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All else equal?: a multidimensional analysis of retail, market order execution quality ☆

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Abstract

The extant execution quality literature generally suggests that brokers routing orders away from the NYSE might not fulfill their fiduciary best execution responsibility. This conclusion is drawn by comparing execution prices across trading venues and presumes that other execution-quality characteristics are equivalent. Using order audit-trail data, we find evidence that retail market orders obtain better trade prices on the NYSE but faster executions, more depth improvement, and order-flow payment at Trimark Securities, a Nasdaq dealer. Thus, non-price dimensions of execution quality are not equivalent across trading venues. Furthermore, considering order flow payments, brokers obtain better net prices with Trimark. If brokers pass enough of these payments through to investors in the form of lower commissions and/or better services, then investors also obtain better net prices with Trimark. Our results suggest that it may be misleading to

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evaluate execution quality or to base policy decisions on comparisons focusing on only execution prices.

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1. Introduction

With few exceptions, the extant literature examining retail market order execution quality across trading venues studies only trade prices because of data limitations.[1] These studies, which typically find that the New York Stock Exchange (NYSE) offers investors better prices, lead many to question whether brokers routing orders away from the NYSE fulfill their fiduciary responsibility to obtain best execution.[2] Because many orders are routed away from the NYSE pursuant to internalization, preferencing, or payment for order flow agreements, these results often are used as a rationale to prohibit these practices.[3]

One must assume that retail market order execution quality is one-dimensional or that the other aspects of execution quality are equivalent across trading venues to draw this conclusion. While offering no specific definition of best execution, the Securities and Exchange Commission (SEC) notes that there are many investor-specific facets of trade quality for retail market orders (SEC, 2000). Considering multiple facets of execution quality allows brokers to focus on the dimensions they believe customers value. For some investors, execution price is paramount. Others might desire the combination of commissions and execution prices producing the lowest net trading costs. Still others might be willing to forgo price improvement for immediate fills at predictable prices. Whether or not one venue offers best execution for all retail investors' market orders is an empirical question that cannot be addressed focusing solely on execution prices. Recognizing that differences can exist, the SEC recently required that execution venues report their execution quality on multiple dimensions (see SEC, 2000). Such reports allow investors to choose brokers with execution services most closely matching their preferences.

[1] See Blume and Goldstein (1992), Lee (1993), Angel (1994), Petersen and Fialkowski (1994), Easley et al. (1996), Huang and Stoll (1996a), Ross et al. (1996), SEC (1997), Bessembinder and Kaufman (1997a, b), Battalio et al. (1998), and Bessembinder (1999). Bacidore et al. (1999) and Securities and Exchange Commission (2001) provide a more inclusive study of retail market order execution quality. Studies of execution quality for institutional orders generally include factors in addition to trade price (e.g., Keim and Madhavan, 1997, 1998).

[2] See Macey and O'Hara (1997) for an in-depth discussion of best execution.

[3] Internalization is the practice of vertically integrated broker-dealers taking the other side of their customers' orders. Preferencing is the practice of brokers routing orders to a particular dealer in exchange for cash payments (payment for order flow) or other inducements.

Using samples of retail market orders routed to the NYSE and to Trimark Securities, Inc., an aggressive purchaser of order flow in Nasdaq's third market, we empirically examine several execution-quality dimensions for the actively traded, high market capitalization stocks included in the S&P100 Index.[4] Initially, we examine traditional measures of execution quality. We find that the average retail market order obtains a better execution price on the NYSE. Examining measures of other execution quality dimensions, we find that Trimark offers faster executions and provides more depth improvement than New York. These results suggest that non-price dimensions of execution quality are not equal across venues.

As noted, we find that traditional estimates of the cost of liquidity are somewhat lower on the NYSE than through Trimark. This comparison, however, ignores the fact that Trimark pays an average of \$0.013 per share for the market orders it receives during the sample period. Considering this payment, our results indicate that Trimark offers *brokers* the lowest net cost of liquidity. If the level of competition in the brokerage industry is such that at least one-third of the payments to brokers are passed through to *investors* in the form of increased services and/or lowered commissions, then our work suggests that liquidity suppliers at Trimark charge less for liquidity in NYSE-listed securities than on the NYSE.

The next section provides a discussion of our data. Section 3 contains a detailed analysis of three dimensions of execution quality: trade price, execution speed, and depth improvement. Section 4 concludes the paper and discusses how order-flow payments affect the traditional conclusions drawn from transaction-price measures of execution quality.

2. Data

We obtain order audit-trail data from two prominent securities firms. One is a retail broker routing substantial order flow in exchange-listed stocks to trading venues including the NYSE.[5] The other data provider is Trimark Securities, Inc., a major Nasdaq dealer. Both firms provide data that include security name, order type, a buy–sell indicator, order quantity, execution price and quantity, the order's to-the-second receipt/submission time, order disposition (executed, canceled, or open), and to-the-second execution/report times during March 1999. For the Trimark data, times are recorded when it receives an order and when it executes an order. For the broker data, times are recorded when the broker routes an order and when the broker receives an execution report. We generically refer to the first time as the order receipt time and the second as the order execution time. We obtain quotes from all market centers trading these securities for March 1999 from the NYSE's

[4] The third market is the means by which exchange-listed securities are traded in the over-the-counter market. That market is currently called Nasdaq InterMarket.

[5] The anonymous brokerage firm is a national, full-service broker with investment banking capabilities. It has significant order flow in both listed and Nasdaq stocks, consistently ranking in the top five brokers based on either orders or shares.

Trades and Quotes (TAQ) database. As in SEC (2001), our order data provide several advantages over the TAQ trade data. Specifically, the data allow us to isolate market orders, to properly classify orders as buyer or seller initiated, to benchmark the trade price to the order-receipt-time quote, to measure execution speed, and to examine orders for fewer than 100 shares (30% of our sample).

We consider regular market orders arriving in business hours after an opening quote is posted. We require valid benchmark quotes when an order is received and up to 7.5 minutes after execution. We also include screens for apparent data errors. Table 1 summarizes our data collection experience.

Because the Trimark data contain orders from many brokers, it is not surprising that its orders are a majority of the sample. Although both markets receive many pre-open orders, Trimark receives proportionally more of them than the sample broker sends to the NYSE. The broker's data exclude most non-regular market orders (e.g., all-or-none, fill-or-kill, and market-on-close), which explains the difference in the frequency of these orders between the samples. Because we are interested in execution quality, we eliminate orders cancelled in either their entirety

Table 1
Description of sample gathering process
We obtain market-order data from a broker routing orders to several trading venues including the New York Stock Exchange (NYSE) and from Trimark Securities, a Nasdaq dealer, during March 1999. We apply the screens in the sequence presented below. To allow for the possibility of clock synchronization problems, we exclude orders received within 10 seconds of the opening quote's posting. Special orders include all-or-none, good-til-canceled, fill-or-kill, do not increase, do not reduce, not held, and market-on-close orders. Valid quotes have positive bid and offer prices, have an offer price exceeding the bid price, and have non-zero sizes associated with both the bid and offer prices. Apparent data errors include orders with execution times preceding the receipt time and orders with execution prices differing from the midpoint of the order-receipt-time national best bid and offer by more than \$5.00. The final data screen is imposed to ensure that we can compute statistics requiring valid quotes up to 7.5 minutes after an order executes.

	NYSE		Trimark	
	Number	%	Number	%
Initial sample of market orders	275,962	100.00	845,891	100.00
Data screens				
Orders submitted before the opening quote	15,382	5.57	139,874	16.54
Special orders	104	0.04	25,526	3.02
Canceled orders	424	0.15	1,545	0.18
Orders not completely filled	781	0.28	325	0.04
Orders with invalid benchmark quotes	7,900	2.86	19,561	2.31
Apparent data errors	1,129	0.41	163	0.02
Orders executed after 3:52:30 eastern time	6,041	2.19	21,244	2.51
Remaining orders	244,201	88.49	637,653	75.38
Orders in NYSE-listed S&P500 stocks	158,929	57.59	380,148	44.94
Orders in NYSE-listed S&P100 stocks	53,016	19.21	123,011	14.54
Shares in NYSE-listed S&P100 stocks	13,761,793	n.a.	36,141,053	n.a.
Number of S&P100 stocks	94	n.a.	95	n.a.

or partially. Most traditional measures of execution quality require a benchmark quoted price at either the order submission time or at a time subsequent to the order's execution. The benchmark quote for a buy (sell) order is the lowest quoted offer price (highest quoted bid price) across all market centers providing a quote, i.e., the national best offer (national best bid) price. If no market center is providing firm quotes or if the national best bid (NBB) price is equal to or greater than the national best offer (NBO) price at the relevant time, then the order is eliminated for lack of a valid benchmark quote. Valid quotes are required at order submission time and 2.5, 5, and 7.5 minutes after order execution. Thus, we eliminate orders filling after 3:52:30 p.m. Finally, we eliminate orders with execution prices differing from the benchmark quote's midpoint by more than $5.00 as data errors. We note that the Trimark and NYSE samples contain approximately the same proportion of orders in the large-capitalization stocks included in the S&P500 (60% of qualifying orders for Trimark versus 65% for the NYSE) and S&P100 (19% versus 22%) stock indexes. Our analysis focuses on NYSE-listed securities in the S&P100 Index to examine a common sample. This results in 36 million shares in 95 securities for Trimark and 13 million shares in 94 securities for the NYSE. Except where otherwise noted, we conduct statistical tests using stock-by-stock averages of the variable of interest (reducing our sample to 95 or fewer observations) because sample order routing decisions typically are made conditional on order size and stock.

It is possible that the orders in the two samples differ in ways making it difficult to compare their execution quality. Conversations with the two data providers suggest that the differences should be minor. Trimark executes most, if not all, of the order flow each of its customers receive in a given stock. The anonymous data provider routed most of the order flow it received in the listed S&P100 stocks to the NYSE at the time of our study. It is possible, however, that the anonymous data supplier used an internal order routing algorithm on some of the order flow. If the broker routed larger or more difficult orders to the NYSE, our results may be biased against the NYSE. To determine whether order characteristics differ substantially between the two samples, we present descriptive statistics on the orders' characteristics in Table 2.

As indicated in the All row of Panel C, the overall quoted national best bid and offer (NBBO) spread at order submission time is similar between the two samples.[6] The Trimark data contain one stock for which the sample broker routes no orders to the NYSE. Although the difference is not statistically significant at traditional levels, the orders routed to Trimark are somewhat *larger* (by 34 shares) than those routed to the NYSE by our sample broker. The average trade prices for the two samples also are indistinguishable statistically. Finally, as a proxy for the information environment at order submission time, we compute a variable we call SLIP. SLIP is the change in the midpoint of the quoted bid–ask spread in the five minutes

[6] All statistical tests use an across-stock, two-tailed t-test. To conduct the t-test, we use the share-weighted average for each stock as the unit of analysis. The only difference between our SLIP measure and the measure of adverse selection used by Bessembinder and Kaufman (1997a, b) and Huang and Stoll (1996a) is that we use order receipt time and five minutes after order receipt time while these papers use quote midpoints which are a function of the order's execution time.

Table 2
Descriptive statistics for the final sample
Spread is the national best offer (NBO) price less the national best bid (NBB) price at order receipt time. VWAP is the volume-weighted average trade price of the orders in the specified category. SLIP measures the change in the midpoint of the national best bid and offer quote in the five minutes after an order is received. SLIP is signed so that the reported figure is positive if the change in security value favors the market maker. The net price improvement rate (NPIR) is: NPIR $= (N_B - N_W)/N$, where N_B (N_W) is the number of shares executed at prices *better* (*worse*) than the relevant order-receipt-time quote and N equals the total number of shares executed. For buy (sell) orders, the relevant quote is the NBO (NBB). The liquidity premium (LP) is: LP $=$ (VWAP $-$ Midpoint)I, where Midpoint is the NBBO's midpoint prevailing at order receipt time and I equals $+1$ for buy orders and -1 for sell orders. Estimates of NPIR, LP, VWAP, and SLIP are share-weighted.

Spread	Number of stocks	Number of orders	Mean order size	VWAP	SLIP	NPIR	LP
Panel A: *Retail market orders routed to the New York Stock Exchange*							
\$0.0625	94	27,298	269	\$54.94	− \$0.0066	5.6%	\$0.0278
\$0.125	93	19,000	252	\$62.68	− \$0.0529	42.5%	\$0.0325
\$0.1875	89	4,584	240	\$70.84	− \$0.0041	50.8%	\$0.0443
All	94	53,016	260	\$59.92	− \$0.0205	23.9%	\$0.0321
Panel B: *Retail market orders routed to Trimark*							
\$0.0625	95	61,123	300	\$57.68	− \$0.0193	− 1.9%	\$0.0348
\$0.125	95	43,056	289	\$68.99	− \$0.0182	43.2%	\$0.0363
\$0.1875	94	12,579	287	\$80.47	− \$0.0029	49.8%	\$0.0623
All	95	123,011	294	\$65.43	− \$0.0194	21.2%	\$0.0410

Panel C: *Differences between Trimark and the NYSE* (*Trimark mean minus NYSE mean*)

Spread	Mean order size	VWAP	SLIP	NPIR	LP
\$0.0625	31	\$2.74	− \$0.0127	− 7.5%	\$0.0070
\$0.125	37	\$6.31	\$0.0347	0.7%	\$0.0038
\$0.1875	47	\$9.63	\$0.0012	− 1.0%	\$0.0180**
All (\$0.0043)	34	\$5.51	\$0.0011	− 2.7%	\$0.0089

**Trimark mean differs statistically from the comparable NYSE mean at the 0.01 level in an across-stock, two-tailed t-test.

following order submission. It is defined as

$$\text{SLIP} = (\text{Midpoint}_{\text{ORT}} - \text{Midpoint}_{\text{ORT+5}})I, \tag{1}$$

where, Midpoint $\equiv$ (NBO $-$ NBB)/2, the ORT (ORT $+$ 5) subscript denotes order receipt time (five minutes after order receipt time), and I is an indicator variable taking a value of $+1$ (-1) for buy (sell) orders. Thus, SLIP is positive if the spread midpoint moves in the market maker's favor (increasing after sell orders and falling after buy orders) and negative otherwise. Once again, there is no statistical difference in the two sample's SLIP measures. The fact that the order-receipt-time NBBO spread, average order size, VWAP, and the change in the NBBO's midpoint during the five minutes after an order is received (SLIP) are statistically equivalent in the

two samples suggests that each venue receives similar orders in comparable stocks under the same market conditions during our sample period.

3. Dimensions of execution quality

3.1. Execution prices

With regard to trade-price quality, we examine net price improvement rates, liquidity premiums, and realized liquidity premiums. We compute the net price improvement rate (NPIR) as follows:

$$\text{NPIR} = (N_{\text{B}} - N_{\text{W}})/N, \tag{2}$$

where N_{B} is the number of shares executing at prices better than the relevant order-receipt-time quote, N_{W} is the number of shares executing at prices worse than the relevant order-receipt-time quote, and N equals the total number of shares trading. For buy orders, the relevant quote is the NBO price and for sell orders, the relevant quote is the NBB price.

Although the NPIR reveals how frequently the average order executes at a price better than the benchmark quote, it does not indicate how much better or how much worse trade prices are than quoted prices. The liquidity premium (LP) corrects this deficiency. For an order, the liquidity premium (LP) is

$$\text{LP} = (\text{VWAP} - \text{Midpoint}_{\text{ORT}})I, \tag{3}$$

where VWAP is an order's volume-weighted average transaction price, Midpoint is the midpoint of the order-receipt-time NBBO, and I equals $+1$ (-1) for buy (sell) orders.[7] If the bid–ask spread is symmetric around the equilibrium price, then the liquidity premium provides a per share estimate of liquidity cost. All else equal, market order investors prefer a high net price improvement rate and a low liquidity premium.

For a given order, the realized liquidity premium (RLP) is

$$\text{RLP} = (\text{VWAP} - \text{Midpoint}_{\text{OET+5}})I, \tag{4}$$

where VWAP is the volume-weighted average transaction price for an order, $\text{Midpoint}_{\text{OET+5}}$ is the midpoint of the NBBO prevailing five minutes *after the trade* is executed, and I equals $+1$ (-1) for buy (sell) orders. Assuming the spread midpoint is a good proxy for the stock's value and that the liquidity provider values incremental inventory positions acquired from trading five minutes after taking the position, the RLP represents a liquidity provider's gross trading revenue. Unlike more conventional execution quality measures, RLP controls for differences in order flow profitability across trading venues. This is important given the work of Easley

[7] Assume, for example that a 5,000-share order requires three executions to fill completely. The first 2,500 shares fill at a price of \$25.00, the next 1,500-share trade occurs at a price of \$25.0625, and the final 1,000 shares trade at \$25.125. The VWAP of this 2,500-share order is \$25.04375 $(= \{[2,500 \times \$25.00] + [1,500 \times \$25.0625] + [1,000 \times \$25.125]\}/5,000)$.

et al. (1996), Battalio et al. (2001), and others suggesting systematic differences in order flow profitability across trading venues. SEC (2000) recognizes the importance of RLP and requires that market centers include it in their mandated execution quality reports.

Because the quote benchmark differs, we report NPIR and LP separately from RLP. The last two columns of Table 2 report share-weighted NPIR and LP. We report conditional LP values in addition to the overall figures because the distribution of potential LP values depend on the order-receipt-time spread. There are few orders in S&P100 securities received when the NBBO spread exceeds \$0.1875 (less than 5% of the sample), so we do not report them separately. The NYSE has a higher share-weighted NPIR and a lower share-weighted LP suggesting it offers better market-order trade prices. The largest difference in the point estimates of NPIR occurs when the order-receipt-time spread is \$0.0625. This is not surprising because Trimark offers no price improvement when the spread is at the minimum price variation (at the time of our sample). Despite this large NPIR difference, the hypothesis that the across-stock, share-weighted mean NPIR or LP are the same on the NYSE and Trimark cannot be rejected by a *t*-test at the 0.10 level.[8] Of the 94 stocks for which the sample contains both NYSE and Trimark trades, however, 63 have lower LP on the NYSE. This fraction differs significantly from 50% at the 0.01 level, implying that the NYSE's LP typically is lower than Trimark's. These results suggest that, although Trimark and the NYSE improve prices at nearly the same frequency (except in markets where the quoted spread is at the minimum price variation), the NYSE provides larger price improvements and/or smaller price dis-improvements.

Execution price quality varies considerably by order size. Table 3 presents descriptive statistics on the quality of execution prices in three order-size categories.[9] Orders for fewer than 100 shares (odd-lot orders) are excluded in most extant work because they are not reported on TAQ. These orders comprise nearly one-third of the sample. We find that odd-lot orders execute at significantly worse prices than orders for 100 or more shares on both the NYSE and Trimark. The negative net price improvement rates indicate that, on average, odd-lots execute outside of the order-receipt-time NBBO.[10] Across-stock comparisons find that Trimark offers significantly higher net price improvement rates and lower liquidity premiums for odd-lot orders received when the NBBO is no wider than \$0.1875. Our second order-size category, 100–499 shares, represents over one-half of the sample orders. On average, Trimark offers significantly higher NPIR and lower LP for these orders. It

[8] Given our sample size, the differences in most variables are significant when orders rather than stocks are the unit of observation.

[9] For each instance in which we compare execution quality statistics between a NYSE sample and a Trimark sample, we also compare average order size, VWAP, and SLIP as in Table 2. Because the differences consistently are insignificant, we do not report them.

[10] The NYSE automatically executes odd lots against the best price quote (BPQ), not the NBBO. The BPQ excludes from the NBBO quotes for which either the bid or ask depth is zero, quotes \$0.25 or more away from the NYSE quote, and quotes occurring when the NYSE's Message Delivery System is closed (see NYSE Rule 124).

Table 3
Net price improvement rates and liquidity premiums conditional on order size
Spread is the national best offer (NBO) price less the national best bid (NBB) price when an order arrives. The net price improvement rate (NPIR) is: NPIR $= (N_B - N_W)/N$, where N_B (N_W) is the number of shares executed at prices *better* (*worse*) than the relevant order-receipt-time quote and N represents the total number of shares executed. For buy (sell) orders, the relevant quote is the NBO (NBB). The liquidity premium (LP) is: LP $=$ (VWAP $-$ Midpoint)I, where Midpoint is the midpoint of the NBBO prevailing at order receipt time and I equals $+1$ for buy orders and -1 for sell orders. Estimates of NPIR and LP are share-weighted. Negative NPIR (positive LP) differences indicate that the NYSE provides better execution prices.

Spread	Order size: <100 shares			Order size: 100–499 shares			Order size: 500–999 shares		
	Orders	NPIR	LP	Orders	NPIR	LP	Orders	NPIR	LP
Panel A: *Retail market orders routed to the New York Stock Exchange*									
\$0.0625	7,843	− 5.17%	\$0.035	15,338	10.91%	\$0.024	2,528	10.45%	\$0.024
\$0.125	5,928	− 1.97%	\$0.064	10,517	52.27%	\$0.024	1,536	52.43%	\$0.026
\$0.1875	1,466	− 0.96%	\$0.095	2,569	64.73%	\$0.030	318	55.05%	\$0.043
All	15,841	− 3.43%	\$0.055	29,681	32.38%	\$0.025	4,536	29.74%	\$0.027
Panel B: *Retail market orders routed to Trimark*									
\$0.0625	19,356	− 0.30%	\$0.032	31,331	1.08%	\$0.031	5,255	0.51%	\$0.031
\$0.125	14,484	1.25%	\$0.062	21,592	87.28%	\$0.008	3,506	36.15%	\$0.040
\$0.1875	4,340	3.84%	\$0.091	6,250	90.98%	\$0.034	1,022	48.60%	\$0.061
All	40,377	1.09%	\$0.054	62,212	44.24%	\$0.022	10,299	20.05%	\$0.040

Panel C: *Differences between Trimark and the NYSE* (*Trimark mean minus NYSE mean*)

Spread	Order size: <100 shares		Order size: 100–499 shares		Order size: 500–999 shares	
	NPIR	LP	NPIR	LP	NPIR	LP
\$0.0625	4.87%**	− \$0.003**	− 9.83%**	\$0.007	− 9.94%**	\$0.007**
\$0.125	3.22%**	− \$0.002**	35.01%**	− \$0.016**	− 16.28%**	\$0.014**
\$0.1875	4.80%**	− \$0.004**	26.25%**	\$0.004	− 6.45%**	\$0.018**
All	4.52%**	− \$0.001	11.86%**	− \$0.003**	− 9.69%**	\$0.013**

**Trimark mean differs statistically from the comparable NYSE mean at the 0.01 significance level in an across-stock, two-tailed t-test.

is interesting to note that, although Trimark offers more frequent net price improvement to orders received when the NBBO spread is \$0.1875, the NYSE provides these traders a lower liquidity premium. This likely reflects the fact that Trimark's price improvement is algorithmic and rarely exceeds \$0.0625 (one price tick) while the NYSE's price improvement arises (at least partially) from the meeting of public orders, which can result in price improvement of more than a single tick. For orders of 500–999 shares (and larger), the NYSE offers significantly higher price improvement rates and lower liquidity premiums. Overall, there appear to be significant differences in the quality of execution prices on the NYSE and Trimark that are a joint function of order size and order-receipt-time spread.

Although trading venues generally must provide execution prices no worse than the NBBO price for orders within the quoted size, no such requirement exists for orders with sizes exceeding quoted size. Assuming the liquidity supply function is upward sloping, it is more costly to provide liquidity to depth-exceeding orders. As a result, comparisons of execution prices across trading venues should condition on an order's size in relation to the depth at the inside quote. We examine this in Table 4.

Table 4
Net price improvement rates and liquidity premiums conditional on order size relative to the depth at the relevant quote
Spread is the national best offer (NBO) price less the national best bid (NBB) price when an order is received. For buy (sell) orders, the relevant quote is the NBO (NBB) when the order is received. The net price improvement rate (NPIR) is: NPIR $= (N_B - N_W)/N$, where N_B (N_W) represents the number of shares executed at prices *better* (*worse*) than the relevant order receipt-time quote and N represents the total number of shares executed. For buy (sell) orders, the relevant quote is the NBO (NBB). The liquidity premium (LP) is: LP $=$ (VWAP $-$ Midpoint)I, where Midpoint represents the NBBO's midpoint prevailing at order receipt time and I equals $+1$ for buy orders and -1 for sell orders. Estimates of NPIR and LP are share-weighted. Negative NPIR (positive LP) differences indicate that the NYSE provides better trade prices.

Spread	Order size no larger than depth			Order size exceeds depth		
	Orders	NPIR	LP	Orders	NPIR	LP
Panel A: *Retail market orders routed to the New York Stock Exchange*						
\$0.0625	26,261	12.01%	\$0.023	1,037	− 32.23%	\$0.0554
\$0.125	18,444	50.40%	\$0.026	556	− 9.24%	\$0.0752
\$0.1875	4,388	59.78%	\$0.035	196	13.47%	\$0.0832
All	51,135	31.18%	\$0.026	1,881	− 18.16%	\$0.0692
Panel B: *Retail market orders routed to Trimark*						
\$0.0625	58,412	1.04%	\$0.031	2,720	− 13.27%	\$0.0503
\$0.125	41,341	54.97%	\$0.028	1,715	− 0.42%	\$0.0671
\$0.1875	11,922	65.25%	\$0.050	657	11.40%	\$0.0925
All	117,540	28.68%	\$0.033	5,471	− 5.05%	\$0.0689

Panel C: *Differences between Trimark and the NYSE* (*Trimark mean minus NYSE mean*)

Spread	Order size no larger than depth		Order size exceeds depth	
	NPIR	LP	NPIR	LP
\$0.0625	− 10.97%**	\$0.008	18.96%**	− \$0.0051
\$0.125	4.57%**	\$0.002	− 8.82%	− \$0.0081
\$0.1875	5.47%	\$0.015**	− 2.07%	\$0.0093
All	− 2.50%	\$0.007**	13.11%*	− \$0.0003

*Trimark mean differs statistically from the comparable NYSE mean at the 0.05 level in an across-stock, two-tailed t-test.

**Trimark mean differs statistically from the comparable NYSE mean at the 0.01 level in an across-stock, two-tailed t-test.

As expected, net price improvement rates are substantially higher and liquidity premiums are substantially lower for orders with less-than-quoted size on both trading venues. The NYSE charges significantly less for providing liquidity to these "small" orders. Although the frequency with which orders exceeding the quoted size receive net price improvement is significantly larger at Trimark, the difference in the liquidity premiums charged by Trimark and the NYSE is statistically insignificant.

Table 5 reports share-weighted RLP conditional on the order-receipt-time NBBO spread. The second and third columns report the total number of orders and the associated RLP. As suggested by a negative SLIP, the RLP is less than the LP reported in Tables 2 and 4. The differences between LP and RLP are significant at the 0.01 level for both NYSE and Trimark trades using an across-stock t-test. This implies that, on average, the stock's value moves in the trader's favor (increases after

Table 5
Realized liquidity premiums
For a given order, the realized liquidity premium (RLP) is: $RLP = (VWAP - Midpoint_{+5})I$, where VWAP represents the volume-weighted average transaction price for an order, $Midpoint_{+5}$ represents the midpoint of the national best bid and offer prevailing five minutes *after* the trade, and I equals +1 for buy orders and −1 for sell orders. The RLP reported are share-weighted means. Spread is the national best offer price less the national best bid price when an order is received. An order is considered to exceed the depth if it requests more shares than are available at the relevant quote. For buy (sell) orders, the relevant quote is the national best offer (bid) when the order is received by the trading venue. Positive RLP differences indicate that the NYSE earns less providing liquidity to retail market orders. None of the Trimark means differ statistically from the comparable NYSE mean at the 0.10 significance level in an across-stock, two-tailed t-test.

Spread	All		Order size within depth		Order size exceeds depth	
	Orders	RLP	Orders	RLP	Orders	RLP
Panel A: *Orders routed to the New York Stock Exchange*						
\$0.0625	27,298	\$0.0213	26,261	\$0.0219	1,037	\$0.0220
\$0.125	19,000	\$0.0212	18,444	\$0.0225	556	\$0.0125
\$0.1875	4,584	\$0.0267	4,388	\$0.0308	196	\$0.0098
All	53,016	\$0.0229	51,135	\$0.0231	1,881	\$0.0218
Panel B: *Orders routed to Trimark*						
\$0.0625	61,132	\$0.0232	58,412	\$0.0279	2,720	\$0.0054
\$0.125	43,056	\$0.0224	41,341	\$0.0225	1,715	\$0.0210
\$0.1875	12,579	\$0.0505	11,922	\$0.0426	657	\$0.0698
All	123,011	\$0.0273	117,540	\$0.0285	5,471	\$0.0232

Panel C: *Differences between RLP on Trimark and the NYSE* (*Trimark mean minus NYSE mean*)

Spread	All	Order size within depth	Order size exceeds depth
\$0.0625	\$0.0019	\$0.0060	− \$0.0166
\$0.125	\$0.0012	\$0.0000	\$0.0085
\$0.1875	\$0.0238	\$0.0118	\$0.0600
All	\$0.0044	\$0.0054	\$0.0014

buy orders and decreases after sell orders) and against the liquidity provider in the five minutes post-trade.[11]

Overall, NYSE liquidity providers reap significantly less revenue than Trimark when *individual orders* are used as the unit of observation, suggesting that the NYSE provides cheaper liquidity than Trimark. The \$0.0044 per share difference between the NYSE's and Trimark's RLP, however, is not statistically significant at traditional levels using either an *across-stock t*-test or a sign test (neither are any of the individual spread-category differences). Although the NYSE's advantage is magnified for orders for less than the quoted size (\$0.0054) and reduced for orders exceeding the quoted size (\$0.0014), neither of these differences is statistically significant using individual stocks as the unit of observation. Thus, to the extent order routing decisions are made on a stock by stock basis, we cannot use differences in RLP to convincingly argue that one trading venue provides liquidity more cheaply than the other.

3.2. Execution speed

As noted in Blume (2000), a recent survey by Sanford C. Bernstein & Co., Inc. finds that 58% of on-line investors claim to value execution speed over execution price when evaluating trade quality. Trimark potentially offers such investors an advantage over the NYSE on this dimension. If the order qualifies for Trimark's automatic execution guarantee, then Trimark provides an immediate fill when the order touches Trimark's computer system.[12] By comparison, the NYSE offered no automatic executions during our sample period. On the NYSE, orders arrive at the specialist's post, are exposed to the auction process, and then are executed manually.

Fig. 1 reports the cumulative frequency distributions of execution speed for market orders routed to Trimark and to the NYSE. Results are reported separately for orders with less-than-quoted and more-than-quoted sizes.

As one might expect, orders tend to fill more quickly when there is sufficient size in the quote. The difference in the execution speed between the NYSE and Trimark is substantial. Trimark fills 89% of the orders received when there is sufficient depth in the market in the same second that the order arrives. It takes the NYSE over 30 seconds to fill the same proportion of orders. Depth-exceeding market orders execute a bit slower on both venues. Trimark executes over 75% of these orders "immediately", while it again takes the NYSE more than 30 seconds to execute this many orders. Overall, it seems unlikely that the time required for inter-computer transmission between the broker and the NYSE accounts for the large difference in

[11] Sensitivity analyses using the midpoint of the NBBO 2.5 and 7.5 minutes after executions suggest the RLP is not significantly affected by the amount of time we allow to elapse after a trade. Furthermore, our conclusions are unaltered if we use a volume-weighted average transaction price during the five minute period as our measure of security value when computing RLP.

[12] To receive this guarantee, an order must come from a pre-approved broker and be for fewer than a specified number of shares in a security on the guarantee list.

execution speeds on the NYSE and through Trimark.[13] This suggests that Trimark's automatic executions may offer an advantage over the NYSE for customers placing a high value on execution speed.[14]

Orders with different execution speeds may differ with regard to order characteristics and the market conditions surrounding order submission. Table 6 reports order size, quoted spread, and changes in the spread midpoint in the five minutes after order receipt (SLIP) conditional on the speed of execution. The quoted spread and the change in that spread's midpoint are intended to proxy for market conditions at the time of and time immediately following order receipt.

Short execution times are associated with small orders. For both NYSE and Trimark executions, the order size for orders filling in ten seconds or less is smaller at the 0.01 significance level than the order size (mean and median) in each of the other execution-speed categories. The relationship between order size and execution speed is not monotonic, however, for longer execution times on the NYSE. Likewise, fast executions are associated with narrow quoted spreads, although the differences in spreads between execution-speed categories for the NYSE are not statistically significant at traditional levels. Overall, this suggests faster fills are associated with small orders in liquid stocks. The final column in Table 6 reports SLIP conditional on execution-speed category. If the spread midpoint represents the security's value, then SLIP represents the change in the security's value immediately following an order's submission. The change is signed considering whether a buyer or seller initiates the order so that the reported figure is positive if the change in security value favors the market maker and is negative if it favors the initiating trader. Although the reported numbers are consistently negative, indicating that quoted prices typically move against the market maker immediately after an order is received, only the greater-than-60-second execution speed category and overall numbers for Trimark are reliably negative at traditional significance levels. The large SLIP associated with the slowest execution-speed category likely reflects the fact that Trimark does not automatically execute orders in "non-normal" market condi-

[13] Note that our median NYSE execution speed (between 10 and 20 seconds) is less than that reported in Bacidore et al. (1999) using internal NYSE data (22 seconds). In April of 2001, the NYSE began offering immediate executions at the NBBO in all of its securities via NYSE Direct+.

[14] Ideally, we measure execution speed from when a customer places an order until the time the customer receives the trade confirmation. Unfortunately, our data do not contain these times. Moreover, the time stamps for our two data sets are not directly comparable. Time stamps in the broker's data represent the time the broker receives the order and the time the confirmed trade returns to the broker. Trimark time stamps contain the time the order arrives at Trimark and the time Trimark completely fills the order. Thus, the broker's data include the time required for its computers to send orders and receive confirmations from the executing venue while the Trimark data do not. Fortunately, the broker from whom we obtain data routes more than 23,000 market orders in 12 NYSE-listed securities in the S&P100 Index to Madoff Investment Securities, another major Nasdaq dealer. Because both Trimark and Madoff provide highly automated execution services for orders in NYSE-listed securities and the Madoff times include the time necessary to communicate with the broker, comparing the speed with which these two Nasdaq dealers execute orders sheds light on the magnitude of the potential bias introduced by the differing time-stamp conventions in our Trimark and broker data. Results suggest that differences in execution times on the NYSE and Trimark exceeding a few seconds are not due to the different time-stamp conventions in our data.

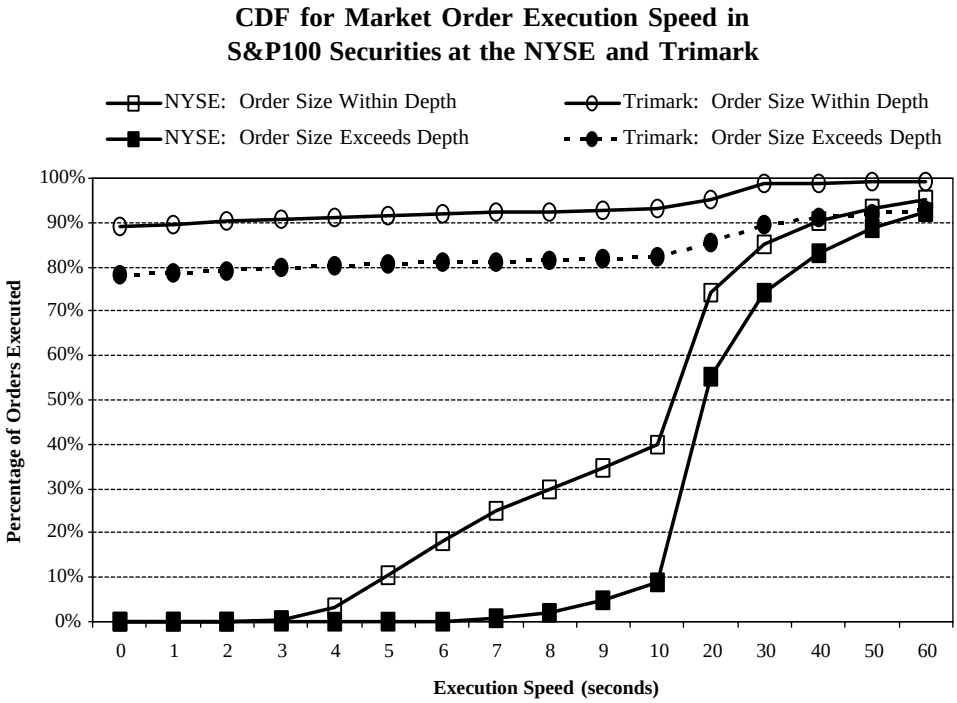

Fig. 1. CDF for market order execution speed in S&P100 securities at the NYSE and Trimark. Note: For the New York Stock Exchange (NYSE), execution speed is measured from the time an order is sent by the broker to the NYSE to the time the broker receives confirmation from the NYSE that the entire order has been executed. For Trimark, execution speed is measured from the time an order is received by Trimark to the time Trimark entirely executes the order. An order is considered to be relatively large if it requests more shares than are available at the relevant quote. Otherwise, an order is considered to be relatively small. For buy (sell) orders, the relevant quote is the national best offer (Bid) when the order is received by the trading venue.

tions.[15] In these cases, orders are routed to market makers who manually choose the price at which the order fills.

3.3. Depth improvement

Depth improvement is the market's ability to execute orders for more than the quoted number of shares at quoted prices (or better).[16] In our sample period,

[15] Trimark's website notes that non-normal market conditions include but are not limited to locked or crossed markets, fast or volatile markets, Trimark/NYSE order imbalances, when an exchange places a stock in "non-firm quote" mode, markets with unusually wide spreads, periods of time surrounding significant news stories, and communications or systems outage.

[16] Handa et al. (1999) and Bacidore et al. (2002) respectively examine depth improvement on the American and New York Stock Exchanges. NBBO quoted depth is the size associated with the best quoted price. If more than one venue is quoting the best price, then we take the largest (not aggregate) size associated with that price.

Table 6
Order characteristics and market conditions conditional on execution speed
Execution speed is measured as the difference between order receipt time and order execution time. For the NYSE, this time includes the time required to send the order from the broker to the market center and receive the confirmation from the market center. For Trimark, the reported time is the time between the market maker's receipt and execution times. Spread is the national best offer price less the national best bid price when an order is received. SLIP measures the change in the midpoint of the national best bid and offer in the five minutes after an order is received. SLIP is signed so that the reported figure is positive if the change in security value favors the market maker. Spread and SLIP are share-weighted.

Panel A: *Orders routed to the New York Stock Exchange*

Execution speed (seconds)	Number of stocks	Number of orders	Mean order size (shares)	Spread	SLIP
0–10	90	20,499	98.89	\$0.0962	− \$0.0355
11–30	92	24,386	349.64	\$0.1026	− \$0.0145
31–60	84	5,525	398.88	\$0.1061	− \$0.0270
> 60	87	2,606	385.42	\$0.1070	− \$0.0265
All	94	53,016	259.58	\$0.1025	− \$0.0205

Panel B: *Orders routed to Trimark*

Execution speed (seconds)	Number of stocks	Number of orders	Mean order size (shares)	Spread width	SLIP
0–10	90	113,950	243.89	\$0.0990	− \$0.0101
11–30	92	7,013	761.85	\$0.1410	− \$0.0157
31–60	84	703	1,182.26	\$0.1155	− \$0.0019
> 60	87	1,345	1,617.75	\$0.1187	− \$0.1538
All	94	123,011	293.80	\$0.1068	− \$0.0194

Trimark guarantees to execute up to 5,000 shares at quoted prices (or better) under normal market conditions. Table 7 documents the frequency of depth improvement at each venue.

We report shares received in orders of the indicated size, the fraction of these shares eligible for depth improvement, and the fraction of eligible shares receiving depth improvement. To compute the fraction of eligible shares, we subtract the relevant quoted size from the order size, cumulate the positive numbers from this calculation, and divide the sum by the total number of shares received. From Table 7, we note that Trimark has a larger portion of shares eligible for depth improvement than the NYSE in our sample (14% versus 8.5%). Furthermore, Trimark offers significantly higher depth improvement rates than the NYSE for all order sizes. For orders seeking to trade fewer than 5,000 shares, the NYSE's depth improvement rate ranges from 60% to 70% while Trimark's exceeds 95%.[17] Indeed, Trimark's depth improvement rate is statistically higher than the NYSE's for each order-size category at the 0.01 level. Depth improvement rates fall on both trading venues for orders in excess of 5,000 shares.

[17] Trimark reserves the right to not honor its guaranteed size in "abnormal" markets.

Table 7
Depth improvement
An order is considered to be eligible for depth improvement if it requests more shares than are available at the relevant national best bid and offer quote. For buy (sell) orders, the relevant quote is the national best offer (Bid) when the order is received by the trading venue. Shares in excess of the depth at the relevant quote are depth improved if they execute at a price no worse than the relevant quoted price. The percentage of shares eligible for depth improvement is determined by dividing the total number of shares in excess of the depth displayed at the relevant quote when orders are received by the total number of shares requested in those orders. The percentage of eligible shares depth improved is determined by dividing the total number of depth improved shares by the total number of shares eligible for depth improvement.

Order size (shares)	Shares ($\times 10^3$)	Mean order size (shares)	% of shares eligible for depth improvement	Mean order size of orders eligible for depth improvement	% of eligible shares depth improved
Panel A: *Orders routed to the New York Stock Exchange*					
100–499	5,769	194	1.86	254	66.02
500–999	2,581	569	5.20	598	70.18
1,000–1,999	2,496	1,105	10.22	1,171	66.06
2,000–4,999	1,392	2,459	21.70	2,506	61.24
> 4,999	890	6,692	48.00	6,964	42.44
All	13,762	260	8.48	1,076	57.19
Panel B: *Orders routed to Trimark*					
100–499	10,960	176	1.99	258	97.38**
500–999	5,909	574	6.35	613	94.10**
1,000–1,999	7,853	1,097	11.66	1,159	95.44**
2,000–4,999	6,118	2,541	26.31	2,614	94.18**
> 4,999	3,774	6,925	50.75	7,264	55.79**
All	36,141	294	13.82	1,465	79.90**

**Trimark mean differs statistically from the comparable NYSE mean at the 0.01 significance level in an across-stock, two-tailed *t*-test.

3.4. Summary

Our analysis of three dimensions of execution quality shows that neither sample trading venue dominates all dimensions. This suggests that regulators should not make market structure and execution quality assessments based solely on execution-price statistics because all else is not equal. The SEC's most recent rule proposals on disclosure and market fragmentation recognize this (SEC, 2000). The SEC, however, appears reticent to place much reliance on non-price execution quality statistics. For example, Arthur Levitt (then Chairman of the SEC) notes in a November 1999 speech delivered to the Securities Industry Association that

> Some firms, for example, have told us that execution speed is the most important factor in their routing decisions...These firms also offer no support for their belief that their customers prefer speedy execution above all else. Sometimes, the

invocation of speed rings as a hollow rationalization for selling order flow or capturing the spread on internally executed orders.

Even focusing on execution price does not provide unambiguous conclusions. Although the NYSE generally offers better execution prices, our results do justify routing some market orders to Trimark (e.g., orders arriving when the quoted spread exceeds \$0.0625 for fewer than 500 shares or orders with sizes exceeding the quoted size). In addition, there is the potential for conflicting conclusions from different execution-price statistics. Our analysis reveals that the NYSE provides a lower LP than Trimark despite the fact that Trimark provides a higher NPIR.

4. Conclusions

Execution quality statistics are increasingly important to trading venues seeking to attract and retain retail order flow and to those evaluating the current regulatory environment. Failure to consider all aspects of execution quality can lead to order routing decisions that may not be in investors' best interests and to suboptimal market design. Extant academic literature virtually unanimously concludes that the NYSE provides better quality executions than other markets. This conclusion is reached by comparing trade prices to quoted prices and may not be robust to changing order type or to considering other dimensions of execution quality. As an example of the former, Battalio et al. (2002) provide empirical justification for the routing of certain types of limit orders in NYSE-listed securities to regional stock exchanges.

We assess retail market order execution quality as a multi-dimensional concept for NYSE-listed securities in the S&P100 Index. Specifically, we examine relative market order execution quality on the NYSE and Trimark, a Nasdaq dealer. We evaluate execution prices, execution speed, and depth improvement on these trading venues. As predicted by Harris (1993), Macey and O'Hara (1997), and Blume (2000), we find that we cannot focus on a single execution-quality facet because all else is not equal. Each trading venue excels on at least one of these dimensions, suggesting that it is potentially misleading to draw conclusions regarding market quality from a one-dimensional analysis. In addition, it is important to consider trading costs other than the price paid (received).

Using both the LP and RLP measures of execution-price quality, we conclude that the NYSE provides investors with more favorable prices. The LP measures the price investors pay (receive) when buying (selling) the security. On this measure, the NYSE provides prices that better Trimark's prices by \$0.0089 per share, on average. RLP provides an estimate of a liquidity provider's trading revenue.[18] Although this

[18] We are not the first to use the RLP as a proxy for trading revenue. Huang and Stoll (1996b), for example, use the realized half-spread as a measure of dealer profit. The RLP allows us to assess the gross cost of liquidity. In an auction market, where traders interact with each other more frequently than in a dealer market, liquidity may be supplied by another market order, which serves to reduce the net cost of liquidity.

measure assumes investors are concerned only with net trading costs, it captures those dimensions of execution quality that are costly to provide. These measures are incomplete, however, because trading venues charge direct costs such as transaction-based fees, membership costs, and order-flow payments (a negative cost). NASD and NYSE membership fees are fixed, implying that their effect on marginal order routing choices is minor (especially when examining the difference). Marginal transaction fees also are nearly zero for brokers routing to the NYSE or to Nasdaq's third market. The NYSE does not charge fees for post-opening orders of fewer than 2,100 shares (most of our sample) and it places a maximum on annual total transaction fees (that our sample broker pays). Trimark does not charge transaction fees. Indeed, by paying for order flow, Trimark imposes a *negative* fee of \$0.013 per share (on average) for market orders in S&P100 stocks during our sample period. In other words, the primary difference in the direct costs imposed by these two trading venues reflects the fact that Trimark pays for order flow while the NYSE does not. Thus, we conclude by adjusting our measure of liquidity costs and gross trading revenue to reflect this difference.

With a difference in overall RLP (LP) of \$0.0044 (\$0.0089) per share, subtracting the average order flow payment from Trimark's share-weighted RLP (LP) provides a net trading revenue (net cost of liquidity) estimate that is less than the NYSE's by \$0.0086 (\$0.0041). Indeed, across all stocks, once the average payment is subtracted from Trimark's RLP, we find that Trimark's net trading revenue estimate is significantly lower than the NYSE's RLP at the 0.01 level. Hence, Trimark appears to be a cheaper source of liquidity *for brokers* than the NYSE. Whether or not Trimark is a cheaper source of liquidity for retail investors depends upon the extent that order flow payments are used by brokers to lower commissions and/or increase services. More generally, these results suggest that payment for order flow and "best execution" are not necessarily mutually exclusive. If payment for order flow is passed on to customers in the form of lower commissions and/or better services, then payment for order flow might be thought of as "certainty equivalent price improvement". That is, a venue can provide frequent, stochastic price improvement without payment for order flow or infrequent, stochastic price improvement with payment for order flow to provide the broker with roughly identical execution quality. The SEC has been reluctant to consider payments for order flow as a positive factor in best execution studies because it is difficult to determine how/if these payments are passed onto investors.

We do not suggest that our results generalize to all Nasdaq dealers. Trimark is a successful market maker and that success might be due to the fact that it offers above average execution quality and/or above average order flow payments. Also, our results might not generalize to all NYSE executions. Although we believe that the comparison broker routed most of its order flow in the sample stocks to the NYSE without conditioning the decision on order characteristics or market conditions, the anonymous broker's orders might differ from Trimark's orders in fundamental ways that our descriptive statistical analysis did not uncover. Instead, our results should be interpreted as providing a counter-example to the notion that one can draw general conclusions regarding execution quality from an examination of trade prices.

We note that many Nasdaq dealers (including Trimark) select their customers/orders while the NYSE is the executor of last resort. This selective execution may impose costs on investors that we do not measure. We also do not analyze the costs and benefits of the dealer market. Traders interact with each other in an auction market, so gains or losses in execution quality are primarily wealth transfers and have little effect on overall investor welfare. Dealers, however, extract compensation. Our findings suggest the benefits of the dealer market outweigh its costs for at least some retail market order traders.

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