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Can Brokers Have it All? On the Relation between Make-Take Fees And Limit Order Execution Quality*

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Abstract

We identify retail brokers that seemingly route orders to maximize order flow payments: selling market orders and routing limit orders to venues paying large liquidity rebates. Because venues offering high rebates also charge liquidity demanding investors high fees, fee structure may affect the arrival rate of marketable orders. If limit orders on low-fee venues fill when similarly priced orders on high-fee venues do not, routing orders to maximize rebates might not always be in customers' best interests. Using proprietary limit order data, we document a negative relation between several measures of limit order execution quality and the relative fee level. Specifically, we show that when 'identical' limit orders are concurrently displayed on two venues, orders routed to the low-fee venue execute more frequently and suffer lower adverse selection. Using the NYSE's TAQ data, we show that the negative relation between take fees and execution quality extends beyond our proprietary dataset.

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Today, every U.S. stock exchange levies fees or pays rebates that are, at least in part, a function of an order's attributes (see Cardella, et al. (2013)). In the 'traditional' model, exchanges charge liquidity demanding orders (i.e., marketable orders) a fee that exceeds the rebate they offer liquidity supplying orders (i.e., nonmarketable limit orders). More recently, a few 'inverted' exchanges began charging liquidity suppliers a fee that exceeds the rebate they pay to liquidity demanders.[1] Although these differential fee schedules give traders increased flexibility, they are controversial. As noted by the Investment Company Institute in their April 2010 letter to the Securities and Exchange Commission (SEC), "brokers may refrain from posting limit orders on a particular exchange because it offers lower liquidity rebates than other markets, even though that exchange offers the best possibility of an execution for those limit orders."[2]

Although the SEC's Order Protection Rule establishes price priority in U.S. equity markets, the rule does not specify who trades first when multiple venues have the best posted price. Angel, Harris, and Spatt (2010) note that across-exchange differences in fee schedules create situations in which equally priced, nonmarketable limit orders resting on separate exchanges have different 'net price' priority. All else equal, when two venues offer the best price, one expects liquidity demanders arriving in the marketplace to first route their orders to the venue with the lower take fee. Consider the case where two exchanges are at the national best bid. If sufficient selling demand arrives, sellers exhaust liquidity by walking down both exchange's limit order books. In this situation, limit order traders who purchased shares at the bid price suffer a short-term loss. However, if the stock price rises before liquidity is exhausted at the national best bid, limit orders on the venue with the higher take fee (and thus, the higher make rebate) can become isolated and miss profitable trading opportunities. Thus, on average, we expect that limit orders sent to venues with high take fees will have lower fill rates and suffer greater adverse selection costs – they are more likely to trade when the price moves against them and less likely to trade

[1] The difference between the fee and the rebate is an important source of exchange revenue. Given the competition between U.S. exchanges, there is a high correlation between the level of an exchange's fee and its rebate. Fee structures at the various exchanges are described in more detail below.
[2] See http://www.sec.gov/comments/s7-02-10/s70210-138.pdf.

when prices move in their favor.[3] This suggests that brokers routing limit orders to venues with the highest take fees (and make rebates) may not be obtaining best execution for their clients.

Why might brokers' and clients' interests diverge? Angel et al. (2010) note that if fees and rebates are passed through to clients, brokers would generally send limit orders to the venue that maximizes the likelihood of execution as brokers receive commissions only when orders execute. The typical situation, however, is for the broker to offer a fixed commission schedule that reflects fees, rebates, and the other costs of doing business. All else equal, in a competitive market, brokers that pay the lowest fees to exchanges can offer the lowest commissions. If investors choose brokers based primarily on commissions (perhaps because they lack the sophistication and/or the necessary information to evaluate limit order execution quality), it may be profit maximizing for brokers to focus on liquidity rebates rather than the probability of limit order execution when making routing decisions.[4]

While we expect fee structure to have an important impact on order routing and the arrival rate of marketable orders, fees may not be the only determinant of limit order execution quality. For example, in volatile stocks or in high-priced stocks where the penny tick size is not binding, limit orders may become marketable regardless of where they are routed. Moreover, brokers may find it optimal to route marketable orders to venues with high take fees if those venues offer sufficient price and/or depth improvement or provide other services such as competitively priced co-location.[5] Finally, the marginal broker/investor may make routing decisions such that limit order execution quality is unrelated to a venue's fee schedule. Given these considerations, the link between make/take fee schedules and limit order execution quality is an empirical issue. In this paper, we analyze the relationship between take fees and limit order execution quality using a number of alternative empirical tests based on both proprietary limit order data and the NYSE's TAQ database.

[3] Fill rates and adverse selection costs (our focus) are but two measures of execution quality for nonmarketable limit orders. See http://www.sec.gov/rules/final/34-43590.htm for a more comprehensive list of considerations.

[4] Although brokers receive commission on limit orders only when the orders execute, unfilled limit orders are frequently canceled and replaced. Thus, routing based on rebates could have an impact on execution quality while having only a limited effect on the commissions earned by the broker.

[5] Price improvement occurs when a marketable order trades at a price that is better than the posted quote. Depth improvement occurs when a marketable order trades against non-displayed liquidity at a price that is no worse than the posted quote. For a discussion, see UBS's Best Execution Statement at http://www.ubs.com/content/dam/static/wmamericas/bestexecution.pdf.

Using Rule 606 reports from the fourth quarter of 2012, we begin by examining the order routing decisions of ten well-known national brokerages. We interpret the routing decisions of four of these brokers as consistent with the objective of harvesting liquidity rebates. In particular, three of these brokers sell market orders to market makers and route limit orders either to market makers or to a single exchange offering the highest liquidity rebates and charging the highest take fees during our sample period.

In an effort to understand whether routing nonmarketable limit orders to venues with high fees results in diminished execution quality, as hypothesized by Angel et al. (2010), we examine the relation between take fees and two measures of limit order execution quality: the likelihood of a fill and the adverse selection associated with fills. We begin by analyzing proprietary limit order data obtained from a major investment bank that uses a sophisticated algorithm to route orders. Univariate statistics suggest a negative relation between take fees and limit order execution quality. However, these summary statistics ignore other factors that may affect both the order routing decision and limit order execution quality.

To control for market conditions and order characteristics, we provide a multivariate analysis of the association between take fees and the probability that a limit order executes and the relation between take fees and execution speed. All else equal, we find that fill rates for displayed limit orders are lower on exchanges with higher fees. In addition, for filled limit orders, executions take longer on high-fee venues than on low-fee venues. These results confirm the negative relation between take fees and limit order execution quality suggested by the univariate results.

As the broker's decision to route limit orders to particular venues is likely not random, our findings may be affected by a selection bias (see Peterson and Sirri (2002)). We utilize a unique feature of our data to address this issue. Frequently, identically priced limit orders in the same stock are displayed concurrently on multiple venues. For these 'identical' orders, differences in fill rates, execution speeds, and adverse selection costs can be linked directly to exchange characteristics such as the make-take fee schedule, hidden liquidity, latency and queue length. Perhaps most important, an analysis of these orders allows us to hold market conditions constant. Using these order pairs, we conduct 'horseraces' between different exchanges. In nearly every comparison we make, the venue with the lower take fee wins more horseraces (i.e., fills when the high-fee venue does not or fills more rapidly) and has less adverse selection than the high-fee venue.[6]

Although high-fee venues might be part of a customer-oriented order routing strategy, the results of our analysis suggest that routing all limit orders to a single exchange that offers the highest liquidity rebate is inconsistent with maximizing limit order execution quality. However, given that our order data are from a single broker and constitute only 1.5% of average daily trading volume, one might question the generalizability of our results. Another concern is that the proprietary order routing system used by our data provider is designed to optimize trade, leading to a potential endogeneity bias. For these reasons, we next use the NYSE's TAQ database to make inferences regarding the across-venue execution quality of at-the-quote limit orders. Assuming that the quotes displayed on each of the traditional and inverted venues are set by limit orders, we can use TAQ data to examine whether take fees influence where limit orders execute when multiple venues are at the inside quote and the adverse selection associated with these executions. In addition, restricting our analysis to those cases when all relevant venues are simultaneously at the inside bid or offer allows us to focus on those situations where the order routing decision should be most relevant.

Consistent with the results of our order data analysis, we find that adverse selection costs are generally increasing in make rebates/take fees for both NYSE- and Nasdaq-listed stocks. In particular, realized spreads are lowest on high-fee venues and are highest on inverted venues. The one exception to this general relation is the NYSE, which does better than expected given its fee structure. This suggests that fees are not the only determinant of cross-venue differences in limit order execution quality. Using a multivariate framework, we find that the negative relation between realized spreads and take fees holds even after controlling for trade characteristics, market conditions, and time-of-day effects. Finally, consistent with Harris (2013), we find that the negative relation between fees and realized spreads is most

[6]We measure adverse selection using the realized spread, with higher adverse selection corresponding to lower realized spreads. The realized spread measures the compensation earned by liquidity providers by assuming trades are unwound at the bid-ask midpoint five minutes after the trade.

pronounced in low-priced stocks and when the aggregate depth at the relevant quote is large.

Although it is not a common practice, some brokers pass fees/rebates directly through to their customers. For these investors, realized spreads adjusted for fees may be a more appropriate measure of limit order execution quality. For at-the-quote limit order executions, we find that the inverted venues and the NYSE (for NYSE-listed securities) offer positive average realized spreads net of rebates/fees. These findings suggest that brokers seeking to optimize execution quality may make different order routing decisions depending upon whether or not they pass fees/rebates on to their customers.

Taken together, our results point to a strong negative relation between take fees and several measures of limit order execution quality. Based on this evidence, we conclude that the decision of some national brokerages to route all nonmarketable limit orders to a single exchange paying the highest rebate is unlikely to be consistent with the broker's responsibility to obtain best execution for customer orders.

The remainder of this paper is as follows. In Section II, we provide a brief literature review. In Section III, we use publicly available data to investigate broker routing decisions. In Section IV, we use proprietary order data to examine the relationship between make-take fees and limit order execution quality. In Section V, we use the NYSE's TAQ database to investigate this relationship in more general settings and for a broader sample of stocks. Section VI concludes.

II. Related Literature

When an asset's trading volume is concentrated on one venue, the (limit) order routing decision is trivial. For U.S. equity markets, the order routing decision became more substantive after the Consolidated Tape introduced pre-trade transparency in 1982. By allowing trading venues to benchmark their trades against each other's quotes, competition for retail order flow became more intense, with venues competing along different dimensions to attract orders. According to the SEC, when making order routing decisions broker-dealers "must consider several factors affecting the quality of execution, including, for example, the opportunity for price improvement, the likelihood of execution (which is particularly important for customer limit orders), the speed of execution, and the trading characteristics of the security, together with other non-price factors such as reliability and service."[7]

Increased competition for customer orders leads naturally to the question of whether execution quality differs across venues. The SEC's 1997 "Report on the Practice of Preferencing," contains one of the first cross-venue analyses of retail limit order execution quality. In their study, the SEC documents fill rates, time-to-execution statistics, and adverse selection costs (as measured by realized spreads) for limit orders that execute on various U.S. exchanges. Their analysis does not, however, control for the endogeneity associated with the order routing decision.

In order to ensure that routing retail limit orders away from the NYSE did not degrade execution quality, regional exchanges implemented rules that benchmarked their limit order executions to NYSE limit order executions. Using a methodology that allows them to control for market conditions and order submission strategies, Battalio et al. (2002) find that these rules were effective at producing limit order execution quality that was competitive with the NYSE.

Concerned that some brokers might maximize order flow payments rather than execution quality, the SEC passed Rule 11ac1-5 (now Rule 605) and Rule 11ac1-6 (now Rule 606) in 2001. Together, these rules are intended to bring sufficient transparency for investors to determine whether their brokers are making optimal order routing decisions. Rule 605 requires exchanges to produce execution quality statistics on a monthly basis. Rule 606 requires brokers to reveal on a quarterly basis the destinations to which they route orders and whether they receive compensation for their routing choices. Consistent with the rules' objectives, Boehmer, Jennings and Wei (2007) find that the routing of marketable order flow became more sensitive to cross-venue changes in execution quality after Rule 605 execution quality statistics were available. However, the Rule 605 limit order execution quality statistics are similar to those used in the SEC's 1997 study in that they do not control for potential endogeneity issues.

More recently, Foucault and Menkveld (2008) examine how market fragmentation and fee differentials affect limit order execution quality when price priority is not enforced across markets. When the two markets they examine are both at the inside quote, they find that smart routers predominately send

[7] http://www.sec.gov/rules/final/34-43590.htm.

orders to the market with the lowest fee. They also find evidence that violations of price priority across the two markets adversely affect liquidity provision. Consistent with the idea that marketable order flow is sensitive to take fees, Cardella, Hao and Kalcheva (2013) find that reductions in relative take fees in U.S. equity markets are associated with increased market share.

Colliard and Foucault (2013) and Foucault, Kadan and Kandel (2013) construct theoretical models to investigate how make-take fees affect liquidity supply. Colliard and Foucault consider how an exchange competing with a dealer market should optimally set its make-take fee schedule. They conclude that the net fee (fee minus rebate) has an ambiguous effect on the execution probability for limit orders and the speed with which the limit order queue moves. Foucault et al. (2013) examine whether it is the net fee or the relative levels of the make and take fees that matter. They argue that exchanges can maximize their trading volume by differentiating their make and take fees. If there is not enough liquidity demand (supply), the venue can decrease (increase) its take fee and its make rebate.

Perhaps due to the availability of superior data, the relation between limit order execution quality and make-take fees has received more attention in the practitioner arena than in academic research.[8] Sofianos, Xiang, and Yousefi (2010) use nonmarketable limit orders placed on six exchanges by the Goldman Sachs smart router, SIGMA, to examine the relation between take fees and limit order execution quality. Using only those limit orders split between two exchanges, Sofianos et al. make pairwise comparisons of execution quality across exchanges. As all non-venue specific factors are the same, they note that differences in execution quality are either due to adverse selection risk or differences in fill rates. They find the venue utilizing an inverted make-take schedule has lower adverse selection costs, faster fills, and higher fill rates than the other five exchanges. Ignoring fees, these results suggest brokers routing nonmarketable limit orders to venues with high take fees disadvantage their clients.

Using a proprietary dataset of orders generated from a Goldman execution algorithm, Bacidore, Otero and Vasa (2011) investigate the benefits of smart routing using five order routing strategies. One

[8] One exception is Yim and Brzezinski (2012), who construct an empirical model that uses publicly available trade and quote data to estimate average limit and market order arrival rates, limit order cancelation rates, and limit order queue lengths for three stocks in April of 2011. For these stocks, the authors find that inverted venues generally have shorter times-to-execution.

strategy follows the 'naïve' approach of maximizing rebates and two strategies attempt to maximize fill rates. When routing marketable order flow, one algorithm minimizes take fees while two consider both take fees and hidden liquidity. They present evidence that the naïve strategy delivers inferior limit order execution quality, even after accounting for liquidity rebates. For marketable orders, they find smaller differences in execution quality across algorithms, which they argue is "intuitive given the Reg. NMS protections on market orders." This said, in large capitalization stocks they find some benefit to routing on the basis of both fees and the prospect of hidden liquidity.

Finally, Pragma Trading (2013) illustrates a broker-customer agency issue related to the conflict we examine. Their focus is the broker's choice of order type rather than the broker's venue choice that we study. After identifying "trading opportunities" based on order imbalances, they consider the decision to trade aggressively by reaching across the quote with a market order versus simply joining the quote with a limit order and altering the limit price if the quote changes. The customer is focused on implementation shortfall, which is fixed for the aggressive order, but the broker also considers the rebates/fees, which vary based on the trading signal's strength for the aggressive order. Thus, the broker sometimes pursues the passive strategy to capture rebates instead of minimizing shortfall.

We contribute to this literature along a number of dimensions. First, we identify several retail brokerages whose order routing decisions appear consistent with the objective of maximizing rebates and examine whether this type of order routing disadvantages limit order traders. In addition to replicating the analysis of Sofianos et al. (2010), we use both proprietary and publicly available data to examine these issues in more general settings. We also examine whether the conclusions of Sofianos et al. (2010) change when fees/rebates are passed through to limit order traders. We provide the first empirical evidence as to the relationship between take fees and multiple dimensions of limit order execution quality.

III. Broker routing decisions.

Market makers profit by selectively purchasing and executing market orders and marketable limit orders from multiple brokers. One constraint on a market maker's ability to interact with purchased order flow is FINRA Rule 5320, which states that a market maker holding a nonmarketable limit order "is prohibited from trading that security on the same side of the market for its own account at a price that would satisfy the customer order."[9] Thus, since market makers pay for orders only when they can trade against them, brokers can obtain higher order flow payments by segregating their marketable and nonmarketable orders. One such strategy is to sell marketable orders to market makers and to route nonmarketable limit orders to venues offering high make rebates. If all brokers routed orders in this fashion, market makers could potentially interact with all of the brokers' marketable orders. [10]

These incentives lead to the question of whether the decision to route nonmarketable limit orders to exchanges with high rebates influences limit order execution quality. As noted earlier, theory suggests that limit order execution quality may be inversely related to the level of maker rebates. If so, a broker routing all of its nonmarketable limit orders to an exchange with the highest maker rebate might not fulfill its obligation to obtain best execution for customer orders. In this section, we present evidence that some U.S. retail brokerages make order routing decisions that appear designed to capture rebates. How these routing decisions affect limit order execution quality is addressed in subsequent sections of the paper.

We begin by identifying brokers appearing in *Barron's* or *Smart Money's* 2012 broker surveys. We next use broker websites to collect Rule 606 reports for the fourth quarter of 2012.[11] Rule 606 requires that brokers reveal the fraction of their orders that were non-directed (i.e., the customer did not choose the routing destination) and to report the percentage of non-directed orders that were market orders, limit orders, and other orders. Furthermore, for each of its top ten routing destinations and for any venue receiving at least 5% of its non-directed orders, Rule 606 requires brokers to report the percentage of market, limit, and other orders routed to that venue. The SEC subsequently clarified this requirement, stating that a broker "is not required to identify execution venues that received less than 5% of non-directed orders" as long as the broker "has identified the top execution venues that in the aggregate

[9] See FINRA's May 2011 Regulatory Notice 11-24.
[10] The former head of order routing for the retail brokerage Ameritrade stated that by routing their market orders to wholesalers and their nonmarketable limit orders to exchanges, Ameritrade could increase revenue. See "Wall Street's 'Most Sophisticated Order Sender'" in the September 2010 issue of *Traders Magazine*.
[11] See Weber (2003) for a time-series analysis of order routing behavior.

received at least 90%" of its total non-directed orders."[12] Consequently, Rule 606 filings may not provide a complete description of a broker's order routing decisions.

We summarize the brokers' self-reported routing decisions during the last quarter of 2012 in Table 1, with results for NYSE-listed securities in Panel A and results for Nasdaq-listed securities in Panel B. For brevity, we focus our discussion on the results for NYSE-listed securities. The results for Nasdaq-listed securities are similar. The brokers in our sample utilize six 'traditional' make-take fee venues. For each of these venues, and for the three venues utilizing 'inverted' fee schedules, the table lists the range of published rebates and fees obtained from *Traders Magazine* and the SEC.[13] The three venues that charge SEC Rule 610's maximum permissible take fee of $0.30 per hundred shares as their base fee are DirectEdge X (EDGX), the Nasdaq Stock Market (NDAQ), and the NYSE-Arca Exchange (ARCA). Of these venues, EDGX offered the highest published liquidity rebate ($0.32 per hundred shares). In contrast, the Nasdaq OMX BX (BX) uses an inverted fee schedule, paying liquidity demanders $0.14 per hundred shares and charging liquidity suppliers $0.15 to $0.18 per hundred shares.

[Insert Table I about here.]

Examining routing decisions, we find that nine of the ten brokers route at least a portion of their orders to market makers that offer payment for marketable orders. Charles Schwab, Morgan Stanley, Edward Jones, Just2Trade, and LowTrade route *all* non-directed orders to market makers that purchase order flow (although LowTrade and Just2Trade indicate that they do not accept payment for order flow, Edward Jones reports "no material economic relationship" with the market makers, and Morgan Stanley reveals no payment for order flow). By routing all of their orders to market makers, these brokers ensure that their limit orders can trade against the purchaser's marketable orders. Whether or not this is preferable to routing limit orders in a different fashion is an empirical question that we cannot address with our data.

[12] See the SEC's Division of Market Regulation: Staff Legal Bulletin No. 13A, "Frequently Asked Questions About Rule 11Ac1-6," which can be found at http://www.sec.gov/interps/legal/mrslb13a.htm#P81_9811.
[13] Actual rates can vary from those published based on various factors, including the amount and type of orders routed.

The five brokers that do not delegate the handing of customer limit orders to market makers route their limit orders to one or more of the 'traditional' exchanges. Of these, Interactive Brokers (IB) was the only broker to utilize more than one exchange. In its Rule 606 filing, IB states that its smart routing system "continually scans competing market centers and automatically seeks to route orders to the best market, taking into account factors such as quote size, quote price, liquidity-taker costs, liquidity-provider rebates and the availability of automatic order execution." Depending on the quality of its order router, IB's Rule 606 filing could provide an example of 'optimized' order routing. As documented in Panel A of Table I, IB routed 30% of its limit orders to two exchanges that charged the maximum permissible liquidity fee and routed 47% of its limit orders to the 'traditional' exchange with the lowest liquidity fee.

Four sample brokers, Ameritrade, E*Trade, Fidelity, and Scottrade, route orders in a way that suggests a focus on liquidity rebates. Three of these brokers sell the vast majority of their market orders to market makers and route their limit orders either to market makers or to the venue offering the most lucrative published liquidity rebates, EDGX. Ameritrade routes 49% of its limit orders to EDGX and 45% to market makers, E*Trade routes 46% of its limit orders to EDGX and 51% to market makers, and Fidelity routes 57% of its limit orders to EDGX and 28% to market makers. Notably, while Ameritrade's and E*Trade's reported routing percentages sum to 94% and 97%, respectively, Fidelity's percentages sum to only 85%. This implies that the remaining 15% of Fidelity's limit orders were routed to venues that received less than 5% of Fidelity's non-directed orders in the fourth quarter of 2012. Thus, while Fidelity's routing appears consistent with maximizing liquidity rebates, without better (non-public) data we cannot rule out the possibility that the remaining 15% of Fidelity's limit orders were routed strategically across multiple venues to optimize execution quality.[14] Finally, Scottrade routed 28% of its limit orders to EDGX, 51% to the Lava ATS (a venue with high rebates), and the remainder to market makers. Since the Rule 606 data do not distinguish between marketable and non-marketable limit orders, we cannot separate routing decisions based on marketability. However, given that these brokers choose to

[14]Fidelity's Rule 606 filing for not held institutional orders for fewer than 10,000 shares reveals a limit order routing strategy that is very different from its retail limit order routing strategy. In the fourth quarter of 2012, Fidelity routed 23% of its institutional limit orders to market makers, 35% to the NYSE (take fee of $0.23), 17% to the BZX (take fee of $0.29), 9% to NDAQ (take fee of $0.30) and 8% to EDGX (take fee of $0.30).

sell their market orders to market makers rather than route them to venues with take fees, it is likely that the majority of limit orders routed by these brokers to market makers are also marketable and the majority of their limit orders routed to EDGX and Lava are nonmarketable.

The evidence presented in Table I suggests that there is heterogeneity in order routing decisions. The routing of five brokerages suggests that they delegate the handling of their limit orders to market makers. Interactive Brokers' routing suggests that it found the NYSE, the venue with the lowest non-negative make rebate and the smallest positive take fee, to be an attractive venue for its limit orders. However, for four of the brokerages we examine, it appears that fees are a significant determinant in where orders are routed. In particular, it appears that these brokers route 100% of their nonmarketable limit orders to the venue offering the highest rebate.

IV. Make-take fees and limit order execution quality: Proprietary order data.

A. Data.

To begin our examination of limit order execution quality, we obtain order data from a major broker-dealer's smart order routing system for October and November 2012. The data include 28,627,467 orders, including orders from the broker-dealer's algorithmic trading system and orders entered directly by customers.[15]

Each record contains data about the order, the destination venue, a time-stamped order history, and information about the order outcome. The order is defined by the ticker symbol, date, order side (buy, sell, and short sell), order size, the amount of that size to be displayed, time in force (all orders are day orders), order type (market, market on open, market on close, limit, limit or better, limit on open, and limit on close), and limit price if applicable. Events in the order's life are time-stamped in microseconds (μs - millionths of a second). Recorded events are order submission time and, if applicable, reject time, first fill time, last fill time, replace time, and cancel time. Should an order receive a full or partial fill, the order history also contains the quantity of shares done and the average fill price.

[15]We treat each order routed to a venue as an independent order. Although it is likely that many of these orders were generated by the same 'parent' order, our data do not allow us to link parent and child orders.

We focus on orders arriving during regular market hours (9:30am through 4:00pm) and, for filled orders, filling by 4:02pm. These restrictions reduce the sample size to 28,456,733 orders (99.4% of the original sample). The data appear to be very high quality. Checking for obvious data errors (e.g., outcome time before order time, negative size or quantity done, or quantity done exceeding order size), we exclude only 29 orders. Because we examine limit orders, we remove the 125,565 (0.4% of the remaining sample) orders that are not simple limit orders. We also discard 11,988 orders with an average trade price worse (higher for buy orders or lower for sell orders) than the limit price.

We use Daily TAQ data to match quote data to order arrival time using the Holden and Jacobsen (2013) corrections. We subjectively discard 97,637 orders with limit prices more than ten percent from the quoted spread midpoint (ask price plus bid price divided by two). The resulting sample includes 28,221,514 limit orders involving 6,594 unique ticker symbols.

[Insert Table II about here.]

Table II provides descriptive statistics for order characteristics. From Panel A, we see that the average order arrives just prior to 1:00pm. The open and close are quite busy; five percent of our orders are placed in the first ten minutes of the trading day and another five percent arrive in the final two minutes. Typical order size is small (mean of 635 shares), but we have some large orders (the 95th percentile is 2,100 shares). We also have considerable variation on share price. The mean display size is 85 shares, only about 13% of mean order size, and the majority of orders are fully non-displayed. Panel B provides additional detail on display choice. Overall, about 63% of orders are non-displayed, 28% are fully displayed, and 9% are partially displayed.[16] As shown in Panel C of Table II, about 52% of the broker's limit orders are buy orders, 27% are sell orders and 21% are short sell orders.

Finally, Panel D of Table II describes where our sample orders were routed. The broker-dealer uses seven destination venues; the New York Stock Exchange (NYSE), ARCA, BATS Z Exchange (BZX), Nasdaq OMX BX (BX), DirectEdge A (EDGA), EDGX, and NDAQ. EDGX received the most displayed orders (29.7%), while NDAQ received the most hidden orders (39.8%). Although not perfect,

[16] Unless stated otherwise, we refer to an order as displayed if at least part of the order is displayed.

there is a positive correlation between an exchange's likelihood of receiving an order and its rebate. Overall, five (four) venues received at least 5% of our data provider's displayed (hidden) limit orders. Panel D also shows that this broker routed relatively few orders to inverted venues.

As retail limit orders are typically displayed and our primary purpose is to examine the relationship between broker order routing practices and limit order execution quality for retail orders, we restrict the sample in the remainder of our order-data analysis to orders that are at least partially displayed. This restriction reduces our sample size to 10,392,406 orders across 5,143 stock symbols. In Table III, we describe order outcomes for these displayed orders. There are four explicit possibilities coded in the data: cancel, fill, replace and reject (the venue rejects the order). As all orders are day orders, we assume that any order not coded with one of these four outcomes expires at the end of the day. A given order might have more than one outcome. For example, it is common to have an order fill partially and then have the remainder cancel or expire. Just over 47% of the orders receive at least a partial fill and the average sample order executes 145 shares (around 45% of average order size). Of orders with at least a partial fill, almost all fill completely. The average (median) time for a filled order to trade is 76 (11.5) seconds. For orders with multiple executions, the average (median) time until the last fill is 118 (19) seconds. A majority of orders are cancelled. Ignoring the 28,964 orders that expire at the end of the day, the mean (median) time to cancel is 180 (31) seconds. Very few orders are replaced or rejected by the destination venue.

[Insert Table III about here.]

Panel B of Table III provides a bit more detail on order outcomes conditional on whether limit orders are unfilled, partially filled, or completely filled. Of the 5,500,313 orders receiving no fills, over 98% are cancelled, and 0.8% expire. Over 44% of our sample limit orders fill completely and another 3% fill partially. Of the 4,892,093 orders receiving at least a partial fill, about 70% have a single execution. There are a non-trivial number of completely filled orders with a cancellation or replacement time stamp. These apparently are instances where cancellation/replacement notice is too late to be effective. The majority of partially filled orders are cancelled.

We use TAQ to determine the positioning of each buy (sell) order's limit price relative to the National Best Bid (Offer). Following Harris (2003), we assign each order to one of four mutually exclusive categories: marketable, inside-the-quote, at-the-quote, and behind-the-quote. A limit order to buy (sell) shares at a price that is greater than or equal to (less than or equal to) the National Best Offer (Bid) is marketable. Inside-the-quote limit orders have limit prices that improve prevailing quotes but are not marketable. A limit order to buy (sell) shares at the National Best Bid (Offer) is at-the-quote. A limit order seeking to buy (sell) shares at a price that is lower (higher) than the prevailing quotes is behind-the-quote.[17] Frequencies related to order aggressiveness are described in Table IV.

[Insert Table IV about here.]

The statistics in Panel A suggest that there is little difference in the aggressiveness of buy versus sell limit orders. Approximately 17% of the limit orders establish a new National Best Bid or Offer while another 63% join the NBBO. Panel B of Table IV describes order aggressiveness conditional on destination venue. Overall, the most popular order aggressiveness choice regardless of venue is an at-the-quote order (except for the NYSE, which is a popular destination for behind-the-quote orders). There is a clear difference in the types of limit orders sent to traditional versus inverted venues. Consistent with the idea that the inverted venues can be used to gain priority at a price, over 99% of the displayed orders routed to the inverted venues are at-the-quote. Conversely, rather than joining the queue at a low fee venue, quote improving orders are much more frequently routed to the traditional venues that offer high liquidity rebates.

B. Univariate Analysis.

We posit that the fee structures used by trading venues influence limit order execution quality. Specifically, the higher the take fee (and, correspondingly, the higher the make rebate), the less attractive it is for liquidity demanders to use the venue. Thus, we expect limit order execution quality to be inversely related to a venue's take fees. As noted earlier, during our sample period, ARCA, EDGX, and

[17] Given the different time stamp precisions (ms for TAQ and μs for the proprietary data), we anticipate that our categorization of limit orders is imperfect.

NDAQ charged a take fee of $0.30 per hundred shares, BATS charged $0.29 per hundred, and the NYSE charged $0.23 per hundred. In contrast, BX and EDGA used inverted fee schedules and paid a rebate to liquidity demanders.

Table V provides several univariate execution-quality statistics for displayed at-the-quote limit orders by venue. We focus on at-the-quote orders as it is difficult to control for the pricing aggressiveness of behind- or inside-the-quote limit orders in our univariate analysis. The measures we provide include fill rate, time to execution, realized spread, and good fill ratio. Fill rates are order weighted, where an order is considered filled if any part of the order fills. Execution speeds are in seconds from the order submission time until first fill time, conditional on an order filling. Realized spreads proxy for the short-term gross revenue earned by liquidity providers. Thus, for executed limit buy orders, the realized spread is twice the difference between the execution price (i.e., the order's limit price) and the midpoint of the bid-ask spread prevailing five minutes after the order executes. For limit sell orders, we multiply by -1. If limit orders on venues with low take fees routinely execute prior to those on venues with high take fees, we expect to find that both fill rates and realized spreads are higher on venues with lower take fees. Introduced by Sofianos and Yousefi (2010), the good fill ratio classifies limit order executions relative to the sign of the realized spread. A limit order execution is classified as a good fill if the order's realized spread is positive (e.g., prices move in the limit order trader's favor after the limit order executes).

[Insert Table V about here.]

Focusing on fill rates for displayed at-the-quote orders, we find that orders on the BX are most frequently filled and orders on the high take venues (EDGX, NDAQ and ARCA) are least frequently filled. Thus, fill rates are negatively correlated with take fees, as expected. Likewise, the mean realized spread and the good fill ratio for displayed orders are negatively correlated with take fees. Only the two inverted venues have positive mean realized spreads.

C. Multivariate Analysis.

It is unlikely that our sample limit orders are distributed randomly across trading venues. Presumably, limit order routing decisions are made conditional on several factors including stock-specific characteristics, market conditions, and liquidity fees. As a result, it is potentially misleading to draw conclusions from unconditional statistics. To address this concern, we conduct multivariate analyses to investigate the determinants of whether a given order fills and, for filled orders, the time required to fill. From the perspective of a limit order trader, we expect the likelihood of a fill to be of primary importance.

We estimate a probit model to examine the likelihood of a fill, where *Fill* equals one if any part of the order fills and zero otherwise. We estimate an OLS regression to estimate *Time-to-Execution,* defined as the number of seconds between Order Time and First Fill Time conditional on at least a partial fill. We conjecture that the relevant independent variables are order characteristics, stock attributes, time of day, and venue traits. The specifications are presented in equations (1) and (2) below:

$$\begin{aligned} Fill &= \beta_0 + \beta_1 \cdot Sell + \beta_2 \cdot ShortSell + \beta_3 \cdot OrderSize + \beta_4 \cdot Moneyness + \beta_5 \cdot Log(Volume) \\ &+ \beta_6 \cdot Price + \beta_7 \cdot Volatility + \cdot \beta_8 \cdot MeanResponseTime + \beta_9 \cdot TakeFee + \sum_{i=2}^{13} \delta_i Period_i + \varepsilon \end{aligned} \quad (1)$$

and

$$\begin{aligned} TimeToExecution &= \beta_0 + \beta_1 \cdot Sell + \beta_2 \cdot ShortSell + \beta_3 \cdot OrderSize + \beta_4 \cdot Moneyness + \beta_5 \cdot Log(Volume) \\ &+ \beta_6 \cdot Price + \beta_7 \cdot Volatility + \beta_8 \cdot MeanResponseTime + \beta_9 \cdot TakeFee + \sum_{i=2}^{13} \delta_i Period_i + \varepsilon \end{aligned} \quad (2)$$

where *Sell* equals one if the order side is "Sell" and zero otherwise; *Short Sell* equals one if the order side is "Short Sell" and zero otherwise; *Order Size* is the number of shares specified in the order divided by the relevant quoted size; *Moneyness* equals 100*((Limit Price/Ask Price) – 1) for sell orders and 100*((Bid Price/Limit Price) – 1) for buy orders; *Volume* equals the stock's average daily share volume during the sample period; *Stock Price* equals the stock's mean closing price during the sample period; *Volatility* equals the stock's average daily squared return during the sample period; *Mean Response Time* for each venue equals the average across all canceled trades on that venue of the difference between Out Time from the venue and Cancel Time from the broker[18]; *Take Fee* equals the venue's take fee during the sample period in dollars per hundred shares; and $Period_2$-$Period_{13}$ are dummy variables identifying each

[18] Response time is intended to proxy for the technological connectivity between the broker and the exchange.

of the 30-minute periods from 10:00 a.m. to 4:00 p.m.

[Insert Table VI about here.]

We present the regression results in Table VI. Given the sample size, all coefficients are statistically significant at beyond the .0001 level. For the probit model, we report both coefficient estimates and the associated marginal probabilities calculated at the mean values of all explanatory variables. Sell (short sell) orders are more (less) likely to fill than are buy orders by about two percentage points. Consistent with the univariate results, more aggressively priced orders are more likely to fill. Although not shown, coefficients on the time period dummies suggest that orders submitted later in the trading day are more likely to fill, with the effect being particularly pronounced during the last 30 minutes of trading. Orders in stocks with higher prices, greater volumes and higher volatilities also are more likely to fill. For a one standard deviation increase in price, volume, and volatility, the likelihood of filling rises by 3.00, 3.46, and 0.45 percentage points, respectively. Orders routed to venues with faster links to the broker are slightly more likely to fill. Of particular interest is the association between take fees and the likelihood of filling. For the displayed orders used in this analysis, the higher the take fee, the less likely the order is to fill. Using the largest possible fee difference (ARCA/EDGX/NDAQ vs. BX), the probit suggest a 5.9% increase in fill likelihood.

Fill times are examined in the third column of Table VI.[19] Sell orders fill slower and short sell orders fill faster than buy orders. Smaller orders and more aggressively priced orders fill faster than large, passive orders. Stocks with higher share prices and greater trading volumes have faster fills. Fills also occur more quickly early and late in the day, with the effect most pronounced during the last 30 minutes of trading (results not reported). As expected, venues with faster connections to the broker fill orders in less time than those with slower connections. Finally, focusing on take fees, we find that orders sent to venues with higher take fees fill more slowly.

Overall, the multivariate results support the hypothesis that limit order execution quality is related

[19] Because Time-to-Execution is non-negative, we repeated the regression using a censored regression model. The results are robust to this alternative regression model.

to the destination venue's take fee. Specifically, we find that displayed orders on venues with high take fees fill less often than similar orders on venues with low take fees and, conditional on filling, fill more slowly. These results provide initial evidence that routing all limit orders to the exchange with the highest make rebate (and correspondingly high take fee) is not consistent with best execution.

D. Horseraces.

One potential concern with our results to this point is that we have not adequately controlled for the factors that affect the routing decision and execution outcomes. Our proprietary data allow another approach to examining differences in across-venue limit order execution quality while controlling for other factors. We find that pairs of identical orders from the broker's order routing system are frequently displayed concurrently on multiple venues. For each pair of identical orders, we begin a "horserace" at the time the orders first co-exist on different venues. We define the winner of the horserace as the venue filling the order first while the competing venue still holds the paired order. To shed light on the economic implications of winning a set of horseraces, we examine the percentage of limit order executions that produce positive realized spreads on each of the paired venues. Assuming that, at a given price, limit orders that execute first incur lower adverse selection costs, we expect a larger proportion of the 'identical' limit orders executed on the low fee venue to have a positive realized spreads. In other words, the low fee venue should have the higher good fill ratio.

To begin this analysis we sort our order data by order date, stock symbol, order side (buy or sell), limit price and, finally, order time using only displayed orders. We then identify orders that have the same order date, stock symbol, order side, and limit price, but different destination venues. We allow order times to differ, but require that the first order in the order-pair still be active when the second order in the order-pair is submitted. As an example, suppose that the first order in a pair is submitted at 10:01:00 a.m. and is first acted upon at 10:02:00 a.m. If the second order in the pair is submitted at, say 10:01:30 a.m., then the two orders overlapped for 30 seconds and are compared. By construction, these paired orders are associated with identical stock characteristics and market conditions, allowing us to attribute differences in execution outcomes to venue characteristics such as take fees. For a horserace to produce a winner, we require that: (1) at least one of the two orders fill (at least partially), and (2) both orders in the pair be outstanding at the time of the first fill. Should both orders fill, a venue wins if it fills the order at least 500 μs before the second order executes.[20] Should one order in the pair fill and the other be cancelled or replaced, the venue filling the order wins. If one order in the pair is rejected, replaced, or cancelled prior to its paired order filling, then we eliminate that pair from our sample. This allows us to focus on order pairs where the losing order retained an apparent trading interest at the time the competing order filled.

We summarize the results of the horseraces in Table VII. To emphasize the effects of fee structure, we aggregate results based on the difference in take fees between the two venues in a pair.[21] For example, the first row in Table VII reports results for all horseraces involving venues pairs with a fee difference of $0.44. These results include three venues pairs: ARCA vs. BX, EDGX vs. BX, and NDAQ vs. BX. As noted earlier, ARCA, EDGX, and NDAQ all have a take fee of $0.30 per hundred shares, while BX has a take fee of -$0.14 per hundred shares.

[Insert Table VII about here.]

For the venue-pairs with a $0.44 fee difference, we have 21,373 horserace observations. The high-fee venue (ARCA, EDGX, or NDAQ) fills about 74% of its orders in the pairs, the low-fee venue (BX) fills over 99%, and both orders fill in nearly 73% cases. More importantly, the low-fee venue in this comparison (BX) wins 77% of the horseraces and the high-fee venue wins less than 4%, with 19% of the horseraces classified as ties. The fact that the difference in the percentage of horseraces won by the high- and low-fee venues is greater than the difference in the respective fill rates suggests that the low-fee venue not only fills more orders than the high-fee venue but also executes orders more quickly when both venues fill the paired orders. Finally, the low-fee venue's good fill rate (60%) exceeds the good fill rate of the high-fee venue (52.8%). Thus, we conclude that the lower fee venue has better limit order execution quality, as we measure it, than the higher fee venue.

[20]Our data provider considers orders filled within 500 μs of one another to be ties. Our results are not sensitive to the exact definition of a tie.

[21]We report detailed horserace results by individual venue and conditional on which venue receives the first order in the Appendix. In each pairwise comparison, we find that receiving the first order of an order pair does not influence the outcomes of the horserace.

In each row of Table VII, we find similar results. The lower fee venue fills a greater percentage of the orders, wins a greater percentage of the horseraces, and has a higher fraction of good fills (i.e., less adverse selection) than the higher fee venue. Of interest is the relation between the fee differential and the advantage the low-fee venue enjoys relative to the high-fee venue. The difference in fill rates declines from nearly 26 percentage points when the fee difference is \$0.44 to only 6 percentage points when the fee difference is \$0.01. The difference in horserace winning percentage is over 73 percentage points when the fee difference is \$0.44 compared to 22 percentage points when the fee difference is \$0.01. Likewise the difference in the good fill ratio slips from 7 percentage points to 1.5 points as the fee differential declines. Although the relation is not monotonic, there is a clear positive association between differences limit order execution quality and differences in take fees. At the same time, the fraction of the order-pairs where both orders fill increases from nearly 73% to over 85% and the fraction of tied horseraces increases from 19% to nearly 50% as the fee difference declines from \$0.44 to \$0.01.

The last row of Table VII provides limited results for the horseraces involving venues with equal take fees. For these horseraces, almost 90% of sample paired orders execute and a majority fill (approximately) simultaneously. As a result, these orders have very similar levels of adverse selection. This contrasts sharply with order pairs on venues with large differences in take fees.

E. Caveats.

Overall, the results of the order data analysis are consistent with a strong negative relation between take fees and retail limit order execution quality. These findings suggest that the decision to route all limit orders to a single venue paying the maximum rebate (and, correspondingly charging the maximum take fee) is inconsistent with a broker's responsibility to obtain best execution. However, there are a few reasons why one might be concerned about the generalizability of our results. First, while the order data allow us to address several questions that cannot be addressed with publicly available trade data, the order data are from a single broker and the related executions comprise only 1.5% of average daily volume. Second, the order data do not span the thirteen U.S. stock venues that utilize the traditional or inverted make-take fee schedules. Specifically, our data provider uses inverted venues relatively sparingly. To address these concerns, we next provide an analysis based on the NYSE's TAQ database. These data allow us to more fully examine the types of stocks/situations in which the routing of limit orders to venues with relatively high take fees is most (least) harmful to limit order execution quality.

V. Make-take fees and limit order execution quality: NYSE TAQ data.

The NYSE's monthly TAQ database contains a time-stamped recording of every trade and every instance that a trading venue's quoted bid or offer changes. Since exchanges today predominately operate as electronic limit order books, marketable orders typically execute against standing limit orders.[22] As a result, TAQ data are well suited to making inferences regarding the execution quality of *executed* limit orders. In particular, TAQ data can be used to determine whether fees influence where marketable orders (as evidenced by trades) execute when multiple venues are simultaneously posting the best quote and the associated execution quality of those trades.[23] Based on the analysis in the prior section, we expect venues with lower take fees to receive a larger share of marketable orders and to provide superior execution quality when all venues display the best quote.

A. Summary Statistics.

From TAQ, we collect all trade and quote data for common stocks listed on the NYSE and Nasdaq during October and November 2012. After eliminating stocks that trade below $1 during this period, the resulting sample includes 3,091 stocks. For each stock, we determine the best bid and offer for each trading venue and the resulting National Best Bid and Offer (NBBO) at each point in time during the trading day.[24] We then employ the Lee-Ready algorithm to determine whether each trade is initiated by a buyer or seller. As we are interested in differences in limit order execution quality across exchanges,

[22] On venues such as NDAQ, NSX, and the NYSE, some of the reported trades may be the result of a liquidity demander interacting with a dealer's non-displayed trading interest. For example, internalized trades may be reported to the NSX and to NDAQ.

[23] Bessembinder (2003) examines quote-based competition for orders in NYSE-listed securities in June 2000. During this time period, virtually no trading volume in NYSE-listed securities was executed on venues offering make-take pricing. Among other things, he finds that venues realize increased market share when their quote has time priority and when the depth at their quote is large.

[24] Standard screens are applied to the trade and quote data. See Corwin and Schultz (2012) for a complete description of these screens.

we eliminate sweep trades, which are designed to trade against all orders posted at the best quote.[25] Finally, we eliminate the Nasdaq TRF from our analysis since most of its trades are internalized.

Table VIII presents summary statistics for time at the inside quote, market share, and realized spreads by trading venue, with results for NYSE-listed stocks in Panel A and results for Nasdaq-listed stocks in Panel B. Venues are ordered based on the take fee/rebate for their least preferred customers. The first four rows of each panel describe the percentage of the trading day that each venue's quotes are equal to the NBB, the NBO, either side of the NBBO, and both sides of the NBBO, respectively. Despite the fact that it executes less than 15% of all trades during our sample period, the NYSE is at either the NBB or the NBO an average of 90.9% of the trading day during October and November 2012. In comparison, Blume and Goldstein (1997) document that the NYSE is at either the NBB or the NBO an average of 99.9% of the trading day and executes 83% of the trades in NYSE-listed securities during the twelve months ending in June 1995. Four other traditional exchanges are at one side of the NBBO at least half of the trading day: ARCA, NDAQ, BZX, and EDGX. The percentage of time spent by inverted venues at either the NBB or the NBO ranges from a low of 24.7% for EDGA to a high of 42.9% for BYX.

[Insert Table VIII about here.]

The next two rows of Panel A describe the percentage of non-sweep trades and non-sweep share volume executed by each trading venue. Five traditional venues have trade and volume market shares of at least 5% in NYSE-listed securities: the NYSE, ARCA, NDAQ, BZX, and EDGX. The remaining traditional venues and the CBSX all have market shares of less than 1% and are thus excluded from the analysis to follow.[26] Market shares on the relevant inverted venues range from 2.5% (1.9%) of trades (volume) on EDGA to 4.4% (2.9%) of trades (volume) on BYX. Overall, the venues with the larger market shares in NYSE-listed trades are also the venues whose quotes are most frequently at the NBBO.

The final three rows of Panel A present unconditional averages for both dollar and percentage

[25] Regulation NMS allows an investor to walk up (down) a venue's limit order book if the investor first sends an intermarket sweep order (ISO) to each venue whose bid (offer) is equal to or better than the venue's best bid (offer). The execution quality of at-the-quote limit orders that provide liquidity to ISOs is identical since ISOs consume all of the liquidity at a price point. For an in-depth analysis of ISOs, see Chakravarty et al. (2012).

[26] The relevant traditional fee venues for the remainder of the analysis are ARCA, BZX, EDGX, NDAQ, and NYSE. The relevant inverted venues are BX, BYX, and EDGA.

realized spreads. As noted earlier, the realized spread provides an estimate of the gross revenue earned by liquidity providers. We find that both dollar and percentage average realized spreads are generally decreasing in take fees. The BX, with a take rebate of $0.14 per hundred, has an average realized spread of $0.0065. In contrast, the three venues charging the maximum permissible take fee have average realized spreads ranging between -$0.0035 and -$0.0060. In all cases, average realized spreads are negative on the traditional venues and positive on the inverted venues. For executed limit orders in NYSE-listed securities, these results suggest that limit order execution quality is decreasing in the size of the take fee. More important, of the eight venues with at least one percent market share, liquidity providers earn the lowest realized spreads on EDGX. This again suggests that routing all limit orders to the single venue offering the most aggressive rebates (and charging the maximum take fee) may be inconsistent with the pursuit of best execution.

We present results for Nasdaq-listed stocks in Panel B. Again, we focus our discussion on those venues earning a market share of at least one percent. Consistent with the results for NYSE-listed securities, the three venues charging the maximum take fee are most frequently at either the NBB or the NBO, while the three inverted venues spend the least time at the best quote. In addition, the traditional venues execute approximately half of non-sweep trades, while the inverted venues execute just over 10%. As is the case in NYSE-listed stocks, average realized spreads for trades in Nasdaq stocks are positive on the inverted venues and negative on the traditional venues. BX again has the highest average realized spreads and EDGX has the lowest.

B. Across-venue quality of limit order executions when all venues are at the inside quote.

When multiple venues are at the best quote, marketable orders can choose where to obtain liquidity. It is in these situations that we expect the limit order routing decision to be particularly important. In this section, we examine whether fees influence which venue receives a marketable order (as evidenced by trades) and the resulting limit order execution quality when all relevant venues are at the best quote. We find that 11.8% (13.7%) of all non-sweep trades in NYSE-listed (Nasdaq-listed) stocks take place at either the NBB or NBO when all eight (seven) relevant venues are at the inside quote. As noted in the bottom two rows of Table IX, this restricted sample of trades involve 1,033 NYSE-listed stocks and 1,072 Nasdaq-listed stocks.

For trades executed at the NBB (NBO) when all relevant venues are at the NBB (NBO), we compute the following statistics: each venue's market share of trades, each venue's average depth at the relevant quote when any venue executes a trade at the quote, each venue's average depth at the relevant quote when it executes a trade at the quote, each venue's average realized spread, each venue's average realized spread net of the make rebate or fee, and each venue's good fill ratio. Assuming the quotes on each venue represent limit order trading interest, these statistics allow us to evaluate execution quality for executed at-the-quote limit orders.[27]

[Insert Table IX about here.]

The results for both NYSE and Nasdaq-listed stock are presented in Table IX. When we restrict attention to trades that execute at the quote when all venues are simultaneously posting the best quote, the market shares of the inverted venues increase and the market shares of the traditional venues fall. For example, while BX's unconditional market share of all non-sweep trades in NYSE-listed stocks is 3.0% (see Table VIII), it climbs to over 9% in Table IX. Indeed, for NYSE-listed stocks, the aggregate market share of trades executed by the three inverted venues increases from an unconditional 9.9% to 23.5% when we restrict the sample of trades. In part, this change in market share may reflect the market conditions that result in all venues being at the inside quote. However, the results are also consistent with Cardella et al. (2012), who find that fees influence the routing of marketable orders.

The depth results in Table IX show that the inverted (traditional) venues tend to have more (less) depth when they execute at-the-quote trades than when at-the-quote trades execute on other venues. Overall, for both NYSE and Nasdaq-listed stocks, average depths at the inside quote on traditional venues are two to three times the size of the average depths on the inverted exchanges. Thus, unless the market order arrival rate is more intense on the traditional venues, which does not generally appear to be the case,

[27]Our data do not allow us to determine the original placement of these limit orders relative to the quotes. It seems likely, however, that a nontrivial percentage of at-the-quote limit orders began their lives as behind-the-quote limit orders.

limit order traders face longer wait times on the traditional exchanges than on the inverted exchanges.

A comparison of the realized spreads in Table IX with those presented in Table VIII reveals that restricting our analysis to at-the-quote trades executed when all venues are at the inside quote increases the difference in realized spreads between the traditional and inverted venues. For NYSE-listed stocks, the across-venue range in average realized spreads increases from 6.4 bps when we examine all non-sweep trades to 9.2 bps when we require all venues to be at the inside quote. For Nasdaq-listed stocks, the range increases from 9.5 bps to 11.8 bps. This suggests that when prices become locally less volatile, as evidenced by all venues being at the best quote, order routing has a greater impact on the quality of limit order executions.

While the results generally support a negative relationship between take fees and limit order execution quality, this finding does not hold for trades executed on the NYSE. When we restrict attention to trades executed when all venues are at the inside quote, we find higher average realized spreads on the NYSE than on all other traditional venues and one inverted venues (EDGA). In fact, the NYSE is the only traditional venue that exhibits positive average realized spreads and a good fill ratio greater than 50% for at-the-quote trades. The results for NYSE executions highlight the fact that routing decisions and execution quality may be driven by many factors other than take fees. However, it is also important to note that the NYSE charges a take fee of $0.23 per hundred shares compared to $0.29 or $0.30 per hundred shares on the other traditional venues, making it the lowest-fee option by a significant margin for participants that choose to utilize only traditional fee venues.[28]

For brokerages such as Interactive Brokers that pass fees/rebates on to their customers, the realized spread net of the make fee/rebate may be a more appropriate measure of execution quality for executed limit orders. We therefore present results based on net realized spread, defined for inverted venues based on the highest make fee charged to non-market makers and for traditional venues based on the highest make rebate available to non-market makers. In general, the conclusions based on net realized

[28]While we cannot determine which, if any, liquidity demanders are not connected to the inverted venues, we can provide illustrative evidence based on participation on the various Nasdaq exchanges. An examination of market participants with memberships on Nasdaq as of February 27, 2014 reveals that of the 341 members of NDAQ (based on unique member names), only 75 are members of BX. In contrast, every member of BX is also a member of NDAQ.

spread are similar to those based on the realized spread before fees, though average net realized spreads in Nasdaq-listed stocks are close to zero on BZX and EDGX. The three inverted venues provide positive net realized spreads for at-the-quote limit order executions in both NYSE and Nasdaq-listed stocks. In addition, net realized spreads for at-the-quote trades in NYSE-listed stocks are also positive for trades executed on the NYSE. In fact, once the differential make rebates/fees on the various exchanges are taken into account, the NYSE offers executed at-the-quote limit orders the best executions.

If fees were the only determinant of where marketable orders are routed, we would expect the BX (with the largest take rebate) to receive 100% of marketable orders when all venues are at the inside. However, other factors likely influence the routing of marketable orders. For example, a liquidity demander may route her order to a venue with a relatively high take fee if there is a greater possibility of price improvement or less execution price risk at the limit price. In untabulated results, we find that over 99% of the trades executed at the quote when all venues are at the inside quote occur when the width of the NBBO is equal to $0.01. This suggests that the expectation of price improvement is not a primary factor in determining which venue executes a trade in this sample. To minimize differences in execution price risk across venues, we repeat the analysis for at-the-quote trades executed when each venue is both at the inside quote and quoting depth of at least 2,000 shares (results not reported). For at-the-quote trades in both NYSE and Nasdaq-listed stocks, the difference between good fill ratios and average realized spreads on the inverted and the traditional venues (with the exception of the NYSE) becomes more pronounced when we require each venue to have a quoted depth of at least 2,000 shares. Again, however, the NYSE dominates both the inverted and traditional venues for at-the quote trades in NYSE-listed stocks, offering the largest average realized spread and net realized spread.

Overall, the results in Table IX suggest there is a nearly monotonic relationship between take fees and execution quality for at-the-quote limit order executions when all venues are at the inside quote. In particular, we find that inverted venues generally have the highest average realized spreads and traditional venues have the lowest. The one exception to this general pattern is the NYSE, which charges a take fee of $0.23 per hundred shares. The NYSE is the only traditional fee venue with a positive average realized spread and a good fill ratio exceeding 50%. As noted above, this may reflect that the NYSE has the lowest take fee among the traditional venues or that execution quality is driven by factors other than fees.

C. Multivariate analysis of take fees and realized spreads for at-the-quote trades.

While the analysis in the prior section suggests that limit order execution quality is negatively related to take fees, that analysis does not control for stock characteristics and market conditions that may affect execution quality. In this section, we use pooled regressions to analyze the relationship between execution quality and take fees after controlling for other factors.

We again focus on trades that take place at the quotes, providing separate results for all at-the-quote trades and at-the-quote trades that occur when all relevant venues are simultaneously at the inside quote. The dependent variable is the realized spread. In each specification, we include intraday time period dummies and controls for average daily volume, trade price, trade size, and daily volatility, as measured by the log daily high-low price ratio. We expect adverse selection risk to be lower for smaller trades in more active stocks.

The main variables of interest are related to the take fee. We define three variables related to the take fee on the venue that executes the trade. The first is a continuous variable defined as the venue's take fee in dollars per hundred shares (Take Fee). The second is a dummy variable equal to one if the venue uses an inverted fee schedule and zero otherwise (Inverted). Finally, we define a series of dummy variables for each level of take fee, where the dummy variable for BX (Take Fee = -$0.14) is excluded. We expect a negative coefficient on the continuous take fee variable and a positive coefficient on the inverted dummy variable. In addition, we expect coefficients on the take fee level dummy variables to be decreasing in the magnitude of the take fee.

In addition to the take fee variables defined above, we define three take fee interaction terms. Following Harris (2013), we expect the impact of take fees on realized spreads to be most pronounced for low-priced stocks and when prices are less volatile. To identify low-priced stocks, we define a dummy variable equal to one if the trade price is less than six dollars (Low_Price). To identify situations in which prices are expected to be locally less volatile, we define a dummy variable equal to one if aggregate depth at the inside quotes is greater than 20,000 shares (High_Depth). We then interact the continuous Take Fee variable with the low price dummy and the high depth dummy. Finally, we expect the impact of a higher take fee to be reduced if a venue has the lowest take fee among venues that are currently offering the best quote. Thus, in the models for all at-the-quote trades, we include an interaction between Take Fee and a dummy variable equal to one if the venue executing the trade has the lowest take among all venues at the inside quote (Min_Fee).[29] We expect the coefficient on this interaction term to be positive.

[Insert Table X about here.]

The regression results are presented in Table X, with results for NYSE-listed stocks in Panel A and results for Nasdaq-listed stocks in Panel B. Regardless of the number of venues at the relevant quote or the exact specification of the regression, realized spreads for both NYSE and Nasdaq-listed stocks tend to be higher for trades that are smaller, in lower priced stocks, in more actively traded securities, and in stocks with lower daily volatility.

Turning to the take fee variables, we find that for both NYSE- and Nasdaq-listed securities, realized spreads are decreasing in take fee. This result holds regardless of whether or not we require all venues to be at the inside quote. These findings confirm our earlier results and show that the negative relation between take fees and execution quality holds after controlling for stock characteristics and market conditions. In the second specification in each set of regressions, we include the three take fee interaction terms. The coefficient on the minimum fee interaction is positive. This suggest that, conditional on the size of the take fee, realized spreads are higher when the executing venue has the lowest take fee of the venues at the relevant quote. In other words, the impact of higher take fees is reduced when the venue has the lowest take fee among venues at the inside quotes. In all specifications, the coefficients on the low price and high depth interaction terms are negative. As expected, this suggests that the negative relation between take fees and execution quality is more pronounced for low priced stocks and in situations where price volatility is low.

[29] When we impose the restriction that all venues are simultaneously at the inside quote, the Min_Fee venue is always BX. As a result, we do not include the Min_Fee interaction term in the model with all venues at the inside.

In the final column of each set of regressions, we present results from the model that includes dummy variables for each level of take fee. Again, the dummy variable for BX is excluded, so the coefficients on the remaining dummy variables can be interpreted as differences relative to the venue with the lowest (most negative) take fee. For both NYSE- and Nasdaq-listed securities, we find that the low fee venue (BX) generates realized spreads that are significantly higher than all other venues. Indeed, with the exception of the -$0.04 and the -$0.02 fee regimes, the results point to a near monotonic negative relationship between realized spreads and take fees. As in the univariate results, the NYSE provides the one important exception to this general pattern. When we focus on all at-the-quote trades, the NYSE falls in line with the general monotonic pattern. However, when we restrict our focus to at-the-quote trades when all venues are simultaneously at the inside quote, realized spreads on the NYSE are significantly higher than all venues except BX. Notably, if we focus only on the traditional venues, the results for the NYSE are consistent with the negative relationship we expected between fees and execution quality. Taken together, our results point to a strong negative relation between realized spreads and take fees and suggest that this relationship is most pronounced in low priced stocks and when volatility is low.

What is the economic significance of these results? One way to quantify the effect is to estimate how large a make rebate the average at-the-quote limit order investor would need to compensate her for executing on the high take fee venue rather than the low take fee venue. Holding the probability of a fill constant, the results in the last column of Table X suggest that, for at-the-quote trades when all venues are simultaneously posting the best quote, the difference in realized spreads between the highest fee venues and the lowest fee venue (BX) is 7.96 bps for NYSE-listed securities and 10.56 bps for Nasdaq-listed securities. For these samples of trades, the average trade prices are $19.38 and $14.76, respectively. Thus, the average at-the-quote limit order execution would have to earn a make rebate of $1.54 per hundred shares ($19.38*0.000796*100) for NYSE-listed securities and $1.56 per hundred shares ($14.76*0.001056*100) for Nasdaq-listed securities to compensate for the lower realized spreads earned on the high fee venue. Even ignoring the fact that rebates are generally not passed through to investors, this required rebate is over five times the highest liquidity rebate observed in the market. This suggests that the potential costs of routing decisions based primarily on maximizing rebates are large.

VI. Conclusion.

We present evidence that four popular retail brokers make order routing decisions in the fourth quarter of 2012 that appear to maximize the liquidity rebates generated from limit order executions. To the best of our knowledge, none of these brokers makes it a practice to directly pass exchange fees/rebates through to their customers. As a result, we argue that limit order execution quality, not liquidity rebates, should determine where these brokers route their limit orders. We provide the first empirical analysis of the relation between order flow rebates/fees and limit order execution quality. Using both proprietary limit order data and publicly available trade and quote data, we present evidence that limit orders routed to venues with lower take fees are executed faster and more frequently than orders on high fee venues and suffer less adverse selection. These results are consistent with Angel et al. (2010), who hypothesize that when multiple venues are displaying the best quote, limit orders resting on venues that pay low/negative liquidity rebates should execute before those on venues that offer high liquidity rebates. Even if fees/rebates are passed directly through to the investor, our results suggest that the decision to use a single venue that offers the highest liquidity rebates does not appear to be consistent with the objective of obtaining best execution.

As with all empirical studies, several caveats are in order. We focus on an important, but possibly narrow, set of execution quality statistics. Although the probability of getting a trade done is likely to be of first-order importance (and is in the SEC's definition of limit order execution quality), we also examine speed of execution and the degree of adverse selection faced by limit order traders on each venue. Other metrics might also matter to some limit order traders. In addition, although most brokers do not remit rebates/fees directly to customers, commissions are likely to be set based on the total revenue the broker receives. As a result, maximizing rebates might well allow brokers to reduce commissions for executed orders. However, lower commissions do not compensate those investors who miss out on profitable limit order executions and retail investors may lack the sophistication and/or information necessary to adequately assess the tradeoff between commissions and expected execution quality.

Despite these caveats, our results suggest that limit order routing decisions have an important impact on at least some measures of limit order execution quality and routing decisions based primarily on rebates/fees appear to be inconsistent with best execution. There is a significant opportunity cost associated with routing all nonmarketable limit orders to a single venue offering the highest liquidity rebates. Thus, we conclude that brokers cannot have it all.

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Table I

The Order Routing Decisions of Ten Retail Brokers in NYSE-Listed Securities

The table describes order routing decisions for ten retail brokers, with results for NYSE-listed securities in Panel A and results for Nasdaq-listed securities in Panel B. Data are from Rule 606 reports for the fourth quarter of 2012. %Mkt (%Lmt) refers to the percentage of a broker's non-directed market (limit) orders routed to the destination. %Lmt includes both marketable and non-marketable limit orders. Brokers are responsible for deciding where non-directed orders are routed. Brokers do not have to disclose destination venues that receive less than 5% of their orders. As a result, percentages may not sum to 100%. Wholesalers/market makers/purchasers includes Citadel, Knight, Citigroup, G1 Execution Services, UBS Securities, National Financial Services, Goldman Global Markets, Two Sigma Securities, and Getco. In the first (second) row under each venue, we provide the venue's most (least) attractive published liquidity rebate and the venue's most (least) attractive published take fee, where positive values are payments to the exchange and negative values are payments from the exchange. These fees are expressed in dollars per hundred shares.

Venue Make Range Take Range	Order Mix	Charles Schwab, Morgan Stanley, Just2Trade, Edward Jones, & LowTrade	Ameritrade	E*Trade	Fidelity	Scottrade	Interactive Brokers
Panel A – NYSE Stocks							
EDGX -$0.23 to -$0.32 +$0.30 to +$0.29	% Mkt		0%	0%	0%	0%	
	% Lmt		49%	46%	28%	28%	
NDAQ -$0.20 to -$0.29 +$0.30	% Mkt						3%
	% Lmt						7%
ARCA -$0.21 to -$0.30 +$0.30	% Mkt						2%
	% Lmt						23%
BZX -$0.25 to -$0.29 +$0.29	% Mkt						5%
	% Lmt						14%
Lava -$0.24 to -$0.27 +$0.28	% Mkt					0%	
	% Lmt					51%	
NYSE -$0.15 to -$0.21 +$0.23	% Mkt						23%
	% Lmt						47%
Purchasers $0.0/≤$0.0 $0.0/≤$0.0	% Mkt	100%	96%	98%	97%	66%	
	% Lmt	100%	45%	51%	57%	21%	
BYX +$0.03 to +$0.02 -$0.02	% Mkt						
	% Lmt						
EDGA +$0.06 to +$0.05 -$0.04	% Mkt						
	% Lmt						
BX +$0.18 to +$0.15 -$0.14	% Mkt						
	% Lmt						

Table I (continued)

Venue Make Range Take Range	Order Mix	Charles Schwab, Morgan Stanley, Just2Trade, Edward Jones, & LowTrade	Ameritrade	E*Trade	Fidelity	Scottrade	Interactive Brokers
Panel B – Nasdaq Stocks							
EDGX -\$0.23 to -\$0.32 +\$0.30 to +\$0.29	% Mkt		0%	0%	0%	0%	
	% Lmt		53%	38%	30%	55%	
NDAQ -\$0.20 to -\$0.29 +\$0.30	% Mkt						17%
	% Lmt						55%
ARCA -\$0.21 to -\$0.30 +\$0.30	% Mkt						6%
	% Lmt						23%
BZX -\$0.25 to -\$0.29 +\$0.29	% Mkt						11%
	% Lmt						13%
Lava -\$0.24 to -\$0.27 +\$0.28	% Mkt					0%	
	% Lmt					24%	
NYSE -\$0.15 to -\$0.21 +\$0.23	% Mkt						
	% Lmt						
Purchasers \$0.0/≤\$0.0 \$0.0/≤\$0.0	% Mkt	100%	98%	98%	93%	97%	
	% Lmt	100%	44%	60%	60%	20%	
BYX +\$0.03 to +\$0.02 -\$0.02	% Mkt						
	% Lmt						
EDGA +\$0.06 to +\$0.05 -\$0.04	% Mkt						
	% Lmt						
BX +\$0.18 to +\$0.15 -\$0.14	% Mkt						
	% Lmt						

Table II
Descriptive Statistics – Proprietary Limit Order Data

The table provides summary statistics related to order characteristics. The sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Order size, time and price are described in Panel A. Order display characteristics and order side are described in Panels B and C, respectively. Order destination is described in Panel D. Take fees and make rebates are expressed in dollars per 100 shares.

Panel A. Order time, size, and price.

Variable	Average	Minimum	25^{th}	Median	75^{th}	Maximum
Order Time	12:52pm	9:30am	10:52am	12:51pm	3:01pm	4:00pm
Order Size (shares)	635	1	100	100	300	999,000
Display Size (shares)	85	0	0	0	100	745,547
Limit Price (dollars)	$15.20	$0.0435	$14.80	$26.89	$46.09	$2,398.97

Panel B. Order display characteristics.

	% of Orders
Full Display	28.07%
Partial Display	8.75%
No Display	63.18%

Panel C. Distribution of buys, sells, and short sells.

Order Side	% of Orders
Buy	51.71%
Sell	26.88%
Short Sell	21.41%

Panel D. Order destination.

Venue	Take Fee	Displayed Order Make Rebate	Hidden Order Make Rebate	% of Displayed Orders (N=10,392,317)	% of Hidden Orders (N=17,829,197)
EDGX	+$0.30	-$0.23/-$0.32	-$0.23	29.72%	31.97%
NDAQ	+$0.30	-$0.20/-$0.29	-$0.10	23.84%	39.76%
ARCA	+$0.30	-$0.21/-$0.30	-$0.21	12.61%	11.36%
BZX	+$0.29	-$0.25/-$0.29	-$0.10	5.26%	2.15%
NYSE	+$0.23	-$0.15/-$0.21	-$0.15	26.72%	14.46%
EDGA	-$0.04	+$0.06/+$0.05	+$0.06	0.20%	0.00%
BX	-$0.14	+$0.18/+$0.15	+$0.18	1.65%	0.30%

Table III
Order Outcomes

The table provides summary statistics related to order outcomes. The initial sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Orders that include no displayed component are excluded. By sample construction, outcome time is later than order placement time, no executions take place after 4:02pm, and the number of shares executed cannot be greater than an order's size. When computing seconds to cancellation for all orders, we assume open day orders are cancelled at 6:00pm. Multiple outcomes can happen to a given order in Panel B.

Panel A. Summary statistics.

	# of Orders	Average	Min.	25^{th}	Median	75^{th}	Max.
# Shares Executed: All Orders	10,392,406	145	0	0	0	100	745,547
# Shares Executed: (Partially) Filled Orders	4,892,093	307	1	100	100	200	745,547
Average Execution Price	4,892,093	$41.62	$0.05	$18.40	$34.54	$56.36	$920.36
Seconds to First Execution	4,892,093	76	< 1	2	11.5	45	23,399
Seconds to Last Execution (> 1 Fills)	1,486,353	118	< 1	4	19	64	23,396
Seconds to Cancellation or Expiration	5,696,685	203	< 1	8	36	85	30,499
Seconds to Cancellation	5,667,721	180	< 1	7	31	80	23,394
Seconds to Order Rejection	597	52	< 1	< 1	2	8	7,165
Seconds until Order is Replaced	118,010	26	< 1	1	4	14	22,279
Ratio of Shares Executed to Order Size	10,392,406	0.45	0.00	0.00	0.00	1.00	1.00
Ratio of Shares Executed to Displayed Size	10,392,406	0.71	0.00	0.00	0.00	1.00	5,000.00

Panel B. Order outcome conditional on fill status.

Fill Status	# of Orders	Rejected	Replaced	Cancelled	One Fill	Expired
No Fill	5,500,313	597	66,186	5,391,256	NA	42,274
Complete Fill	4,595,727	0	1	10,432	3,244,667	NA
Partial Fill	296,366	0	18	294,997	179,073	1,351
All Orders	10,392,406	597	66,205	5,696,685	3,423,740	43,625

Table IV
Order Aggressiveness

The table provides frequencies related to order aggressiveness. The initial sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Orders that include no displayed component are excluded. A marketable order is a limit order to buy (sell) shares at a price that is greater than or equal to (less than or equal to) the National Best Offer (Bid). Inside-the-quote limit orders have limit prices that improve prevailing quotes. A limit order to buy (sell) shares at the National Best Bid (Offer) is at-the-quote, and a limit order seeking to buy (sell) shares at prices that are more advantageous than the prevailing quotes are behind-the-quote. Traditional (inverted) venues charge (pay) liquidity demanders and charge (pay) liquidity suppliers. Under each venue, we provide the take fee/rebate for the venue's least preferred customer. Take fees are expressed in cents per 100 shares.

Panel A. Order aggressiveness conditional on order side.

Limit Order Type	Order Side	
	Buy Orders	Sell Orders
Behind-the-quote	9.95%	6.70%
At-the-Quote	31.40%	31.95%
Inside-the-Quote	8.43%	8.34%
Marketable	0.28%	1.11%

Panel B. Order aggressiveness conditional on destination venue.

	Traditional Venue					Inverted Venue	
	EDGX $0.30	NDAQ $0.30	ARCA $0.30	BZX $0.29	NYSE $0.23	EDGA -$0.04	BX -$0.14
Behind-the-quote	5.90%	14.91%	18.33%	7.71%	39.76%	0.10%	0.22%
At-the-Quote	81.77%	60.56%	60.37%	88.97%	39.19%	99.87%	99.44%
Inside-the-Quote	11.48%	22.42%	19.78%	0.96%	20.45%	0.00%	0.22%
Marketable	0.92%	2.40%	1.73%	2.50%	0.68%	0.24%	0.27%

Table V

Unconditional Limit Order Execution Quality Statistics for At-the-Quote Limit Orders

The table provides summary statistics related to limit order execution quality for at-the-quote limit orders. The initial sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Orders that include no displayed component are excluded. A limit order to buy (sell) shares at the National Best Bid (Offer) is at-the-quote. An order is displayed if at least part of the order's size is shown on the venue's limit order book. The table lists the take fee/rebate for the venue's least preferred customer, where take fees/rebates are expressed in dollars per 100 shares. Fill Rate is the ratio of orders that have at least one share executed to the total number of orders. Speed represents the average time that it takes executed limit orders to receive their first (and perhaps only) execution. For executed nonmarketable limit buy orders, the Realized Spread is equal to twice the difference between the midpoint of the bid ask spread prevailing five minutes after order receipt and the limit price. For sell orders, the Realized Spread is equal to twice the difference between the limit price and the bid/ask midpoint five minutes after order receipt. The Good Fill Ratio is the percentage of executed limit orders with positive realized spreads.

Venue	Take Fee/Rebate	# Orders	Fill Rate	Fill Speed (seconds)	Realized Spread	Good Fill Ratio
EDGX	$0.30	2,525,513	53.96%	111	-$0.0021	49.32%
NDAQ	$0.30	1,500,240	47.96%	59	-$0.0020	49.19%
ARCA	$0.30	791,087	53.11%	61	-$0.0019	49.44%
BZX	$0.29	486,375	54.66%	76	-$0.0028	50.42%
NYSE	$0.23	1,088,393	56.75%	40	-$0.0011	50.39%
EDGA	-$0.04	20,529	56.85%	105	$0.0011	57.36%
BX	-$0.14	170,736	74.51%	33	$0.0011	54.81%

Table VI

Multivariate Analysis of Displayed Limit Order Execution Quality

We use Probit to examine the relationship between fees and the probability that a displayed limit order executes, where *Fill* equals one if any part of the order fills and zero otherwise. We use Ordinary Least Squares to examine the relationship between fees and *Time-to-Execution*, where *Time-to-Execution* equals the number of seconds between Order Time and First Fill Time conditional on at least a partial fill. The initial sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Orders that include no displayed component are excluded. The independent variables are defined as follows: *Long Sell* equals 1 if the order side is "Sell" and 0 otherwise; *Short Sell* equals 1 if the order side is "Short Sell" and 0 otherwise; *Moneyness* equals [(Limit Price/Ask Price) – 1]*100 for sell orders and [(Bid Price/Limit Price) – 1]*100 for buy orders; *Order Size* is the number of shares specified in the order relative to the quoted size; *Avg. Volume* equals the stock's average daily share volume during the sample period; *Avg. Price* equals the stock's average closing price during the sample period; *Volatility* equals the stock's average squared daily return during the sample period; *Venue Response Time* equals the average across all canceled trades on the venue of the difference between Out Time from the venue and Cancel Time from the broker; and *Take Fee* is defined for each venue as the take fee/rebate for the venue's least preferred customer, expressed in dollars per 100 shares. Indicator variables are added for each of the 30 minute-periods from 10:00 a.m. to 4:00 p.m.

	Probability of Fill (N = 10,392,406)		Time-to-Execution (N = 4,892,093)
	Coefficient Estimate	Marginal Probability	Coefficient Estimate
Intercept	-0.8334		304.1138
Long Sell	0.0522	0.0198	1.7936
Short Sell	-0.0505	-0.0191	- 12.8996
Moneyness	-2.5155	-0.9539	543.6606
Order Size	0.0008	0.0003	1.3833
Log(Avg.Volume)	0.0532	0.0202	- 19.7875
Avg. Price	0.0021	0.0008	- 0.5104
Volatility	0.4781	0.1813	396.8411
Venue Response Time	-0.2342	-0.0858	- 360.4005
Take Fee	-0.3567	-0.1353	163.2113
Intraday Dummies Included	Yes		Yes
R^2	0.1039		0.0419

Table VII
Horseraces

An Order Pair horserace involves a pair of displayed limit orders that have the same stock symbol, same order date, same order side (buy or sell), same limit price, but different destination venues. We require that the first order in the order-pair still be active when the second order in the order-pair is routed. Hi (Low) Fee venue is the venue with the higher (lower) take fee. Fee Diff. is the difference in take fees (per 100 shares). Both Fill refers to the percentage of order pairs in which both orders receive at least a partial execution. Hi (Low) Fee Trades First is the percentage of horseraces won by the Hi (Low) Fee venue. We declare a horserace a tie if both orders execute within 500 μs of one another. The Good Fill Ratio is the percentage of executed limit orders with positive realized spreads. The initial sample includes over 28 million orders from a major broker-dealer's smart order routing system during October and November 2012. Orders that include no displayed component are excluded.

Hi Fee Venue(s) vs. Low Fee Venue	Fee Diff.	# of Order Pairs	Univariate Statistics			Horseraces				
			Hi Fee Fill Rate	Low Fee Fill Rate	Both Fill	Hi Fee Trades First	Low Fee Trades First	Tie	Good Fill Ratio: Hi Fee	Good Fill Ratio: Low Fee
ARCA, EDGX, & NDAQ vs. BX	$0.44	21,373	73.53%	99.23%	72.75%	3.77%	77.12%	19.02%	52.8	60.0
BZX vs. BX	$0.43	8,320	76.94%	99.04%	75.97%	5.05%	73.52%	21.43%	57.5	61.8
NYSE vs. BX	$0.37	5,603	78.10%	99.13%	76.19%	6.24%	76.02%	17.74%	54.9	60.0
ARCA, EDGX, & NDAQ vs. EDGA	$0.34	2,988	76.00%	98.83%	74.83%	4.75%	75.43%	19.81%	55.5	63.3
BZX vs. EDGA	$0.33	1,164	79.55%	97.43%	76.81%	10.22%	62.11%	27.67%	59.8	64.4
NYSE vs. EDGA	$0.27	671	78.22%	97.62%	72.58%	9.39%	76.00%	14.60%	53.6	59.7
EDGA vs BX	$0.10	997	85.76%	98.09%	83.85%	10.63%	58.88%	30.49%	61.6	65.1
ARCA, EDGX, & NDAQ vs. NYSE	$0.07	74,296	86.94%	97.43%	83.96%	14.96%	48.39%	36.65%	52.6	55.4
BZX vs. NYSE	$0.06	17,140	88.18%	96.33%	84.16%	21.06%	44.78%	34.16%	54.5	56.7
ARCA, EDGX, & NDAQ vs. BZX	$0.01	67,363	89.59%	95.88%	85.44%	14.18%	36.37%	49.45%	53.4	54.9
ARCA, EDGX, & NDAQ	$0.00	84,886	NA	NA	87.87%	NA	NA	55.88%	NA	NA

Table VIII
Time at the Inside Quotes, Market Share, and Realized Spread by Trading Venue

The table provides summary statistics for time at the inside quote, market share, and effective spread decomposition by trading venue. The sample period includes all trading days during October and November of 2012 and the sample includes all NYSE and Nasdaq-listed common stocks that trade above $1 during this period. Time at the inside is computed for each stock-day and each venue as the proportion of seconds during the day for which the venue posts quotes at the NBBO bid, the NBBO ask, or both. Time at the inside for each venue is averaged across all trading days for each stock and the table lists the cross-sectional average of these stock-specific means. Market share is computed for each venue as the proportion of trades (volume) executed on that venue, excluding trades resulting from intermarket sweep orders. Spread components are calculated for each venue as an equal-weighted average across all non-sweep trades executed on that venue. Trade direction is determined based on the Lee-Ready algorithm. For buy (sell) trades, the Realized Spread is defined as two (negative two) times the difference between the trade price and the NBBO midpoint five minutes after the trade and the Percentage Realized Spread is defined as the Realized Spread divided by the NBBO midpoint at the time of the trade. Realized spreads for CHX are not listed, as this venue executes fewer than 3,000 of the sample trades during this period. Panels A and B provide separate results for stocks listed on the NYSE and Nasdaq, respectively. Market share for the Nasdaq TRF are not reported. For each venue, the table also lists the take fee/rebate for the venue's least preferred customers, stated in dollars per hundred shares. Based on all trades, TRF market share of trades (volume) is 24.17% (34.94%) for Nasdaq stocks and 23.57% (31.86%) for NYSE stocks. Based on no sweep trades, TRF market share of trades (volume) is 38.01% (50.57%) for Nasdaq stocks and 38.59% (47.99%) for NYSE stocks.

Table VIII (continued)

Venue	AMEX	ARCA	CHX	EDGX	NDAQ	BZX	NSX	NYSE	PSX	BYX	EDGA	BX	CBSX
Take Fee	(0.30)	(0.30)	(0.30)	(0.30)	(0.30)	(0.29)	(0.29)	(0.23)	(0.19)	(-0.02)	(-0.04)	(-0.14)	(-0.17)
Panel A - NYSE Stocks (N=1199)													
Time at the Inside:													
At Bid	NA	55.63	0.00	37.69	52.54	42.56	10.77	73.68	10.88	26.44	14.37	22.23	19.90
At Ask	NA	55.78	0.00	37.39	52.97	42.54	10.61	73.88	11.10	26.95	14.66	22.51	20.13
At One Side	NA	74.77	0.01	54.03	70.02	59.39	17.09	90.94	17.11	42.91	24.68	38.49	34.98
At Both Sides	NA	36.65	0.00	21.06	35.49	25.70	4.29	56.62	4.87	10.48	4.36	6.25	5.04
Market Share:													
% Trades	0.00	9.44	0.00	6.25	13.35	9.26	0.12	11.86	0.50	4.43	2.45	3.01	0.75
% Volume	0.00	7.65	0.05	5.97	9.95	6.69	0.14	13.63	0.51	2.91	1.90	2.10	0.52
Bid-Ask Spreads:													
Total Trades (000)	NA	21,044	2	14,092	29,778	20,340	264	25,362	1,108	9,514	5,116	5,971	1,584
Realized Spread (¢)	NA	-0.46	-	-0.60	-0.35	-0.27	-0.45	-0.11	-0.10	0.33	0.22	0.65	0.87
Realized Spread (bps)	NA	-1.85	-	-2.75	-1.65	-1.18	-2.87	-0.01	-0.52	2.26	1.85	3.65	5.68
Panel B – Nasdaq Stocks (N=1892)													
Time at the Inside:													
At Bid	2.38	42.19	0.02	35.56	69.25	33.16	8.28	NA	6.24	20.09	9.70	16.52	19.59
At Ask	2.48	43.15	0.01	34.74	70.38	33.47	8.36	NA	6.62	21.17	10.29	17.23	20.48
At One Side	3.16	62.34	0.02	53.13	88.43	49.35	13.56	NA	9.74	33.61	16.86	27.96	35.08
At Both Sides	1.70	22.99	0.01	17.17	51.20	17.27	3.08	NA	3.12	7.65	3.13	5.79	4.99
Market Share:													
% Trades	0.05	10.74	0.00	7.14	19.91	12.24	0.13	0.00	0.55	4.39	2.53	3.53	0.77
% Volume	0.09	8.35	0.02	6.84	16.39	9.29	0.14	0.00	0.75	2.82	1.93	2.30	0.51
Bid-Ask Spreads:													
Total Trades (000)	67	13,102	1	8,790	23,402	14,728	163	NA	671	5,190	2,946	3,953	890
Realized Spread (¢)	0.25	-0.40	-	-0.62	-0.45	-0.17	-0.41	NA	-0.13	0.40	0.36	0.89	1.03
Realized Spread (bps)	4.71	-1.87	-	-3.31	-2.15	-0.73	-3.21	NA	0.21	3.74	3.28	6.14	9.37

Table IX

Market Share and Execution Outcomes for At-the-Quote Trades when all Relevant Venues are at the Inside

The table provides summary statistics for market share and trade outcomes for at-the-quote trades when all relevant venues are simultaneously at the inside quote. The sample period includes all trading days during October and November of 2012 and the sample includes all NYSE- and Nasdaq-listed common stocks that trade above $1 during this period. The analysis is limited to trades that occur at the NBBO bid (ask) when all relevant venues are simultaneously posting quotes equal to the NBBO bid (ask), where trades resulting from intermarket sweep orders are excluded. The relevant exchanges considered include BX, EDGA, BYX, NYSE, BZX, NDAQ, ARCA, and EDGX. AMEX, NSX, CHX, PSX, and CBSX have less than one percent average market share and are excluded from the analysis. Market Share is defined across all trades on all venues and Quoted Depth is defined as an equal weighted average across all trades. Quoted Depth on Own Trades, Realized Spread, and Good Fill Ratio are defined as equal weighted averages across all relevant trades on a particular venue. Quoted depth is a venue's posted depth on the relevant side of the market. Good Fill ratio is defined as the proportion of trades with realized spread greater than zero. Trade direction is determined based on the Lee-Ready algorithm. For buy (sell) trades, the percentage Realized Spread is defined as two (negative two) times the difference between the trade price and the NBBO midpoint five minutes after the trade, divided by the NBBO midpoint at the time of the trade. Realized Spread Net of Fee is defined as the Realized Spread net of any make fee or rebate. For each venue, the table also lists the take fee/rebate for the venue's least preferred customers, stated in dollars per hundred shares. Results are reported separately for stocks listed on the NYSE and Nasdaq.

		NYSE Stocks						Nasdaq Stocks					
Exchange	Take Fee ($)	Market Share (%)	Qtd Depth All Trades (000)	Qtd Depth Own Trades (000)	Realized Spread (bps)	Realized Spread Net of Fee (bps)	Good Fill Ratio (%)	Market Share (%)	Qtd Depth All Trades (000)	Qtd Depth Own Trades (000)	Realized Spread (bps)	Realized Spread Net of Fee (bps)	Good Fill Ratio (%)
BX	-0.14	9.36	2.55	3.16	5.37	3.38	58.61	9.58	2.35	3.09	7.52	4.82	60.94
EDGA	-0.04	6.00	2.53	3.05	2.91	2.26	55.14	5.53	2.25	2.82	3.61	2.72	56.44
BYX	-0.02	8.18	3.03	3.87	4.18	3.84	56.89	7.90	2.87	4.49	5.44	5.01	58.17
NYSE	0.23	6.95	13.67	11.44	3.94	5.34	56.12	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
BZX	0.29	6.51	9.04	6.24	-3.49	-1.20	47.07	9.29	11.01	8.36	-3.31	-0.36	48.32
ARCA	0.30	6.77	11.80	9.01	-3.00	-1.11	47.45	7.70	11.71	9.05	-4.01	-1.49	46.96
EDGX	0.30	5.58	9.81	7.59	-3.36	-1.12	46.98	6.04	10.03	8.34	-3.21	0.00	47.75
NDAQ	0.30	10.10	12.36	8.06	-3.78	-2.04	46.31	12.97	21.11	13.66	-4.28	-1.88	47.04
Number of Stocks		1,033						1,072					
Average Trades per Stock		26,652						16,401					

Table X

Realized Spread Regressions

The table describes results from pooleds regression of realized spreads on stock and trade characteristics. The sample period includes all trading days during October and November of 2012 and the sample includes all NYSE- and Nasdaq-listed common stocks that trade above $1 during this period. The initial trade sample includes all non-sweep trades that execute on one of the relevant make-take fee exchanges and for which the realized spread could be calculated. The relevant exchanges considered include BX, EDGA, BYX, NYSE, BZX, NDAQ, ARCA, and EDGX. AMEX, NSX, CHX, PSX, and CBSX have less than one percent average market share and are excluded from the analysis. We then focus on the subset of trades that take place at the quotes and the subset of at-the-quote trades that occur when all relevant venues are at the inside quote. Trade direction is determined based on the Lee-Ready algorithm. For buy (sell) trades, the percentage Realized Spread is defined as two (negative two) times the difference between the trade price and the NBBO midpoint five minutes after the trade, divided by the NBBO midpoint at the time of the trade. Average Volume is the average daily share volume computed over the six months prior to the sample period. Trade Price and Trade Size are the price and number of shares in the current trade. Daily High/Low is defined for each stock-day as the ratio of the highest and lowest trade price for the stock on that trading day. Take Fee is the fee charged (per hundred shares) to liquidity takers by the venue associated with the current trade, where rebates are defined as negative fees, and take fee dummy variables identify each level of take fee. Inverted is a dummy variable equal to one if the trade occurred on a venue with an inverted fee schedule. Min_Fee is a dummy variable equal to one if the trade venue has the lowest take fee of all venues at the inside quote at the time of the trade. High_Depth is a dummy variable equal to one if the aggregate depth at the relevant inside quote is at least 20,000 shares. Low_Price is a dummy variable equal to one if the trade price is less than $6. Intraday dummy variables are used to define 30-minute intervals within the trading day. Results for NYSE- and Nasdaq-listed stocks are listed in Panels A and B, respectively.

Table X (Continued)

Panel A – NYSE Stocks								
	At-the-Quote Trades				At-the-Quote Trades with All Venues at the Inside			
Intercept	0.0570	0.0518	0.0223	0.0701	0.1016	0.1103	0.0553	0.1147
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln(Avg. Volume)	0.0026	0.0035	0.0023	0.0033	0.0025	0.0033	0.0026	0.0042
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln(Trade Price)	-0.0024	-0.0077	-0.0024	-0.0028	-0.0200	-0.0300	-0.0204	-0.0203
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln(Trade Size)	-0.0111	-0.0099	-0.0104	-0.0126	-0.0121	-0.0115	-0.0121	-0.0160
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln(Daily High/Low)	-0.5062	-0.5014	-0.5116	-0.5011	-0.1886	-0.1665	-0.1963	-0.1607
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Take Fee	-0.1320	-0.1152	-	-	-0.1708	-0.1147	-	-
	(0.000)	(0.000)			(0.000)	(0.000)		
Take Fee * Min_Fee	-	0.0128	-	-	-	-	-	-
		(0.000)						
Take Fee * Low_Price	-	-0.1267	-	-	-	-0.2087	-	-
		(0.000)				(0.000)		
Take Fee * High_Depth	-	-0.0701	-	-	-	-0.0491	-	-
		(0.000)				(0.000)		
Inverted Dummy	-	-	0.0420	-	-	-	0.0566	-
			(0.000)				(0.000)	
Take Fee =−$0.04	-	-	-	-0.0171	-	-	-	-0.0229
				(0.000)				(0.000)
Take Fee =−$0.02	-	-	-	-0.0150	-	-	-	-0.0129
				(0.000)				(0.000)
Take Fee =+$0.23	-	-	-	-0.0350	-	-	-	-0.0022
				(0.000)				(0.000)
Take Fee =+$0.29	-	-	-	-0.0538	-	-	-	-0.0799
				(0.000)				(0.000)
Take Fee =+$0.30	-	-	-	-0.0592	-	-	-	-0.0796
				(0.000)				(0.000)
Intraday Period Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	104.8M	104.8M	104.8M	104.8M	14.6M	14.6M	14.6M	14.6M
Adjusted R^2	0.0017	0.0019	0.0015	0.0018	0.0042	0.0050	0.0038	0.0053
F (*p*-value)	10234.2	9846.8	9221.6	8761.5	3637.6	3839.8	3244.0	3725.3
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table X (Continued)

Panel B – Nasdaq Stocks								
	At-the-Quote Trades				At-the-Quote Trades with All Venues at the Inside			
Intercept	0.1261 (0.000)	0.1278 (0.000)	0.0685 (0.000)	0.1566 (0.000)	0.0458 (0.000)	0.0560 (0.000)	-0.0217 (0.000)	0.0806 (0.000)
Ln(Avg. Volume)	0.0010 (0.000)	0.0020 (0.000)	0.0010 (0.000)	0.0007 (0.000)	0.0083 (0.000)	0.0107 (0.000)	0.0082 (0.000)	0.0082 (0.000)
Ln(Trade Price)	-0.0034 (0.000)	-0.0131 (0.000)	-0.0034 (0.000)	-0.0032 (0.000)	-0.0215 (0.000)	-0.0451 (0.000)	-0.0215 (0.000)	-0.0214 (0.000)
Ln(Trade Size)	-0.0160 (0.000)	-0.0146 (0.000)	-0.0161 (0.000)	-0.0158 (0.000)	-0.0165 (0.000)	-0.0158 (0.000)	-0.0166 (0.000)	-0.0163 (0.000)
Ln(Daily High/Low)	-0.6756 (0.000)	-0.6366 (0.000)	-0.6765 (0.000)	-0.6712 (0.000)	-0.3285 (0.000)	-0.2831 (0.000)	-0.3289 (0.000)	-0.3270 (0.000)
Take Fee	-0.1957 (0.000)	-0.1579 (0.000)	-	-	-0.2353 (0.000)	-0.0948 (0.000)	-	-
Take Fee * Min_Fee	-	0.0068 (0.000)	-	-	-	-	-	-
Take Fee * Low_Price	-	-0.1678 (0.000)	-	-	-	-0.3628 (0.000)	-	-
Take Fee * High_Depth	-	-0.0400 (0.000)	-	-	-	-0.0584 (0.000)	-	-
Inverted Dummy	-	-	0.0700 (0.000)	-	-	-	0.0872 (0.000)	-
Take Fee =−$0.04	-	-	-	-0.0254 (0.000)	-	-	-	-0.0365 (0.000)
Take Fee =−$0.02	-	-	-	-0.0232 (0.000)	-	-	-	-0.0215 (0.000)
Take Fee =+$0.29	-	-	-	-0.0736 (0.000)	-	-	-	-0.0985 (0.000)
Take Fee =+$0.30	-	-	-	-0.0905 (0.000)	-	-	-	-0.1056 (0.000)
Intraday Period Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	55.7M	55.7M	55.7M	55.7M	9.3M	9.3M	9.3M	9.3M
Adjusted R^2	0.0025	0.0028	0.0024	0.0026	0.0060	0.0085	0.0059	0.0061
F (*p*-value)	8194.4 (0.000)	7845.2 (0.000)	8028.3 (0.000)	7124.1 (0.000)	3338.7 (0.000)	4230.1 (0.000)	3260.8 (0.000)	2862.9 (0.000)

Appendix Table I
Detailed Horserace Results

An Order Pair Horserace involves a pair of displayed limit orders that have the same stock symbol, same order date, same order side (buy or sell), same limit price, but different destination venues. We require that the first order in the order-pair still be active when the second order in the order-pair is routed. The 1st (2nd) venue receives the first (second) order of the order pair. Take fee is the cost of accessing 100 shares of liquidity on the given venue. % Both Fill refers to the percentage of order pairs in which both orders receive at least a partial execution. For the order pairs where both orders execute, Difference in Time to 1st Fill is the difference in times to execution for each of the two orders in the order pair. If the order resting at the first venue executes before (after) the order on the second venue's order book fills, this difference is negative (positive). % 1st Venue Trades First (% 2nd Venue Trades First) is the percentage of horseraces won by the first (second) venue. We declare a horserace a tie if both orders execute within 500 μs of one another. The Good Fill Ratio is the percentage of executed limit orders with positive realized spreads. Take fees are expressed in dollars per 100 shares.

Order Pair		# of Order Pairs	1st Venue Fill Rate	2nd Venue Fill Rate	Both Fill	Difference in Time to 1st Fill	1st Venue Trades First	2nd Venue Trades First	Tie	Good Fill Ratio	
1st Venue (take fee)	2nd Venue (take fee)									1st Venue	2nd Venue
ARCA ($0.30)	**BSX (-$0.14)**	5,220	74.83%	**98.91%**	73.75%	91	5.23%	**75.37%**	19.41%	54.0	**60.1**
BSX (-$0.14)	ARCA ($0.30)	2,565	**98.83%**	75.83%	74.66%	-108	**72.55%**	6.78%	20.66%	**63.5**	56.6
NDAQ ($0.30)	**BSX (-$0.14)**	5,190	73.01%	**99.15%**	72.14%	84	3.68%	**74.57%**	21.75%	53.8	**59.4**
BSX (-$0.14)	NDAQ ($0.30)	2,125	**99.11%**	71.95%	71.06%	-90	**72.14%**	4.33%	23.53%	**63.3**	53.4
EDGX ($0.30)	**BSX (-$0.14)**	4,358	73.15%	**99.79%**	72.90%	95	1.10%	**85.73%**	13.17%	50.3	**57.4**
BSX (-$0.14)	EDGX($0.30)	1,915	**99.69%**	70.91%	70.60%	-89	**80.83%**	1.46%	16.71%	**58.7**	46.9
BZX ($0.29)	**BSX (-$0.14)**	4,864	75.66%	**99.18%**	74.84%	95	4.15%	**77.53%**	18.32%	57.3	**60.7**
BSX (-$0.14)	BZX ($0.29)	3,456	**98.84%**	78.73%	77.55%	-79	**67.88%**	6.31%	25.81%	**63.3**	57.7
NYSE ($0.23)	**BSX (-$0.14)**	4,204	78.47%	**99.19%**	76.71%	60	6.42%	**74.98%**	18.60%	54.5	**58.9**
BSX (-$0.14)	NYSE ($0.23)	1,399	**98.95%**	77.00%	74.61%	-80	**79.16%**	5.68%	15.16%	**63.3**	56.1
ARCA ($0.30)	**EDGA (-$0.04)**	385	73.51%	**97.14%**	70.65%	24	12.73%	**68.83%**	18.44%	60.8	**66.3**
EDGA (-$0.04)	ARCA ($0.30)	300	**97.67%**	75.00%	72.67%	-87	**68.33%**	9.00%	22.67%	**71.0**	58.2

Appendix Table I (Continued)

Order Pair		# of Order Pairs	1st Venue Fill Rate	2nd Venue Fill Rate	Both Fill	Difference in Time to 1st Fill	1st Venue Trades First	2nd Venue Trades First	Tie	Good Fill Ratio	
1st Venue (take fee)	2nd Venue (take fee)									1st Venue	2nd Venue
NDAQ ($0.30)	**EDGA (-$0.04)**	527	74.38%	**98.29%**	72.68%	137	4.93%	**78.37%**	16.70%	58.9	**64.3**
EDGA (-$0.04)	NDAQ ($0.30)	385	**99.74%**	70.91%	70.65%	-201	**79.74%**	1.56%	18.70%	**66.7**	54.2
EDGX ($0.30)	**EDGA (-$0.04)**	815	79.75%	**99.51%**	79.26%	89	3.07%	**75.58%**	21.35%	54.3	**58.7**
EDGA (-$0.04)	EDGX ($0.30)	576	**99.48%**	77.78%	77.26%	-64	**77.78%**	1.56%	20.66%	**60.7**	50.5
BZX ($0.29)	**EDGA (-$0.04)**	679	79.97%	**97.35%**	77.03%	81	10.60%	**61.56%**	27.84%	60.2	**61.9**
EDGA (-$0.04)	BZX ($0.29)	485	**97.53%**	78.97%	76.49%	-134	**62.89%**	9.69%	27.42%	**67.9**	59.3
NYSE ($0.23)	**EDGA (-$0.04)**	396	80.01%	**96.21%**	73.23%	66	11.36%	**73.23%**	15.40%	57.1	**60.6**
EDGA (-$0.04)	NYSE ($0.23)	275	**99.64%**	75.64%	71.64%	-49	**80.00%**	6.55%	13.45%	**58.4**	48.6
EDGA (-$0.04)	**BSX (-$0.14)**	431	88.63%	**96.98%**	85.61%	50	13.69%	**57.08%**	29.23%	**64.7**	64.1
BSX (-$0.14)	EDGA(-$0.04)	566	**98.94%**	83.57%	82.51%	-64	**60.25%**	8.3%	31.45%	**65.9**	59.2
ARCA ($0.30)	**NYSE ($0.23)**	11,601	88.18%	**97.02%**	85.04%	24	13.90%	**46.00%**	37.11%	54.3	**55.3**
NYSE ($0.23)	ARCA ($0.30)	11,074	**96.73%**	86.50%	83.00%	-28	**48.46%**	17.28%	34.25%	**57.5**	54.5
NDAQ ($0.30)	**NYSE ($0.23)**	13,351	87.97%	**97.53%**	85.31%	26	15.35%	**44.87%**	39.78%	53.2	**54.6**
NYSE ($0.23)	NDAQ ($0.30)	16,695	**97.01%**	86.12%	82.80%	-27	**46.91%**	15.81%	37.29%	**56.9**	53.5
EDGX ($0.30)	**NYSE ($0.23)**	11,039	86.92%	**98.27%**	84.41%	42	11.55%	**53.56%**	34.89%	50.5	**53.3**
NYSE ($0.23)	EDGX ($0.30)	10,536	**98.25%**	86.05%	83.42%	-36	**52.33%**	12.11%	35.56%	**51.2**	48.3
BZX ($0.29)	**NYSE ($0.23)**	7,903	88.45%	**96.51%**	84.60%	39	20.50%	**45.31%**	34.19%	55.5	**56.2**
NYSE ($0.23)	BZX ($0.29)	9,237	**96.18%**	87.94%	83.78%	-37	**44.32%**	21.54%	34.13%	**57.1**	53.6

Appendix Table I (Continued)

Order Pair		# of Order Pairs	1st Venue Fill Rate	2nd Venue Fill Rate	Both Fill	Difference in Time to 1st Fill	1st Venue Trades First	2nd Venue Trades First	Tie	Good Fill Ratio	
1st Venue (take fee)	2nd Venue (take fee)									1st Venue	2nd Venue
ARCA ($0.30)	**BZX ($0.29)**	20,376	90.44%	**94.96%**	85.37%	20	17.31%	**34.04%**	48.65%	**55.0**	54.4
BZX ($0.29)	ARCA ($0.30)	11,714	**95.33%**	89.28%	84.58%	-30	**37.07%**	16.14%	46.79%	**56.5**	52.6
NDAQ ($0.30)	**BZX ($0.29)**	13,610	91.20%	**95.84%**	87.03%	20	14.83%	**31.64%**	53.53%	**55.0**	54.3
BZX ($0.29)	NDAQ ($0.30)	8,836	**96.92%**	88.04%	84.87%	-50	**37.31%**	11.23%	51.46%	**59.0**	54.8
EDGX ($0.30)	**BZX ($0.29)**	7,067	87.53%	**96.99%**	84.52%	21	8.89%	**43.89%**	47.22%	49.6	**51.6**
BZX ($0.29)	EDGX ($0.30)	5,760	**97.36%**	88.33%	85.68%	-22	**43.66%**	8.58%	47.46%	**53.1**	48.3
ARCA ($0.30)	EDGX ($0.30)	8,507	**95.66%**	91.63%	87.26%	-8	**28.40%**	18.08%	53.52%	**53.0**	49.6
EDGX ($0.30)	ARCA ($0.30)	6,698	91.40%	**96.15%**	86.98%	15	16.63%	**30.52%**	52.85%	**50.4**	49.5
ARCA ($0.30)	NDAQ ($0.30)	13,744	**94.69%**	93.24%	87.85%	-8	**23.60%**	20.56%	55.84%	**56.2**	54.5
NDAQ ($0.30)	ARCA ($0.30)	20,947	93.88%	**94.03%**	87.86%	7	**22.15%**	21.05%	56.80%	**54.9**	53.9
EDGX ($0.30)	NDAQ ($0.30)	10,773	93.45%	**94.76%**	88.26%	4	19.45%	**25.43%**	55.12%	**53.5**	52.1
NDAQ ($0.30)	EDGX ($0.30)	11,390	**94.93%**	93.63%	88.52%	-4	**23.53%**	17.97%	58.51%	**52.0**	49.5