

Why do Brokers who do not Charge Payment for Order Flow Route Marketable Orders to Wholesalers?

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Abstract: We present evidence that in May 2022 several retail brokers who do not charge wholesalers for their marketable orders routed most of their marketable orders to wholesalers for order handling and execution. Using proprietary marketable order flow data from one or more wholesaler(s) for May 2022, we evaluate several dimensions of wholesaler execution quality. As measured by reporting rules established by the Securities and Exchange Commission, we find that the wholesaler(s) provided about \$78 million of savings to investors for the month. This swells to over \$388 million including odd lot and short sell orders and the execution of large orders at better prices than an investor would have received if the wholesaler(s) simply executed these orders at order-receipt-time depth-of-book displayed prices aggregated across all exchanges. To better understand why brokers route orders to wholesalers, we conclude by conducting a “near-neighbor” analysis between executions on exchanges and “equivalent” marketable orders routed to the data provider(s). Ignoring access fees on exchanges, we find that seemingly identical trades received better prices from the wholesaler(s) in over 68% of the comparisons and equivalent prices in another 19% of the comparisons. When exchange fees are included, the wholesaler(s) win almost 91% of the time. We believe that this difference in execution quality supports retail brokers routing most of their marketable orders to competing wholesalers.

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In a cease-and-desist order issued in December 2020, the United States Securities and Exchange Commission (SEC) writes that “rather than sending customer orders to buy or sell equity securities directly to national exchanges, Robinhood, like other retail broker-dealers, routed its orders to other broker-dealers (often referred to as ‘principal trading firms’ or ‘electronic market makers’) to either execute those orders or route them to other market centers.”¹ The SEC notes that these principal trading firms, commonly referred to as wholesalers, “offer incentives to retail broker-dealers to send them order flow.” According to the cease-and-desist order, at least one wholesaler told Robinhood that “there was a trade-off between payment for order flow on the one hand and price improvement on the other” and that if Robinhood negotiated higher payment for order flow revenue there would be less money available for the wholesalers to provide price improvement to Robinhood’s customers.² More recently, in a June 2022 speech, SEC Chairman Gary Gensler stated that “payment for order flow can raise real issues around conflicts of interest” and that he had instructed his staff “to make recommendations for the Commission’s consideration around how to enhance order-by-order competition.” Together, these passages suggest that brokers would not route order flow to wholesalers if they could not charge wholesalers for their orders. In this paper we present strong evidence that this claim is demonstrably false.

The SEC’s Rules 605 and 606³ require brokers to make publicly available quarterly reports that contain specific information as to the brokers’ routing of held, non-directed orders including

¹ See SEC Administrative Proceeding File NO. 3-20171 in the matter of Robinhood Financial, LLC., respondent. “Order instituting administrative and cease-and-desist proceedings pursuant to Section 8A of the Securities Act of 1933 and Section 15(b) of the Securities Exchange Act of 1934, making findings, and imposing remedial sanctions and a cease-and-desist order.”

² In its cease-and-desist order, the SEC notes that “Robinhood explicitly offered to accept less price improvement for its customers than what the principal trading firms were offering, in exchange for receiving a higher rate of payment for order flow for itself.”

³ Rule 606 reports are published by routing brokers and specify the percent of orders routed to each venue or market center and the details of any economic relationships (including PFOF). These reports are aggregated by S&P500 securities and non-S&P 500 securities. Rule 605 reports are published by venues or market centers (including

a breakdown of the venues to which the broker routes orders by order type and size, various execution quality statistics, and a discussion of the material aspects of the broker's relationship with the destination entity (including payment for order flow).⁴ Using information in these reports, we identify six brokers who do not charge payments for their marketable orders in S&P500 stocks in May 2022: Fidelity, Vanguard Brokerage, Open to the Public Investing, UBS, Citigroup, and Wells Fargo.⁵ In May, Fidelity routed 99.99% of its market orders and 92.98% of its marketable limit orders to five wholesalers and Vanguard routed 100% of its market and marketable limit orders to four wholesalers.⁶ Thus, based on our data, it appears that routing to wholesalers need not be driven by a monetary inducement. In this paper, we present evidence that provides strong support for the decision of retail brokers to route their marketable orders to wholesalers independent of receiving payment to do so.⁷

The Financial Industry Regulatory Authority's (FINRA) rules state that when reviewing and comparing the execution quality of their current order routing and execution arrangements to the execution quality of other markets, brokers should consider the following factors: the frequency with which orders trade at better and/or worse prices than the National Best Bid or Offer

wholesalers) and include execution quality statistics that are detailed by security, order type, size, time, and execution quality statistics.

⁴ A held order is an order that brokers must fill immediately subject to the order's limit price, if it has one. An order is non-directed if the investor does not instruct the broker to send the order to a specific trading venue. Thus, brokers have discretion as to where to route non-directed customer orders. The Financial Industry Regulatory Authority's Rule 5310 requires members to execute market and marketable limit orders fully and promptly.

⁵ Interactive Brokers provides two options for accounts, one accepting payment for order flow and one that does not. Because they file but a single Rule 606 report, which we use to study order routing, we exclude them from our list of brokers not charging wholesalers to access their order flow.

⁶ Interestingly, in May 2022 Robinhood routes 83.10% of its market orders in S&P500 securities to Citadel Securities, Virtu Financial, and G1 Execution Services while Vanguard Brokerage routes 80.28% of its market orders in S&P securities to these three wholesalers. We tabulate the order routing decisions of brokers who do not (do) charge payment for order flow in Appendix Table A1 (A2).

⁷ Brokers typically route non-marketable limit orders to be displayed at exchanges, frequently at exchanges that offer liquidity making rebates. Battalio et al (2016) investigates these routing decisions and the execution quality these orders receive.

(NBBO), the likelihood of execution of limit orders, the speed of execution, the size of execution, transaction costs, customer needs and expectations, and the existence of internalization or payment for order flow arrangements.⁸ Fidelity, one of the brokers that does not charge payment for marketable orders, writes on its website that execution quality is defined by four metrics: price improvement (i.e., executing orders at better-than-quoted prices), the percentage of shares executed at or within the NBBO, execution speed, and the effective spread (i.e., execution price compared to the midpoint of the order receipt time NBBO).⁹ Schwab, a broker that charges order flow payments, explains on its website that because “no one sole metric defines execution quality,” it reviews a number of factors when evaluating its order routing decisions. These factors include execution price, speed and accuracy, liquidity, automatic execution guarantees, opportunities for price improvement, service levels, and the cost of executing orders.¹⁰

Both Fidelity (no payment for order flow) and Schwab (payment for order flow) publish execution quality statistics on their websites for their customer orders.¹¹ These data indicate that Fidelity (Schwab) executed 99.15% (99.1%) of its marketable orders seeking to trade between 100 and 499 shares of S&P500 stocks in the second quarter of 2022 within the NBBO.¹² Fidelity (Schwab) reports that 88.30% (95.8%) of the marketable orders in this order size bucket received price improvement and the average execution speed for these orders was 0.239 (0.05) seconds. Consistent with Schwarz et al. (2022), these statistics suggest that, in the second quarter of 2022, payment for order flow might not explain differences in execution quality. In this paper, we use a

⁸ See FINRA rule 5310.

⁹ https://clearingcustody.fidelity.com/app/item/RD_13569_21687/trade-execution-quality-overview.html.

¹⁰ <https://www.schwab.com/execution-quality>.

¹¹ See <https://www.investopedia.com/online-broker-battlefield-shifts-from-costs-to-execution-quality-4774026>.

¹² According to the Rule 606 reports filed for the second quarter of 2021, Fidelity routed 99.99% of its market orders in S&P500 stocks to six wholesalers and Schwab routed 99.97% of its market orders in S&P500 stocks to five wholesalers.

dataset containing all of the marketable retail orders sent to one or more wholesaler(s)¹³ during May 2022 to characterize execution quality on multiple dimensions, including executing outsized orders at better prices than those provided by an aggregate view of all displayed round and odd lot and depth of book quotes across all exchanges, offering price improvement for odd lots and short sell orders (excluded from Rule 605 statistics), and providing customers with better prices than the wholesaler(s) receives when routing orders to an external venue.¹⁴ Assuming the market for order flow is competitive and that brokers conduct regular and rigorous reviews of their order routing to optimize customer execution quality, our results are indicative of the execution quality received by brokers that utilize wholesalers.

We begin by documenting the execution quality the data-providing wholesaler(s) gives client marketable orders in May 2022. Orders that fill completely with the wholesaler(s) from wholesaler(s) inventory (i.e., fully internalized orders) receive an average of \$0.0085 per share of price improvement, which demonstrates that the wholesaler(s)' betterment of the quoted price is more than de minimis. In fact, almost 46% of fully internalized trades occur at the order-receipt-time quoted spread mid-point price or better. Although odd lot and short sell orders are not covered in the Rule 605 reports, we find that these orders frequently receive price improvement. This adds about 17% to the officially reported price improvement dollar value provided (even after adjusting the national best quotes to include displayed round and odd lot limit orders). Finally, we find that the wholesaler(s) receives and executes many orders for shares in excess of the quoted size – in

¹³ For literary convenience and brevity, we refer to “one or more wholesale(s)” with simply wholesaler(s) in the remainder of the paper when referring the data providing wholesaler(s).

¹⁴ Perhaps the biggest dimension of execution quality not captured in our analysis is the ability to adjust trade prices to accommodate client requests. Although it is easy (and costly) for a wholesaler to adjust a trade price for a client, it is extremely difficult to adjust exchange trade prices as the exchange is not the counter-party. In addition, exchanges have limited liability in the event of operational failures that broker-dealers (e.g., wholesalers) are not granted implying that routing to exchanges might leave brokers exposed to losses in the event of customer harm by exchange operational glitches.

the sample month, over 52% of the total shares traded by the wholesaler(s) are from orders with a size exceeding the quoted size. The wholesaler(s) frequently fills these “oversized” orders at better prices than the order would have received had they simply been executed at prices consistent with an aggregate view of all displayed odd lot and top of and depth of book quotes from all exchanges. The estimated value of this “size improvement”, which is not recognized by Rule 605 reports, more than doubles the dollar amount of price improvement provided by the wholesaler(s) for internalized orders. Of the total shares in orders with a size exceeding the National Best Bid or Offer (NBBO) quoted size, the wholesaler(s) executes over 80% inside the NBBO. The fact that we find executions at prices better than the NBBO for odd lots, short sell orders, orders exceeding the quoted size suggests that brokers do not allow wholesalers to focus best execution efforts on only orders covered by SEC Rule 605.

We also formally examine the execution quality of orders that the wholesaler(s) fills completely with liquidity sourced from external venues such as exchanges, Alternative Trading Systems (ATSs), and other sources when not internalizing, i.e., fully externalized orders. A wholesaler(s) might choose to externalize an order due to internal conditions such as position limits and risk appetite, regulatory considerations, or when the wholesaler(s) assesses that the external venue offers an attractive liquidity-sourcing opportunity. These orders receive \$0.0013 per share price improvement on average. However, the proprietary data show that wholesaler(s) provides a service that is not widely recognized: they frequently adjust the execution prices on externalized trades to provide better prices to the customer than the wholesaler(s) obtains directly from external venues when routing an order away (i.e. wholesalers give buyers lower prices and sellers higher prices than the wholesalers actually receives on the away venues). In May 2022, this service (designated supplemental price improvement in this paper) provides \$0.0016 per share price

improvement, on average. The fact that the supplemental price improvement dollar amount exceeds the Rule 605 price improvement dollar amount implies that the away executions (externalized orders) would have received price disimprovement (i.e., trading prices are worse than the order-receipt-time quoted price) on average without the wholesalers(s)'s intervention.

In order to provide a more broad-based analysis of execution quality by wholesalers as a group compared to exchanges, we next gather Rule 605 reports for our sample month of May 2022 from six wholesalers' websites and compare their marketable order execution quality statistics to two exchanges that are popular for sourcing external liquidity – Nasdaq and NYSE Arca. In our formal analyses, we ignore the access fee (\$0.003 per share) that these two exchanges charge for liquidity demanding orders. For market orders, the six wholesalers, on average, beat Nasdaq's (NYSE Arca's) price improvement rate in more than 75% (90%) of S&P 500 stocks during the sample month. The wholesalers' price improvement rate advantage increases with order size. Similarly, the wholesalers provide a better average effective spread relative to Nasdaq (NYSE Arca) for more than 75% (95%) of sample stocks. The differences in execution quality for marketable limit orders are a bit less dramatic. Wholesaler price improvement rates, on average, are higher for 95% of the S&P 500 stocks during the sample month for small order sizes but fall somewhat as order size increases (to 75% versus Nasdaq and to 90% versus NYSE Arca). Somewhat surprisingly, wholesalers do not consistently win the majority of the gross effective spread comparisons despite higher price improvement rates and typically lower price disimprovement rates suggesting that market conditions might not be held constant in the Rule 605 reports. To partially address this "all else equal issue", we normalize the effective spread by the quoted spread at order receipt time – producing a statistic that is analogous to what the industry calls the EQ measure. Because, on average, wholesalers receive marketable orders when a stock's

quoted spread is wider than when exchanges receive such orders, the wholesalers' effective-spread-to-quoted-spread ratio (ES/QS) is consistently better than the exchanges' ratio for market orders. Wholesalers win 90% (95%) of the individual stock ES/QS comparisons for Nasdaq (Arca). For marketable limit orders, the competition is a bit more balanced but the wholesalers win 95% of the stock-by-stock ES/QS comparisons for small order sizes and a majority of comparisons for the large order sizes. Since quoted spread is not likely to hold everything else constant, we return to our proprietary data for a more controlled study.

Specifically, our final analysis with the proprietary data is to construct "near-neighbor comparisons" (NNCs) pitting orders routed to the wholesaler(s) with "equivalent" orders submitted to the two sample exchanges by someone other than the wholesaler(s). We select exchange trades for these comparisons with an exact match on stock, order side, and quoted spread, require that the exchange trade be no larger than the wholesalers(s)'s trade, and require that the wholesaler(s) order arrival time and exchange trade time differ by no more than five seconds with the stipulation that the NBBO be identical. We judge the winner of the near-neighbor comparison to be the venue with the lowest effective spread for the trade. Under these circumstances, the wholesaler(s) wins more than 68% of the comparisons and the exchanges win less than 13% (in the remainder of the NNCs the effective spreads are identical) prior to considering exchange access fees. With access fees considered, the data-providing wholesaler(s) wins almost 91% of the NNCs.

Employing a logit analysis to explain NNC outcomes we determine that order characteristics and market conditions appear to influence when wholesaler(s) win or lose a paired comparison. In the with-fee comparisons, the wholesaler(s) are more likely to win when market conditions are such that the exchange trade involves hidden liquidity provision and for buy orders.

From these analyses, we conclude that wholesalers provide a valuable service to their clients in fulfilling their best execution requirements and, when measured by Rule 605 reports or placed in a controlled competition with two popular exchanges, furnish clients with an advantage over the execution quality provided by the sample exchanges. Thus, we conclude that retail brokers route orders to wholesalers even when they do not choose to charge wholesalers to interact with their marketable order flow because of the superior execution quality provided to these orders, which is commercially advantageous to retail brokers and is consistent with a retail brokers best execution obligations.

Following a literature review in the next section of the paper, we describe our proprietary data and produce some descriptive statistics regarding the value of the execution services offered by the wholesaler(s) in May 2022. We then compare the execution quality of wholesalers as a group to two sample exchanges via Rule 605 reports. In the following section, we describe the NNC methodology and describe the results. Finally, we conclude.

Section II. Literature Review

There is a long literature examining the relative execution quality provided by wholesalers and exchanges. Among the earliest articles published on this topic are Lee (1993) and Petersen and Fialkowski (1994), both of which examine data generated years before Regulation NMS, which currently governs trading in U.S. equity markets.¹⁵ Each of these papers uses execution price as the sole metric of execution quality. Utilizing publicly available trade and quote data, Lee finds that trades executed on the New York Stock Exchange (NYSE) receive more favorable prices than comparable trades executed by wholesalers on Nasdaq. Lee writes that “in light of these price

¹⁵ Each of these papers cite a working paper by Blume and Goldstein titled, “Differences in execution prices among the NYSE, the regionals and the NASD,” which examines this issue and finds similar results. Lee cites the 1991 working paper and Peterson et al. cite the 1992 working paper.

differences, the broker's primary responsibility could be compromised by order flow inducements" (see page 1034). Peterson and Fialkowski obtain proprietary market order data from three large retail brokers and order data from the NYSE's TORQ dataset to examine the extent to which marketable orders trade inside the NBBO. They find that orders routed to the NYSE receive more favorable execution prices than comparable orders routed to regional stock exchanges, where orders were often internalized.

The next innovation in this literature was to consider dimensions of execution quality other than price. Handa et al. (1999) are among the first to examine quantity improvement, which they define as occurring "when an order larger in size than the posted bid size or ask size is executed at the best bid or offer." Bacidore et al. (2003) use a dataset of market orders routed to the NYSE to evaluate the percent of orders receiving depth improvement, the percent of single price executions, and the speed with which orders are executed. Bacidore et al. (2002) introduce a new measure they refer to as adjusted price improvement, or API, which they argue "combines conventional price improvement and depth improvement." More specifically, using a dataset of marketable orders routed to the NYSE, the authors compute API as the difference between a marketable order's volume-weighted trade price and the volume-weighted price at which the order would have executed had it traded against the displayed liquidity on the NYSE's limit order book. This is one of the first measures that places a value on depth improvement. In this paper, we extend the API measure by comparing a marketable order's execution price to the price at which the order would have executed had it traded with the displayed liquidity on all order books. We refer to this measure as the volume-weighted displayed price, or VWDP.

Using order audit-trail data obtained from two securities firms, Battalio et al. (2003) examine the relative execution quality received by marketable orders routed to a wholesaler and

comparable orders routed to the NYSE on multiple dimensions. They find that retail market orders receive better trade prices on the NYSE, but faster executions, more depth improvement, and order flow payments from the wholesaler. The authors note that if brokers pass enough of the order flow payments through to investors in the form of lower commissions and/or better services, then investors also receive better net transaction prices with the wholesaler. Boehmer et al. (2007) utilize data provided in SEC Rule 605 filings, which contains both price and non-price execution quality statistics, to evaluate the impact of the disclosure of public execution quality statistics on order routing. The authors find that trading venues reporting relatively low trading costs and fast executions subsequently receive more orders.

Schwab (2022) argues that retail brokerage use of wholesalers allows the two institutions to focus on their comparative advantages to the benefit of the retail investor. The wholesalers compete to deliver superior execution quality, develop cutting-edge and reliable technology, invest in sophisticated order routing and liquidity sourcing (e.g., access liquidity pools that Schwab does not have access to and navigate complex order types and fee schedules), share efficiencies by employing advanced risk management capabilities to better manage inventory risk, and support retail brokers in ways that exchanges cannot (e.g. offer additional flexibility). Based on comparing the prices Schwab actually received in 2021 to prices reported on exchanges Rule 605 reports for comparable orders, Schwab estimates that wholesalers saved it clients \$3.4 billion.

Dyhrberg et al (2022) use SEC Rule data to compare wholesaler execution quality to exchange execution quality for the period January 2019 through March 2022. They compare gains from price improvement and the cost of providing liquidity, with the former favoring wholesalers and the latter favoring exchanges. Specifically, they find that, on average, the wholesaler effective spread is 26% of quoted spread while the exchange provides only 4% of quoted spread price

improvement. However, the exchange realized spread is only one-tenth that of wholesalers. On balance, they conclude that forcing retail trade onto exchanges would cost retail traders and benefit institutional traders, potentially by billions of dollars per year. As one of our analyses, we perform a complementary comparison of wholesaler and exchange execution quality as measured by Rule 605 reports.

Recently, two papers place real marketable orders with brokers who charge wholesalers different per share payments for their marketable order flow to examine the association between per share order flow payments and execution prices. Schwarz et al. (2022) place identical market orders with different brokers to evaluate the relationship between order flow payments and execution prices. They find that execution prices differ systematically across brokers and conclude that differences in the amounts that brokers charge wholesalers for order flow cannot explain the across-broker differences in execution price quality.¹⁶ Lynch (2022) places identical orders with three brokers: one broker that allows direct access and does not charge order flow payments and two brokers that charge wholesalers for their marketable orders. He utilizes two order sizes, \$1,000 and \$4,000, and he examines both execution prices and execution speed. Lynch provides evidence that for small marketable orders, the broker that receives a higher per share order flow payment receives less price improvement. Our work is different than both of these papers because we seek to understand why brokers who do not charge wholesalers for their marketable orders route their marketable order flow to wholesalers. In addition, our data contain a wide range of retail order characteristics (e.g., stocks of interest to retail traders and marketable orders' sides, sizes, and types) and retail traders' endogenous order timing.

¹⁶ Battalio et al. (2001) present evidence that a broker's identity allows wholesalers to differentiate between customers when pricing market making services.

Section III. Data.

A. Summary statistics.

We analyze all of the data-providing wholesalers(s)'s marketable retail order flow for the month of May 2022. To be included in our sample, orders and their associated trades must occur during regular market hours and the orders must be received when the NBBO is not crossed (i.e., the NBB must be less than or equal to the NBO).¹⁷ The final dataset contains 40,713,735 orders resulting in 53,147,634 trades in 11,899 ticker symbols. Table 1 contains descriptive sample statistics. All statistics are order-weighted.

[Insert Table 1 about here.]

Panel A provides summary statistics that characterize the sample orders and market conditions prevailing when the wholesaler(s) receives the orders. Although the average order quantity and trade size are modest, the wholesaler(s) receives and executes orders that might not fit the typical view of a retail order. The largest market (marketable limit) order is for 3,413,000 (2,081,000) shares. To the nearest full share, market orders fully execute on the day the order is placed. This is not the case, however, for marketable limit orders as the mean order size of 539 shares is 58 shares higher than the mean number of shares in an order that is filled.¹⁸ Not-completely-filled orders represent a very small portion of total orders and are almost exclusively limit orders. (In results not reported we find that less than 0.18% of orders are not filled completely and 95% of those are limit orders). As suggested by the number of security symbols handled, there

¹⁷ We also eliminate orders with a first execution timestamp prior to the order arrival time as data errors and a very small number of orders in which there was insufficient aggregate market-wide limit order book depth to fill the order (as this is necessary for anticipated analysis). The eliminated orders are such a small fraction of the total that none of our conclusions change if they are included.

¹⁸ This typically happens because the marketable limit order's size exceeds the available liquidity so it cannot be immediately executed fully within the limit price and/or the NBBO price changes to make the order non-marketable.

is a very wide range of security prices. The mean width of the NBBO prevailing when orders are received by the wholesaler(s) is \$0.12.

Adams and Kasten (2021) report that five retail brokers in the United States eliminated commissions on equity trades in October 2019. A search of the internet on August 16, 2022 suggests that institutional investors, in addition to retail traders, are taking advantage of commission-less trading. On its institutional website, TD Ameritrade advertises that it offers zero commissions and executed 98.1% of its marketable volume at or within the NBBO in the second quarter of 2022. An inspection of the Rule 606 reports for TD Ameritrade, Inc. and TD Ameritrade Clearing, Inc. reveal 99% of their marketable orders are held and are non-directed. Moreover, the reports reveal that 100% of their marketable orders in S&P500 stocks were routed to wholesalers whom TD Ameritrade charges payment for order flow during the second quarter of 2022. The Rule 606 report for Fidelity's institutional brokerage indicates that all of its marketable orders were routed to wholesalers in May 2022.¹⁹ Together, these data suggest that unlike twenty years ago, when all brokers charged commissions, today both retail investors and some institutional investors place orders with brokers commonly referred to as 'retail' brokers without paying commissions.

Consistent with anecdotal evidence, we find that in May 2022 the wholesaler(s) received orders that do not fit the traditional notion of retail order flow. Panel B1 of Table 1 presents the execution speed and the distribution of order sizes for our sample 266,061 marketable orders seeking to trade at least 10,000 shares. In Panel B2, we report similar statistics for 266,588 orders with notional value (average execution price times order quantity) of at least \$312,500 (cutoff selected to provide approximately the same number of orders as the 10,000-share cutoff in Panel

¹⁹ National Financial Services LLC's Rule 606 report for the second quarter of 2022 indicates that 10.09% of the orders seeking to trade S&P500 securities placed with Fidelity's institutional brokerage in May 2022 are non-directed and over 99% of these orders are marketable.

B1). For these collections of large orders, the 50th percentile order size is 12,680 shares (\$485,227) and the 75th percentile order size is 20,300 shares (\$757,823). Over five percent of these large orders are for at least 57,734 shares (\$1.68 million). The panels also illustrate that a 95th percentile marketable order based on shares takes 25.46 seconds to fully execute (24.44 seconds for the 95th percentile of notional value), while the 75th percentile marketable order executes in under one second.

Panels C and D of Table 1 respectively present the distribution of marketable orders by order side and order type. 57.04% of our sample marketable orders are buy orders, 38.37% are (long) sell orders, and 4.59% are short sell orders. Sell orders tend to be larger than buy orders so that the fraction of shares in sell orders is 45.15%. Perhaps reflecting the fact that the wholesaler(s) is willing to provide liquidity for more shares than are displayed in the aggregate NBBO at the order-receipt-time (ORT) NBBO, over 69% of our sample orders are market orders. Despite the enhanced liquidity provided by the wholesaler(s), market orders tend to be a bit smaller than marketable limit orders (as noted in Panel A), resulting in 62.5% of the order shares being contained in market orders.

One criticism of wholesalers²⁰ is that orders routed to them do not interact with institutional orders routed to exchanges and/or ATs (e.g., dark pools). In Panels E and F of Table 1, we provide descriptive statistics about the distribution of the wholesalers(s)'s execution venue choices. Although most of the order flow in our sample is filled internally, about 11% of the orders and almost 19% of share volume is completely externalized where the wholesaler(s) fills the retail

²⁰ See the speech by SEC Chair Gary Gensler "Market Structure and the Retail Investor" presented at the Piper Sandler Global Exchange Conference on June 8, 2022. <https://www.sec.gov/news/speech/gensler-remarks-piper-sandler-global-exchange-conference-060822>

order with liquidity from other markets. Another 1.8% of the orders are partially internalized.²¹ Orders that are at least partially externalized are larger and for a particular subset (based on the difference in the average order execution price) of the overall sample securities traded. On average, for the largest orders, the wholesaler(s) utilizes both internal and external liquidity sources. Fully internalized orders, on average, execute in 1.01 trades. Conversely, because they are much larger and require sophisticated routing practices, partially internalized orders generate an average of 9.03 trades (results not tabulated).

B. Basic price improvement statistics.

In order to begin our examination of why brokers route orders to be handled and executed by wholesalers despite not charging order flow payments, we calculate basic SEC Rule 605 price improvement statistics. This compares the actual execution price to the relevant order receipt time quoted price and noting when the retail investor receives a price better than the relevant quoted price. For a buy (sell) order, price improvement is buying (selling) at a price less than (greater than) the ORT NBO (NBB). Rule 605 covers marketable orders and includes only order sizes of at least one round lot (typically 100 shares) and excludes short sales. Table 2 describes the average order's experience for those orders that are fully internalized and fully externalized by the wholesaler(s).²²

[Insert Table 2 about here.]

In Panel A of Table 2, we evaluate all fully internalized marketable orders. As Rule 605 excludes odd lots and short sales, the first column of statistics excludes these orders when

²¹ As can be seen in Table 1, partially internalized orders are quite large. So, despite being only 1.8% of the orders they represent 23.5% of the shares trades. Approximately 15% of the trades and 51.33% of the shares of the Partially Internalized orders are executed with liquidity provided by the wholesaler(s).

²² We formally examine only fully internalized and fully externalized orders as they provide a cleaner sample from which to draw conclusions regarding the sources of execution quality. Orders accessing both internal and external liquidity sources are much larger than those orders fully internalized or fully externalized (20 times fully internalized and 7.65 times externalized) and face a considerably more complex execution strategy.

computing Rule 605 statistics. Only about 31% of the original roughly 35.5 million fully internalized orders (representing about 90% of the shares traded) are included in these Rule 605 reported numbers. From Panel A of Table 2, we see that the wholesaler(s) provides price improvement in 86.38% of the trades. This results in about \$7.14 per order (\$0.0085 per share) of official price improvement as defined by SEC Rule 605 for a total of nearly \$78 million dollars.

The size improvement rate compares the number of trades from orders where an order's quantity is greater than the aggregate size at the NBBO quote with a price that betters the NBB(O) to the total number of trades from orders that outsized the NBB(O) size. We see that 83.61% of trades from orders with excessive quantities receive this size improvement. We estimate the wholesalers(s)'s value-added when executing marketable orders seeking to trade more shares than are available at the NBBO by replacing the benchmark NBBO price with the volume-weighted average execution price at which the order would have executed if it had successfully accessed all of the displayed liquidity on each exchange's order book depth, including odd lots, top of book and depth of book quotes. We compute this benchmark price, which we refer to as the volume-weighted displayed price (VWDP), using the full depth of order book feed from each U.S. stock exchange. When the relevant ORT NBBO quote is replaced with the VWDP, the value of price improvement provided by the wholesaler(s) doubles (on both a per share and a per order basis).²³

Standard Rule 605 execution quality statistics specifically exclude odd lots and short sales. Including odd lots in the next column introduces some additional value provided by the wholesalers(s)'s executions. In this setting, we include odd lot orders but also include displayed odd lot quoted prices when computing the benchmark price. Not surprisingly, the price and size

²³ Note that **successfully** accessing all order-receipt-time displayed liquidity on all exchanges sets a difficult standard to obtain in practice given the speed with which orders can be cancelled/replaced, but we assume this is achieved to be conservative.

improvement rates decline slightly with odd lots, by 2.44 and 3.12 percentage points, respectively. Considering odd lots increases the total dollar value of price improvement offered by the wholesaler(s) by about 9.6%. Finally, we consider short sales, which increase the total dollar value of price improvement provided by a bit over 6%. Thus, for fully internalized orders, we see that the wholesaler(s) provides about 230% of price improvement relative to the official Rule 605 reports (\$177.9mm versus \$77.9mm) when we include price improvement to odd lot and short sell orders and the value of the size improvement. Again, this is consistent with the notion that the wholesaler(s) is doing more than simply maximizing the officially reported Rule 605 statistics.

We also provide equivalent numbers for orders that the wholesaler(s) chooses to externalize in Panel B. The choice to externalize is endogenous; externalizing an order might be due to internal considerations such as position limits and appetite for risk and/or to the wholesalers(s)'s assessment of the liquidity available externally. External venues provide lower price and size improvement rates compared to the rates achieved when the wholesaler(s) internalizes the order (about 60% versus over 83% in price improvement and 45% versus over 80% in size improvement).

Externalized orders provide an illustration of another service that wholesalers provide. Measuring execution quality using the base Rule 605 method, the externalized shares receive \$0.0012 per share price improvement on average compared to \$0.0085 per share for the internalized orders. Panel B of Table 2 has an additional row labeled "Supplemental PI". Supplemental PI illustrates the fact that the wholesaler(s) sometimes provides a better price to the client than was obtained on the external venue. That is, if the best price that the wholesaler(s) can find on an exchange when externalizing a buy order is \$40.10, the wholesaler(s) might improve the retail investor's trade at its own cost by giving it a price of \$40.0985 implying Supplemental

PI of \$0.0015 per share. Wholesalers do this because retail brokers measure and reward wholesalers based on the execution quality provided on all orders a broker routes to them not just the orders they internalize, thus externalized order execution quality is important.

In the base case in Panel B, the per share Supplemental PI (the price improvement provided by the wholesaler(s) over and above anything obtained on the external venue) exceeds the per share amount obtained using a strict Rule 605 approach, which implies that without the wholesaler(s)'s price adjustment the customer would have received price disimprovement, on average, if the external venue represented the sole source of price improvement for the wholesaler(s)'s client. This represents a direct cost to the wholesaler(s); in this case a cost of nearly \$4.3mm ($= \$0.0016 * 2.7$ billion shares). This results in a net price improvement to retail investors of the reported \$3.3mm, which suggests the best liquidity available on external venues provided \$1.1mm in price disimprovement. In addition, the cost of accessing liquidity on exchanges can be as high as \$0.0030 per share, which wholesalers do not pass along to brokers.²⁴ As with the internalized orders, the value of size improvement provided to externalized trades is substantial; in fact, as a multiple of Rule 605 price improvement it is larger than that for internalized orders. Adding odd lots and/or short sell orders to the sample provides the same relative comparison between internalized and externalized orders.

In summary, we see that the wholesaler(s) provides substantial price improvement on the orders that they internally execute, on average a bit less than a penny per share. The wholesaler(s) also provides economically significant price improvement by executing orders that are larger than the quoted size at the NBBO at better prices than they would have gotten had the order walked the combined order books of all U.S. stock exchanges. Considering price improvement that the

²⁴ Again, with 2.7 billion shares externalized the take fees represent as much as \$8.1 million in the sample month.

wholesaler(s) routinely provides to odd lot and short sale orders increases the total price improvement by over 16%. In addition, we see that the price improvement for externalized orders is provided by the wholesaler(s) at its expense by improving the prices obtained on external venues (at the wholesaler(s)'s expense) for investors. As with the internalized orders, benchmarking prices against the VWDP substantially increases the amount of price improvement provided by the wholesaler(s) on externalized orders.²⁵ Together, fully internalized and fully externalized orders adjusting for size improvement, odd lots, and short sells increases the Rule 605 defined price improvement from \$81.2 million to \$223.3 million, a 2.75-fold increase.

Section IV. Using information in Rule 605 reports to evaluate relative execution quality.

We continue our investigation of why brokers who do not charge order flow payments route most of their marketable order flow to wholesalers by using execution quality statistics reported in monthly Rule 605 reports to compare the relative execution quality of market and marketable limit orders in S&P500 stocks in May 2022 as published by six wholesalers and two exchanges. More specifically, we aggregate execution quality statistics for the six wholesalers and compare the aggregate data separately with execution quality statistics from NYSE Arca and from Nasdaq, which are two of the exchanges frequently used by the proprietary data provider(s) to externalize orders. The six wholesalers are Citadel Securities, G1X Execution Services, Jane Street, Two Sigma Securities, UBS, and Virtu Financial. Rule 605 statistics include information on covered orders and shares received disaggregated across stocks, order types, and order size buckets, execution time buckets, effective spread, shares receiving price improvement, executing

²⁵ In results not reported in Table 2, we examine partially internalized orders, which have the largest order size on average. Not surprisingly, the Rule 605 price improvement statistic is negative (-\$0.0056 per share on average despite the fact that the wholesaler(s) provides \$2.5m in price improvement to the customer by improving the prices received on external venues). However, considering the size enhancement via our VWDP benchmark, price improvement averages \$0.0417 per share or almost \$165mm. Thus, in total, the wholesaler(s) provides \$388mm of price improvement during the sample month.

at the quoted price and those receiving prices worse than the order-receipt-time quoted price (i.e., price disimprovement), execution times of price improved, price neutral, and price disimproved shares and the per share amount of price improvement and disimprovement.²⁶ In addition, the data allow us to infer the order receipt time quoted spread, which we use to compute the ratio of effective spread to quoted spread (ES/QS).²⁷ ES/QS is a commonly used industry statistic that considers the possibility that market conditions as reflected in the quoted NBBO spread might vary by security and from moment to moment. ES/QS recognizes that a venue might have a higher aggregate effective spread because of lower quality executions or because that venue receives orders in different securities or under market conditions that make delivering a low effective spread difficult. To the extent that the quoted spread for a stock is wider under adverse market conditions, deflating effective spread by quoted spread at least partially addresses these concerns. We focus on marketable orders (Rule 605 order type categories 11 and 12) for stocks included in the S&P 500 during the sample month. Using S&P 500 stocks provides some commonality in the sample studied and increases the likelihood that there are sufficient transactions to allow meaningful inferences. Aggregation of the six wholesalers' Rule 605 data across stock/order-type/order-size categories are weighted by shares traded.

The aggregated wholesalers' data are compared to the Rule 605 reported data for NYSE Arca and Nasdaq across stocks by order-type/order-size bins. Table 3 (Table 4) reports differences between the selected Rule 605 statistics for market (marketable limit) orders for the wholesalers and Nasdaq and Table 5 (Table 6) compare the wholesalers and NYSE Arca. We compute the

²⁶ The Rule 605 time-to-execution buckets are somewhat antiquated – the fastest bucket being 0-9 seconds – so we do not focus on execution speed in this analysis.

²⁷ The industry standard is referred to as the EQ statistic. EQ normalizes the effective-to-quoted-spread ratio so that an execution at the far touch (buying at the bid or selling at the offer) has a value of 100, trading at the near touch (buying at the offer or selling at the bid) has a value of -100, and trading at the midpoint has a value of 0.

difference between the wholesaler number and the exchange number (wholesaler minus exchange) across stocks for each statistic and report distributional information on the tables. We denote comparisons where the wholesalers offer better execution quality by italicizing the reported number. The number of comparisons is reported in each panel (and sometimes in each column of each panel) in the tables. In general, sample size falls as order size increases because wholesalers tend to receive larger marketable orders than those sent to exchanges (even for S&P 500 stocks).

[Inset Tables 3 and 4 about here.]

Table 3 addresses market order executions for the six wholesalers and Nasdaq. Across S&P 500 stocks, the wholesalers' execution quality generally exceeds Nasdaq's execution quality and the wholesalers' advantage increases with order size. For the smallest market orders (100-499 shares), the wholesalers provide more frequent price improvement and better effective spreads for more than 75% of the S&P 500 stocks. However, when comparing effective-to-quoted spread (ES/QS), we find that the wholesalers better Nasdaq for over 90% of the sample stocks. The fact that wholesalers are more dominant with the effective spread divided by quoted spread compared to simple effective spread suggests that, for a given security, market conditions (as proxied by a wider quoted spread) are not the same at order receipt time for the wholesalers and Nasdaq. For the largest order-size category (5,000 to 9,999 shares), wholesalers provide more frequent price improvement for more than 95% of stocks and a better effective spread for more than 90% of the stocks.

The wholesalers' price disimprovement rate (shares in trades with prices worse than the benchmark quoted spread divided by total shares traded) advantage increases with order size. For the smallest order size, the wholesalers have a slightly higher price disimprovement rate for at least 50% of the stocks (median price disimprovement rates for both the wholesalers and Nasdaq are

less than one percent for the smallest order size category). For the largest order size, the wholesalers have a lower price disimprovement rate for between 90% and 95% of the stocks (for the largest order size category, the median wholesaler price disimprovement rate is 19% compared to 77% for Nasdaq). The wholesalers' advantage in price improvement rates swamps the small disadvantage they exhibit in price disimprovement rates (e.g., for the smallest orders, the advantage in price improvement rate is over 60% while the deficit in disimprovement rate is less than 0.5% at the 95th percentiles).

Turning to marketable limit orders in Table 4, we see that the wholesalers' advantage in price improvement rates over Nasdaq continues, although it is somewhat more dominant for smaller order sizes. The wholesaler price disimprovement rate is slightly lower than the Nasdaq rate for the smallest order size category (again, median rates are both less than one percent) and slightly larger for the larger order size categories. However, the ES/QS measure strongly suggests that the six wholesalers and Nasdaq receive marketable limit orders under different market conditions (again, proxied by the quoted spread). In the smallest (largest) order size category, wholesalers report a better effective spread for over 25% of the sample stocks but a better ES/QS measure for over 95% (75%) of the stocks. Furthermore, if one considers the \$0.003 per share access fee, the median sample stock has a lower effective spread using the wholesalers.

[Insert Tables 5 and 6 about here.]

In Tables 5 (market orders) and 6 (marketable limit orders), we report the results of similar Rule 605 Reports analysis for the six wholesalers compared to NYSE Arca. The wholesalers enjoy a substantial advantage over NYSE Arca in price improvement rates, effective spreads, and ES/QS metrics. For the market orders analyzed in Table 5 and the marketable limit orders analyzed in Table 6, the wholesalers' price improvement rate exceeds comparable NYSE Arca rates for at least

90% of the S&P 500 stock sample. For market orders, the wholesalers' effective spread and ES/QS are more favorable than NYSE Arca's for more than 95% of the stocks even prior to considering the access fee. For marketable limit orders, the wholesalers' effective spread and ES/QS is better than the NYSE Arca measures for the majority of the stock-by-stock comparisons even before considering the access fee. In addition to dominating NYSE Arca with respect to price improvement rates, the wholesalers generally offer lower price disimprovement rates than NYSE Arca for the median S&P 500 stock.

Overall, we find that Rule 605 Reports provide strong evidence that, as a group, wholesalers provide better execution quality for most S&P 500 stocks. Wholesalers dominate the two sample exchanges in price improvement rates. In addition, for most order-type, order-size categories, wholesalers also have lower price disimprovement rates for the median sample stock. The wholesalers also generally outperform the sample exchanges for market orders using effective spread as an execution quality metric. Ignoring the access fee, Nasdaq (and NYSE Arca for smaller order sizes) appears to be competitive using the effective spread as a measure of execution quality, however, using the Rule 605 reports to compare stock-by-stock execution quality does not hold constant market conditions. The fact that the wholesalers have better ES/QS metrics than the exchanges even when the wholesalers' effective spread is wider strongly implies that the order receipt time quoted spread can be quite different when wholesalers receive an order than when exchanges receive an order. To address those potential issues, we turn to an analysis using order-pairs submitted nearly simultaneously to the data-providing wholesalers and to either of the two sample exchanges.

Section V. Near-Neighbor Comparisons

A. Documenting Wholesaler(s) Execution Quality versus Comparable Exchange Executions

Using SEC-mandated Rule 605 execution quality reports to evaluate execution quality across venues as we did in the previous section is difficult as venues receive orders in different securities and in different market conditions (see Battalio et al (2016)). Likewise, comparing orders that the data-providing wholesaler(s) internalized to externalized orders (in Table 2) potentially suffers from similar issues. For this reason, we construct near-neighbor comparisons (henceforth NNCs) between marketable orders routed to the data-providing wholesaler(s) and trades on two exchanges that are frequently used by the wholesaler(s) to source external liquidity, Nasdaq and NYSE Arca. This allows us to evaluate the relative execution quality provided by these venues for comparable orders in similar market conditions.

An NNC between a marketable order received by the wholesaler(s) and a trade executed by Nasdaq or NYSE Arca is constructed using exchange market data feeds and the wholesaler(s)'s order handling system as follows. We require the two events to be in the same stock and on the same side (e.g., buy or sell). We also require that the exchange trade occurs on one of the two exchanges within five seconds of the wholesaler(s)'s marketable order arrival. We conduct separate analyses based on whether the sample exchange trade or the wholesaler(s) order has the earlier timestamp.²⁸ Although multiple trades can occur within the five second window, we select the single exchange trade occurring closest in time to the wholesaler(s) order. Finally, within each

²⁸ As we cannot observe marketable order arrivals on the exchanges without more detailed data, we use a trade on the exchange presumably caused by the recent arrival of a marketable order. In most cases, marketable orders trade very quickly. For example, the mean (median) time between order arrival and trade is 0.06361 (0.006184) seconds for the wholesaler(s) fully internalized orders. If the exchange order arrival times equaled exchange execution times, the NNCs become legitimate horseraces. The exchange marketable orders frequently take liquidity from a displayed limit order on the exchange and we can therefore definitively assign a side to the marketable order. Sometimes the exchange marketable order executes against a non-displayed exchange liquidity-supplying order and we use the Lee and Ready (1998) methodology to type the liquidity-demanding order. Under one-quarter of NYSE Arca trades execute against hidden liquidity as do about one-third of Nasdaq trades.

NNC, we require that the exchange trade be no larger than the marketable trade routed to the wholesaler(s) but the wholesaler(s) trade can be larger than the exchange trade. For the analysis reported, we also require that the prevailing NBBO be the same for the two events. The venue executing the trade at the best price (i.e., lowest effective spread) wins the NNC.

We construct NNCs between the wholesaler(s) and NYSE Arca and the wholesaler(s) and Nasdaq using data from May 2022. For more detail on our analysis, consider the following example. One of the NNCs created on May 18, 2022, is between a market order to buy 1,000 shares of Occidental Petroleum Corporation (ticker: OXY) that the wholesaler receives at 11:56:34.74863am and a buy trade for 40 shares of OXY that occurs on NYSE Arca at 11:56:34.43358am. In this NNC, NYSE Arca trades first and the wholesaler receives the second marketable order 0.31505 seconds later. The NBB is \$65.26 and the NBO is \$65.29 at both the NYSE Arca trade time and at the order receipt time for the wholesaler. The 40-share trade occurs at a price of \$65.27 on NYSE Arca.²⁹ The wholesaler fills the 1,000-share market order at a price of 65.2709. The 40-share trade executed on NYSE Arca pays an effective spread of $2 \times (\$65.27 - \$65.275) = -\$0.0100$ per share. The 1,000-share market order executed by the wholesaler pays an effective spread of $2 \times (\$65.2709 - \$65.275) = -\$0.0082$ per share. Because it offered the lowest effective spread, NYSE Arca is declared the winner of this NNC (we ignore the fact that the wholesaler's trade was 25 times larger than the exchange trade and, for the moment, the fact that NYSE Arca charges a liquidity take fee that makes the gross effective spread non-representative of the cost of trading there).

NNCs can end in a tie because both trades occur at the same price. For example, on May 31, 2022, we pair a buy trade for 100 shares of Geovax Labs Inc (ticker: GOVX) on NYSE Arca

²⁹ Note that because the passive sell order resting on NYSE Arca's limit order book is seeking to trade less than 100 shares, it is not reflected in the NBBO.

with a market order to buy 3,770 shares of GOVX routed to the wholesaler(s). The events occurred within 1.57211 seconds of each other. When both events occur on the respective trading venues, the NBB for shares of GOVX is \$1.95 and the NBO is \$1.97. As each of these orders executes at the mid-point price of \$1.96 per share, each order incurs an effective spread of \$0.0000 and the NNC is declared a tie. As before, the designation of this as a tie ignores the exchange liquidity fee and the size differential between the orders.³⁰

Prior to imposing equal NBBOs, our NNC construction exercise results in 10,439,207 pairs: 1,954,333 (1,907,820) wholesaler(s) orders paired with an NYSE Arca trade occurring before (after) a wholesaler(s) order and 3,192,193 (3,384,861) Nasdaq trades occurring before (after) a wholesaler(s) order. The median absolute time differences between exchange trade and wholesaler(s) order ranges from 0.96 seconds to 1.31 seconds across the four groups. On average, the mean wholesaler(s) trade is 526 shares and the mean exchange trade is 68 shares. As Easley and O'Hara (1987) demonstrate, it can be costlier to provide liquidity for larger orders. Thus, we potentially create a bias against the wholesaler(s) providing lower effective spreads by ignoring the fact that wholesaler(s) executes larger orders.

[Insert Table 7 about here.]

In Table 7, we summarize the results for all of the near-neighbor comparisons for which the order-time wholesaler(s) trade NBBO equals the execution-time exchange trade NBBO in Panel A and, in Panel B, we further restrict the comparisons to the pairs where the absolute time difference between the exchange trade and the wholesaler(s) order arrival is less than one second. We see that the wholesaler(s) loses no more than 20% of the effective spread comparisons regardless of sub-group examined. The wholesaler(s) wins a higher fraction of the NNCs when the

³⁰ Overall, in our sample comparisons, 93.5% of the ties occur with the trade price equal to the spread midpoint.

wholesaler(s) order arrives before the exchange trade. From Panel A, we see that, overall, the wholesaler(s) wins almost 70% of the comparisons and another 19% end in ties. Before considering the liquidity fee charged by exchanges, exchanges win just over 12% of the sample's comparisons. These two exchanges both charged the maximum liquidity fee of \$0.003 per share in May 2022, which means that they also pay the largest make rebate and tend to have the deepest pools of liquidity. Adding twice the liquidity fee to the exchange's effective spread (to account for a round-trip trade), results in the wholesaler(s) winning almost 91% of the NNCs. Restricting the absolute difference between wholesaler(s) order arrival time and the execution time of the paired order to be less than one second in Panel B marginally improves the wholesaler(s)'s relative performance.³¹

The results reported in Table 7 support the decision of brokers and other clients to route orders to the data-providing wholesaler(s) rather than the two sample exchanges regardless of whether the routing clients charge the wholesaler(s) for their order flow. The wholesaler(s) consistently wins a large majority of the execution quality comparisons when order characteristics and market conditions are controlled. This conclusion ignores the fact that differences in the orders' sizes are unaccounted for (to the disadvantage of the wholesaler(s)) and is strengthened by the fact that the exchanges charge liquidity fees. We address the latter issue in Table 8.

[Insert Table 8 about here.]

In Table 8, we provide insight into the magnitude of the effective spread differences between the wholesaler(s) and the sample exchanges for the paired trades conditional on the chronological ordering of the events in the NCC. For each set of NNCs, Table 8 contains the

³¹ In further robustness checks we examined the set of NCCs where 1.) the width of the NBBO was \$0.01 and 2.) the size of the exchange and wholesaler(s) trade were the same. Neither sample refinement altered the findings reported in Table 7 substantively. Tightening the time difference allowed between trades, as reported in Panel B of Table 7, is the most sensitive robustness check examined.

cumulative percentage of NNCs for which the difference in the per share effective spreads paid by the two marketable orders in the NNC (the wholesaler(s) minus exchange) is less than the indicated amount. This means that, when the difference in effective spreads is negative, the marketable order routed to the wholesaler(s) paid the least for liquidity.

Of most interest are the rows labeled “ $\leq -\$0.0001$ ” representing the fraction of NNCs won by the wholesaler(s) before considering the exchange liquidity fee and “ $< \$0.0060$ ” representing the fraction of NNCs won by the wholesaler(s) considering the round-trip exchange liquidity fee (i.e., the percentage of NNCs where the exchange wins the gross effective spread comparison by less than the liquidity fee). As documented in Table 7, the wholesaler(s)’s win rate ranges from 63% to 72.5% without considering the exchange liquidity fee and from 86% to almost 94% when the exchange fee is factored into the exchanges’ net effective spread. In addition to the higher win rate, we see that the wholesaler(s) tends to win in the tails of the distribution of differences in effective spreads by a considerably larger amount than by which it loses in the tails. Consider the first and last rows of the table. About 9% of the time the wholesaler(s) wins by at least five cents per share but loses by more than four cents in less than one-half percent of the comparisons.

We can address the marginal price improvement provided by the wholesaler(s) over and above the price improvement provided by the exchanges with a few straight forward calculations. For each NNC, we require the NBBO to be identical for the two trades examined and have computed both exchange and wholesaler(s) effective spreads relative to that NBBO. Therefore, the difference in effective spreads between the wholesaler(s) and exchanges represents the marginal per share price improvement (including any size improvement) – negative numbers in Table 8 favoring the wholesaler(s) and positive numbers favoring the exchanges – for a round-trip trade. Multiplying one-half of this per share marginal per share price improvement by trade size

provides the marginal dollar price improvement provided by the wholesaler(s) for the single trade. If the exchange shares traded were from retail investors and had been executed by the wholesaler(s) at the same effective spread as the wholesaler(s)'s provided, these retail investors would have saved \$4.08 million in the sample month. That is, these retail investors would have received \$4.08 million in additional price/size improvement compared to what they received from exchanges. Additionally, if the (larger) wholesaler(s) retail investor orders had been executed at the same effective spread as the exchange shares received, retail investors would have lost almost \$33.46 million in price/size improvement. Thus, *ceteris paribus*, compared to the exchanges, the wholesaler(s) provide over \$37 million dollars of marginal price improvement to investors based on these near neighbor trades in the month studies.

B. Determinants of the Outcome of Near Neighbor Comparisons

What variables influence the likelihood that the wholesaler(s) win a given NNC? To examine that question we turn to a trinomial logit regression using “Tie” as the reference group to determine what explains the relative likelihood of “Win” and “Loss”. Several variables are candidates for inclusion in such an investigation. We focus on the width of the quoted spread relative to the quoted spread's midpoint, whether the exchange liquidity-demanding order interacts with a hidden passive order, the difference in time between the exchange trade and the wholesaler(s) order, and the size difference between the wholesaler(s) trade and the exchange trade. If quote spread width is relatively large, then there are more potential price points at which trades might occur. At a minimum, we expect to see fewer ties with a wide spread. Hidden orders can encourage competition to provide liquidity (see Buti and Rindi (2013) and have observable associations with market- and execution-quality statistics, market participation, and order strategies (see, e.g., Lee and Albert (2022) and Edwards et al (2021)). Thus, we anticipate that

evidence of the existence of hidden exchange liquidity provides an indication that market conditions differ from when the active exchange order trades at the quote. We also know that our NNCs differ in timing and trade size by construction – the exchange trade can occur before or after the wholesaler(s) order and the wholesaler(s) trade size is always at least as large as the exchange trade. Both of these variables might provide competitive advantages to one side or the other in the NNC competition. Finally, we control for active order side and time-of-day. Thus, our logit regression takes the form

$$\text{Outcome} = \alpha + \beta_1(\text{PctQS}) + \beta_2(\text{Buy}) + \beta_3(\text{Time-of-Day}) + \beta_4(\text{Hidden}) + \beta_5(\text{TimeDif}) + \beta_6(\text{SizeDif}) + \varepsilon$$

where:

Outcome = -1 for wholesaler(s) losses (wholesaler(s) effective spread is larger than exchange's), 0 for ties (effective spreads are the same), and +1 for wholesaler(s) wins (the wholesaler(s) effective spread is less than the exchange's);

PctQS = quoted spread/quoted spread midpoint (measured at time of exchange trade and time of wholesaler order arrival and, by construction, both numerator and denominator are required to be identical for each venue represented in an NNC);

Buy = 1 if the order is a buy (or the trade is typed as a buy order) and zero otherwise;

Time-of-day = seconds past midnight for the exchange trade/wholesaler(s) order time;

TimeDif = the time of the wholesaler(s) order minus the time of the exchange trade (in seconds);

and,

SizeDif = the size of the wholesaler(s) trade minus the size of the exchange trade (in shares).

[Inset Table 9 about here.]

Panel A of Table 9 provides the coefficient estimates and standard errors that result from estimating the equation above in a logistic regression. There are two estimates for each variable: one for Win versus Tie and one for Loss versus Tie given that we made Tie our reference group.

With the exception of “Arca back” (the NYSE Arca trade occurred before the wholesaler(s) order arrived), as the percent quoted spread becomes higher, the log likelihood of a tie decreases. For the Arca-back group, the log likelihood the wholesaler(s) wins increases. Thus, as expected, a wide quoted spread makes a tie less likely (at a minimum, less likely than a win). If the active side of the exchange order interacts with hidden liquidity, the log likelihood of a tie increases. Recall, that most of the ties are instances where both the exchange trade and the wholesaler(s) trade occur at the spread midpoint (i.e., the effective spread is zero). As many hidden exchange passive orders are midpoint orders, this result is somewhat expected. Looking at the coefficient estimates on the time difference, we find that the results differ depending on whether the exchange trade occurs before or after the wholesaler(s) order. When the exchange trade occurs first, the log likelihood of either a win or a loss decreases (tie log likelihood increases). When the wholesaler(s) receive the order earlier than the exchange trade, the log likelihood of a wholesaler win increases relative to a tie or loss. Finally, as the size difference between the wholesaler(s) trade and the exchange trade increases, the log likelihood of a wholesaler win decreases as one might expect. However, except for the Arca-forward sample, the log likelihood of wholesaler loss also decreases. Thus, at a minimum, the wholesaler(s) appears to be able to mitigate the disadvantage of a larger order in our NCCs.

The wholesaler(s) seems to have a competitive advantage with buy orders – the log likelihood of a win relative to a tie increases for buy orders and the log likelihood of a loss decreases. Except for the Arca back sample, as the trading day advances, the log likelihood of a tie increases.

The estimated coefficients and their standard errors provide evidence of a statistically significant (or not) relation but do not address the economic significance of estimated changes in

probabilities. In addition, likelihoods are a non-linear function of the coefficient estimates and thus subject to possible misinterpretation. In Panel B of Table 9, we compute model estimated probabilities from the logit regression coefficient estimates (and resulting odds ratios) for various scenarios altering a single explanatory variable for each scenario. In the base case, all binary variables are set equal to zero and all continuous variables are set equal to their medians. In a given scenario, one explanatory variable is changed. If examining the effect of a binary variable, the value of the binary variable is changed from zero to one. If examining a continuous variable, the value is changed from the 25th percentile value to 75th percentile value. When examining the likelihood sensitivities of a given variable all other binary variable(s) remain at zero and all other continuous variables remain at medians.

As can be seen from the resulting changes in the model estimated likelihoods, the most important variable affecting estimated NNC outcome likelihoods is the binary variable Hidden (whether the active exchange order interacts with a hidden passive order). If Hidden = 1, it is nearly certain that the NNC ends in a tie (and almost all ties are at the quoted spread midpoint). NNCs later in the trading day are also somewhat more likely to end in ties. Buy orders are slightly less likely to be wholesaler(s) losses. For Nasdaq, wider percentage quoted spreads are a bit less likely to be ties, suggesting that the wider spread gives the two participants more price points at which to print the trade. Interestingly, the size differential is an example of a statistically significant effect but not an economically meaningful effect, i.e., the changes in estimated likelihoods of moving from the 25th percentile of trade size difference (around 10 shares) to 75th percentile (400+ shares) does not substantively decrease the likelihood of the wholesaler(s) winning the NCC.

[Insert Table 10 about here.]

In Table 10, we examine the likelihood of a wholesaler win in each NNC relative to a loss when two times the exchange liquidity take fee is added to the exchange effective spread to capture the net effective spread difference rather than the gross effective spread. We have no ties in this scenario. Thus, all of the ties (mostly quote midpoint fills) become wholesaler wins. Because of this, we employ a simple binomial logistic regression using Loss as the base case.³²

As can be seen from Panel A of Table 10, a larger percentage quoted spread provides a clear increase in the log likelihood of a wholesaler win for comparisons with NYSE Arca. Interestingly, that wholesaler advantage is diminished/eliminated with comparisons to Nasdaq. Because all ties in the analysis without considering exchange fees becomes wholesaler wins, the fact that the exchange trade occurs with a hidden limit order as counterparty increases the log likelihood of the wholesaler(s) winning. Likewise, as the difference in the timing of the trade/order increases, so does the log likelihood of the wholesaler(s) winning when ties are eliminated by incorporating the exchange liquidity fee. Finally, as expected, the size difference disadvantages the wholesaler(s), however, the estimated coefficient is small. Again, the wholesaler(s) enjoy an advantage with buy orders and, when ties become wins cum liquidity fee, the wholesaler(s) advantage increases as the trading day passes.

As in the no-fee analysis, we compute model probabilities for various scenarios regarding controlled changes in explanatory variables in Panel B of Table 10. The approach mirrors that of Table 9 Panel B. The base case is the binary variables set to zero and the continuous variables set to their medians and the changes are moving the binary variables to one and the continuous variables from their 25th percentiles to their 75th percentiles, one change at a time. All the estimated model probability changes are consistent with the signs of the associated estimated regression

³² Because almost all ties are at the spread midpoint, the size of the exchange liquidity fee is irrelevant for the Win versus Loss analysis. Any positive liquidity take fee from the exchange changes a Tie into a wholesaler(s) Win.

coefficients (ignoring the two statistically insignificant regression coefficients). As with the no-fee analysis, the most impactful change is setting the Hidden binary variable to one. In this scenario, the projected (and actual) likelihood of the wholesaler(s) winning the comparison exceeds 99%. As the previous analysis suggested that nearly all without-exchange-liquidity-fee NCCs ended in ties, it is unsurprising that the wholesaler(s) wins almost all of those NCCs when the fee is considered. Increases in the time difference between the wholesaler(s) order and the exchange trade, a buy order compared to a sell order, and a trade later in the trading day marginally increase the likelihood of a wholesaler win. Increases in the difference in size between the wholesaler trade and the exchange trade barely affect the estimated likelihood of a wholesaler win.

In summary, model estimated probability changes are generally consistent with the signs of the respective estimated logit regression coefficients. The only explanatory variable with clear economic significance is Hidden – a binary variable equal to one if the passive side of an exchange order is a hidden order. NNCs are much more likely to be ties in the no-fee comparisons and wins in the with-fee comparisons if the passive side of the exchange order is a hidden order. The wholesaler is marginally more likely to win if the percent quoted spread is larger, if the liquidity demanding order is a buy order, and as it gets later in the trading day. For NNCs where the exchange trade occurs after the wholesaler(s) order arrives, the larger wholesaler size very marginally decreases win rate.

Section VI. Conclusions

In this paper, we investigate whether retail brokers and other clients of wholesalers can justify their order routing decisions based solely on their efforts to obtain best execution. We begin with the observation that in May of 2022, several retail brokers who do not charge payment for marketable order flow route their marketable orders to the same venues as brokers who do charge

payment for their marketable orders. Each set of brokers routes most of their marketable order flow to wholesalers. Thus, brokers who do not charge wholesalers for interacting with their order flow must receive some other benefit to using wholesalers' services. We next examine the execution practices of the data-providing wholesaler(s) in May 2022 to quantify the benefits they provide to routing brokers.

We document substantial levels of price improvement for orders that the data-providing wholesaler(s) internalizes (e.g., the wholesaler(s) takes the other side of the trade as principal risk) and for orders that the wholesaler(s) executes by sourcing liquidity from external venues. The wholesaler(s)'s price improvement rate exceeds 82% of all trades executed internally. We find that the wholesaler(s) provides a number of services to customers that add value but are not currently measured and reported. First, it is quite common that the wholesaler(s) executes orders for more size than is available in aggregate at the NBBO at prices that better those prices available in an aggregate view of all displayed odd lot, top of book and depth of book quotes from all exchanges. For our sample, the estimated value of this "size improvement" more than doubles the price improvement reported in the mandated SEC Rule 605 reports. At a more basic level, the wholesaler(s) executes more than 80% of trades associated with orders having a desired quantity exceeding the quoted size at prices better than the quoted prices. Also, in addition to providing price improvement to orders in the scope of Rule 605 reporting execution quality statistics, the wholesaler(s) offers price improvement to odd lots (even after adjusting the quote benchmark prices to include displayed odd lot limit orders) and short sell orders. Together, this adds about 17% to the dollar value of price improvement that the wholesaler(s) provided to marketable retail orders in May 2022. Finally, we find that even when wholesaler(s) choose not to internalize an order, they improve the prices received from other trading venues. In our sample data, the

wholesaler(s) provides sufficient supplemental price improvement at their expense to turn what would have resulted in price disimprovement for the average externalized order in May 2022 into a modest level of price improvement. In total, the wholesaler(s) provided a benefit of \$388 million in better-than-quoted executions for marketable orders in the sample month.

In order to broaden our examination of wholesaler execution quality beyond our data providers, we examine the SEC Rule 605 reports of the six major wholesalers. We compare their average executions to two exchanges that charge the maximum permissible access fee of \$0.003 per share (Nasdaq and NYSE Arca) and, therefore pay the highest rebates for providing liquidity which tends to produce the deepest levels of displayed liquidity. Focusing on S&P 500 stocks because they are widely traded by most venues, we find that the wholesalers offer considerably more price improvement and, generally speaking, no more price disimprovement than the exchanges. In most settings, this also leads to better effective spreads from wholesalers. For the larger order-size categories of marketable limit orders, more price improvement and comparable price disimprovement is associated with higher effective spreads by the wholesalers, however, this incongruence leads us to conclude that market conditions are not comparable for the comparisons we are making. To partially adjust for differences in market conditions, we compute an alternative execution quality measure that is not provided on the Rule 605 reports but is used as the industry standard metric in practice. ES/QS is defined as the effective spread (as reported on Rule 605 reports) divided by the quoted spread (which can be inferred from Rule 605 reports). Using the ES/QS measure, we find that the wholesalers' execution quality relative to the exchanges' execution quality is substantially improved compared to the unadjusted effective spread – particularly with marketable limit orders – even without considering the exchanges' access fee. The differences in execution quality between the effective spread versus the ES/QS metric imply

that market conditions must be considered when measuring execution quality, we conduct a controlled experiment.

Specifically, we develop a pair of executed orders – one trade generated by a marketable order arriving at the data-providing wholesaler(s) and one resulting from a marketable order trading at either NYSE Arca or Nasdaq – where we control the stock, the order side, the time of order event, the quoted national best bid and offer, and (to an extent) order size. We find that the wholesaler(s) wins over 68% of the NNCs, the exchanges win less than 20%, and the remaining cases are ties. Considering the exchanges’ access fees, the wholesaler(s) wins 91% of the NNCs. The wholesaler(s) win rate is in spite of the fact that their average order size is several times the exchange order size.

Finally, we investigate order characteristics and market conditions that are associated with the outcomes of the NNCs. The most important variable explaining outcome is whether the active exchange order in the paired comparison executes against a hidden or displayed passive order. When using a hidden order for liquidity, it is much more likely that the NNC ends in a tie when we ignore the exchange liquidity fee and a wholesaler win using cum-fee effective spreads. Clearly the market conditions existing when hidden liquidity is available on the exchange differs from the times when it does not. Other variables have a very small effect on projected outcome likelihoods; the wholesaler(s) fare better with buy orders than sell orders and later in the trading day and wide quoted spreads are less likely to end in ties. The larger, on average, wholesaler(s) trade sizes, although statistically significantly unfavorable to the wholesaler(s) make very little difference in the estimated win likelihood

In summary, we believe that we present ample evidence that wholesalers provide marketable retail orders with a higher level of execution quality than they would currently receive

on exchanges. The data suggest that retail brokers have a compelling competitive and regulatory reason to route marketable orders to wholesalers even in the absence of payment for order flow. Indeed, we document that some of the largest retail brokers do not charge order flow payments and yet route most of their marketable orders to wholesalers in an efforts to obtain the best execution for their clients.

We believe that this evidence should inform the decision about whether to ban payment for order flow and, importantly, speaks to the real magnitude and frequency of benefits provided to retail investors from the current market structure. Clearly, some brokers have a business model that allows them to operate without marketable order flow payments. Furthermore, our results are consistent with the findings of Schwarz et al. (2022), who document no correlation between the size of per share order flow payments and wholesaler execution quality. To address potential agency issues associated with order flow payments, we suggest regulators require brokers to disclose monthly execution quality statistics.

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Table 1. Descriptive Statistics.

The wholesaler(s)'s qualifying marketable order flow in May 2022 provides 40,713,735 orders that generate 53,147,634 trades. Externalized orders are executed by the data provider sourcing liquidity from an exchange, an ATS or another off-exchange venue. Partially (Fully) Internalized orders are orders that are partially (fully) filled with liquidity provided by the wholesaler(s).

Panel A. Characterization of the orders and the market conditions prevailing when orders are received by the wholesaler(s).

Variable	Mean	Minimum	Maximum
Order Receipt Time (ORT)	12:23:01.55	9:30:00.00	15:59:59.99
Order Qty.\-Market Orders	392	1	3,413,000
Filled Qty-Market Orders	392	1	1,331,865
Order Qty-Marketable Limit Orders	539	1	2,081,000
Filled Qty-Marketable Limit Orders	481	1	2,081,000
Volume-Weighted Execution Price	\$142.47	\$0.0003	\$4,681.47
ORT Spread Width	\$0.12	\$0.0001	\$18.29

Panel B1. Distribution of order size and execution speed (seconds) for the 266,016 marketable orders seeking to trade 10,000 or more shares.

	Mean	Percentile					Max.
		25 th	50 th	75 th	90 th	95 th	
Order Size (shrs.)	22,019	10,000	12,680	20,300	40,000	57,734	3,413,000
Execution Speed	34.32	0.01	0.02	0.07	9.68	25.46	23,025.76

Panel B2. Distribution of notional order size and execution speed (seconds) for the 266,588 marketable orders with notional value of at least \$312,500.

	Mean	Percentile					Max.
		25 th	50 th	75 th	90 th	95 th	
Notional Size ('000)	\$709.4	\$380.7	\$485.2	\$757.8	\$1,204.3	\$1,682.4	\$53,137.5
Execution Speed	38.33	0.01	0.02	0.59	9.66	24.44	18,524.52

Panel C. Order side.

	Frequency	Percent	Shares ('000)	Percent
Buy	23,221,796	57.04%	8,806,728	49.53%
Sell	15,622,071	38.37%	8,028,047	45.15%
Short Sell	1,869,868	4.59%	945,417	5.32%

Table 1. (continued)

Panel D. Order type.

	Frequency	Percent	Shares ('000)	Percent
Market	28,350,477	69.63%	11,113,484	62.50%
Marketable Limit	12,363,258	30.37%	6,666,708	37.50%

Panel E. Order result.

	Frequency	Percent	Shares ('000)	Percent
Externalized	4,491,689	11.03%	3,368,652	18.95%
Fully Internalized	35,494,932	87.18%	10,237,795	57.58%
Partially Internalized	727,114	1.79%	4,173,745	23.47%

Panel F. Characterization of the orders and the market conditions prevailing when orders are received by the wholesaler(s) by order result.

Variable	Order Result		
	Fully Internalized	Partially Internalized	Externalized
Average Order Quantity	288	5,740	750
Average Filled Quantity	286	5,447	656
Average Order Execution Price	\$149.64	\$74.99	\$96.72
ORT Spread Width	\$0.14	\$0.05	\$0.07

Table 2. Price improvement provided by the wholesaler(s) to marketable retail orders in May 2022.

We report orders that the wholesaler(s) fully internalize and compare them to fully externalized orders. SEC Rule 605 compares the execution price to the relevant side of the order receipt time NBBO to determine price improvement. We estimate the size improvement value provided when executing marketable orders demanding more shares than are available at the NBBO in aggregate across all exchanges by replacing the benchmark price with the volume-weighted average execution price at which the order would execute if it successfully accessed the necessary size of displayed liquidity on each exchange's order book – including odd lots and depth of book quotes. Supplemental PI illustrates the fact that the wholesaler(s) sometimes provides a better price to the client than it obtained on an exchange or ATS in the externalized trade. The PI rate is the number of trades for which the trade price betters the NBB(O) divided by the total number of trades. The Size Improvement (SI) rate is the number of trades from an order with an order quantity exceeding quoted size across the NBBO with a trade price better than the NBB(O) divided by the number of trades from orders with an order quantity exceeding quoted size.

Panel A. Fully internalized orders.

	No Odd Lots or Short Sales	No Short Sales	All Orders
PI Rate per Trade	86.38%	83.94%	83.66%
605 PI per Order	\$7.14	\$2.53	\$2.57
605 PI per Share	\$0.0085	\$0.0090	\$0.0090
SI Rate per Trade	83.61%	80.49%	80.42%
Value of Size Improvement per Order	\$14.49	\$4.91	\$5.01
Value of Size Improvement per Share	\$0.0172	\$0.0175	\$0.0175
Total 605 PI	\$77,859,942	\$85,853,586	\$91,298,588
Total Value of Size Improvement	\$158,043,805	\$166,425,800	\$177,895,200

Table 2. (continued)

Panel B. Externalized orders.

	No Odd Lots or Short Sales	No Short Sales	All Orders
PI/SI Rate per Trade	58.35%	62.83%	62.57%
605 PI per Order	\$1.59	\$0.90	\$0.91
605 PI per Share	\$0.0012	\$0.0014	\$0.0014
SI Rate per Trade	45.22%	45.01%	45.22%
Value of Size Improvement per Order	\$20.60	\$10.20	\$10.20
Value of Size Improvement per Share	\$0.0156	\$0.0157	\$0.0156
Supplemental PI per Order	\$2.12	\$1.08	\$1.10
Supplemental PI per Share	\$0.0016	\$0.0017	\$0.0017
Total 605 PI	\$3,279,723	\$3,770,744	\$4,010,672
Total Value of Size Improvement	\$43,041,910	\$43,029,587	\$45,353,439

Table 3. Differences in Market Order Execution Quality in S&P 500 stocks in May 2022 as Computed from Rule 605 Reports.

This table presents the share-weighted differences in the percentage of shares in trades that are executed at prices that are better (% Improved), equal to (% At-the-Quote), and worse than (% Disimproved) the relevant order receipt time quote, differences in the share-weighted gross-of-take-fee effective spread (ES) and differences in the share-weighted gross effective spread normalized by quoted spread (ES/QS). We aggregate execution quality statistics from Citadel Securities, G1X Susquehanna, Jane Street, Two Sigma, UBS, and Virtu Financial on a share-weighted basis. The differences reported in the table is the share-weighted wholesaler metric minus the exchange's reported number. *Italicized numbers indicate that the wholesalers have the more favorable execution quality statistic.* Because % At-the-quote cannot be designated as good or bad independent of the % Improved and % Disimproved, we do not use italics in that column.

Panel A. Across-stock differences for market orders for 100 to 499 shares. For the median stock, the wholesalers (Nasdaq) execute 762,739 shares (1,924 shares).

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved N = 482	% At-the-Quote N = 482	% Disimproved N = 482	ES N = 440	ES/QS N = 440
5 th	-4.62%	-59.24%	-11.76%	-\$0.3305	-0.6491
10 th	-3.70%	-49.66%	-7.02%	-\$0.1812	-0.6054
25 th	11.82%	-33.60%	-2.96%	-\$0.0622	-0.5447
50 th	23.70%	-21.29%	0.08%	-\$0.0204	-0.4364
75 th	37.52%	-10.34%	0.23%	-\$0.0043	-0.2994
90 th	52.59%	3.37%	0.33%	\$0.0026	-0.0649
95 th	61.45%	4.41%	0.45%	\$0.0171	0.2484

Panel B. Across-stock differences for market orders for 500 to 1,999 shares. For the median stock, the wholesalers (Nasdaq) execute 1,116,903 shares (3,380 shares).

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved N = 372	% At-the-Quote N = 372	% Disimproved N = 372	ES N = 323	ES/QS N = 323
5 th	-8.59%	-64.44%	-69.64%	-\$0.5179	-0.5723
10 th	-0.62%	-52.24%	-47.62%	-\$0.3094	-0.5537
25 th	24.59%	-36.13%	-29.25%	-\$0.1177	-0.4959
50 th	45.57%	-22.78%	-14.79%	-\$0.0410	-0.4112
75 th	63.01%	-10.10%	0.63%	-\$0.0107	-0.3151
90 th	80.33%	2.60%	1.83%	\$0.0007	-0.1005
95 th	87.42%	7.44%	2.62%	\$0.0157	0.2938

Table 3. (continued)

Panel C. Across-stock differences for market orders for 2,000 to 4,999 shares. For the median stock, the wholesalers (Nasdaq) execute 1,312,654 shares (4,600 shares).

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved N = 177	% At-the-Quote N = 177	% Disimproved N = 177	ES N = 169	ES/QS N = 169
5 th	-4.07%	-49.15%	-87.81%	-\$0.7987	-0.4249
10 th	14.76%	-40.51%	-82.25%	-\$0.4520	-0.3720
25 th	41.45%	-25.44%	-70.61%	-\$0.1503	-0.2967
50 th	69.99%	-10.11%	-46.65%	-\$0.0587	-0.2341
75 th	80.82%	-0.95%	-18.65%	-\$0.0213	-0.1460
90 th	85.82%	4.66%	0.77%	-\$0.0061	-0.0508
95 th	87.46%	7.20%	4.49%	\$0.0028	0.1104

Panel D. Across-stock differences for market orders for 5,000 and more shares. For the median stock, the wholesalers (Nasdaq) execute 1,609,159 shares (10,000 shares).

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved N = 88	% At-the-Quote N = 88	% Disimproved N = 88	ES N = 87	ES/QS N = 87
5 th	4.74%	-44.54%	-80.91%	-\$0.9424	-0.1868
10 th	20.99%	-33.61%	-78.89%	-\$0.5945	-0.1406
25 th	51.31%	-14.50%	-72.40%	-\$0.1443	-0.0951
50 th	64.80%	-1.89%	-60.08%	-\$0.0542	-0.0201
75 th	74.61%	3.03%	-28.47%	-\$0.0157	0.0380
90 th	79.25%	6.77%	-5.19%	-\$0.0048	0.0648
95 th	82.75%	10.01%	1.56%	\$0.0046	0.6000

Table 4. Differences in Marketable Limit Order Execution Quality in S&P 500 stocks in May 2022 as Computed from Rule 605 Reports.

This table presents the share-weighted differences in the percentage of shares in trades that are executed at prices that are better (% Improved), equal to (% At-the-Quote), and worse than (% Disimproved) the relevant order receipt time quote, differences in the share-weighted gross-of-take-fees effective spread (ES) and differences in the share-weighted gross effective spread normalized by quoted spread (ES/QS). We aggregate execution quality statistics from Citadel Securities, G1X Susquehanna, Jane Street, Two Sigma, UBS, and Virtu Financial on a share-weighted basis. The differences reported in the table is the share-weighted wholesaler metric minus the exchange's reported number. *Italicized numbers indicate that the wholesalers have the more favorable execution quality statistic.* Because % At-the-quote cannot be designated as good or bad independent of the % Improved an % Disimproved, we do not use italics in that column.

Panel A. Across-stock differences for marketable limit orders for 100 to 499 shares. For the median stock, the wholesalers (Nasdaq) execute 237,640 shares (2,848,414 shares). N = 501 stocks.

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved	% At-the-Quote	% Disimproved	ES	ES/QS
5 th	6.90%	-61.57%	-1.72%	-\$0.0028	-0.1911
10 th	11.96%	-54.27%	-1.44%	-\$0.0019	-0.1679
25 th	19.57%	-41.69%	-0.76%	-\$0.0005	-0.1220
50 th	28.54%	-28.30%	-0.18%	\$0.0033	-0.0893
75 th	42.00%	-19.00%	0.10%	\$0.0165	-0.0617
90 th	54.56%	-11.19%	0.35%	\$0.0739	-0.0449
95 th	61.52%	-6.34%	0.50%	\$0.1243	-0.0316

Panel B. Across-stock differences for marketable limit orders for 500 to 1,999 shares. For the median stock, the wholesalers (Nasdaq) execute 115,430 shares (237,407 shares). N = 500 stocks.

Percentile	Difference: Wholesalers - Nasdaq				
	% Improved	% At-the-Quote	% Disimproved	ES	ES/QS
5 th	-1.23%	-64.50%	-3.38%	-\$0.0237	-0.2086
10 th	6.36%	-59.11%	-2.15%	-\$0.0028	-0.1622
25 th	19.87%	-49.10%	-0.77%	-\$0.0003	-0.1211
50 th	36.02%	-36.24%	0.00%	\$0.0076	-0.0788
75 th	48.20%	-20.39%	1.14%	\$0.0305	-0.0354
90 th	58.89%	-6.60%	3.06%	\$0.0999	0.0086
95 th	64.74%	0.99%	4.75%	\$0.1862	0.0343

Table 4. (continued)

Panel C. Across-stock differences for marketable limit orders for 2,000 to 4,999 shares. For the median stock, the wholesalers (Nasdaq) execute 49,154 shares (47,342 shares). N = 484 stocks.

Percentile	Difference: Wholesalers - Nasdaq			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	-19.97%	-74.91%	-18.32%	-\$0.0994	-0.2565
10 th	0.00%	-65.97%	-9.99%	-\$0.0506	-0.1622
25 th	24.05%	-55.35%	-2.54%	-\$0.0058	-0.1079
50 th	40.17%	-41.70%	0.17%	\$0.0015	-0.0538
75 th	54.04%	-25.24%	8.23%	\$0.0287	-0.0038
90 th	62.69%	-8.79%	21.27%	\$0.1060	0.1025
95 th	70.25%	12.70%	30.00%	\$0.2417	0.5236

Panel D. Across-stock differences for marketable limit orders for 5,000 and more shares. For the median stock, the wholesalers (Nasdaq) execute 50,393 shares (28,286 shares). N = 392 stocks.

Percentile	Difference: Wholesalers - Nasdaq			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	-28.70%	-87.09%	-30.23%	-\$0.0957	-0.3481
10 th	-10.63%	-78.54%	-15.66%	-\$0.0505	-0.2474
25 th	15.85%	-65.46%	-2.38%	-\$0.0076	-0.1485
50 th	40.05%	-50.66%	2.29%	\$0.0026	-0.0759
75 th	55.52%	-29.58%	23.50%	\$0.0248	0.0130
90 th	68.61%	-1.20%	48.72%	\$0.1055	0.1111
95 th	83.01%	9.44%	68.30%	\$0.2367	0.2649

Table 5. Differences in Market Order Execution Quality in S&P 500 stocks in May 2022 as Computed from Rule 605 Reports.

This table presents the share-weighted differences in the percentage of shares in trades that are executed at prices that are better (% Improved), equal to (% At-the-Quote), and worse than (% Disimproved) the relevant order receipt time quote, differences in the share-weighted gross-of-take-fees effective spread and differences in the share-weighted effective spread normalized by quoted spread (ES/QS). We aggregate execution quality statistics from Citadel Securities, GIX Susquehanna, Jane Street, Two Sigma, UBS, and Virtu Financial on a share-weighted basis. The differences reported in the table is the share-weighted wholesaler metric minus the exchange's reported number. *Italicized numbers indicate that the wholesalers have the more favorable execution quality statistic.* Because % At-the-quote cannot be designated as good or bad independent of the % Improved an % Disimproved, we do not use italics in that column.

Panel A. Across-stock differences for market orders for 100 to 499 shares. For the median stock, the wholesalers (NYSE Arca) execute 841,356 shares (997 shares). N = 407 stocks.

Difference: Wholesalers - NYSE Arca					
Percentile	% Improved	% At-the-Quote	% Disimproved	ES	ES/QSQ
5 th	-4.19%	-95.54%	-18.90%	-\$0.4439	-0.7615
10 th	10.39%	-94.81%	-14.04%	-\$0.3308	-0.7225
25 th	37.55%	-83.23%	-5.64%	-\$0.1472	-0.6632
50 th	65.87%	-61.12%	0.06%	-\$0.0445	-0.5897
75 th	89.26%	-33.51%	0.23%	-\$0.0156	-0.5056
90 th	94.89%	-7.69%	0.34%	-\$0.0063	-0.3901
95 th	95.58%	3.95%	0.39%	-\$0.0028	-0.3213

Panel B. Across-stock differences for market orders for 500 to 1,999 shares. For the median stock, the wholesalers (NYSE Arca) execute 1,175,010 shares (3,908 shares). N = 298 stocks.

Difference: Wholesalers - NYSE Arca					
Percentile	% Improved	% At-the-Quote	% Disimproved	ES	ES/QS
5 th	19.42%	-90.90%	-58.03%	-\$0.5090	-0.6308
10 th	42.40%	-82.17%	-45.38%	-\$0.3271	-0.6035
25 th	64.55%	-71.63%	-26.67%	-\$0.1392	-0.5432
50 th	80.29%	-57.63%	-15.18%	-\$0.0479	-0.4835
75 th	88.47%	-41.34%	0.11%	-\$0.0154	-0.4018
90 th	91.18%	-23.65%	1.83%	-\$0.0047	-0.3140
95 th	92.97%	-12.14%	2.29%	-\$0.0003	-0.2359

Table 5. (continued)

Panel C. Across-stock differences for market orders for 2,000 to 4,999 shares. For the median stock, the wholesalers (NYSE Arca) execute 1,555,755 shares (6,500 shares). N = 151 stocks.

Percentile	Difference: Wholesalers - NYSE Arca			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	57.59%	-87.45%	-87.39%	-\$0.4022	-0.4855
10 th	64.67%	-79.24%	-82.63%	-\$0.2820	-0.4324
25 th	74.77%	-59.08%	-61.44%	-\$0.1453	-0.3586
50 th	82.34%	-35.85%	-40.35%	-\$0.0518	-0.2673
75 th	86.16%	-17.34%	-15.51%	-\$0.0190	-0.2110
90 th	89.49%	-3.74%	1.98%	-\$0.0084	-0.1588
95 th	91.31%	1.30%	5.33%	-\$0.0046	-0.1280

Panel D. Across-stock differences for market orders for 5,000 and more shares. For the median stock, the wholesalers (NYSE Arca) execute 1,919,639 shares (12,734 shares). N = 70 stocks.

Percentile	Difference: Wholesalers - NYSE Arca			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	45.91%	-86.80%	-85.13%	-\$0.3326	-0.2991
10 th	58.57%	-78.60%	-76.94%	-\$0.2395	-0.2423
25 th	66.91%	-46.68%	-63.66%	-\$0.1185	-0.1259
50 th	72.46%	-27.59%	-39.96%	-\$0.0388	-0.0540
75 th	79.30%	-6.96%	-21.36%	-\$0.0164	0.0071
90 th	82.98%	7.12%	1.54%	-\$0.0059	0.0413
95 th	90.70%	8.76%	9.70%	-\$0.0043	0.0570

Table 6. Differences in Marketable Limit Order Execution Quality in S&P 500 stocks in May 2022 as Computed from Rule 605 Reports.

This table presents the share-weighted differences in the percentage of shares in trades that are executed at prices that are better (% Improved), equal to (% At-the-Quote), and worse than (% Disimproved) the relevant order receipt time quote, differences in the share-weighted gross-of-take-fees effective spread and differences in the share-weighted effective spread normalized by quoted spread (ES/QS). We aggregate execution quality statistics from Citadel Securities, GIX Susquehanna, Jane Street, Two Sigma, UBS, and Virtu Financial on a share-weighted basis. The differences reported in the table is the share-weighted wholesaler metric minus the exchange's reported number. *Italicized numbers indicate that the wholesalers have the more favorable execution quality statistic.* Because % At-the-quote cannot be designated as good or bad independent of the % Improved an % Disimproved, we do not use italics in that column.

Panel A. Across-stock differences for marketable limit orders for 100 to 499 shares. For the median stock, the wholesalers (NYSE Arca) execute 237,640 shares (1,324,398 shares). N = 499 stocks.

Difference: Wholesalers - NYSE Arca					
Percentile	% Improved	% At-the-Quote	% Disimproved	ES	ES/QS
5 th	14.83%	-62.33%	-6.08%	-\$0.0105	-0.1911
10 th	19.35%	-55.27%	-4.44%	-\$0.0057	-0.1629
25 th	26.21%	-43.88%	-2.97%	-\$0.0025	-0.1279
50 th	35.40%	-33.17%	-1.82%	-\$0.0003	-0.0971
75 th	46.19%	-24.09%	-1.08%	\$0.0103	-0.0701
90 th	57.66%	-17.05%	-0.45%	\$0.0492	-0.0551
95 th	64.10%	-12.59%	-0.06%	\$0.0933	-0.0394

Panel B. Across-stock differences for marketable limit orders for 500 to 1,999 shares. For the median stock, the wholesalers (NYSE Arca) execute 116,329 shares (134,292 shares). N = 497 stocks.

Difference: Wholesalers - NYSE Arca					
Percentile	% Improved	% At-the-Quote	% Disimproved	ES	ES/QS
5 th	12.48%	-62.52%	-17.53%	-\$0.0457	-0.1813
10 th	17.91%	-57.17%	-13.19%	-\$0.0159	-0.1502
25 th	28.55%	-47.75%	-9.00%	-\$0.0037	-0.1035
50 th	41.46%	-35.40%	-5.31%	\$0.0006	-0.0543
75 th	52.38%	-22.24%	-2.26%	\$0.0179	-0.0132
90 th	62.48%	-11.28%	-0.12%	\$0.0828	0.0292
95 th	68.87%	-1.18%	0.92%	\$0.1980	0.0559

Table 6. (continued)

Panel C. Across-stock differences for marketable limit orders for 2,000 to 4,999 shares. For the median stock, the wholesalers (NYSE Arca) execute 50,318 shares (34,651 shares). N = 477 stocks.

Percentile	Difference: Wholesalers - NYSE Arca			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	-3.44%	-71.18%	-51.38%	-\$0.1442	-0.2262
10 th	10.11%	-61.74%	-41.45%	-\$0.0832	-0.1456
25 th	31.04%	-50.06%	-21.87%	-\$0.0191	-0.0655
50 th	46.73%	-34.00%	-10.25%	-\$0.0029	0.0017
75 th	59.48%	-15.00%	-1.44%	\$0.0175	0.0595
90 th	67.85%	9.56%	6.91%	\$0.0957	0.1563
95 th	75.93%	29.14%	17.73%	\$0.2110	0.4742

Panel D. Across-stock differences for marketable limit orders for 5,000 and more shares. For the median stock, the wholesalers (NYSE Arca) execute 54,509 shares (24,526 shares). N = 378 stocks.

Percentile	Difference: Wholesalers - NYSE Arca			ES	ES/QS
	% Improved	% At-the-Quote	% Disimproved		
5 th	-7.15%	-84.62%	-71.20%	-\$0.2239	-0.2967
10 th	0.00%	-76.77%	-54.22%	-\$0.0887	-0.2201
25 th	26.77%	-57.27%	-26.66%	-\$0.0326	-0.1032
50 th	46.96%	-37.86%	-5.96%	-\$0.0044	-0.0082
75 th	60.76%	-17.70%	7.52%	\$0.0142	0.0704
90 th	76.84%	7.12%	33.97%	\$0.0905	0.1775
95 th	92.58%	27.98%	49.98%	\$0.2434	0.3533

Table 7. Near-Neighbor Effective Spread Comparisons between Wholesaler(s) Orders and Trades Executing on Nasdaq or NYSE Arca.

A Near-Neighbor Comparison (NNC) between a marketable order received by the wholesaler(s) and a marketable order executed by Nasdaq or NYSE Arca is constructed using exchange feeds and the wholesaler(s)'s order handling system during May 2022 as follows. We require the two marketable orders to be in the same stock and on the same side (e.g., buy or sell). We also require that the exchange order trades on one of the two venues within five seconds of the wholesaler(s)'s marketable order arrival (with separate analyses for which competing venue has the earlier timestamp) and that the prevailing NBBO be the same for the two events. Finally, within each NNC, we require that the exchange trade be no larger than the trade resulting from the marketable order routed to the wholesaler(s) but the wholesaler(s) trade can be larger than the exchange trade. The venue executing the order at the best price (i.e., lowest effective spread) wins the comparison.

Panel A. Require that the NBBO be the same at Wholesaler(s) Order Receipt Time and Exchange Trade Time and that Time between Wholesaler(s)s Order Receipt Time and Exchange Trade Time be Less Than Five Seconds.

Comparison	Observations	Without Considering Exchange Liquidity Fees			With Exchange Liquidity Fees	
		% Win	% Tie	% Loss	% Win	% Loss
NYSE Arca trade before wholesaler(s) order	1,777,917	63.23	16.73	20.04	86.02	13.98
NYSE Arca trade after wholesaler(s) order	1,710,215	72.52	15.15	12.34	91.36	8.64
Nasdaq trade before wholesaler(s) order	2,903,697	64.50	22.21	13.29	90.71	9.29
Nasdaq trade after wholesaler(s) order	3,035,177	71.79	19.63	8.58	93.93	6.07

Table 7. (continued)

Panel B. Require that the NBBO be the same at Wholesaler(s) Order Receipt Time and Exchange Trade Time and that Time between Wholesaler(s) Order Receipt Time and Exchange Trade Time be Less Than One Second.

Comparison	Observations	Without Considering Exchange Liquidity Fees			With Exchange Liquidity Fees	
		% Win	% Tie	% Loss	% Win	% Loss
NYSE Arca trade before wholesaler(s) order	852,304	64.07	16.36	19.57	86.43	13.57
NYSE Arca trade after wholesaler(s) order	724,548	76.67	13.53	9.80	92.98	7.02
Nasdaq trade before wholesaler(s) order	1,431,532	64.35	22.05	13.60	90.50	9.50
Nasdaq trade after wholesaler(s) order	1,410,574	74.46	18.55	6.99	94.92	5.08

Table 8. Cumulative distribution of Near-Neighbor Comparison (NNC) results by the difference in the wholesaler(s)'s effective spread and the exchange's effective spread.

The table characterizes the outcomes of all NNCs constructed between the wholesaler(s) and NYSE Arca and the wholesaler(s) and Nasdaq for May of 2022. The venue listed first (second) in the column heading records the first (second) trade in the NNC. The difference in effective spreads is the wholesaler(s) effective spread minus the exchange effective spread – negative numbers indicate that the wholesaler(s) provide better effective spreads. For reference, the liquidity fee on a round trip liquidity demanding trade on each exchange is \$0.006 per share. Thus, the number reported in the table is the difference in gross effective spreads and does not include the liquidity fee. The cum liquidity fee difference in effective spreads that indicate a tie between the wholesaler(s) and the exchange would be \$0.0060.

Difference in Effective Spread	Cumulative Distribution			
	Nasdaq then Wholesaler	Wholesaler then Nasdaq	NYSE Arca then Wholesaler	Wholesaler then NYSE Arca
$\leq -\$0.0500$	6.81	9.55	9.06	12.62
$\leq -\$0.0250$	11.48	14.63	14.82	19.14
$\leq -\$0.0100$	41.52	48.88	42.77	49.81
$\leq -\$0.0050$	61.25	71.15	62.00	70.09
$\leq -\$0.0040$	61.36	71.25	62.16	70.22
$\leq -\$0.0030$	61.68	71.47	62.58	70.50
$\leq -\$0.0020$	61.92	71.69	62.96	70.81
$\leq -\$0.0010$	62.99	72.27	64.30	71.59
$\leq -\$0.0001$	63.20	72.48	64.49	71.77
$\leq \$0.0000$	79.96	87.66	86.71	91.42
$< \$0.0060$	86.02	91.36	90.71	93.93
$\leq \$0.0100$	94.32	96.08	96.08	97.37
$\leq \$0.0200$	99.28	99.32	99.20	99.28
$\leq \$0.0300$	99.50	99.46	99.42	99.42
$\leq \$0.0400$	99.31	99.54	99.55	99.52

Table 9 – Explaining Ex-Fee Near Neighbor Comparisons’ Outcomes.

In this table, we estimate the following logit regression equation explaining near neighbor comparisons (NNC) between wholesaler(s) execution quality and exchange execution quality ignoring exchange liquidity fees.

$$\text{Outcome} = \alpha + \beta_1(\text{PctQS}) + \beta_2(\text{Buy}) + \beta_3(\text{Tim-of-Day}) + \beta_4(\text{Hidden}) + \beta_5(\text{TimeDif}) + \beta_6(\text{SizeDif}) + \varepsilon$$

where: Outcome = -1 for wholesaler(s) losses (wholesaler(s) effective spread is larger than exchange’s), 0 for ties (effective spreads are the same), and +1 for wholesaler(s) wins (the wholesaler(s) effective spread is less than the exchange’s); PctQS = quoted spread/quoted spread midpoint (measured at time of exchange trade and time of wholesaler order arrival and, by construction, both numerator and denominator are required to be identical for each venue represented in an NNC); Buy = 1 if the order is a buy (or the trade is typed as a buy order) and zero otherwise; Time-of-day = seconds past midnight for the exchange trade/wholesaler(s) order time; TimeDif = the time of the wholesaler(s) order minus the time of the exchange trade (in seconds); and, SizeDif = the size of the wholesaler(s) trade minus the size of the exchange trade (in shares). Tie is the reference group. The estimation simultaneously considers wholesaler(s) Win versus Tie and Wholesaler(s) Loss versus Tie. Two sets of regression coefficients are created for each variable; one for Win and a second for Loss. Four NNC samples are estimated separately: NYSE Arca trades that occur before the wholesaler(s) order – Arca back, NYSE Arca trades that occur after the wholesaler(s) order – Arca Forward, Nasdaq trades that occur before the wholesaler(s) order – Nasdaq Back, and Nasdaq trades that occur after the wholesaler(s) order – Nasdaq Forward. NNCs require events (trades for the exchange and orders for the wholesaler(s)) in the same stock within five seconds of each other with the quoted spread being identical at the two events. The wholesaler(s) trades cannot be smaller than the exchange trade, but the exchange trade can be smaller than the wholesaler(s) trade.

Table 9 (continued)

Panel A. Coefficient Estimates and Standard Errors

Coefficient (Standard Error)	Arca back	Arca forward	Nasdaq back	Nasdaq forward
Intercept – win	2.2578*** (0.0132)	2.8967*** (0.0146)	2.2498*** (0.0096)	2.8255*** (0.0102)
Intercept – loss	1.1282*** (0.0166)	1.1716*** (0.0199)	0.8669*** (0.0139)	0.7799*** (0.0160)
% Quoted Spread – win	43.5010*** (1.2816)	53.0076*** (1.4174)	71.4427*** (0.0139)	80.2649*** (1.1144)
% Quoted Spread – loss	-12.1779*** (1.8851)	6.2868*** (2.2569)	63.6071*** (1.6191)	86.5102*** (1.7004)
Buy order – win	0.0550*** (0.0043)	0.0626*** (0.0047)	0.0555*** (0.0031)	0.0527*** (0.0033)
Buy order – loss	-0.0664*** (0.0054)	-0.0483*** (0.0065)	-0.0264*** (0.0045)	-0.0299*** (0.0052)
Seconds Past Midnight – win	-7.89E-6*** (2.781E-7)	-7.72E-6*** (3.025E-7)	-7.43E-6*** (1.989E-7)	-6.34E-6*** (2.094E-7)
Seconds Past Midnight – loss	-7.23E-7 (3.505E-7)	-7.23E-6*** (4.17E-7)	-1.93E-6*** (2.895E-7)	-7.41E-6*** (3.344E-7)
Hidden passive order exchange – win	-1.3643*** (0.0044)	-2.0858*** (0.0048)	-1.6879*** (0.0032)	-2.2982*** (0.0035)
Hidden passive order exchange – loss	-6.3512*** (0.0369)	-6.3443*** (0.0381)	-6.4724*** (0.0270)	-6.4163*** (0.0278)
Time difference – win	-0.0454*** (0.0015)	0.1354*** (0.0016)	-0.0373*** (0.0011)	0.0964*** (0.0011)
Time difference – loss	-0.0527*** (0.0019)	-0.0138*** (0.0021)	-0.0920*** (0.0016)	-0.4000*** (0.0017)
Size difference – win	-0.00009*** (1.997E-6)	-0.00010*** (2.115E-6)	-0.00009*** (1.563E-6)	-0.00001*** (1.639E-6)
Size difference – loss	-0.00001*** (2.584E-6)	-4.29E-7 (2.96E-6)	-0.00002*** (2.331E-6)	-0.00001*** (2.592E-6)

*** significant at beyond the .0001 level.

** significant at beyond the .001 level.

* significant at beyond the .01 level.

Table 9 (continued)

Panel B. Estimated Model Probability Changes – We compute the model estimated change in likelihood using the estimated coefficient from Panel A. For the base case, the likelihood is computed setting all binary variables equal to zero and all continuous variables equal to their medians. To compute the changes in estimated likelihoods for the binary variables, we recompute likelihoods leaving the other binary variable set equal to zero and the continuous variables at their medians. This revised likelihood is compared to the base case likelihood and the difference (revised – base case) is reported in the table. For a continuous variable, we compute the likelihood using the 25th percentile of the continuous variable of interest leaving all binary variables at zero and the other continuous variables at their medians. We compare this to the estimated likelihood with the variable of interest set at its 75th percentile and report the change in likelihood in the table. Win and Loss are from the perspective of the wholesaler(s).

Panel B1. NYSE Arca backward matching – NYSE Arca trade occurs before the wholesaler(s) order.

Variable Changed	Variable change	Change in Estimated Likelihood of Win vs Tie	Change in Estimated Likelihood of Loss vs Tie
QS/QS Midpoint	25 th to 75 th percentile	.0028	-.0013
Buy order	0 to 1	.0062	-.0131
Time of day	25 th to 75 th percentile	-.0135	-.0021
Hidden passive order	0 to 1	-.2425	-.7329
Time difference	25 th to 75 th percentile	-.0115	-.0224
Size difference	25 th to 75 th percentile	-.0049	-.0009

Panel B2. NYSE Arca forward matching – NYSE Arca trade occurs after the wholesaler(s) order.

Variable Changed	Variable Change	Change in Estimated Likelihood of Win vs Tie	Change in Estimated Likelihood of Loss vs Tie
QS/QS Midpoint	25 th to 75 th percentile	.0023	.0008
Buy order	0 to 1	.0047	-.0101
Time of day	25 th to 75 th percentile	-.0089	-.0224
Hidden passive order	0 to 1	-.3404	-.7022
Time difference	25 th to 75 th percentile	.0261	-.0069
Size difference	25 th to 75 th percentile	-.0036	-.0000

Table 9 (continued)

Panel B3. Nasdaq backward matching – Nasdaq trade occurs before the wholesaler(s) order.

Variable Changed	Variable Change	Change in Estimated Likelihood of Win vs Tie	Change in Estimated Likelihood of Loss vs Tie
QS/QS Midpoint	25 th to 75 th percentile	.0045	.0079
Buy order	0 to 1	.0062	-.0059
Time of day	25 th to 75 th percentile	-.0129	-.0065
Hidden passive order	0 to 1	-.3174	-.6661
Time difference	25 th to 75 th percentile	-.0091	-.0436
Size difference	25 th to 75 th percentile	-.0040	-.0017

Panel B4. Nasdaq forward matching – Nasdaq trade occurs after the wholesaler(s) order.

Variable Changed	Variable Change	Change in Estimated Likelihood of Win vs Tie	Change in Estimated Likelihood of Loss vs Tie
Percent quoted spread	25 th to 75 th percentile	.0027	.0107
Buy order	0 to 1	.0029	-.0063
Time of day	25 th to 75 th percentile	-.0070	-.0261
Hidden passive order	0 to 1	-.3300	-.6978
Time difference	25 th to 75 th percentile	.0128	-.0190
Size difference	25 th to 75 th percentile	-.0002	-.0008

Table 10. Explaining Cum-Fee Near Neighbor Comparisons' Outcomes.

In this table, we estimate the following logit regression equation explaining near neighbor comparisons (NNC) between wholesaler(s) execution quality and exchange execution quality considering exchange liquidity fees.

$$\text{Outcome} = \alpha + \beta_1(\text{PctQS}) + \beta_2(\text{Buy}) + \beta_3(\text{Tim-of-Day}) + \beta_4(\text{Hidden}) + \beta_5(\text{TimeDif}) + \beta_6(\text{SizeDif}) + \varepsilon$$

where: Outcome = -1 for wholesaler(s) losses (wholesaler(s) effective spread is larger than exchange's), 0 for ties (effective spreads are the same), and +1 for wholesaler(s) wins (the wholesaler(s) effective spread is less than the exchange's); PctQS = quoted spread/quoted spread midpoint (measured at time of exchange trade and time of wholesaler order arrival and, by construction, both numerator and denominator are required to be identical for each venue represented in an NNC); Buy = 1 if the order is a buy (or the trade is typed as a buy order) and zero otherwise; Time-of-day = seconds past midnight for the exchange trade/wholesaler(s) order time; TimeDif = the time of the wholesaler(s) order minus the time of the exchange trade (in seconds); and, SizeDif = the size of the wholesaler(s) trade minus the size of the exchange trade (in shares). Tie is the reference group. After adding twice the exchange liquidity fee to the exchange effective spread, there are no ties. Thus, we take Loss as the base case. Four NNC samples are estimated separately: NYSE Arca trades that occur before the wholesaler(s) order – Arca back, NYSE Arca trades that occur after the wholesaler(s) order – Arca Forward, Nasdaq trades that occur before the wholesaler(s) order – Nasdaq Back, and Nasdaq trades that occur after the wholesaler(s) order – Nasdaq Forward. NNCs require events (trades for the exchange and orders for the wholesaler(s)) in the same stock within five seconds of each other with the quoted spread being identical at the two events. The wholesaler(s) trades cannot be smaller than the exchange trade, but the exchange trade can be smaller than the wholesaler(s) trade.

Panel A. Coefficient Estimates and Standard Errors.

Coefficient Estimate (standard error)	Arca back	Arca forward	Nasdaq back	Nasdaq forward
Intercept	1.6066*** (0.0137)	1.7929*** (0.0172)	1.5741*** (0.0127)	2.0685*** (0.0151)
% Quoted Spread	65.6409*** (1.8300)	60.6040*** (2.2694)	10.4192*** (1.5412)	-2.8506 (1.6203)
Buy order	0.1066*** (0.0045)	0.1049*** (0.0056)	0.0718*** (0.0042)	0.0692*** (0.0049)
Seconds past Midnight	-2.85E-7 (-2.92E-7)	9.239E-6*** (3.649E-7)	2.584E-6*** (2.696E-7)	9.556E-6*** (3.213E-7)
Hidden passive order exchange	5.1907*** (0.0438)	4.6096*** (0.0444)	4.9990*** (0.0300)	4.4737*** (0.0307)
Time difference	0.0104*** (0.0016)	0.1184*** (0.0018)	0.0575*** (0.0015)	0.1047*** (0.0016)
Size difference	-0.00003*** (2.327E-6)	-0.00005*** (2.78E-6)	-0.00003*** (2.295E-6)	-0.00004*** (2.632E-6)

Table 10 (continued)

Panel B. Estimated Model Probability Changes – We compute the model estimated change in likelihood using the estimated coefficient from Panel A. For the base case, the likelihood is computed setting all binary variables equal to zero and all continuous variables equal to their medians. To compute the changes in estimated likelihoods for the binary variables, we recompute likelihoods leaving the other binary variable set equal to zero and the continuous variables at their medians. This revised likelihood is compared to the base case likelihood and the difference (revised – base case) is reported in the table. For a continuous variable, we compute the likelihood using the 25th percentile of the continuous variable of interest leaving all binary variables at zero and the other continuous variables at their medians. We compare this to the estimated likelihood with the variable of interest set at its 75th percentile and report the change in likelihood in the table.

Panel B1. NYSE Arca backward matching – Arca trade occurs before wholesaler(s) order.

Variable	Minimum	Maximum	Win Likelihood Change
QS/QS Midpoint	.0001746	.0007286	.0050
Buy Order	0	1	.0141
Time of Day	10:23:53	14:28:18	-.0006
Hidden Passive Exchange Order	0	1	.1636
Time Difference (seconds)	0.33053	2.50575	.0031
Size Difference (shares)	13	480	-.0019

Panel B2. NYSE Arca forward matching – Arca trade occurs after wholesaler(s) order.

Variable	Minimum	Maximum	Win Likelihood Change
QS/QS Midpoint	.000187	.000765	.0035
Buy Order	0	1	.0101
Time of Day	10:24:49	14:33:00	.0137
Hidden Passive Exchange Order	0	1	.1124
Time Difference (seconds)	-2.83795	-0.41847	.0297
Size Difference (seconds)	12	471	-.0023

Panel B3. Nasdaq backward matching – Nasdaq trade occurs before wholesaler(s) order

Variable	Minimum	Maximum	Win Likelihood Change
QS/QS Midpoint	.000177	.000741	.0007
Buy Order	0	1	.0088
Time of Day	10:30:17	14:42:45	.0049
Hidden Passive Exchange Order	0	1	.1470
Time Difference (seconds)	0.311316	2.431089	.0152
Size Difference (shares)	10	400	-.0015

Table 10 (continued)

Panel B4. Nasdaq forward matching – Nasdaq trade occurs after the wholesaler(s) order.

Variable	Minimum	Maximum	Win Likelihood Change
QS/QS Midpoint	.000191	.000785	-.0002
Buy Order	0	1	.0074
Time of Day	10:30:19	14:41:29	.0112
Hidden Passive Exchange Order	0	1	.1234
Time Difference (seconds)	-2.614088	-0.338219	.0268
Size Difference (shares)	9	400	-.0017

Appendix Table A1. Routing of several brokers that do not charge payments for marketable orders in May 2022

Panel A. Fidelity's routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 96.27%. 58.77% of the non-directed orders are market orders, 5.08% are marketable limit orders, and 32.69% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	21.30%	38.25%	\$0.00	38.47%	\$0.00
Virtu	11.67%	24.30%	\$0.00	24.30%	\$0.00
G1 Exec. Svc.	8.84%	19.40%	\$0.00	14.38%	\$0.00
Jane Street	8.20%	18.09%	\$0.00	13.52%	\$0.00
Two Sigma	0.51%	1.07%	\$0.00	0.80%	\$0.00
NYSE	19.00%	0.00%	\$0.00	2.77%	-\$4.07
Nasdaq	16.67%	0.01%	-\$16.23	4.18%	-\$15.24
EDGX	3.29%	0.00%	\$0.00	0.13%	\$0.00
MEMX	1.09%	0.00%	\$0.00	0.03%	\$0.00

Panel B. Vanguard Brokerage Services' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 50.78% of the non-directed orders are market orders, 5.35% are marketable limit orders, and 40.13% are nonmarketable limit orders. Vanguard does not charge liquidity rebates

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	41.63%	43.84%	\$0.00	39.29%	\$0.00
Virtu	21.73%	18.26%	\$0.00	20.55%	\$0.00
G1 Exec. Svc.	17.33%	18.18%	\$0.00	17.61%	\$0.00
UBS	19.31%	19.71%	\$0.00	19.51%	\$0.00

Appendix Table A1 (continued)

Panel C. Open to the Public Investing's routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 85.27% of the non-directed orders are market orders, 0.24% are marketable limit orders, and 13.35% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Instinet LLC	100.00%	100.00%	\$0.00	100.00%	\$0.00

Panel D. UBS Financial Services' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 95.37% of the non-directed orders are market orders, 0.20% are marketable limit orders, and 1.04% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
UBS	97.37%	97.34%	\$0.00	98.24%	\$0.00

Panel E. Citigroup Global Markets' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 26.88% of the non-directed orders are market orders, 7.00% are marketable limit orders, and 64.14% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	16.81%	29.10%	\$0.00	28.82%	\$0.00
Virtu	7.47%	11.78%	\$0.00	9.85%	\$0.00
G1 Exec. Svc.	12.45%	24.75%	\$0.00	23.24%	\$0.00
Jane Street	5.60%	11.63%	\$0.00	2.71%	\$0.00
Two Sigma	6.14%	12.45%	\$0.00	3.13%	\$0.00
UBS	7.41%	9.99%	\$0.00	24.38%	\$0.00
NYSE	11.17%	0.14%	-\$18.51	2.18%	-\$39.98
Nasdaq	29.36%	0.16%	-\$11.23	5.61%	-\$46.00

Appendix Table A1 (continued)

Panel F. Wells Fargo Clearing Services' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 64.80% of the non-directed orders are market orders, 1.17% are marketable limit orders, and 28.84% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	21.18%	19.19%	\$0.00	32.63%	\$0.00
Virtu	16.84%	14.30%	\$0.00	20.20%	\$0.00
G1 Exec. Svc.	21.05%	19.80%	\$0.00	34.35%	\$0.00
Jane Street	14.72%	22.02%	\$0.00	5.21%	\$0.00
Two Sigma	4.28%	1.46%	\$0.00	3.61%	\$0.00
UBS	7.86%	1.54%	\$0.00	3.93%	\$0.00
Wells Fargo Sec.	14.06%	21.69%	\$0.00	0.07%	\$0.00

Appendix Table A2. Routing of several brokers that do charge payments for marketable orders in May 2022

Panel A. TD Ameritrade's routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 24.11% of the non-directed orders are market orders, 6.30% are marketable limit orders, and 30.01% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	44.19%	58.74%	\$365,164.00	57.15%	\$88,505.00
Virtu	38.55%	40.26%	\$247,722.00	39.46%	\$64,668.00
Two Sigma	17.27%	1.01%	\$6,639.00	3.39%	\$3,194.00

Panel B. E*Trade Securities' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 99.60%. 52.31% of the non-directed orders are market orders, 5.51% are marketable limit orders, and 30.56% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	27.78%	35.33%	\$363,154.17	33.50%	\$64,678.58
Virtu	18.74%	22.34%	\$237,847.87	21.01%	\$37,413.37
G1 Exec. Svc.	23.21%	20.36%	\$203,101.90	20.08%	\$38,363.71
Jane Street	10.78%	15.52%	\$172,612.74	15.59%	\$30,031.65
Two Sigma	10.31%	4.23%	\$40,053.25	5.72%	\$8,390.40
UBS	5.91%	2.21%	\$15,842.75	3.91%	\$10,754.98
Nasdaq	1.66%	0.00%	\$0.00	0.08%	-\$775.62
EDGX	1.61%	0.00%	\$0.00	0.11%	-\$72.17

Appendix Table A2 (continued)

Panel C. Robinhood Securities' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 100.00%. 29.49% of the non-directed orders are market orders, 18.29% are marketable limit orders, and 8.63% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	53.33%	44.89%	\$155,979.22	44.30%	\$79,642.81
Virtu	26.74%	20.16%	\$154,852.32	20.16%	\$85,803.77
G1 Exec. Svc.	10.37%	18.05%	\$175,889.05	18.05%	\$97,306.46
Jane Street	8.39%	14.79%	\$205,632.43	14.79%	\$107,281.41

Panel D. Charles Schwab's routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 99.74%. 58.49% of the non-directed orders are market orders, 4.19% are marketable limit orders, and 29.37% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
Citadel	30.55%	30.69%	\$260,812.41	28.68%	\$38,886.82
Virtu	23.23%	24.85%	\$250,322.90	24.39%	\$37,909.16
G1 Exec. Svc.	20.45%	17.58%	\$164,744.89	20.11%	\$25,247.65
Jane Street	11.58%	18.09%	\$175,208.75	16.32%	\$23,148.97
Two Sigma	2.97%	1.99%	\$20,552.95	2.25%	\$3,317.12
UBS	9.88%	5.61%	\$48,076.16	6.90%	\$22,699.41
Nasdaq	0.88%	1.15%	\$0.00	1.27%	-\$52.61
MEMX	0.25%	0.00%	\$0.00	0.03%	\$0.00
EDGX	0.22%	0.05%	-\$30.40	0.04%	-\$4,749.21

Appendix Table A2 (continued)

Panel E. Interactive Brokers' routing of orders in S&P 500 Stocks in May 2022. The ratio of non-directed orders to total orders is 66.26%. 0.24% of the non-directed orders are market orders, 15.03% are marketable limit orders, and 83.43% are nonmarketable limit orders.

Venue	% of Non-Directed Orders	% Market Orders	Net Payment Received	% Marketable Limit Orders	Net Payment Received
IBKR ATS	5.66%	0.00%	\$0.00	36.74%	\$0.00
Nasdaq	39.11%	1.82%	-\$173.00	6.85%	-\$98,121.00
EDGX	31.19%	0.00%	\$0.00	1.59%	-\$36,134.00
NYSE	10.58%	0.00%	\$0.00	2.72%	-\$35,182.00
Pearl	1.99%	0.00%	\$0.00	0.71%	-\$8,617.00
NYSE Arca	1.79%	0.00%	\$0.00	3.33%	-\$69,998.00