportion far behind the best quotes. Retail traders typically do not have the same tools as faster traders who have better control of order placement and are typically associated with rapid placement and cancellation of limit orders. For example, a within or at-the-quote retail order may end up as marketable by the time it travels through the broker to the market center. Orders behind the quote may be a response to this speed disadvantage. We also find that retail limit orders are left open for long periods with an average order duration of more than 1,200 seconds. For the least aggressive orders, the average duration is longer than 3,000 seconds. We document that a majority of retail limit orders are likely to be routed to market makers. Of the executed shares in limit orders, market makers act as Principal for approximately 26% of them; and execute most of the remaining shares as Riskless Principal.

We examine the execution quality of retail limit orders. We find that these orders fill frequently with an average fill rate of 65%; even orders placed far behind the quotes fill 50% of their intended shares on average. These results indicate that slower traders who leave their orders open in the market experience fill rates that are reminiscent of those documented in Harris and Hasbrouck (1996) using data from 1990-91. We use implementation shortfall to evaluate execution quality because it accounts for the opportunity costs of unfilled orders, which can be important for limit orders. Since recent studies have found good execution outcomes for retail marketable orders, and because marketable orders are the obvious alternative to limit orders, we use retail marketable orders as the benchmark to assess retail limit order execution quality. We find robust results that retail limit orders have lower implementation shortfalls than marketable orders, even after controlling for stock, broker clientele effects, trade direction and time of submission,.

Overall, we find that limit orders are a reasonable option relative to marketable orders for retail traders who are willing to bear the extra frictions associated with placing and monitoring limit orders.

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Appendix

OATS Data Filters

We apply several filters to the OATS data:

- The unfiltered data consist of 46,818,433 order lifecycles.
- To ensure data quality, we remove top orders associated with (1) more than one trading day, (2) more than one top event (3) more than one stock, and (4) orders marked as merged from the sample. These filters result in 43,360,811 order lifecycles.
- We remove modified top orders from the sample as most modifications in our sample are associated with a relatively small number of top orders, potentially reflecting more sophisticated automated order submission strategies. This filter results in 40,793,186 order lifecycles.
- To ensure data quality, we remove order lifecycles that do not come to a logical end (i.e. cancellation or execution). This filter results in 38,563,008 order lifecycles.
- To ensure data quality, after a top order is routed to individual venues, we require that subsequent venue orders each be associated with one new order event. This filter results in 37,574,795 order lifecycles.
- After a top order is routed to individual venues, we require that subsequent venue orders also not be modified. This filter results in 34,331,412 order lifecycles.
- To facilitate attribution of order execution outcomes, we examine routed directly to a market maker, routed directly to an exchange, or initially routed to market maker, then subsequently routed by that market maker to an exchange. This filter results in 30,566,626 order lifecycles.
- To ensure data quality, we remove top orders with a fill rate greater than a 100%, absolute value of implementation shortfall be less or equal to 10%, and time-to-execution or time-to-route of less than negative 2 seconds. Of these orders, we examine simple marketable and non-marketable orders. We allow marketable orders to be marked as immediate-or-cancel (IOC). These filters result in 29,874,649 order lifecycles.
- To facilitate measurement of execution quality, we remove top orders routed to an execution venue outside of regular trading hours. This filter results in 27,267,191 order lifecycles.
- To ensure that the results are representative of typical retail investors, we exclude top orders of 5,000 shares or greater. This filter results in 27,144,948 order lifecycles.

Figure 1: Limit Order Usage This figure reports statistics on the relative usage of marketable (market and marketable limit) and non-marketable limit orders. We report the proportion of the number of top orders that are non-marketable limit orders, total share quantity associated with non-marketable limit orders, and total shares executed using non-marketable limit orders. We report non-marketable limit order statistics for the full sample and for the 100 stocks in each market capitalization tercile.

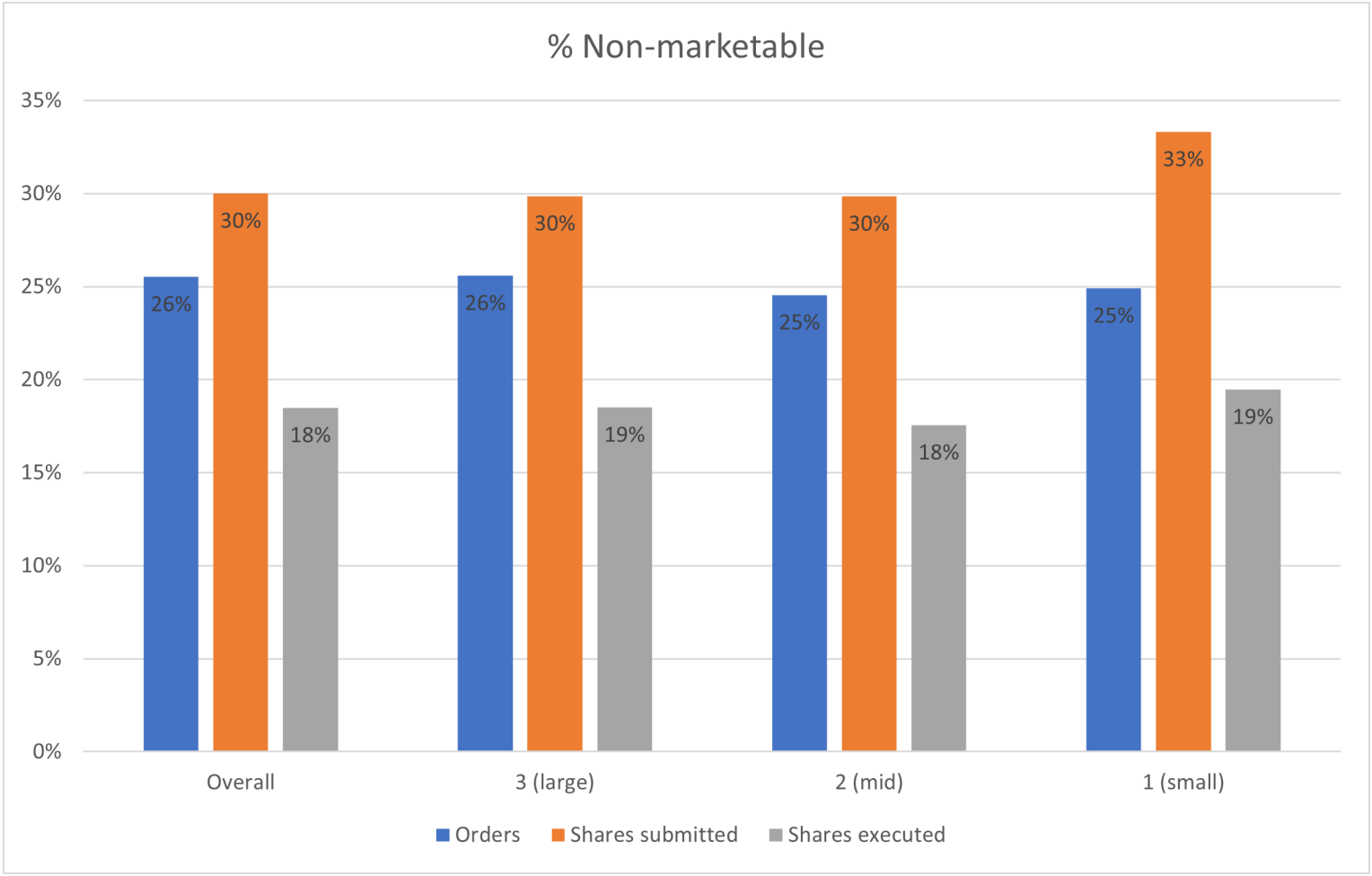


Figure 2: Limit Order Usage by Aggressiveness Level This figure reports the proportion of limit orders submitted in different aggressiveness categories. We report the proportions of the number of top orders submitted, total share quantity submitted, and total shares executed for each aggressiveness category. We separate nonmarketable limit orders into: orders with a limit price within the NBBO, at the passive NBBO side price (bid for buy orders, ask for sell orders), behind the passive quote by an amount less than or equal to 5 times the prevailing spread, and behind the passive quote by an amount greater than 5 times the prevailing spread.

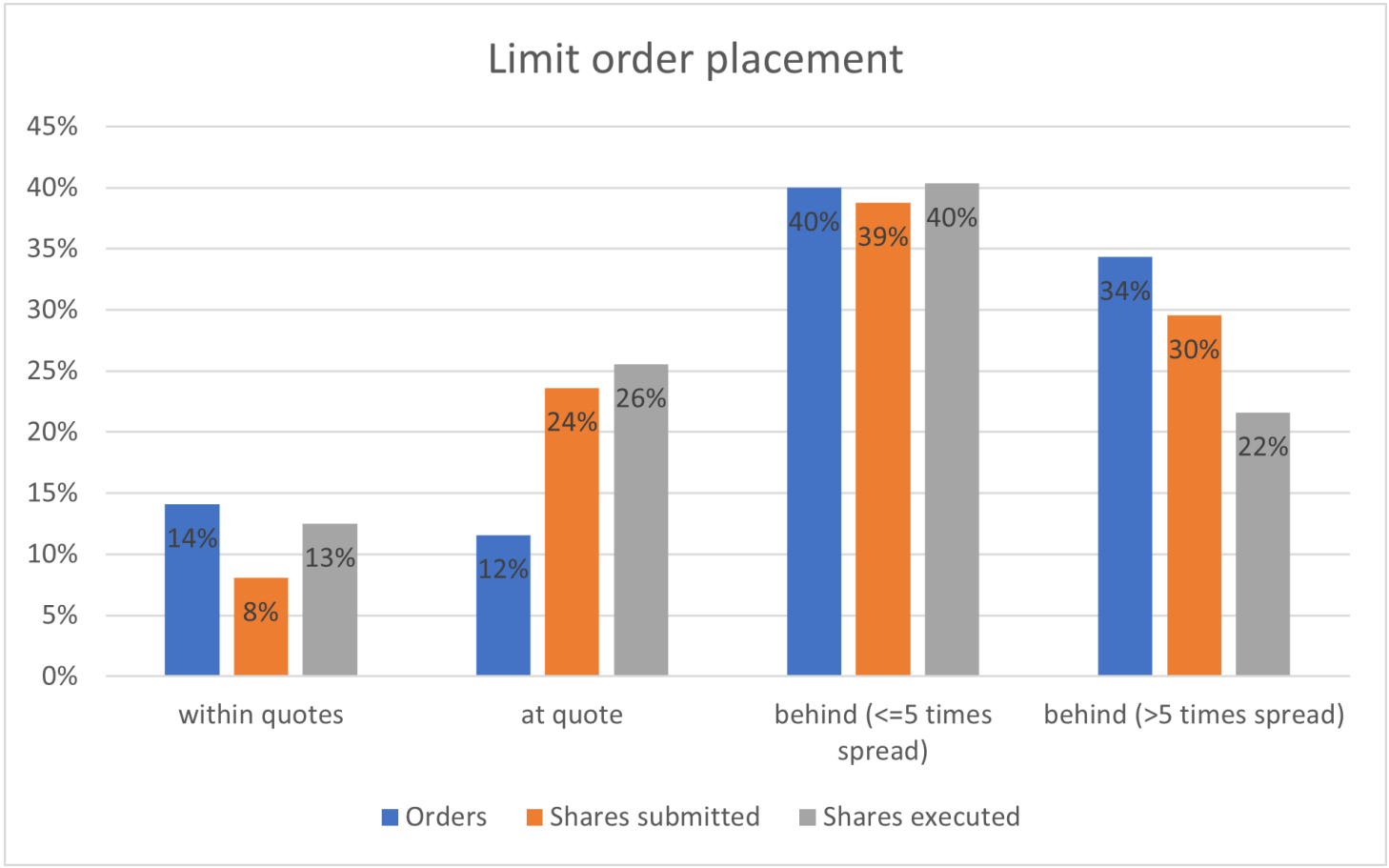


Figure 3: Retail Order Handling This figure reports statistics on retail order handling. The first group of bars reports the proportion of share quantity routed to market makers for marketable and limit orders. The second group of bars reports the proportion of shares executed at market makers for marketable and limit orders. The third group of bars reports the proportion of shares executed at market makers in a principal capacity for marketable and limit orders.

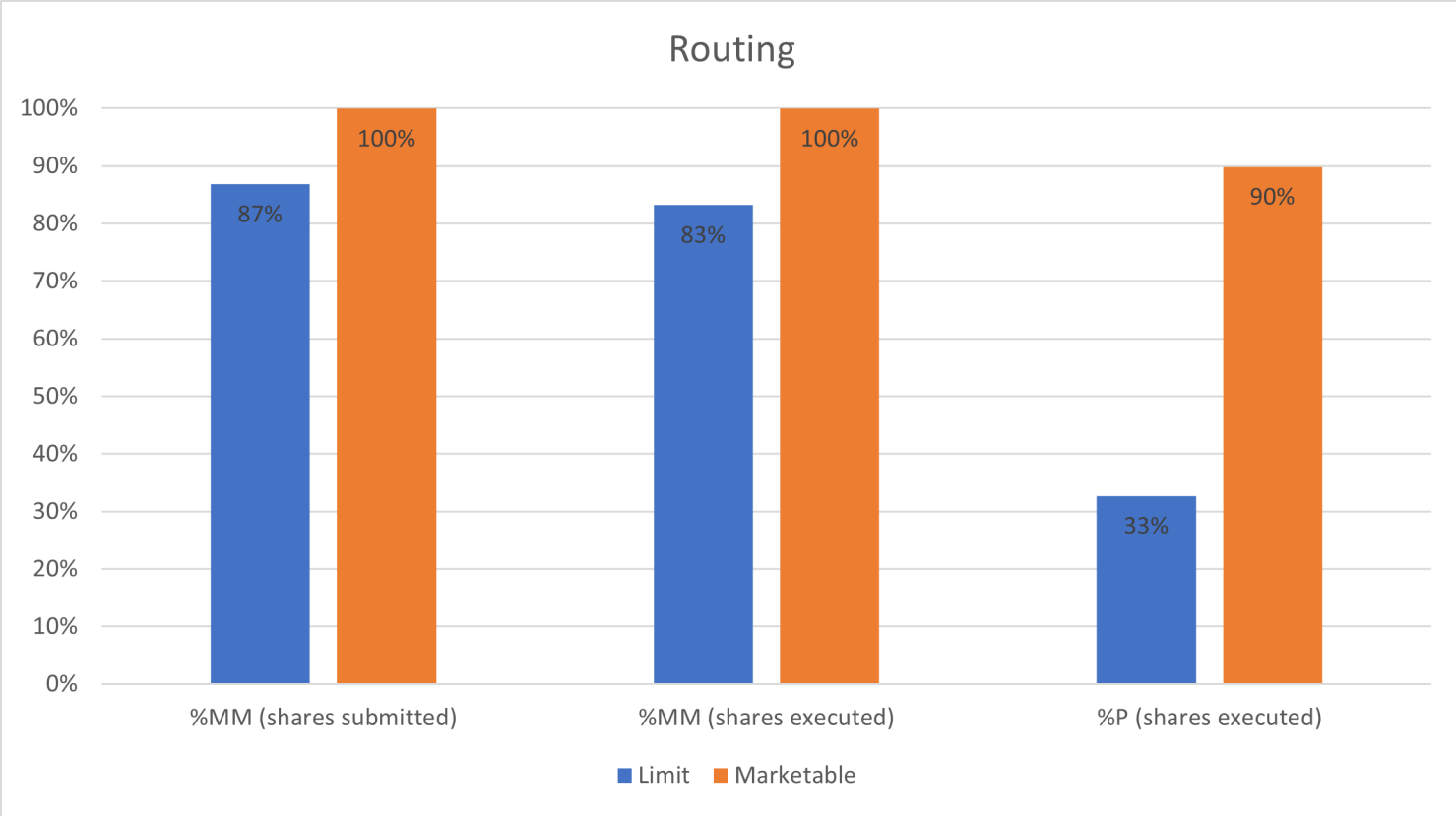


Table 1: Sample Description

This table reports statistics on the relative usage of marketable (market and marketable limit) and nonmarketable limit orders. For each order type, we report the total number of top orders, total share quantity, and total shares executed. We report order type statistics for the full sample in Panel A, statistics for the 100 stocks in each market capitalization tercile in Panel B, and statistics by order aggressiveness level in Panel C. We separate nonmarketable limit orders into: orders with a limit price within the NBBO, limit orders at the passive NBBO side price (bid for buy orders, ask for sell orders), limit orders with prices behind the passive quote by an amount less than or equal to 5 times the prevailing spread, and limit orders with prices behind the passive quote by an amount greater than 5 times the prevailing spread.

Panel A: Full Sample

Order type	**Number of orders**	**Total shares**	**Total shares traded**
Market(able)	20,218,075	2,931,860,473	2,922,445,070
Nonmarketable limit	6,926,873	1,256,853,825	662,648,369
%Nonmarketable	25.5%	30.0%	18.5%

Panel B: By Market Capitalization Tercile

Order type		**Number of orders**	**Total shares**	**Total shares traded**
Market cap. Tercile				
Large	Market(able)	18,778,755	2,632,549,563	2,626,099,743
Large	Nonmarketable limit	6,454,932	1,120,819,452	596,221,373
Medium	Market(able)	835,475	182,045,178	180,629,450
Medium	Nonmarketable limit	271,669	77,457,476	38,462,718
Small	Market(able)	603,845	117,265,732	115,715,877
Small	Nonmarketable limit	200,272	58,576,897	27,964,278

Panel C: By Order Aggressiveness Level

Order type		**Number of orders**	**Total shares**	**Total shares traded**
Aggressiveness				
Market(able)		20,218,075	2,931,860,473	2,922,445,070
Nonmarketable limit	within quotes	976,227	101,339,809	82,836,876
Nonmarketable limit	at quote	802,154	296,897,939	169,353,970
Nonmarketable limit	behind ($<= 5$ times spread)	2,770,413	487,273,434	267,338,309
Nonmarketable limit	behind (> 5 times spread)	2,378,079	371,342,643	143,119,214

Table 2: Execution outcomes, univariate statistics

This table reports statistics on the execution quality of marketable (market and marketable limit) and nonmarketable limit orders. For each order type, we report the average volume-weighted time to execution (in seconds), order duration (in seconds), fill rate (the ratio of executed quantity to top order quantity), Effective spread (the percentage difference between the order's volume weighted average execution price and the NBBO midpoint at the time of order arrival at the broker), and implementation shortfall (using the opposite NBBO quote price: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). We report execution quality statistics for the full sample in Panel A, statistics by market capitalization tercile in Panel B, and statistics by order aggressiveness level in Panel C. We separate nonmarketable limit orders into: orders with a limit price within the NBBO, limit orders at the passive NBBO side price (ask for buy orders, bid for sell orders), limit orders with prices behind the passive quote by an amount less than or equal to 5 times the prevailing spread, and limit orders with prices behind the passive quote by an amount greater than 5 times the prevailing spread.

Panel A: Full Sample

Order type	Time to execution (seconds)	Order duration (seconds)	Fill rate	Eff. Spreads	Implementation shortfall
Market(able)	3	6	99.8%	0.0104%	0.0107%
Nonmarketable limit	951	1,254	65.0%	-0.2015%	-0.0804%

Panel B: By Market Capitalization Tercile

Order type		Time to execution (seconds)	Order duration (seconds)	Fill rate	Eff. Spreads	Implementation shortfall
Market cap. Tercile						
Large	Market(able)	3	6	99.8%	0.0074%	0.0075%
Large	Nonmarketable limit	945	1,235	65.2%	-0.1845%	-0.0760%
Medium	Market(able)	4	8	99.8%	0.0343%	0.0356%
Medium	Nonmarketable limit	1,070	1,485	65.2%	-0.3893%	-0.1463%
Small	Market(able)	4	9	99.7%	0.0700%	0.0759%
Small	Nonmarketable limit	1,020	1,567	60.2%	-0.5184%	-0.1322%

Panel C: By Order Aggressiveness Level

Order type		Time to execution (seconds)	Order duration (seconds)	Fill rate	Eff. Spreads	Implementation shortfall
Aggressiveness						
Market(able)		3	6	99.8%	0.0104%	0.0107%
Nonmarketable limit	within quotes	30	40	83.0%	-0.0049%	0.0169%
Nonmarketable limit	at quote	95	106	76.2%	-0.0319%	0.0059%
Nonmarketable limit	behind ($<= 5$ times spread)	485	506	68.4%	-0.1289%	-0.0373%
Nonmarketable limit	behind (> 5 times spread)	2,784	3,012	49.9%	-0.5424%	-0.1996%

Table 3: Execution Outcomes, Regression Analysis

This table reports results for regressions comparing implementation shortfalls of marketable and limit orders. The outcome variable is implementation shortfall (using the opposite NBBO quote price at the end of the order: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Explanatory variables include Marketable, an indicator variable equal to one for marketable (market and marketable limit) orders and equal to zero for limit orders; natural log of the order size in shares; and the NBBO percentage spread at the time of order arrival. Standard errors clustered by stock and day are presented in parentheses. Panel A reports results for the full sample while Panel B reports results for medium and small tercile stocks.

Panel A: All Stocks

	Dependent variable:					
	Implementation Shortfall (bp)					
	(1)	(2)	(3)	(4)	(5)	(6)
Market(able)	9.2946***	9.4298***	10.7026***	10.7811***	10.4282***	8.8502***
	(0.9927)	(1.0156)	(1.0694)	(1.0838)	(1.0470)	(0.9699)
Log Order Size		0.2836***		0.2978***	0.2687***	0.2491***
		(0.0585)		(0.0537)	(0.0347)	(0.0374)
Arrival Spread (bp)		0.2516***		0.2478***	0.2348***	0.2847***
		(0.0178)		(0.0179)	(0.0187)	(0.0178)
Stock-Day FE	Y	Y	Y	Y	N	N
Broker FE	N	N	Y	Y	N	N
Stock-Day-Side FE	N	N	N	N	Y	N
Stock-5min-Side FE	N	N	N	N	N	Y
Observations	27,144,948	27,144,948	27,144,948	27,144,948	27,144,948	27,144,948
Adjusted R^2	0.0320	0.0336	0.0402	0.0417	0.0532	0.0982

*p<0.1; **p<0.05; ***p<0.01

Panel B: Medium and Small Stocks

	Dependent variable:			
	Implementation Shortfall (bp)			
	(1)	(2)	(3)	(4)
Market(able)	19.6977***	20.4216***	21.4376***	22.0908***
	(1.4469)	(1.4615)	(1.4530)	(1.4568)
Log Order Size		0.6435***		0.9734***
		(0.0780)		(0.1009)
Arrival Spread (bp)		0.2886***		0.2807***
		(0.0153)		(0.0152)
Stock-Day FE	Y	Y	Y	Y
Broker FE	N	N	Y	Y
Observations	1,911,261	1,911,261	1,911,261	1,911,261
Adjusted R^2	0.0423	0.0481	0.0512	0.0574

*p<0.1; **p<0.05; ***p<0.01

Table 4: Execution Outcomes by Aggressiveness Level

This table reports results for regressions examining execution quality of marketable and limit orders. The outcome variable is implementation shortfall (using the opposite NBBO quote price at the end of the order: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Explanatory variables include Marketable, an indicator variable equal to one for marketable (market and marketable limit) orders and equal to zero for limit orders; natural log of the order size in shares; and the NBBO percentage spread at the time of order arrival. Standard errors clustered by stock and day are presented in parentheses. Results are reported for regressions comparing marketable and nonmarketable limit orders: with limit prices inside of the NBBO ((1) and (2)), limit prices at the passive quote (bid for buy orders, ask for sells) ((3) and (4)), limit prices behind the passive quote by an amount less than or equal to 5 times the prevailing spread ((5) and (6)) and limit prices behind the passive quote by an amount greater than 5 times the prevailing spread ((7) and (8)).

	Dependent variable:			
	Implementation Shortfall (bp)			
	(1)	(2)	(3)	(4)
Market(able)	0.0779	0.3340***	0.9769**	0.9579**
	(0.0741)	(0.0708)	(0.3614)	(0.3780)
Log Order Size		0.0703***		0.0724***
		(0.0096)		(0.0114)
Arrival Spread (bp)		0.3678***		0.4012***
		(0.0123)		(0.0129)
Subsample	Inside Quote Limit	Inside Quote Limit	At-Quote Limit	At-Quote Limit
Stock-Day FE	Y	Y	Y	Y
Broker FE	Y	Y	Y	Y
Observations	21,194,302	21,194,302	21,020,229	21,020,229
Adjusted R^2	0.1075	0.1540	0.0957	0.1424

*p<0.1; **p<0.05; ***p<0.01

	Dependent variable:			
	Implementation Shortfall (bp)			
	(5)	(6)	(7)	(8)
Market(able)	5.2911***	5.3587***	21.9503***	21.9197***
	(0.8458)	(0.8550)	(2.4651)	(2.4660)
Log Order Size		0.1157***		0.2147***
		(0.0155)		(0.0479)
Arrival Spread (bp)		0.2466***		0.3740***
		(0.0173)		(0.0198)
Subsample	$<= 5\times$ Spread	$<= 5\times$ Spread	$> 5\times$ Spread	$> 5\times$ Spread
Stock-Day FE	Y	Y	Y	Y
Broker FE	Y	Y	Y	Y
Observations	22,988,488	22,988,488	22,596,154	22,596,154
Adjusted R^2	0.0377	0.0425	0.0778	0.0799

*p<0.1; **p<0.05; ***p<0.01

Table 5: Execution Outcomes: Interaction Effects

This table reports results for regressions examining interaction effects when comparing implementation shortfalls of marketable and limit orders. The outcome variable is implementation shortfall (using the opposite NBBO quote price at the end of the order: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Explanatory variables include Marketable, an indicator variable equal to one for marketable (market and marketable limit) orders and equal to zero for limit orders; natural log of the order size in shares; the NBBO percentage spread at the time of order arrival; Sell, an indicator variable equal to one for sell orders and equal to zero for buy orders; and RV, the daily sum of five-minute squared stock returns. Standard errors clustered by stock and day are presented in parentheses.

	Dependent variable:		
	Implementation Shortfall (bp)		
	(1)	(2)	(3)
Market(able)	10.2541***	7.9621***	8.6049***
	(2.0928)	(0.9078)	(0.9482)
Log Order Size	0.2759***	0.2992***	0.2884***
	(0.0421)	(0.0606)	(0.0581)
Arrival Spread (bp)	0.2519***	−0.0614	0.2552***
	(0.0177)	(0.0483)	(0.0174)
Sell	1.8570		
	(3.0885)		
Market(able) × Sell	−2.0690		
	(3.1222)		
Market(able) × Arrival Spread (bp)		0.5054***	
		(0.0596)	
Market(able) × Volatility			0.0648**
			(0.0227)
Stock-Day FE	Y	Y	Y
Observations	27,144,948	27,144,948	27,144,948
Adjusted R^2	0.0339	0.0360	0.0346

*p<0.1; **p<0.05; ***p<0.01

Table 6: 5-min Intervals With and Without Retail Limit Orders

This table reports results for regressions comparing the execution quality of retail marketable orders submitted during 5-minute periods with submitted nonmarketable limit orders and retail marketable orders submitting during 5-minute periods without submitted nonmarketable limit orders. The outcome variable is implementation shortfall (shortfall using the opposing NBBO quote price at the end of the order: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Explanatory variables include an indicator variable equal to one for marketable orders during 5-minute intervals without submitted nonmarketable limit orders and equal to zero otherwise; natural log of the order size in shares; and the NBBO spread at the time of order arrival. Standard errors clustered by stock and day are presented in parentheses.

	Dependent variable:	
	Implementation Shortfall (bp)	
	(1)	(2)
Market(able) Order In 5-min Interval	−0.0198	−0.0255
	(0.0243)	(0.0234)
Log Order Size	−0.0307***	0.0614***
	(0.0053)	(0.0092)
Arrival Spread (bp)	0.4157***	0.4142***
	(0.0131)	(0.0130)
Stock-Day FE	Y	Y
Broker FE	N	Y
Observations	20,218,075	20,218,075
Adjusted R^2	0.1753	0.1842

*p<0.1; **p<0.05; ***p<0.01

Table 7: Retail Order Handling

This table reports statistics on how retail orders are routed and executed. Panel A reports venue choice statistics for marketable (market and marketable limit), and limit orders routed directly by brokers to exchanges and market makers. We report the average top order share quantity size, the total submitted top order share quantity, the average top order share execution size, the total executed share quantity, total executed share quantity by market makers in a principal capacity, and the total executed share quantity by market makers in a riskless principal capacity. Execution quality statistics include average fill rate (the ratio of executed quantity to top order quantity), effective spread (the percentage difference between the order's volume weighted average execution price and the NBBO midpoint at the time of order arrival at the broker), and implementation shortfall (using the opposite NBBO quote price: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Panel B reports statistics for non-marketable limit orders by aggressiveness. We separate nonmarketable limit orders into: orders with a limit price within the NBBO, at the passive NBBO side price (ask for buy orders, bid for sell orders), behind the passive quote by an amount less than or equal to 5 times the prevailing spread, and behind the passive quote by an amount greater than 5 times the prevailing spread.

Panel A: Venue Choice for Retail Orders

Market/limit	Venue Choice	N	Average top quantity	Total top quantity	Average executed quantity	Total executed quantity	Total executed quantity (P)	Total executed quantity (R)	Imp. Shortfall	Effective spread	Fill rate
Limit	Exchange	758,543	218.70	165,896,613	146.94	111,460,288	-	-	-0.096%	-0.246%	70.3%
Limit	Market Maker	6,168,330	176.86	1,090,957,212	89.36	551,188,081	172,403,384	354,798,891	-0.078%	-0.196%	64.4%
Market(able)	Exchange	34,309	67.95	2,331,434	67.21	2,305,851	-	-	0.017%	0.016%	99.9%
Market(able)	Market Maker	20,183,766	145.14	2,929,529,039	144.68	2,920,139,219	2,618,177,586	296,082,193	0.011%	0.010%	99.8%

Panel B: Venue Choice for Retail Limit Orders by Aggressiveness

Routed to	Order aggressiveness	N	Average top quantity	Total top quantity	Average executed quantity	Total executed quantity	Avg Ex Qty (P)	Total executed quantity (P)	Avg Ex Qty (R)	Total executed quantity (R)	Imp. Shortfall	Effective spread	Fill rate	P/(P+R)
Exchange	within quotes	88,711	124.04	11,003,993	108.41	9,617,240	-	-	-	-	0.013%	-0.007%	91.6%	
Exchange	at quote	61,243	390.62	23,922,774	303.73	18,601,598	-	-	-	-	-0.003%	-0.030%	88.3%	
Exchange	behind (<= 5 times spread)	276,413	219.94	60,793,852	167.36	46,260,655	-	-	-	-	-0.048%	-0.129%	79.1%	
Exchange	behind (> 5 times spread)	332,176	211.26	70,175,994	111.33	36,980,795	-	-	-	-	-0.183%	-0.562%	54.1%	
Market Maker	within quotes	887,516	101.78	90,335,816	82.50	73,219,636	29.42	26,108,661	52.22	46,347,075	0.017%	-0.005%	82.2%	36.0%
Market Maker	at quote	740,911	368.43	272,975,165	203.47	150,752,372	82.44	61,081,753	120.13	89,002,323	0.007%	-0.032%	75.2%	40.7%
Market Maker	behind (<= 5 times spread)	2,494,000	171.00	426,479,582	88.64	221,077,654	24.31	60,632,909	61.19	152,616,436	-0.036%	-0.129%	67.2%	28.4%
Market Maker	behind (> 5 times spread)	2,045,903	147.20	301,166,649	51.88	106,138,419	12.01	24,580,061	32.67	66,833,057	-0.202%	-0.539%	49.2%	26.9%

Table 8: Execution Quality, Principal, and Riskless Principal Executions

This table reports results for regressions comparing the implementation shortfall of retail non-marketable orders executed by market makers on principal or riskless principal basis. The outcome variable is implementation shortfall (using the opposite NBBO quote price at the end of the order: ask for buy orders, bid for sell orders as the fill price for the unexecuted portion of the order). Explanatory variables include the proportion of an executed order that is executed on a principal basis $(P/(P+R))$; natural log of the order size in shares; and the NBBO spread at the time of order arrival. Standard errors clustered by stock and day are presented in parentheses.

	Dependent variable:			
	Implementation Shortfall (bp)			
	(1)	(2)	(3)	(4)
$\frac{P}{P+R}$	-0.6636^{***}	-0.3472^{**}	-0.7106^{***}	-0.3972^{**}
	(0.1862)	(0.1597)	(0.1796)	(0.1535)
Log Order Size	0.2248^{***}	0.2926^{***}	0.1861^{***}	0.2635^{***}
	(0.0515)	(0.0435)	(0.0451)	(0.0364)
Arrival Spread (bp)	-1.0426^{***}	-1.0398^{***}	-1.0887^{***}	-1.0858^{***}
	(0.1030)	(0.1023)	(0.1082)	(0.1076)
Stock-Day-Agg FE	Y	Y	N	N
Stock-Day-Agg-Side FE	N	N	Y	Y
Broker FE	N	Y	N	Y
Observations	3,698,820	3,698,820	3,698,820	3,698,820
Adjusted R^2	0.5765	0.5782	0.5866	0.5881

*p<0.1; **p<0.05; ***p<0.01