

Alternative Trading Systems: Description of ATS Trading in National Market System Stocks

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This paper is the first in a series of DERA staff white papers planned to analyze off-exchange trading of NMS stocks. While this paper is limited to discussing descriptive statistics, other papers in the series will provide more quantitative analysis on the pricing of trades, and will extend analysis of off-exchange activity beyond that occurring on ATSs.

ABSTRACT

This paper discusses descriptive statistics on U.S. equity Alternative Trading Systems (ATSs, some of which are referred to as “dark pools”).² The paper is intended to inform public discussion of the role and regulation of ATSs.

While ATSs operate markets similar in some ways to the registered exchanges, there are important institutional differences. Although both exchanges and ATSs provide marketplaces for buyers and sellers to transact in securities, ATSs do not necessarily provide public information on the best prices available to traders within their system. They also do not set rules governing the conduct of subscribers and they perform no self-regulation, while exchanges perform all of these functions. Additionally, because ATSs are regulated as broker-dealers, they comply with a different set of regulations than traditional exchanges.³

¹ This memorandum was prepared for Craig Lewis, Director and Chief Economist of the Division of Economic and Risk Analysis (DERA). It was reviewed by Amy Edwards and Jennifer Marietta-Westberg, DERA, and Michael Gaw and Dan Gray, Division of Trading and Markets (TM). Michael Gaw provided substantial assistance with Form ATS-R filings and knowledge of institutional detail of individual venues; Michael Gaw and Dan Gray provided substantial comments and feedback. The U.S. Securities and Exchange Commission, as a matter of policy, disclaims responsibility for any private publication or statement of any of its employees. The views expressed herein are those of the author and do not necessarily reflect the views of the Commission or of the author’s colleagues upon the staff of the Commission.

² Throughout this paper, I describe a venue as “dark” if it does not publicly disseminate top of book information and consider as “lit” a venue that does distribute this data.

³ See [Release No. 34-40760](#) for a more detailed discussion of exchange versus ATS regulatory requirements.

Trading on ATSs regularly comprises 10-15% of U.S. equity trading volume.⁴ However, academic and public understanding of ATSs lags that of traditional exchanges partially due to a lack of publicly available data on ATSs.⁵ Using a five-day sample of regulatory data from May 7-11, 2012, this paper discusses summary statistics on ATS participation in the trading of National Market System (NMS) stocks, including common stocks and many exchange-traded products (ETPs).⁶

Summary of main findings:

- 35 broker-dealer firms operate 44 ATSs that actively trade NMS stocks.
- ATSs execute an estimated 11.31% of NMS dollar volume, and 12.12% of NMS share volume.
- The distribution of reported trade⁷ sizes on dark ATSs⁸ is remarkably similar to that observed on traditional exchanges.
- The five ATSs with average order sizes exceeding 1,000 shares collectively comprise 2.94% of ATS dollar volume and 3.01% of ATS share volume.
- 1.11% of ATS orders receive at least a partial fill, and 0.69% of shares routed to an ATS are filled.
- For all market-capitalization groups of stocks, at least 10% of trading dollar volume (11.37% of share volume) is attributable to ATSs, with the largest market share occurring in medium capitalization stocks (12.30% of dollar volume and 12.86% of share volume).
- 7.39% of ETF dollar volume and 8.49% of ETF share volume is executed on ATSs as opposed to 12.83% of the dollar volume and 12.80% of the share volume in other NMS stocks.

⁴ See for example <http://www.bloomberg.com/news/2012-03-01/dark-pools-capture-record-share-of-declining-u-s-equity-volume.html>.

⁵ See for example Buti, Rindi and Werner (2011), who discuss the limited academic research on dark pools. (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1630499).

⁶ The legal definition of “NMS stocks” includes ETPs. Most ETPs in the sample are exchange-traded funds (ETFs), but the sample includes other exchange-traded products as well. See 17 CFR 240.600(b)(47) (defining “NMS stock” as any NMS security other than an option); 17 CFR 240.600(b)(46) (defining “NMS security” as any security or class of securities for which transaction reports are collected, processed, and made available pursuant to an effective transaction reporting plan, or an effective national market system plan for reporting transactions in listed options).

⁷ Throughout this document, I use “fill” to denote an execution in association with the order that generated it. A “trade” is an execution event involving multiple fills and is considered in isolation of the orders that generated it. For example, two resting buy orders for 100 shares each may cross with a 200 share sell order. This generates three or four fills, depending on whether the sell-side fills are aggregated before reporting. One or two trades will be reported to the consolidated tape totaling 200 shares.

⁸ The subsample of dark ATSs excludes Electronic Communication Networks (“ECNs”) where possible because they distribute top of book information and are therefore considered to be lit venues for the purpose of this analysis.

I. Description of Data and Data Limitations

Generally only limited data on ATSs is publicly available. Although some data vendors provide subscription sources of information on ATS trading, these data vendors rely on self-reported data and sometimes include venues in their analyses that may generally be regarded as dark pools but are excluded from this analysis because they do not file Form ATS-R⁹. Furthermore, the information provided by commercial sources is limited in scope. Generally, information on order characteristics, activity levels in the cross section of stocks, and fill rates is not available to commercial data vendors or the public.

The data used in this paper is comprised of all FINRA OATS¹⁰-reported ATS orders and trades¹¹ for NMS stocks for the five-day period covering May 7-11, 2012, representing 26 firms reporting designated ATS orders and trades within OATS. I am unable to distinguish ATS order and execution data from other data in OATS for nine venues comprising 11.30% of ATS transacted dollar volume based on 2012Q2 Form ATS-R¹² filings with the Commission.^{13 14}

My results are based on 2.9 billion ATS orders resulting in 32.2 million ATS fills representing \$229.1 billion in trading.¹⁵ A one- week sample of data permits me to examine order and trade characteristics

⁹ See [Release No. 34-40760](#) for information on the scope of Reg ATS. Also see Footnote 30.

¹⁰ FINRA's OATS data includes order, trade, routing and quote information that can be used to recreate most order life cycle events for orders in NMS stocks routed in the over the counter (OTC) markets. All FINRA-member firms are required to report data to FINRA electronically. Further information on OATS is available on FINRA's web site (<http://www.finra.org/industry/compliance/markettransparency/oats/>).

¹¹ See <http://www.finra.org/finramanual/rules/r7400/>.

¹² Each ATS is required to submit a Form ATS-R to the Commission within 30 days of the end of each calendar quarter. Form ATS-R requires reporting of, among other things, the total units and dollar volume traded by the ATS in several categories of securities. See [Release No. 34-40760](#).

¹³ Most, but not all, venues which are not represented in our ATS sample are small venues with limited volume. I have no reason to believe that these venues have order flow that is characteristically different from the venues with ATS data represented in our sample.

¹⁴ The data for the 11.30% of ATS volume that I cannot identify is likely to be present within OATS, but possibly results from certain intra-firm transfer events that are excluded from OATS reporting requirements.

¹⁵ These numbers are not adjusted for double-counting. Generally, all ATS executed transacted dollar volume within OATS is double-counted; two 100-share orders (one seeking to buy, the other seeking to sell) will generate a 100-share trade and result in two 100-share execution (fill) reports in OATS. However, two resting orders of 100 shares may cross with a single 200 share order, creating three order and execution fill records, of which one or two (of total size 200 shares) will be reported to the consolidated tape through the trade reporting facility (TRF). Choosing to report only the buy or sell side of trades would allow me to arrive at single-counted order and execution numbers, but would possibly bias order and trade size results depending on whether large orders tended to be buys or sells during the sample week. I adjust for this double-counting in calculations of ATS market share of trading by halving executed transacted dollar or share volumes reported in OATS. On exchanges, only one side of a reportable trade reports to the consolidated tape, avoiding this double-counting.

and market share at a point in time, but does not allow me to examine changes in these metrics over time¹⁶ or the evolution of NMS structure in response to market and regulatory changes.

I identify ATS orders¹⁷ via a combination of receiving department code and the reporting firm's market participant identification code (MPID).¹⁸ I include as orders all records with message types of new order, combined order/execution, combined order/routing, and cancel/replace.¹⁹ The sample does not exclude routings between ATSs.²⁰ I also check Form ATS-R filings from the second quarter of 2012 to help validate data identification techniques and identify venues that are not represented in the ATS sample.

I construct the sample of securities in the following manner. I begin with 6,686 NMS stocks for which I have Center for Research in Security Prices (CRSP) volume, price and share class information²¹ for April 2012. I remove 2 securities of issuers that have corporate actions that affect security characteristics (such as delistings, splits, equity offerings or listing venue changes), and 4 securities for which no ATS orders or executions occur during the sample week. The final sample is 6,680 stocks.

¹⁶ See for example Buti, Rindi and Werner (2011), who examine the evolution of market quality measures over time in relation to dark pool activity levels (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1630499).

¹⁷ To validate the order identification procedure, I compare OATS-identified order flow to quarterly volume reported to the Commission by ATSs during 2012Q2. Among venues with substantial market share, for many venues I find execution volumes of expected magnitude. My analysis suggests some venues may double-count volume in their quarterly filings with the Commission.

¹⁸ MPID and receiving department code are OATS data elements. Further information on OATS is presented in Footnote 10.

¹⁹ Order types of cancel, desk, combined order/routing, and routing are excluded from consideration of order-receiving events. When market participant A routes an order to ATS B, two records are generated within OATS. One routing message is submitted by A and one order received message is submitted by B. I focus the ATS order identification methodology on the messages generated by ATS B.

²⁰ As a robustness check, I implement a second definition of ATS orders that includes only the first ATS order in a parent-child order chain (see Appendix A). This alternate definition excludes all routes between ATSs, as well as all order modifications occurring on ATSs. 72.41% of ATS orders qualify for inclusion in this sub-sample. Generally, order characteristics are largely unchanged. However, there are significant differences across venues in the proportion of orders and executions that this excludes from the subsample. Some large venues have over 97% of their sample retained in this alternate definition, while other large venues have their sample reduced by 90%. I am unable to determine if this is due to differences in how order modification is accomplished on these venues (some may lack a formal cancel/replace order type), or whether it is due to differences in routing activity between ATSs.

²¹ Price and volume information is required to assign securities to pre-determined price and average daily dollar volume groups elsewhere in the analysis. Share class information is needed to differentiate the trading of securities with multiple share classes in OATS.

II. Overview of ATSs

In the second quarter of 2012, 90 ATSs were registered with the Commission; 21 reported no volume information and appeared to be inactive. In Table 1, I describe the traded asset classes and activity level of the 69 active ATSs using information from 2012Q2 Form ATS-R filings.

Of the 69 active ATSs, 45 trade in NMS stocks. While the majority of ATSs transact in stocks, the notional value of derivatives transacted on ATSs comprises 51.04% of ATS dollar volume.²² Fixed income securities and credit instruments comprise 44.86% of ATS dollar volume, and NMS stocks comprise 4.05% of ATS dollar volume. No other category accounts for more than 0.04% of ATS dollar volume.

Table 1: Activity Level of Active ATSs by Asset Class

Venue Type	N	Dollar Volume (MM)	Proportion of Dollar Volume (%)
Agricultural	2	1	0.00%
Credit / Fixed Income	8	24,158,681	44.86%
Derivative	6	27,486,746	51.04%
Specialized Assets	6	24,061	0.04%
Private Securities	2	364	0.00%
NMS Securities	45	2,181,183	4.05%
Total	69	53,851,036	100.00%

The remainder of this paper focuses on the trading of NMS stocks on ATSs. There are 13 national exchanges that trade NMS stocks. In addition to these traditional trading venues there are 44 operational ATSs that transact in NMS stocks; three of these were classified as ECNs.²³ The 44

²² Venues that trade derivative or credit / fixed income securities often trade multiple classes of assets.

Furthermore, there is some overlap between these asset classes; for instance, a credit security may also be a derivative security. Consequently, my assignment of venues to these classifications is somewhat subjective.

²³ ECNs publicly display their top-of-book price and depth information and are therefore not considered to be dark pools. They are ATSs, however, and I include them in the data analysis. I estimate that these lit venues comprise 11.42% of ATS dollar volume using 2012Q2 Form ATS-R filings.

operational equity ATSs represent 35 distinct firms, some of which operate multiple ATSs.²⁴ 26 of these firms are represented in my ATS data sample.²⁵

Three ATSs operate as electronic communications networks (ECNs), which display quotations in NMS stocks in the national market system. However, a majority of ATSs that trade NMS stocks do not display quotations. These ATSs are colloquially known as “dark pools,” although some of them may not be completely dark, because they may provide information about orders in their systems to select market participants but not to the general public.

III. Overall and Venue Market Shares

In this section, I estimate that over 11% of dollar volume in NMS stocks is transacted on ATSs, and document the significant market share variation across venues.

Table 2 presents the calculation of aggregate ATS market share. During the five trading days of the sample, 6,677²⁶ stocks had CRSP-reported dollar volume of \$1.142 trillion. I identify \$114.6 billion²⁷ in ATS dollar volume, or 10.04% of total CRSP-reported dollar volume. As mentioned previously, approximately 11.30%²⁸ of ATS dollar-volume is not represented within our ATS data sample. Adjusting for these venues implies roughly 11.31%²⁹ of NMS dollar volume (12.12% of share volume) is transacted on ATSs.³⁰

²⁴ When a single broker-dealer operates multiple ATSs, OATS does not allow each ATS to be uniquely identified. I treat such venues as if they comprised a single ATS. For most firms with multiple ATSs, one is clearly dominant in size, but there are exceptions.

²⁵ See Footnote 14.

²⁶ The estimation of overall ATS market share requires that I exclude odd-lot trades from the ATS volume estimate because odd lots are not included in consolidated tape volume. To facilitate this, I exclude three securities with nonstandard lot sizes from this estimation.

²⁷ I halve OATS dollar volume to adjust for double-counting, and exclude odd-lot transactions. If odd-lot trades are more (or less) common on ATSs than elsewhere in the markets, my estimate of over ATS market share of trading would be downward (or upward) biased.

²⁸ I estimate the market share of venues not represented in the ATS sample from 2012Q2 Form ATS-R filings. Volume figures on these filings are denominated in dollars. Where needed for market share calculations based on shares, I assume that market share across ATSs in share volume are proportional to market share expressed in dollar volume.

²⁹ To clarify the adjustment methodology: single-counted ATS dollar volume from trades of 100 shares or more observed in OATS represents 10.04% of CRSP-reported dollar volume. Adjusting for the 11.30% of ATS market share attributable to venues not represented in the ATS sample implies 11.32% adjusted ATS market share of CRSP-reported trading. $10.04\% / (1 - .113) = 11.3231\%$. Henceforth, I adjust ATS market shares to reflect the estimate of market share attributable to the venues not represented in the ATS sample unless otherwise stated.

³⁰ One source of disparity between my estimation of overall ATS participation in NMS trading and estimates from commercial sources commonly reported in the press is that these sources often include certain venues that are not registered as ATSs. (See [Release No. 34-40760](#) for details on off-exchange trading venues that are excluded from Regulation ATS requirements.)

Table 2: Aggregate ATS Market Share

	<u>Dollar Volume</u>	<u>Share Volume</u>
CRSP Reported Volume	1,142,300,000,000	34,467,036,007
ATS OATS Reported Volume^a	114,642,981,900	3,704,261,531
Unobserved ATS Market Share	11.30%	11.30% ^b
Estimated Total ATS Market Share	11.31%	12.12%

a ATS volume is adjusted for double counting and excludes odd-lots which are not reported to the consolidated tape at the time of our sample

b Because Reg ATS filings do not include share volume information, we assume the share volume weighted market share of missing venues is equal to the dollar-volume weighted market share.

There is significant variation in relative trading volume across the 26 identified venues. During the sample week the largest venue contributed 11.92% of ATS dollar volume (10.64% share volume). The five largest accounted for 49.02% of ATS dollar volume (47.07% share volume), and eleven venues each accounted for less than 1% of total ATS dollar and share volume.

IV. Order and Fill Sizes

Popular press and academic articles sometimes describe ATSs as venues used by institutions to trade blocks.³¹ In this section, I describe order sizes and fill rates across venues. I also compare trade sizes between lit and dark venues. My analyses reveal similarity in order and fill sizes across most venues, with the exception of five ATSs with average order sizes exceeding 1,000 shares that collectively comprise less than 3% of ATS dollar-volume trading. I show that trade size distributions between lit and dark venues are very similar.

I present tables and figures that describe the distribution of order and fill sizes on ATSs, as well as the distribution of consolidated tape reported trade sizes (excluding those trades reported to the trade

³¹ Popular press and academic articles often describe ATSs as facilitating dark block transactions. See for example *Don't Be Afraid of the Dark Pools* (<http://www.forbes.com/2009/05/18/dark-pools-trading-intelligent-investing-exchanges.html>) and *Do "Dark Pools" Threaten the Health of America's Financial Markets?* (<http://business.time.com/2012/06/22/do-dark-pools-threaten-the-health-of-americas-financial-markets>). On the academic side, see for example *Diving into Dark Pools* (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1630499), and *Determinants of Volume in Dark Pools* (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1361234).

reporting facility, so as to compare only exchange trades with ATS trades³²⁾ for all NMS stocks in the sample.³³ Table 3 presents average order and fill size statistics. Aggregate order and fill counts are presented in millions; for each row, the market share of ATS dollar volume is adjusted to reflect the 11.30% of ATS orders that are not represented in the ATS sample, thus all venues reporting represent 88.70% of ATS market share. The average ATS order size is 374 shares, and the average aggregate ATS fill size³⁴ is 232 shares. I also describe order and aggregate fill sizes for the five and ten largest venues, which respectively represent 49.02% and 76.72% of dollar volume. Their order and aggregate fill sizes are slightly smaller but comparable to those for the full sample. Finally, the last row of Table 3 shows statistics for the five venues that have average order sizes that exceed 1,000 shares, which I refer to as “Large Order Venues”. On these venues, the average aggregate fill size exceeds the average order size.³⁵ Collectively these large-order venues represent 2.94% of ATS dollar volume (3.01% of share volume).

Table 3: Order and Fill Sizes, All ATS Venues

	Orders (MM)	Fills (MM)	Average Order Size	Average Aggregate Fill Size	Share of ATS Trading Dollar Volume	Share of ATS Trading (Share Volume)
All venues	2,890	32	374	232	88.70%	88.70%
Five largest venues	1,495	18	364	219	49.02%	48.16%
Ten largest venues	2,296	28	360	225	76.27%	75.01%
Five large-order venues	1.47	0.03	6,220	9,487	2.94%	3.01%

³² I exclude TRF-reported trades because they include the trades of ATSS, as well as preferenced and internalized order flow.

³³ The consolidated tape reported trades are from New York Stock Exchange’s Trade and Quote (TAQ) trade files, which contain execution data from all exchanges and the TRF.

³⁴ When an order generates multiple fills, the aggregate size of all fills associated with the order is defined as “aggregate fill size”. Consideration of fill sizes in aggregate allows comparison of order size and the trading activity that resulted from placing the order. Fill size is presented fully disaggregated in Figure 2 for comparison with exchange trade sizes.

³⁵ This can occur when certain counterparties tend to require large minimum fill sizes, but the venue does not restrict incoming order size. For example, assume institutions place large orders and specify that they will not accept fills below 5,000 shares. The venue may receive many 100 share orders which could interact with the institutional order, were it not for the minimum fill size specified by the institutional customer. In this case, the average order size may be smaller than the average fill size.

Figure 1 shows order and aggregate fill size distributions for all ATS orders and fills. The modal size of both orders and aggregate fills on ATSs is 100 shares. Odd-lot orders comprise 1.16% of ATS orders and account for 6.30% of ATS fills. Using the traditional 10,000+ share definition of blocks, block orders comprise only 0.33% of ATS orders and 0.10% of fills.

Figure 1: ATS Order and Fill Size Distribution, All ATS Venues

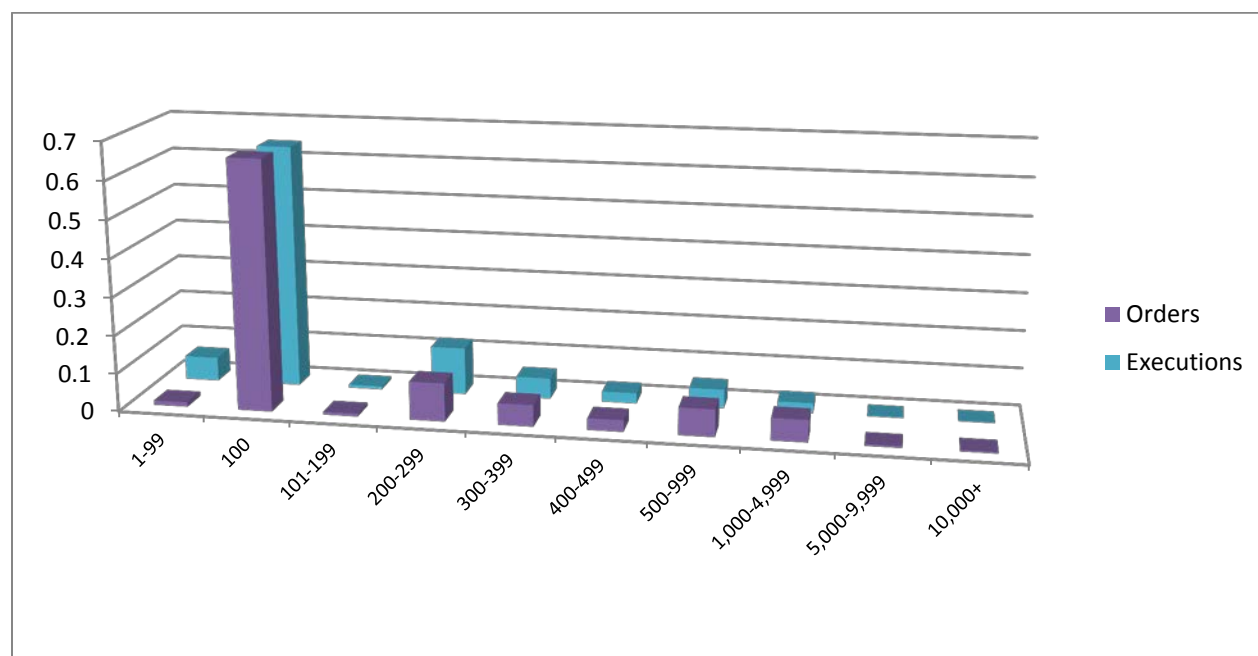


Figure 2 shows dark³⁶ ATS and lit exchange³⁷ trade sizes. The dark subsample excludes ECN trades where possible. I estimate that the dark subsample consists of 98.90% dark trades.³⁸ This subsample

³⁶ Using my definitions of dark and lit described in Footnote 2, ECNs are lit venues. One ECN is operated by a firm that also operates a sizeable dark venue; when a single broker-dealer operates multiple ATSs, OATS does not allow each ATS to be uniquely identified. I elect to include this partially lit flow in the dark subsample due to the relatively small size of the lit venue. The sample of dark venues is not fully comparable to those discussed in trade publications because I do not include venues that are dark but do not file Form ATS-R.

³⁷ All TAQ-reporting venues are included with the exception of the trade reporting facility (TRF), where most ATS trades are printed. The TRF is also the reporting destination for other off-exchange trades that would not properly be classified as “lit”, such as internalized and preferenced trades. This segregation of TRF trades, and the removal of most ECN trades from the “dark” subsample provides the sharpest possible comparison between lit and dark trades I can construct with the data. However, just as the dark off-exchange sample includes some lit ECN trades, the lit exchange sample also includes some trades that resulted from hidden exchange orders, as well as the trading of ECNs that at the time of my sample printed trades to a registered exchange. Although this comparison is imperfect, I believe the imperfections are not substantial enough to explain the apparent similarity between the sample distributions.

also excludes trades of less than 100 shares³⁹ (which are generally not required to be reported to the consolidated tape), which allows us to make a more precise comparison of trade sizes between the two samples for trades of at least 100 shares. The modal trade size on both lit exchanges and dark ATSs is 100 shares. On lit exchanges, 71.21% of trades reported to the consolidated tape are 100-share round lots. On dark ATSs, the proportion is 69.58%. Very large trades are rare on both dark ATSs and lit exchanges. 0.10% of dark ATS trades and 0.07% of lit exchange trades are for sizes that meet the traditional block definition of 10,000+ shares. Although some dark ATS trading likely results from the shredding of larger orders into smaller units for execution over time, the similarity between lit exchange and dark ATS trade sizes does not appear to support the characterization of dark ATSs as venues specializing in block transactions.

Figure 2: Distribution of Dark ATS and Lit Exchange Execution Sizes (Excluding Odd-Lots)

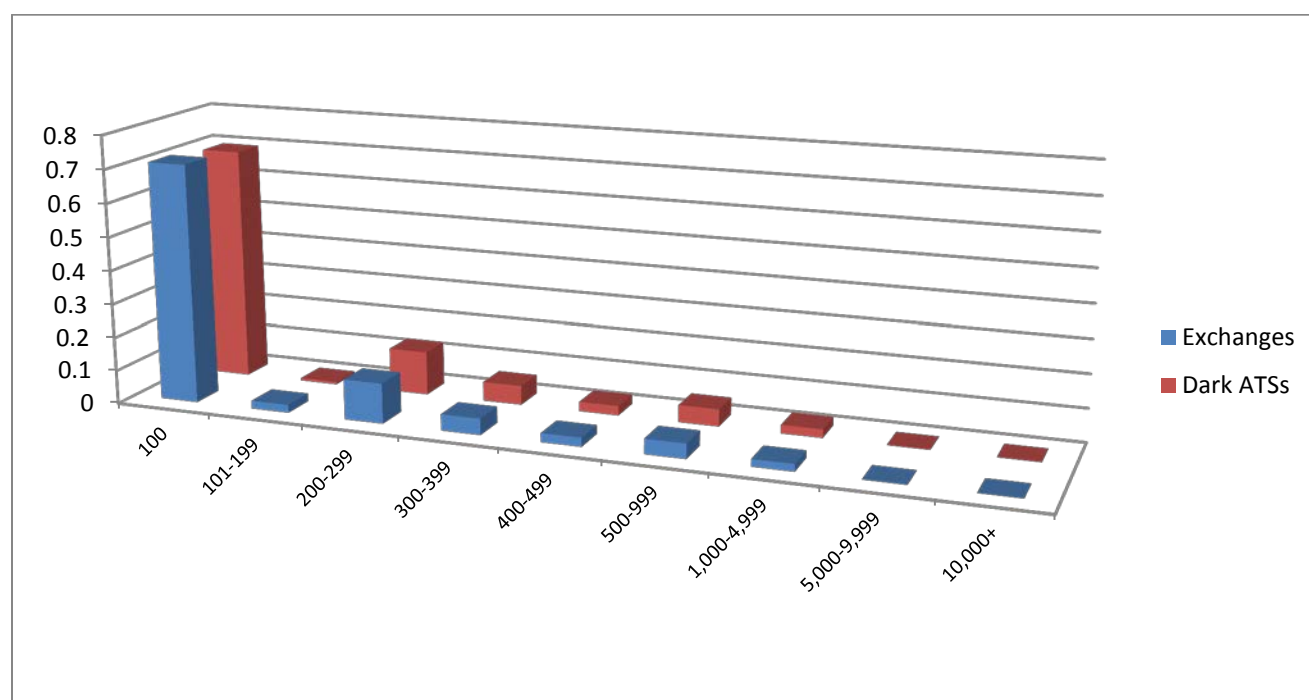


Table 4 describes trade size distribution across venues. I focus on the 14 dark venues with ATS market share over 1% of all ATS dollar volume, excluding smaller venues for which one week of data may be inadequate to capture typical trade size distributions. I present the minimum, maximum, median and interquartile range statistics for the percentage of trades within each trade size category by venue.

³⁸ Estimate is based on 2012Q2 Form ATS-R filings to the Commission, and assumes that the proportion of ECN to dark trades for the mixed-type firm (has both a lit and dark ATS) during the sample week is equal to the proportion of ECN to dark dollar volume for that firm during 2012Q2.

³⁹ I exclude data for three securities with ordinary lot sizes other than 100 shares.

Generally, these statistics suggest that some venues have distributions that are not similar to lit markets. For example, consider the 100-share order percentage. Here the first-quartile cutoff is 63.77% and the third-quartile cutoff is 71.23% suggesting there is significant clustering of venues around the median of 67.17%. By contrast, the minimum percentage of 100-share orders is 33.63%, revealing that at least one venue typically transacts in different sizes. Examining the statistics for 10,000+ share orders, the first- and third-quartile cutoffs are 0.06% and 0.10% respectively, but the maximum is 20.60%, once again indicating that some venues specialize in different trade sizes. In this case, at least one venue does specialize in larger trades than the typical dark ATS. Statistically, the venue or venues that do not focus on single lot trades must be small; otherwise the aggregate presentation in Figure 2 would reveal a higher proportion of large orders.

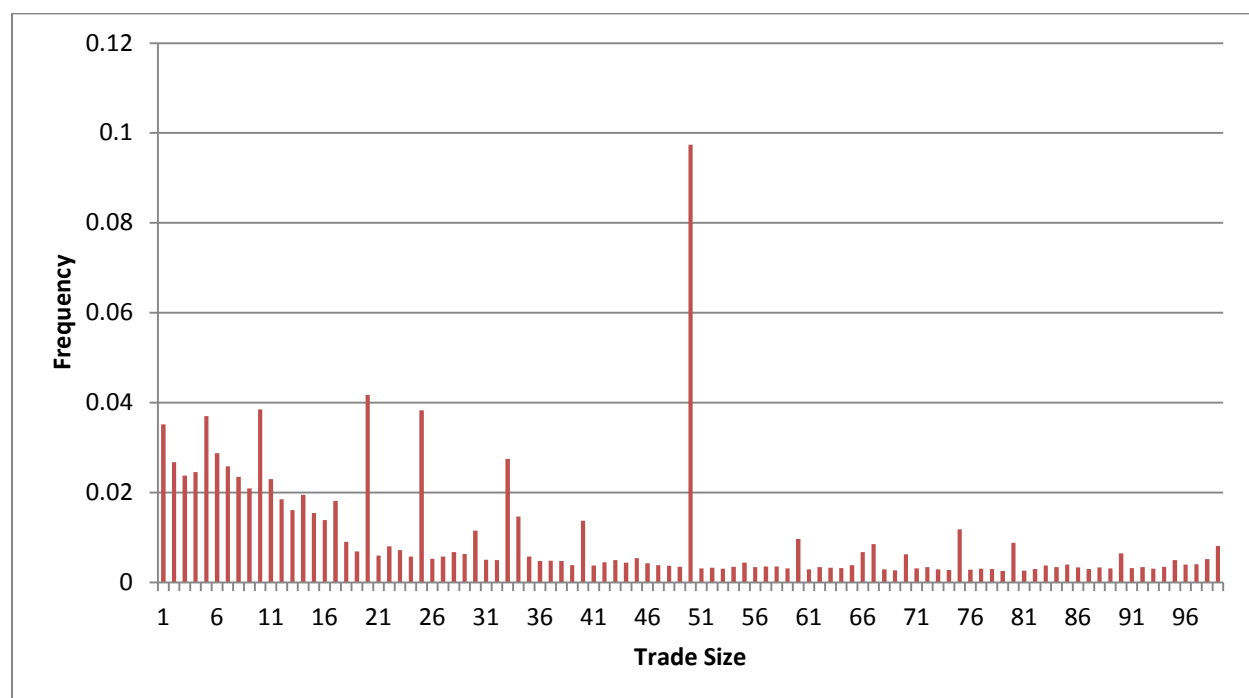
Table 4: Descriptive Statistics for Trade Size Distribution Across Venues

	100	101-199	200-299	300-399	400-499	500-999	1,000-4,999	5,000-9,999	10,000+
Minimum	33.63%	0.00%	9.48%	4.76%	2.27%	3.71%	1.54%	0.07%	0.02%
Maximum	75.14%	2.88%	17.01%	10.17%	4.84%	9.62%	10.18%	3.29%	20.60%
Mean	65.00%	0.60%	13.33%	6.47%	3.12%	6.06%	3.46%	0.40%	1.57%
Median	67.17%	0.36%	13.40%	6.05%	3.16%	5.86%	3.23%	0.18%	0.08%
Quartile 1	63.77%	0.00%	12.30%	5.33%	2.60%	5.07%	2.02%	0.11%	0.06%
Quartile 3	71.23%	0.89%	14.23%	6.77%	3.48%	6.85%	3.80%	0.22%	0.10%

The analysis in Figure 2 excludes the odd-lot trades of ATSs to facilitate comparison with exchange-reported execution data. In Figure 3, I describe these omitted trades on ATSs. Odd-lot executions comprise 5.8% of all (dark and lit) ATS trades. Like O'Hara, Yao and Ye (2011)⁴⁰ who examine odd lots in 120 NASDAQ stocks, I find the modal odd-lot trade size to be 50 shares, with minor peaks in the distribution at round numbers and a general skew toward smaller round lots.

⁴⁰ [What's Not There: The Odd-Lot Bias in TAQ Data](#), Johnson School Research Paper Series #31-2011.

Figure 3: Distribution of Odd-Lot Trade Sizes on ATs



V. Probability of a Fill

In this section, I document the proportion of ATS orders that generate at least a partial fill. I also compare fill rates across venues.

Table 5 presents statistics on the probability of an order⁴¹ being at least partially filled. On ATs, the probability of receiving at least a partial fill is 1.11% and 0.69% of shares ordered through ATs are filled. Fill rates are highest on venues that specialize in large orders. The overall order fill rate⁴² for these large-order venues is 1.81% of orders, with 2.76% of ordered shares being filled. Statistics on maximum and minimum venue-level average fill rates are also presented, with three venues excluded due to data identification issues.⁴³ At the venue level, the maximum average fill rate for orders is 3.17%, and 8.38% for average percent shares filled.

⁴¹ Here an “order” refers to any type of order, either immediate or cancel (IOC) or resting in the ATS.

⁴² An order is deemed filled if it generates an execution of any size; the second statistic (ordered shares filled) measures the percentage of shares ordered in the venue that are eventually filled.

⁴³ I exclude fills that are not associated with an explicitly flagged ATS order from all fill-rate calculations. I exclude three venues with very high fill rates from the analysis of minimum/maximum venue-level fill rates and interpret the overall fill rates cautiously. See Footnote 14 regarding certain internal transfers that are not mandatory OATS reporting events.

Table 5: Fill Probabilities on ATSS

	% Orders Filled	% Shares Filled	(Max,Min) % Average Order Fill Rates ^a	(Max,Min) % Average Quantity Fill Rates ^a
All venues	1.11%	0.69%	(3.17%,0.73%)	(8.38%,0.03%)
5 largest venues	1.21%	0.73%	(2.56%,0.73%)	(1.21%,0.36%)
9 of 10 largest venues	1.16%	0.71%	(3.17%,0.73%)	(2.35%,0.36%)
5 venues with large order sizes	1.81%	2.76%	(2.96%,0.15%)	(8.38%,0.29%)

^a Three venues are excluded due to data identification issues⁴⁴

VI. Cross-Sectional Characteristics of ATS Volume

In this section, I investigate the relation between security characteristics, namely market capitalization levels, price levels, and order and fill characteristics.⁴⁵ Although the majority of ATS dollar volume is transacted in large cap stocks, I show that for all NMS stock capitalization levels, at least 10% of trading volume occurs on ATSS. The probability of receiving a fill is generally increasing in market capitalization level and decreasing in share price.

In Table 6, I present summary statistics of ATS activity by market capitalization and price. I classify NMS stocks by share price groups based on the closing price on the final day of trading in April 2012. I define market capitalization groups as follows:

- Micro Cap: < \$500MM
- Small Cap: \$500MM - \$1 Bln.
- Medium Cap: \$1 -10 Bln.
- Large Cap: > \$10 Bln.

⁴⁴ See Footnote 43.

⁴⁵ See for example Ready (2013), who examines determinants of trading volume for Nasdaq securities within two ATSS primarily targeted to institutional order flow (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1361234).

The proportion of dollar-volume trading occurring on ATSs ranges from 10.00% for micro capitalization stocks to 12.86% for medium capitalization stocks. ATS trading share tends to be higher for stocks with low prices. For example, consider large capitalization stocks; 13.26% of dollar volume for stocks with prices less than \$20 per share⁴⁶ occurs on ATSs, while 9.58% of volume is executed on ATSs for stocks with prices over \$100. This pattern generally holds for other capitalization groups, though the relation is not reliably monotone across price groups. Order sizes for large capitalization stocks tend to be slightly lower than for other capitalization levels, but average fill sizes are similar across market capitalization levels. The probability of receiving a fill is generally increasing in market capitalization level and decreasing in share price.

⁴⁶ There are no large capitalization securities with share price less than \$5 during the sample period.

Table 6: ATS Trading Characteristics by Market Capitalization Level and Share Price

Market Capitalization Level	Price Level	N	ATS Market Share (Dvol)	ATS Market Share (Vol)	Average Order Size	Average Aggregate Fill Size	Probability of Fill
All	All	6680	11.32%	12.12%	374	232	1.11%
Large	All	393	10.98%	11.62%	344	233	1.53%
	> \$100	53	9.58%	8.82%	489	201	0.84%
	\$85-100	19	12.01%	11.81%	210	157	1.10%
	\$20-85	289	11.53%	11.82%	299	216	1.56%
	\$5-20	32	13.26%	12.29%	470	334	2.58%
	< \$5	0	-	-	-	-	-
Medium	All	1542	12.30%	12.86%	378	232	1.11%
	> \$100	54	12.40%	11.61%	203	150	0.48%
	\$85-100	35	11.50%	11.42%	175	148	0.44%
	\$20-85	1048	11.96%	11.91%	302	182	0.86%
	\$5-20	386	13.33%	13.24%	583	253	1.80%
	< \$5	19	15.48%	15.49%	1,431	731	4.26%
Small	All	774	10.04%	11.61%	401	222	0.79%
	> \$100	12	6.43%	5.97%	461	174	0.17%
	\$85-100	6	9.30%	9.23%	341	130	0.17%
	\$20-85	325	9.32%	9.75%	297	186	0.41%
	\$5-20	393	11.11%	11.64%	520	220	1.07%
	< \$5	38	14.60%	14.37%	421	282	2.44%
Micro	All	3971	10.00%	11.37%	400	231	0.58%
	> \$100	32	5.92%	5.55%	661	168	0.06%
	\$85-100	19	6.29%	6.12%	221	123	0.14%
	\$20-85	946	8.88%	9.31%	358	184	0.16%
	\$5-20	1674	11.55%	11.93%	433	212	0.69%
	< \$5	1300	11.22%	11.51%	386	266	1.70%

VII. ETF Trading on ATSS

In this section, I examine the trading of 1,178 exchange-traded funds (ETFs) on ATSS. Generally, ATSS fill a lower proportion of ETF dollar volume than they fill for other NMS stocks. ETF order and fill sizes on ATSS are larger than those for other stocks.

During the sample week, 27.50% of CRSP-reported dollar volume for NMS stocks is ETF dollar volume, but only 16.85% of dollar volume on ATSS results from ETF trading. As shown in Table 7, ATSS' share of dollar volume is lower in ETFs than it is in other NMS stocks,⁴⁷ with 7.39% of ETF dollar volume (8.49% of share volume) executed on ATSS as opposed to 12.83% of dollar volume (12.80% of share volume) for other NMS stocks. The average ETF order size on an ATSS is 899 shares, which is larger than the average order size for other NMS stocks of 249 shares. The associated average aggregate fill sizes respectively are 351 and 222 shares. The probability of at least partial fill on an ATSS is lower for ETFs than for other NMS stocks, with only 0.43% of ATSS orders for ETFs receiving at least a partial fill compared to 1.28% for other stocks.

Table 7: ETF Trading on ATSS

Security Type	N	ATS Market Share (Dvol)	ATS Market Share (Vol)	Average Order Size	Average Aggregate Fill Size	Probability of Fill
All	6,680	11.32%	12.12%	374	232	1.11%
Other NMS Stocks	5,502	12.83%	12.80%	249	222	1.28%
ETFs	1,178	7.39%	8.49%	899	351	0.43%

VIII. Conclusion

This study discusses general descriptive statistics on ATSS and reveals a number of empirical facts. First, at the time of the sample, slightly more than half of registered ATSS transacted in NMS stocks, and many

⁴⁷ The ETF subsample includes 1,178 ETFs. The "Other NMS Stocks" subsample is comprised primarily of stocks, but includes other exchange-traded products as well, primarily exchange-traded notes and closed-end funds. Although ETFs are also exchange-traded products, I view ETFs as characteristically different than exchange-traded notes and closed-end funds and worthy of consideration as an asset class of their own in this analysis due to their substantial contribution to aggregate dollar volume of trading (27.50% of CRSP-reported dollar volume during the sample week).

of these venues are quite small. Market share is concentrated, with the ten largest ATSs accounting for 76.27% of ATS dollar volume.

ATS activity comprises 11.31% of NMS dollar volume and although the majority of trading is in large capitalization issues, ATSs account for at least 10% of dollar volume in all market capitalization classes. By comparison, ATS market share in the ETF market only is 7.39%. The share of trading attributable to ATSs decreases in share price.

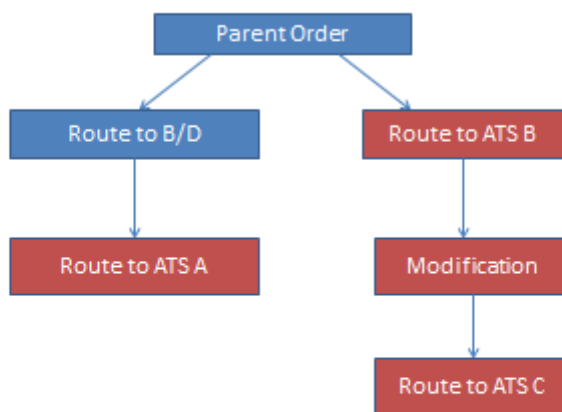
The aggregate trade size distribution on dark ATSs is similar to that observed for lit exchanges and does not seem to support the characterization of dark ATSs as venues that specialize in block transactions. On ATSs, 1.11% of orders receive at least a partial fill, and 0.69% of shares ordered are filled.

Appendix A

My methodology in this paper does not allow me to simply exclude ATS-to-ATS routes because new order records in OATS do not specify which department within an MPID routed an order.⁴⁸ To investigate how these routings affect the results, I construct an alternate sample of ATS orders that includes only the first ATS order in a parent-child order chain. To illustrate my methodology, consider the following order chain that shows the orders generated by a “parent order”⁴⁹:

In my original definition of ATS orders, all events except “parent order” and “Route to B/D” qualified as ATS orders. In this alternate definition, only the first ATS routing from this chain would be included in the ATS order sample, either “Route to ATS A” or “Route to ATS B”, depending upon which had the earlier timestamp. This excludes all ATS-to-ATS routings and all order modifications. Some top-level ATS orders generated through order splitting, however, also are excluded (as in this example).

When I use this alternate definition, the sample is reduced from 2.9 to 2.1 billion ATS orders but the sample characteristics are largely unchanged.



⁴⁸ For instance, assume both Firm A and Firm B have ATSs. If Firm B’s ATS receives an order from Firm A, the new order record within OATS does not allow me to determine if the routing originated from Firm A’s ATS or other departments within Firm A. Reconstructing the order life cycle would allow this determination, but such an analysis is beyond the scope of this paper.

⁴⁹ This is not necessarily a true parent order; it is the first order in a chain of linked orders within OATS.