Is Market Fragmentation Harming Market Quality?

by

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Equity markets world-wide have seen a proliferation of trading venues and the consequent fragmentation of order flow. In this paper, we examine how fragmentation of trading is affecting the quality of trading in U.S. markets. We use newly-available TRF (trade reporting facilities) volumes to measure fragmentation levels in individual stocks, and we use a matched sample to compare execution quality and efficiency of stocks with more and less fragmented trading. We find that market fragmentation generally reduces transactions costs and increases execution speeds. Fragmentation does increase short-term volatility, but prices are more efficient in that they are closer to being a random walk. Our results that fragmentation does not appear to harm market quality have important implications for regulatory policy.

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One of the more striking changes in U.S. equity markets has been the proliferation of trading venues. While the traditional exchanges continue to execute orders, they now face a host of competitors ranging from electronic platforms such as ECNS (electronic communication networks) and ATS (alternative trading systems), to the trading desks of broker/dealer firms, and even to a variety of new entrants such as futures and options markets. The addition of these new trading venues has created a marketplace in which equity trading can take place in ways and places unimagined but a few years ago. And these changes are not just confined to the U.S. markets. European equity trading has seen dramatic growth of electronic platforms such as Chi-X and BATS, and even Canada, where the Toronto Stock Exchange (now known as the TMX group) enjoyed a virtual monopoly on trading, faces the prospect of a fragmented market with the addition of electronic venues such as Alpha, Pure and MATCH Now[1].

What is less clear is how this fragmentation of trading is affecting the quality of trading. Certainly, the addition of new trading venues has increased competition, forcing the traditional exchanges to lower trading charges and other fees.[2] The proliferation of venues has also provided a wealth of trading options to the trading community, fostering innovations such as greater latency and more sophisticated crossing networks. But there is a deeper concern that the fragmentation of trading may also be harming the quality of markets overall by reducing the liquidity available not only in individual markets but in the aggregate market as well. A related

[1] In the year since its launch, Chi-X has captured 5% of EU trading volume market share and is the fourth largest trading venue in terms of volume. Alternative trading venues are still very small in Canada with an estimated 2-4% market share, but the launch of the consortia-owned Alpha trading system on November 7, 2008 is expected to draw large volumes away from the TMX.

[2] See, for example, "NYSE Adjusts Charges in Bid to Draw Traders", Wall Street Journal, Feb. 3, 2009, which discusses the NYSE's strategy of lowering trading fee rebates to attract more high frequency traders.

concern is that not all traders can access all trading venues, raising the specter that markets may not be fragmenting so much as they are fracturing into many disparate pieces.

In this research, we investigate how fragmentation is affecting equity market quality. While this question has long been of interest to researchers, empirical investigations have been limited due to the difficulty of measuring both the extent of fragmentation and the quality of executions in diverse venues. Our analysis draws on new data sources to provide better metrics for addressing these issues. In particular, we can calculate the extent of trading fragmentation in individual stocks by using the volumes reported by the newly-established Trade Reporting Facilities (TRFs). TRFs were mandated by the SEC as a condition for approval of Nasdaq's application for exchange status. Whereas before off-exchange volume was simply aggregated with exchange-executed volume for reporting purposes, now exchanges must report only their on-exchange volumes, with off-exchange volumes handled by the TRFs.[3] Because all trades must be reported to the consolidated tape, TRF data provides an accurate measure of the extent of trades being executed in non-exchange venues. These data allow us to determine two metrics for fragmentation: the amount of volume transacting in non-exchange settings, and the volume being executed away from the listing exchange.[4]

To address market quality issues, we use SEC Rule 605 data, which is a set of execution metrics that must be reported monthly on a per stock basis by all execution venues.[5] This data

[3] The SEC required that as of March 5, 2007, all non-exchanges must report to a trade reporting facility, which in turn would report trades to the consolidated tape.

[4] TRF data does not disaggregate trades into specific execution venues so we cannot determine the specific volume of trading in each of the many non-exchange venues. We can determine the aggregate off-exchange volume per stock, however, giving us a comparable, and much improved, metric for fragmentation.

[5] Rule 605 data arises from an SEC requirement that all market centers publicly disclose on a monthly basis execution quality statistics. Not all trade executions must be included, but data must be provided for orders meeting the following criteria: orders must be held; limit price must be less than 10 cents from the quote; order must be straight market or limit order; and the order must be for 10,000 shares or less. Bennett and Wei [2006] also use what was then known as SEC 11Ac1-5 data to address market quality in their study of firms moving from the Nasdaq to the NYSE, as do Goldstein et al [2008] in their interesting study of competition for Nasdaq securities.

was generously provided to us by TAG/Audit, and it allows us to compare execution quality as measured by effective spreads, realized spreads and execution speeds across stocks with more fragmented or more consolidated trading. We also use more standard TAQ microstructure data to investigate quality issues related to price efficiency. Our analysis here examines short-term return volatility, variance ratio tests, and return autocorrelations.

We employ a matched-sample approach to compare the execution quality of stocks with more fragmented trading to that of stocks with more consolidated trading. As previous authors have demonstrated (see SEC [2001]; Boehmer [2005]), matching is needed because different stocks may have different costs of trading for reasons unrelated to the fragmentation of trading. For example, it is well known that small stocks generally have higher trading costs. If trading in such stocks is also more likely to fragment, then a finding of higher trading costs for fragmented stocks may be spurious due to the failure to control for firm size. In our analysis, we adopt the matching approach recommended by Davies and Kim [2008] to control for such exogenous effects. We also use a far larger sample size of stocks than in previous work to investigate whether fragmentation is a feature of all or only a subset of stocks.

Our analysis yields a number of important results. We provide compelling new evidence on the extent and nature of fragmentation in U.S. equity markets. We find that off-exchange venues are now executing almost 30% of all equity volume, and more than 50% of volume is trading away from the listing exchange. We show that while fragmentation levels vary widely across stocks, all firms now exhibit fragmented trading. Interestingly, we find that fragmentation is more prevalent for large NYSE-listed stocks and for small Nasdaq-listed stocks. If fragmentation is measured by trading off of the listing exchange, then NYSE-listed stocks are

more fragmented. If, instead, we measure fragmentation by TRF volumes, then Nasdaq-listed stocks are more fragmented.

Turning to the main focus of our paper, we find that trading away from the listing exchange has little effect on execution quality or efficiency. Viewing fragmentation as captured by TRF volumes, we find that market fragmentation generally reduces transaction costs and increases execution speed. The specific effects of this fragmentation differ across various sizes of firms, and it differs as well for NYSE-listed and Nasdaq-listed firms. For large firms, fragmentation reduces effective spreads and decreases execution time. For small firms, effective spreads also decline, but there are no significant effects on speed. For NYSE-listed stocks, large, liquid stocks appear to gain the most from fragmentation, whereas for the Nasdaq-listed stocks, it is small, illiquid stocks who benefit from fragmentation. Fragmentation does increase short-term return volatility, but prices appear to be more efficient in the sense that they are closer to being a random walk. These efficiency effects also exhibit differences with respect to firm size and listing venues. Overall, we conclude that fragmentation does not appear to harm market quality.

An immediate application of our results is to the on-going policy debate regarding the desirability of allowing fragmentation to occur in markets. In the United States, fragmentation was an expected outgrowth of Reg NMS, particularly because of the changes required by Rule 611 (the "trade through" rule). Our research provides a first analysis of how market quality has fared in this new market structure.[6] In Europe and in Canada, fragmentation is just beginning, and our results may be helpful for regulators struggling to decide whether to encourage or discourage more off-exchange trading. In many emerging markets, off-exchange trading is

[6] Reg NMS, originally proposed in June 2006, entailed a variety of changes to market linkages and structure. Among the most important changes was Rule 611 which essentially imposed a price priority rule across all market centers. By requiring that orders must be sent to the market center with the best price, this rule allowed for greater competition by non-exchange venues. Rule 611 was very contentious, and was only fully implemented for all stocks in October 2007.

prohibited.[7] Our finding that fragmentation can have beneficial effects on market quality suggests reconsidering such policies.

Our results here are also useful for reconciling disparate findings in the literature. While there is an extensive theoretical literature on fragmentation, due to data limitations most empirical work on the subject has focused on particular event studies, or has simply assumed that one market is more fragmented than another. Our results that the effects of fragmentation differ conditional on the types of stock and on the dimension of quality considered suggest that past conflicting results on market fragmentation may have been partially due to sample selection.

This paper is organized as follows. The next section sets out the theoretical arguments surrounding market fragmentation, and reviews the literature, both theoretical and empirical, on this topic. Section 2 then sets out our data and sample period, as well as our empirical testing approach. In this section we also discuss trade reporting rules, and the role played by the newly-established trade reporting facilities. Section 3 presents results on the current state of fragmentation, both in the aggregate and conditional on firm and market characteristics. Section 4 presents results from our analysis of how fragmentation affects various metrics of market quality. Section 5 is a short conclusion.

1. Fragmentation versus Consolidation

Whether trading is best consolidated into a single setting or dispersed across multiple venues has long been a topic of interest to researchers. The arguments underlying this debate generally rely on features of the trading process (specifically, the fixed cost structure of markets and network externalities) on the one hand, and the role of competition on the other. Traditionally, setting up exchanges or markets was extremely costly. Trading involved not only

[7] China, for example, strictly prohibits all off-exchange trading, as do most Asian markets.

the expenses related to the trading platform, but also to the ancillary services such as the monitoring and listing functions, and the costs of clearing and settlement.[8] With much of this cost fixed, it followed that the larger the scale, the smaller could be the trading cost per share traded, and so the greater the gains that would follow from consolidation. Network externalities convey a similar benefit in that the ability to match buyers and sellers is greater the more buyers and sellers there are in a market, and so trading costs would similarly benefit from greater scale. Thus, the notion that "liquidity begets liquidity" favors consolidation, even leading some to view exchanges as natural monopolies. Of course, the downside of a monopoly is that it behaves non-competitively, so one argument for fragmentation is that the increased competition it engenders reduces trading costs.

Much of the early theoretical work looking at fragmentation and consolidation issues argued in favor of consolidation. Mendleson [1987] was perhaps the first to advance the network argument, while Pagano [1989] argued that equilibrium with trading in two markets was inherently unstable as orders would naturally gravitate to the market with greater liquidity. Chowdry and Nanda [1991] advanced another argument for consolidation by arguing that in the presence of asymmetric information adverse selection costs increase with the number of markets trading the asset. Madhavan [1995] argued that consolidated markets would not fragment if trade disclosure rules were mandatory across markets, but would do so otherwise. In his model with non-disclosure, dealers benefit from fragmentation by being less competitive, and informed traders and large traders also benefit by being able to hide their trades. Madhavan argued that "fragmentation increases price volatility and induces other distortions as well."[9]

[8] See, for example, Macey and O'Hara [1999] for a discussion of issues relating to exchange and trading system functions.
[9] See Madhavan [1995] pg. 581.

More recent research has focused on whether competitive effects might shift the arguments in favor of fragmented markets. Economides [1996] argued theoretically that the welfare losses connected with monopoly providers are not offset by network externalities, suggesting welfare improvement can obtain under fragmentation. Harris [1993] noted that markets fragment in part because traders differ in the types of trading problems that they confront. Hendershott and Mendelson [2000] demonstrated that fragmentation can reduce the inventory risk of individual dealers.

Empirically, Battalio [1997] found that spreads narrowed on the NYSE after a third-market broker (Madoff Securities) initiated trading. Boehmer and Boehmer [2003] found a similar positive effect on liquidity when the NYSE began trading ETFs listed on the American Stock Exchange. Fong, Madhavan, and Swan [2001] found positive effects on trading costs for large Australian stocks executed off-exchange. Foucault and Menkveld [2008] looked at competition for Dutch stocks between EuroSETS, the London Stock Exchange trading platform, and NSC, the trading platform of Euronext Amsterdam. They concluded that liquidity as measured by depth increased when trading expanded, supporting the notion that fragmentation may be the better outcome.

Yet other empirical work reaches a different conclusion. Bennett and Wei [2006] examine stocks voluntarily moving from the more fragmented Nasdaq market to the more consolidated NYSE, and find that overall execution costs fell when the stocks began trading on the NYSE. A study by the SEC [2001] also found lower effective spreads on the NYSE than on the Nasdaq for a matched sample of stocks, although other execution quality measures were mixed. Gajewski and Gresse [2007] examine trading in Europe, and they find that trading costs are lower in a

centralized order book than they are when orders are split between an order book and competing dealers.[10]

Overall, the research evidence to date is mixed as to whether market quality is higher in a fragmented or consolidated market. Part of the divergence in results may reflect difficulties in comparing studies across different markets and time periods, but it may also be due to difficulties in measuring and even defining concepts such as fragmentation or market quality. In the next section, we set out a new approach for investigating how fragmentation affects market quality.

2. Measurement Issues, Data, and Sample Selection

In this section we discuss measurement issues, data, and our sample selection criteria. An immediate issue confronting our investigation is the difficulty of measuring either fragmentation or market quality. We discuss the metrics we use to address these issues, and the advantages these measures have over prior proxies. There is also an important methodological issue that arises because transactions costs, one of our measures of market quality, may differ for reasons unrelated to the fragmentation effects we investigate here. We discuss the matched sample methodology we use to control for such effects.

A. Measuring Market Fragmentation

Market fragmentation refers to the extent trades are executed in different locales. Traditionally in the U.S., trading in listed securities occurred only on stock exchanges, or since 1971 in the Nasdaq stock market, but this has changed dramatically in recent times. The advent of new technologies has given rise to a range of new trading venues such as ECNs and ATS platforms, and regulatory changes have removed barriers that generally favored exchange

[10] Domowitx et al [2008] add a new dimension to this debate by looking at execution statistics for orders left in a single dark pool as opposed to sent sequentially to many dark pools. They find that resting orders in a single venue enhances execution quality, consistent with an inter-termporal consolidation story.

locales. Of particular importance for this development was the passage of Regulation National Market System (or Reg NMS) in 2006 which changed order routing priorities and imposed caps on access charges that exchanges and other venues could impose. The result in the U.S. has been an explosion of trading venues, with more than 40 trading platforms available to traders in 2008. While these include the seven U.S. registered stock exchanges, during the sample period we consider there were also 5 ECNs, 20 or more ATS platforms, as wells as a variety of new entrants to equities trading such as the Chicago Board of Options Exchange, the International Securities Exchange (an electronic options market), and the Chicago Mercantile Exchange (a futures market). Add to this the internalization of orders by numerous broker/dealer firms, and the number of venues executing trades becomes larger still.

Ideally, one would measure fragmentation by simply collecting data on the location of trade executions by venue on a per-stock basis. Unfortunately, such data is not available. To understand why, it is useful to differentiate between execution and reporting venues. In the U.S., all trades of listed equity securities must be reported to the consolidated tape. Until recently, only exchanges could report trades, meaning that any off-exchange venue had to report trades to an exchange, who in turn would report those trades to the tape. Such trades would indicate only the reporting venue's identifier, resulting in the reported trades of the Nasdaq, for example, including both trades executed there and trades that were not executed, but only reported there. This aggregation greatly limited previous studies of fragmentation as it was not possible to know where trades actually executed. Several studies, including SEC [2001] and Bennett and Wei [2006], simply assumed that the Nasdaq was more fragmented than the NYSE, and analyzed the differences between market executions using venue as a proxy for fragmentation.

In addition to complicating matters for researchers, these reporting protocols also raised important competitive issues. As exchanges and markets converted to for-profit status, exchange volumes became a competitive metric, with venues vying for listing business based on their claims of market size. The SEC, responding to concerns of bias in these numbers, required as a condition of approval for Nasdaq's exchange application that trades only reported on venues be separated from trades actually executed there. Such segregation would be accomplished by the establishment of Trade Reporting Facilities, which would now also report directly to the consolidated tape. As of March 5, 2007, all non-exchange executed trades must report to a TRF.

In our analysis, we use both exchange-reported volumes and TRF volumes to measure fragmentation on a stock-by-stock basis. Because exchange-reported volume now includes only trades executed on that exchange, we can determine how much of a stock's volume is trading on each exchange venue. The TRF data provide us with an accurate measure of the volume of trade in a stock being executed in off-exchange venues. Because a substantial volume of trading involves routing across multiple venues, these data allow us to determine accurately the extent to which trading is captured by the listing venue or is instead being dispersed across other trading locales. These data are not perfect, however, in that we cannot determine specific volumes for non-exchange execution venues (i.e. by individual ECN or ATS, for example). [11]

In our analysis, we consider two measures of fragmentation. It seems sensible that stocks with greater TRF volumes are also stocks with more fragmentation due to the very fact that a larger amount of their trades are taking place in the myriad off-exchange venues. We combine the daily TRF volumes from the three then active TRFs, as well as the data from the

[11] Due to concerns about the size and significance of off-exchange trading venues such as dark pools, the SEC has proposed adopting a uniform method for reporting equity trading volumes by venue. Such a reporting protocol would provide greater transparency into where volume is actually executing.. As of August, 2009, however, this proposal has not been adopted.

NASD's ADF (the Alternative Display Facility), to determine this fragmentation measure for each stock.[12] A second measure of fragmentation is simply the extent to which trades are executing away from the primary listing exchange. To calculate this measure, we combine all volume executing outside of the listing exchange.

B. Measuring Market Quality

Market quality refers to a market's ability to meet its dual goals of liquidity and price discovery. In general, markets with lower transactions costs are viewed as being of higher quality, as are markets in which prices exhibit greater efficiency. While these concepts are straightforward in theory, actually measuring such effects is problematic. Transactions costs can be measured in a variety of ways, and different traders may place different values on different execution features. Market efficiency is even more difficult to measure, with a variety of proxies used in the literature to capture this concept.

In our analysis, we use three measures to capture the transactions cost aspects of market quality. These measures are the effective spread, the realized spread, and the execution speed. As is discussed in more detail later in the paper, the Rule 605 data we use is based on orders, not simply on trade executions.[13] Thus, the effective spread we examine is given by the difference between the trade price minus the midpoint of the consolidated best bid or offer at the time of order receipt. The effective spread is a standard measure in microstructure studies, and it captures the overall cost of executing the trade from the point-of-view of the trader. The realized spread is defined as the difference between the execution price and the midpoint of the

[12] While all reporting exchanges have established Trade Reporting Facilities, over our sample period only the NYSE TRF, the Nasdaq TRF, and the National Stock Exchange (NSX) TRF were active. In addition, the Alternative Trade Facility (ADF) also operated as a TRF. The ADF was originally created by the NASD in response to the Nasdaq market's conversion to for-profit status. The ADF includes both a reporting and display facility, allowing trading platforms who do not wish to post quotes on the Nasdaq an alternative venue in which to display quote and trade information.

[13] Boehmer (2005) provides an excellent discussion of the properties and potential problems with Rule 11Ac1-5 data, which is now known as Rule 605 data.

consolidated quote five minutes after the trade. The realized spread is sometimes viewed as a proxy for the profits available to market makers in making the trade. Our third measure, the execution speed, measures the time from order receipt until execution. For some traders, speed of execution is more important than are spread effects. In general, faster markets are viewed as being of higher quality.

We measure price efficiency using three standard proxies from the literature. These measures are short term volatility, the variance ratio, and return autocorrelations. Short-term volatility is simply the return volatility measured over a 15-minute interval. Short-term volatility is a crude measure of trading frictions, so markets with lower volatility are viewed as being more efficient. Return autocorrelations are simply the first order autocorrelation of these 15-minute returns. Markets with small return autocorrelations are assumed to be more efficient in that price changes are less correlated. Our third measure, the variance ratio test (see Lo and MacKinlay [1988]) captures a related dimension of price efficiency. The variance ratio is defined as the absolute value of the ratio of the variance of 30 minute log returns divided by 2 times the variance of 15 minute log returns minus one. The closer is this number to zero, the more prices behave like a random walk, and so the more efficient is the market.

Hasbrouck [1993] suggests using a variance decompostion approach to measure price efficiency in markets. This approach essentially uses signed order flow to separate the noise variance component of price movements from the information-based variance component.. We do not use this approach in our analysis because the aggregation of volumes across the various market venues means that the TRF trades are not homogenous. An added complication is the difficulty of assigning trade direction in our data, a problem that is becoming increasingly important as more and more trades take place within the quoted spreads.

C. Matching Firm Methodology

Our general goal is to determine how the market quality measures described above differ between stocks that have more fragmented trading and stocks that have more consolidated trading. An immediate difficulty in doing so is that different stocks may have different costs of execution for reasons unrelated to fragmentation. The standard approach in the literature to deal with this problem is to use a matched sample (see SEC [2001]; Bennett and Wei [2006]). In our analysis, we draw on research by Davies and Kim [2008] who suggest matching firms on market capitalization and price. We separate stocks into those listed on the NYSE and those listed on the Nasdaq.[14] We select every 10th stock in the sample and calculate a matching error defined as:

$$D_{ij} = \left| \frac{MCAP_i}{MCAP_j} - 1 \right| + \left| \frac{PRC_i}{PRC_j} - 1 \right|$$

We form the matched pair by selecting the stock that minimizes the matching error. For each pair of stocks, we place the stock with the higher TRF volume into the fragmented group, and the other stock into the consolidated group.[15] By construction, the firms in our TRF-fragmented sample have higher TRF volumes, but otherwise are identical to our firms in the consolidated sample. We use a similar sorting approach to form alternative fragmented and consolidated groups using volume-off-the-listing exchange as our fragmentation metric.

[14] Traditionally, stocks tended to trade where they listed, but this has become much less important in current markets. It remains the case, however, that listing standards differ between the NYSE and the Nasdaq, as do trading platforms. Separating the firms by listing allows us to control for these other effects.

[15] To understand how large a difference we can find between the two groups, consider the following: suppose the percentage of TRF volume follows a normal distribution $N(\mu, \sigma^2)$. Then the difference between two independent random variables for two random variables follows a normal distribution of $N(0, 2\sigma^2)$. We put the one with lower TRF volume in to the consolidated group and the one with higher TRF volume to the fragmented group. The difference between TRF volumes in these two groups is the absolute value of the random variable from the normal distribution $N(0, 2\sigma^2)$. Therefore, the difference in TRF volumes for the fragmented group and consolidated group follows a folded normal distribution, with a mean of $\frac{2}{\sqrt{\pi}}\sigma \approx 1.13\sigma$

D. Data and Sample Selection

Our data are drawn from the TAQ database, the CRSP data base, and from SEC Rule 605 data provided to us by TAG Audit. Trading volume and price information are taken from the TAQ data. We also use the TAQ data to calculate the short-term return volatility, return autocorrelation, and variance ratio. We use CRSP data to provide information on market capitalization and price. We get effective spread data, realized spread data, and execution speed from the Rule 605 data.

The time period for our analysis is January 2 – June 30, 2008. We use the initial three-month period January – March 2008 to measure the volume by trading locale for each stock in our sample. We then use the sub-period April – June 2008 to investigate how our market quality measures differ between the fragmented and consolidated sample firms. This segregation avoids any contamination due to hindsight bias.

Table 1 gives information on our sample selection criteria. Our sample includes all listed stocks on the NYSE and the Nasdaq. We follow the approach of Boehmer (2005) and apply standard filters to remove non-common equities, dual class shares, REITS, and common stocks of non-US companies. We also exclude stocks with prices below $5.00, with mean daily volume below 1000 shares, stocks with missing volume information or SEC Rule 605 information, and stocks not in the CRSP data base. We also delete Our final sample is 2754 stocks, with 1588 firms being Nasdaq-listed and 1166 firms listed on the NYSE. The matching-firm sample contains 150 pairs of Nasdaq-listed stocks, and 112 pairs of NYSE listed stocks.

3. Market Fragmentation

How fragmented is trading in U.S. equity markets? We address this basic question in the aggregate by first looking at trading volumes across the various executing and reporting venues for the period January – March 2008. During this interval there were 9 exchanges, 3 TRFs, and the ADF reporting trades. Table 2 provides data on the trading volumes reported by each venue. As is apparent, the Nasdaq had the largest volume, followed by the New York Stock Exchange. Archipelago, the fourth largest venue, is part of the NYSE group, but it is treated as a separate location for reporting purposes (combining ARCA and NYSE volume results in larger overall volume than on Nasdaq). The data also show that the regional exchanges (the National Stock Exchange, the American Stock Exchange, the Chicago Stock Exchange, and the Philadelphia Stock Exchange) are executing a very small fraction of trades in the market.[16] Similarly, the new non-equity exchange entrants (the Chicago Board of Options Exchange and the International Stock Exchange) did not establish any significant market presence during this time period.

This is not the case for the Trade Reporting Facilities, which rank 3rd, 5th, and 6th in overall trade volume. In aggregate over this period, the TRFs reported approximately 27% of trading volume. The overall role of the TRFs can be better seen in Figure 1, which depicts the share of trading volume for all Nasdaq-listed equities, AMEX-listed equities and NYSE-listed equities. For Nasdaq-listed equities, more than one-third of trading volume is taking place in the TRFs. For NYSE and AMEX-listed securities, the TRFs play a smaller role, but they are still reporting almost 25% of volume in those stocks.[17] By any metric, it appears that TRFs are

[16] The Boston Stock Exchange, which was acquired by the Nasdaq, was not active during this time period. Similarly, while most exchanges had set up TRFs, most of these were not active during our sample period.

[17] This finding that trading in Nasdaq-listed stocks is more fragmented than trading in NYSE-listed stocks is consistent with the intuition of earlier researchers such as SEC [2001] and Bennett and Wei [2006]. However, this early research viewed the internal differences between the two markets as the cause of fragmentation (the NYSE being a more centralized market than the dealer-based Nasdaq market) while our analysis here is more focused on

reporting a substantial fraction of total U.S. equity volume. As these trades are actually executing in myriad off-exchange venues, it is clear that fragmentation is an important feature of the US equity markets.

How important fragmentation is for individual stocks can be seen by looking at the distribution of volumes across listed securities. As Figure 2 (a) shows, for individual Nasdaq-listed stocks, trading in the TRFs ranges from a low of approximately 15% to a high of greater than 75% of volume. For individual NYSE-listed stocks, depicted in Figure 2(b), the dispersion is smaller, but at the upper range the TRFs are reporting almost 40% of the volume in some stocks. Figures (c) and (d) give the corresponding distributions for volumes executed away from the primary listing exchange. By definition, these distributions are even higher, with NYSE-listed securities ranging to 82% of volume trading away from the exchange, and Nasdaq-listed securities range to 85% of volume trading away.[18] What is equally significant is that fragmentation appears to be a feature for all stocks; there are no stocks in our sample for which either TRF volumes or off-primary exchange volumes are zero.

These results illustrate a number of important features of the current competitive landscape for equity trading. The sheer size of the TRF volumes testifies to the important competitive challenges that off-exchange trading is posing for established markets. Both the NYSE and the Nasdaq have been losing market share to the TRF venues, and the regional exchanges are diminishing in importance as well. For at least some stocks (i.e. those in the right tail of these volume distributions), it appears that off-exchange trading is now the "market" in terms of trade execution. However, there can be important differences between trading that takes

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the fragmentation of trades away from markets. It seems likely that the decentralized nature of the Nasdaq market made it easier to attract trades away, consistent with our findings here.

[18] The NYSE numbers treat volumes trading in Arcapelago as being away from the primary listing market. Thus, even though Arcapelago is owned by NYSE/Euronext, for fragmentation purposes Arca is a different trading platform and orders to the NYSE are separate from orders submitted to Arca.

place in one venue versus another. In particular, because many alternative trading venues involve order matching, they do not provide price discovery. Moreover, most alternative venues do not feature designated market makers or specialists to provide price support or other stabilization activities. These differences underscore the importance of investigating how this fragmentation is affecting market quality.

An interesting question is how does fragmentation differ across firms of different sizes? One might conjecture that small firms are less likely to fragment because the benefits of consolidated order flow might be particular important to such firms. Alternatively, small firms might benefit the most from being able to trade in ECNS or other ATS as this reduces the monopoly power of the market makers in those stocks. To address this issue, we divided the firms in our sample into large, medium, and small sub-samples based upon firm market capitalization as of January 2, 2008. Because firm sizes differ dramatically between the Nasdaq and NYSE, we report results separately for Nasdaq-listed and NYSE-listed firms.

Table 3 demonstrates different fragmentation patterns across NYSE-listed and Nasdaq-listed stocks. For Nasdaq stocks, TRF fragmentation is more important, and it affects small stocks more than it does large stocks. As small stocks tend to have the highest trading costs, these data are consistent with the hypothesis that off-exchange locales are attracting order flow by providing a more competitive alternative for high trading cost stocks. For NYSE-listed stocks, TRFs play a smaller role, but other exchange competitors are taking an even greater share of trading volume. Interestingly, for NYSE-listed stocks, fragmentation is higher for large stocks than it is for small stocks.

In summary, we have found that U.S equity markets feature substantial fragmentation. There is considerable dispersion in fragmentation across individual stocks, however, suggesting

that the competitive pressures that lead to fragmentation also differ across stocks. These differences may also lead to differences in market quality, an issue we investigate in the next section.

4. Fragmentation and Market Quality: A Matched Firm Approach

If fragmentation affects market quality, then we would expect to find significant differences in market quality metrics between stocks with greater fragmented trading and those with more consolidated trading. Testing for market quality differences requires care because of two potential biases. One such bias arises because execution costs and other market quality measures may differ across stocks for a wide range of reasons unrelated to fragmentation. We address this concern by using a matched-pairs analysis to control for other firm-specific factors that could also affect market quality. A second problem is that as markets fragment, orders go to new locales and leave old ones. While we can see the execution metrics in both venues, we cannot know whether the types of orders that have moved to the new venue are the same as the orders remaining on the old venue. In our analysis, we control for this potential bias by comparing execution metrics only for specific order types.

Our matched-pairs analysis features 150 pairs of Nasdaq stocks and 112 pairs of NYSE stocks.[19] We define fragmentation using two metrics: the level of TRF trading in each stock (denoted the TRF sample); and the amount of trading executed off the primary listing exchange (denoted the OEX sample). Using data from the period January- March 2008, we sort our matched pairs into fragmented and consolidated samples. We use execution data from the period

[19] We formed the matched sample by selecting every 10th firm in each market. Because there are more stocks listed on Nasdaq than on the NYSE, the two sub-samples are different sizes.

April – June 2008 to test for statistical differences in the two samples with respect to our market quality measures.

A. Execution Quality Results

We use Rule 605 data to provide execution quality measures relating to transactions costs. SEC Rule 605 requires all stock exchanges, dealers, and other market centers that execute orders to provide specific data on selected order executions. Rule 605 requires these disclosures monthly on a stock by stock basis.[20] The data do not include all executed trades, and are limited to specific order types. In our analysis, we use data based on marketable limit orders for 9999 shares or less. This data captures the largest category of transactions and seems most representative of general market quality.

Each market center reports this data separately, so the data must be aggregated to provide an average execution metric for that stock. We used data provided to us by TAG/Audit to form a volume-weighted average execution measure for each stock. We focus our analysis on effective spreads, realized spreads, and execution speed. The data exhibited substantial outliers, so following standard practice we winsorize the data to set outliers to the 2.5 and 97.5 percentile levels. We report both t-tests based on averages and Wilcoxon signed ranked tests based on medians.

Table 4 provides evidence on these trading cost measures across our total fragmented and consolidated samples. In the post-Reg NMS world, effective spreads are extremely low, with average spreads in the 3-4 cent range. Looking first at the TRF sample in Panel A, the data show that effective spreads are lower in the fragmented sample on average by .29 cents, with

[20] These include all orders meeting the following criteria: orders must be held; the limit price must be less than 10 cents from the quote; order must be straight market or limit order; and the order must be for less than 10,000 shares.

median spreads lower by .11 cents. These results are statistically significant, consistent with the hypothesis that fragmentation generally lowers effective spreads. As effective spreads are a measure of the trading costs from a trader's perspective, this result suggests that traders are better off with fragmentation as measured by TRF volumes. Fragmentation also appears to lower average execution speed, with significant differences on the order of 7 seconds between the consolidated and fragmented sample.

Defining fragmentation by the broader measure of Off-Primary Listing Exchange volume, we do not find significant differences in either effective spreads or average speeds. However, we do find significant differences in realized spreads across the consolidated and fragmented samples. Realized spreads are usually interpreted as the profit available to markets makers or liquidity providers in these stocks, and our results here suggest fragmented stocks exhibit lower realized spreads.

Table 5 reports our results segmented by firm size for the TRF sample in Panel (A) and for the OEX sample in Panel (B). We divided our 262 pairs of stocks into two groups based on market capitalization. For the TRF sample, our results show that fragmentation tends to benefit large and small stocks, but in different ways. Effective spreads are statistically significantly lower for small stocks but are essentially unchanged for large stocks. Average execution speed falls for large stocks, but it is unaffected for small stocks. These differential effects across firm sizes are intriguing, and they suggest that different forces may be at work in explaining why trading fragments for different firm types.

Looking at the results in the OEX sample, we find that large stocks have statistically smaller realized spreads in the fragmented sample. The other execution quality results are not statistically different , suggesting that fragmentation of order flow away from the listing

exchange appears to benefit trading in larger firms without significantly harming execution quality for other firms.

To investigate these effects further, we examine in Table 6 execution costs segmented by firm size for Nasdaq-listed stocks and for NYSE-listed stocks for the TRF sample. Segmenting by firm sizes across markets helps us to control for listing standard effects as well the fact that Nasdaq-listed stocks are smaller in general than are NYSE listed stocks. Looking first at the Nasdaq-listed results, we find significant differences in both average and median effective spreads for small firms. These differences are consistent with small fragmented firms having lower spreads than their consolidated matched firms. This effect is not statistically significant for large firms. Turning to the NYSE-listed results, we find no significant effects on spreads, but average speeds are improved by fragmentation for small firms. Because NYSE firms are larger overall, this result clarifies that execution speeds improvements are accruing not to the largest firms but rather to firms in the lower half of the NYSE size distribution. Overall, our results suggest that fragmentation as measured by TRF volumes generally helps small firms, and does not harm larger firms.

Interestingly, we do not find any significant difference in execution quality when we look at the off-exchange volume samples.[21] In our sample period, Nasdaq executed a substantial amount of trading in NYSE-listed stocks, reflecting the trend towards decoupling of the listing and trading decisions. Our matched sample result that stocks trading away from their listing exchange had the same execution quality as stocks trading on the listing exchange is evidence that this form of fragmentation is not detrimental to market quality.

Our implication of these findings is that the conflicting results in the literature on fragmentation issues may be at least partially due to sample selection biases. Bennett and Wei

[21] For brevity, we have not included this table, but results are available from the authors.

[2006], for example, find that both effective spreads and execution speeds decrease for their sample of firms moving their listing from the Nasdaq to the NYSE. They attribute these beneficial effects to the consolidation of trading on the NYSE relative to the Nasdaq, and so conclude that fragmentation is harmful to stocks. But most stocks shifting from Nasdaq to the NYSE are the larger stocks in the Nasdaq market, and as we show here fragmentation has no significant effects on those stocks. A more likely explanation for Bennett and Wei's result is that their differences are due to different trading rules or corporate governance requirements between the two venues.[22]

B. Market Efficiency Results

Could fragmentation harm other aspects of market quality such as market efficiency? To address this issue, we look at the differences across our fragmented and consolidated pairs with respect to three standard measures of efficiency, specifically, the short term return volatility, return autocorrelations, and the variance ratio. We divide the trading day into 26 fifteen-minute intervals starting at 9:30 a.m.[23] We calculate the return over each interval based on the spread midpoint at the beginning and ending of each interval.[24]

The short-term volatility is defined as the standard deviation of these returns over the three-month period. Greater volatility is viewed as a trading friction, so the lower the volatility the more efficient the market. Return autocorrelations are calculated using these 15 minute

[22] One such rule could be the NYSE requirement in place during their sample period that specialists faced restrictions on the size and movement of spreads. Macey, O'Hara, and Pompilio [2009] found that firms delisted from the NYSE had differential effects on trading costs when moving to the Pink Sheets. While the spreads of large firms actually decreased due to the sub-penny pricing allowed on the Pink Sheets, the spreads of small and medium-sized firms increased. These authors attribute this worsening to the cross-subsidization of smaller stocks by larger stocks on the NYSE.

[23] We also computed the short-term volatility, return autocorrelation and variance ratio for 5 minute intervals and the results are similar.

[24] An interesting problem arises with respect to the treatment of the close-open period. Deleting this period introduces noise into the variance ratio test because the sums of log returns from 3:45 p.m. to 4:00 p.m. and log returns from 9:30 a.m. to 9:45 a.m.(both one period log returns) is not equal to the log return from 3:35 p.m. to 9:45 a.m. (the two period log return). To deal with this heteroscedacticity problem, we included the overnight return, although statistically whether we include the close-to-open interval has a very limited impact.

returns. In an efficient market, returns should be un-correlated, as prices should follow a random walk. We examine the absolute value of return autocorrelations, with values closer to zero interpreted as evidence of greater efficiency. The variance ratio test captures a similar concept in that a ratio of zero is consistent with stocks following a random walk. Hence, a smaller number is better in terms of efficiency.

In computing the variance ratio test, we follow the method of Lo and MacKinlay (1988). The intuition of this test is that if the stock price follows a random walk then the variance of two-interval log returns should be twice as large as the variance of one-interval log returns. We define P_t as the stock price and

$$p_t = \ln P_t .$$

Define the estimator of mean of the one-interval return as

$$\hat{\mu} = \frac{1}{n}\sum_{k=1}^{n}(p_k - p_{k-1}) .$$

The estimator for the one-interval return variance is given by

$$\bar{\sigma}_1^2 = \frac{1}{n-1}\sum_{k=1}^{n}(p_k - p_{k-1} - \hat{\mu})^2$$

and the estimator for a half of the two interval variance is

$$\bar{\sigma}_2^2 = \frac{1}{m}\sum_{k=2}^{n}(p_k - p_{k-2} - 2\hat{\mu})^2$$

where $m = q(n-q+1)(1-\frac{q}{n})$ and $q = 2$ is an adjustment made in the denominator of the 2-weekly variance estimator to accommodate overlapping observations .

Then the variance ratio is defined as

$$\text{ratio} = \left|\frac{\bar{\sigma}_1^2}{\bar{\sigma}_2^2} - 1\right| .$$

Under the random walk hypothesis, this ratio should be equal to 0. We consider deviations from 0 as a measure of price inefficiency.

Table 7 presents our results for the 262 paired-firm TRF sample and OEX sample. The results here are mixed, and they point to an interesting divergence in the effects of fragmentation across trading venues. In particular, we find negative results with respect to volatility; fragmented stocks are more volatile as measured by means and medians for the OEX sample, with a much weaker effect only on medians for the TRF sample. The results for our other efficiency measures, however, point to the opposite result. For the TRF sample, the variance ratio is smaller for the fragmented sample, consistent with the prices of these stocks behaving more like a random walk. Similarly, the return autocorrelation of the fragmented sample is lower, which is also consistent with greater efficiency. However, these beneficial effects are not found in the OEX sample, where the autocorrelations and variance ratio are found to be the same in the fragmented and consolidated samples. Overall, we interpret these results as generally supporting the hypothesis that fragmentation away from exchange trading does not harm market efficiency, although it does appear to increase volatility.

Examining these results by listing-firm market, however, reveals some interesting divergences. As Table 8 shows, in the TRF sample the positive effects on the variance ratio and return autocorrelation are due to Nasdaq-listed firms; these effects are not significant for the NYSE-listed sample. Conversely, the negative effect of fragmentation on short-term volatility is true primarily for the NYSE-listed firms; for Nasdaq-listed firms the effect is only marginally significant for medians and not for means. These findings raise the intriguing possibility that fragmentation has enhanced the efficiency of Nasdaq-listed firms while simply increasing volatility for NYSE-listed firms.

To investigate these intra-market effects in more detail, we divide our sample into size groups by listing market. Tables 9 and 10 present these results. In the TRF sample, the Nasdaq-listed results clearly indicate that fragmentation is uniformly beneficial for small stock efficiency. Small fragmented stocks have lower volatility than their consolidated counterparts, and they also have lower variance ratios and return auto-correlations. Large Nasdaq stocks exhibit no statistical differences between the fragmented and consolidated firms. Interestingly, the Nasdaq-listed results from the broader OEX sample in Table 10 show no ameliorative effects from fragmentation and only a weak negative effect on volatility for large firms. Hence, it appears that the negative volatility effects are arising from intra-market competition rather than from fragmentation into the TRFs. Overall, these results suggest that for Nasdaq stocks fragmentation into the TRFs has helped some stocks without harming others.

For the NYSE-listed sample, the results are more complex. Consolidated stocks have lower volatility for both large and small stocks in both the TRF and OEX samples. However, in the TRF sample there is weak statistical evidence from the variance ratio test that prices for small fragmented stocks are closer to being a random walk. For large stocks, the OEX sample also shows marginal significance for both variance ratio medians and return autocorrelation medians. Fragmentation thus appears to raise volatility for NYSE-listed stocks but does not appear to harm (and may actually help) other metrics of price efficiency.

5. Conclusions

Is market fragmentation harming market quality? Our results suggest that the answer is generally no. From a transactions cost perspective, fragmentation appears to reduce effective spreads and increase execution speeds. While the magnitude of these effects differs across

listing and size regimes, we find that fragmentation is particularly beneficial for small stocks, suggesting that fragmentation has increased competition for traditionally less liquid stocks. Moreover, while short-term volatility appears to have increased particularly for NYSE-listed stocks, overall efficiency seems to be enhanced in that prices of stocks with more fragmented trading exhibit behavior closer to being a random walk. These results suggest that fragmentation has enhanced the competitive nature of U.S. equity markets without degrading its transactional or informational efficiency.

One might wonder how these ameliorative effects have arisen given the presumed positive network externality effects that arise from consolidated trading? We believe the answer lies in recognizing that while the U.S. equity markets are spatially fragmented, they are, in fact, virtually consolidated. The development of sophisticated order routing combined with the existence of a consolidated tape and the "trade through" rule have resulted in a single virtual market with many points of entry. This has allowed the positive benefits of greater competition and specialization to prevail without the negative effects that accompany the loss of consolidation.

This result has particular importance for the debates surrounding fragmentation in other global markets. In Europe, the development of multi-lateral trading facilities (MTFs) has accelerated the movement of trades away from the established exchanges. However, the lack of a consolidated tape collecting price feeds from all execution venues greatly inhibits the ability to establish market-wide trade-through protection. Without such protection, it is hard to see how a single virtual market can emerge. Similarly, in Canada, nascent fragmentation has begun, but there is not yet a regulatory policy regarding access to new venues, nor is there a trade-through

rule to require that orders flow to the most competitive venue. It remains to be seen whether the benefits from fragmentation can emerge without such protections.

Finally, we believe our results may have particular importance for developing economies. While such economies have traditionally banned off-exchange trading, the benefits of new trading technologies can be substantial if combined with appropriate regulatory protections. In the case of China, for example, putting in place trade-through protection and unified trade and price reporting protocols could set the stage for substantial improvements in market quality. Conversely, in markets where such protections have not or cannot be implemented, fragmentation is likely to be more detrimental than not, suggesting that off-exchange trading prohibitions may be appropriate.

Figure 1: This figure gives the percentage share of trading volume for all NASDAQ, AMEX (now know as NYSE Alternext U.S.) and NYSE-listed equities. The sample period is from January 2, 2008 to March 31, 2008

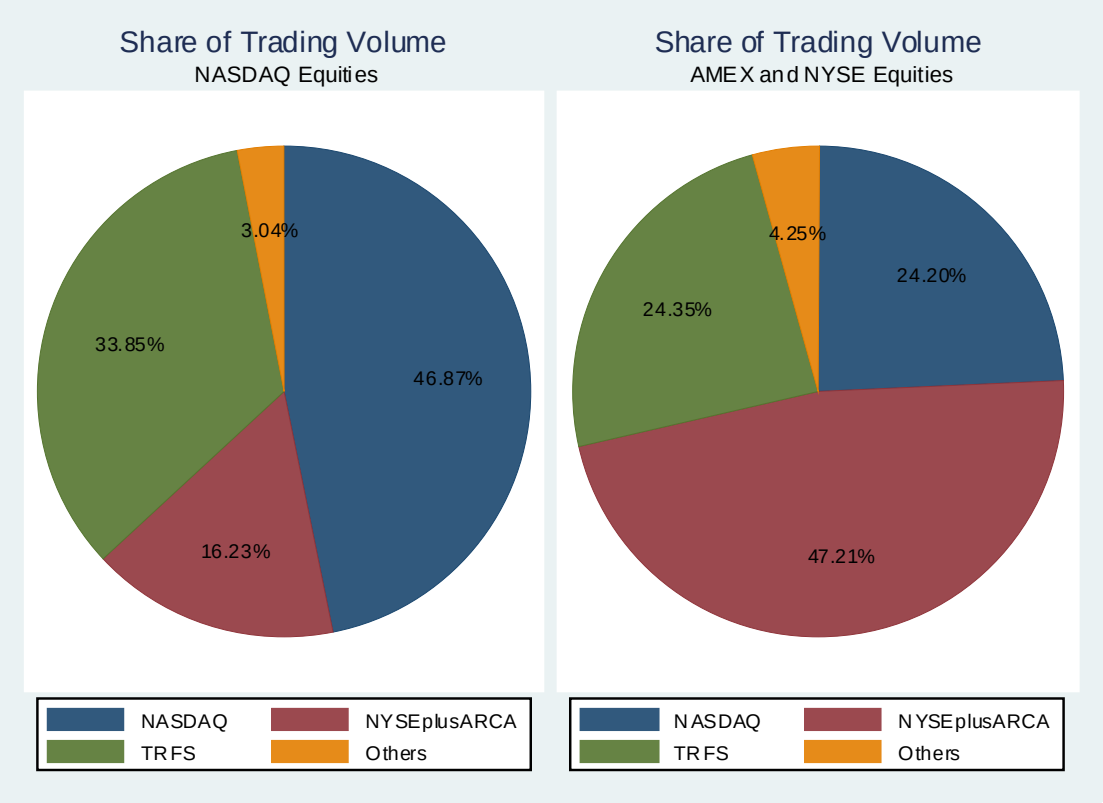

Figure 2: Distribution of Volume in Trade Reporting Facilities (TRFs) and Off-Primary Exchange

Figures (a) and (b) demonstrate the distribution of share of volume in TRFs for the 1588 NASDAQ and 1166 NYSE stocks in our filtered sample. The x axis demonstrates the share of volume in TRF, with each bin has a width of 0.02. The y axis counts the number of shares that fall in each bin. Figures (c) and (d) provide the distribution of the share of volume in each stock executing off of the primary listing market. The sample period is from January 2, 2008 to March 31, 2008

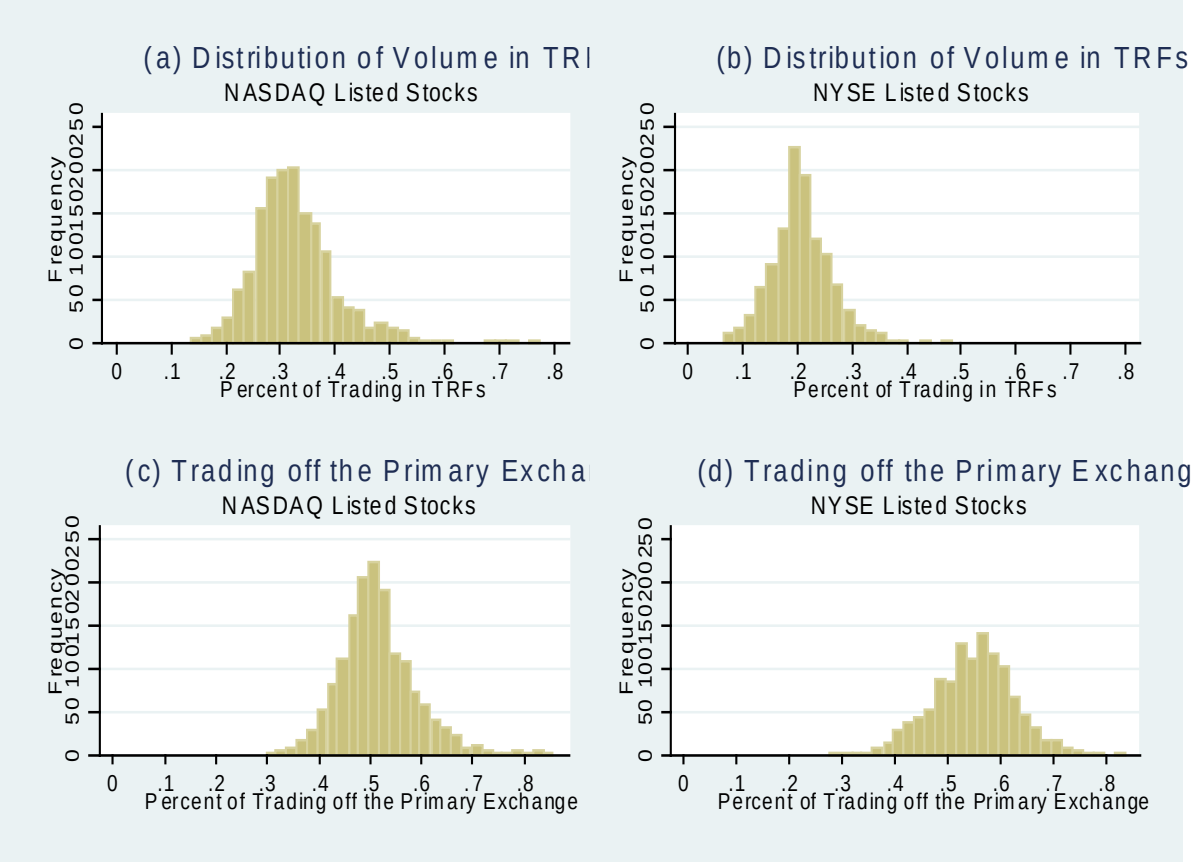

Table 1: Sample Selection Criteria

The sample is selected from all listed securities in January 2, 2008. We remove all securities that are not included in CRSP at December 31, 2007. Those include warrants, preferred, and units bundled with warrants. We apply CRSP filters to remove non-common stock equities, common stocks of non-U.S. companies, close-end funds, Real Estate Investment Trusts, and Americus Trust components and dual class stock. Volume and quote filters are applied to eliminate infrequently traded stocks and low price stocks

Criterion	NASDAQ	NYSE
CRSP Filter (December 31, 2007)		
All securities in Jan 2, 2008	3134	3251
No data in CRSP on December 31, 2007	-104	-762
Non-common stock equities (ADRs, units, certificates and Shares of Beneficial Interest)	-159	-564
Common stocks of non-U.S. companies, close-end funds, Real Estate Investment Trusts and Americus Trust Components	- 211	-551
Dural class stock	-123	-145
	2537	1229
Volume and Quote Filter (January 2, 2008-March 31, 2008)		
Missing volume, any day	-507	-17
Price<5	-442	-46
Mean daily volume<1000	0	0
Final Sample	1588	1166

Table 2: Consolidated volume by reporting venue

The consolidated volumes of all securities listed in NYSE, NASDAQ, American Stock Exchange (now known as NYSE Alternext U.S.) and NYSE ARCA. Sample period is from January 2, 2008 to March 31, 2008

Trading Venue	Volume in Millions of Shares	Share of Total Volume in percent
Consolidated Volume	495548	100
NASDAQ	153743	31.025
NYSE	105418	21.273
NASDAQ TRF	88302	17.819
ARCA	82305	16.609
NYSE TRF	31643	6.385
National Stock Exchange TRF	12207	2.463
National Stock Exchange	7701	1.554
International Stock Exchange	5259	1.061
American Stock Exchange	2872	0.58
ADF	2684	0.542
Chicago Stock Exchange	2260	0.456
Chicago Board Options Exchange	717	0.145
Philadelphia Stock Exchange	439	0.089
Boston Stock Exchange	0	0
American Stock Exchange TRF	0	0
Boston Stock Exchange TRF	0	0
International Stock Exchange TRF	0	0
Chicago Stock Exchange TRF	0	0
ARCA TRF	0	0
Chicago Board Options Exchange TRF	0	0
Philadelphia Stock Exchange TRF	0	0

Table 3 Fragmentation for large, medium and small NYSE and NASDAQ listed stocks

The total sample has 1166 NYSE-listed stocks and 1588 NASDAQ-listed stocks. Large stocks are the largest one third of stocks in each market, small stocks are the smallest one-third and medium stocks are in-between. Panel A presents the mean of share of the TRF volume; Panel B presents the result of T-Test for the statistical significance. Panel C presents the mean of share of the volume outside the primary exchange; Panel D presents the result of t-Test for the statistical significance. The sample period is from January 2, 2008 to March 31, 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

Panel A – TRF Volumes				
	NYSE Stocks		**NASDAQ Stocks**	
	Observations	**Mean**	**Observations**	**Mean**
Large	388	0.219	529	0.301
Medium	389	0.205	529	0.314
Small	389	0.204	530	0.368
Panel B – TRF Volumes				
	Difference	**P-Value**	**Difference**	**P-Value**
Large-Medium	0.014***	0.00	-0.032***	0.00
Large-Small	0.016***	0.00	-0.095***	0.00
Medium-Small	0.002	0.35	-0.063***	0.00

Panel C– Off Primary Exchange Sample				
	NYSE Stocks		**NASDAQ Stocks**	
	Observations	**Mean**	**Observations**	**Mean**
Large	388	0.585	529	0.492
Medium	389	0.532	529	0.498
Small	389	0.528	530	0.554
Panel D – Off-Primary Exchange Sample				
	Difference	**P-Value**	**Difference**	**P-Value**
Large-Medium	0.053***	0.00	-0.006**	0.05
Large-Small	0.057***	0.00	-0.062***	0.00
Medium-Small	0.004	0.21	-0.056***	0.00

Table 4: Execution Quality Statistics for Consolidated and Fragmented Samples

The table contains the pair-wise difference of execution quality statistics of the112 NYSE pairs and 150 NASDAQ pairs in our sample. Those pairs are matched based on market capitalization and closing price on January 2, 2008. We consider marketable limit order of all sizes executed in all market centers. Effective spread and realized spread are in cents and average speed is in seconds. All the three variables are calculated using weighted averages based on executed shares across different sizes and market centers in the SEC 605 data. The sample period for execution statistics is from April 2008 to June 2008. Panel A divides stocks into consolidated and fragmented samples based on TRF volumes. Panel B divides stocks into consolidated and fragmented samples based on Off-Primary Listing exchange volumes. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

Panel A. TRF Sample

		Consolidate	Fragment	Consolidate -Fragment	p-value
Effective Spread					
T-test	Mean	3.61	3.33	0.29*	0.07
Wilcoxon Signed Rank Test	Median	2.48	2.26	0.11**	0.05
Realized Spread					
T-test	Mean	0.97	1.07	-0.09	0.31
Wlicoxon Signed Rank Test	Median	0.56	0.47	-0.08	0.25
Average Speed					
T-test	Mean	86.58	79.18	7.40*	0.08
Wlicoxon Signed Rank Test	Median	64.11	55.74	3.68*	0.07

Panel B. Off-Primary Listing Exchange Sample

		Consolidate	Fragment	Consolidate -Fragment	p-value
Effective Spread					
T-test	Mean	3.49	3.52	-0.03	0.45
Wilcoxon Signed Rank Test	Median	2.47	2.27	0.06	0.26
Realized Spread					
T-test	Mean	1.15	0.89	0.26*	0.10
Wlicoxon Signed Rank Test	Median	0.61	0.45	0.11*	0.06
Average Speed					
T-test	Mean	84.76	81.35	3.41	0.26
Wlicoxon Signed Rank Test	Median	57.51	59.47	1.06	0.47

Table 5: Execution Quality Statistics for Large and Small Stocks

The table contains the pair-wise difference of execution quality statistics of large and small stocks based on market cap. Each category has one half of the observation in our 262 pairs of NYSE and NASDAQ stocks. We consider marketable limit order of all sizes executed in all market centers. Effective spread and realized spread are in cents and average speed is in seconds. All the three variables are calculated using weighted average based on executed shares across different sizes and market centers in the SEC 605 data. Panel A divides stocks into consolidated and fragmented samples based on TRF volumes. Panel B divides stocks into consolidated and fragmented samples based on Off-Primary Listing Exchange volumes. The sample period for execution statistics is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

A. TRF Volume Sample		**Large Stocks**		**Small Stocks**	
Effective Spread		**Consolidate-Fragment**	**p-value**	**Consolidate-Fragment**	**p-value**
T-test	Mean	0.13	0.33	0.45**	0.05
Wilcoxon Signed Rank Test	Median	0.04	0.36	0.23**	0.03
Realized Spread					
T-test	Mean	0.11	0.34	-0.30	0.11
Wilcoxon Signed Rank Test	Median	0.01	0.43	-0.24	0.13
Average Speed					
T-test	Mean	10.12**	0.03	4.68	0.31
Wilcoxon Signed Rank Test	Median	4.33**	0.03	2.84	0.34

B. OEX Volume Sample.		**Large Stocks**		**Small Stocks**	
Effective Spread		**Consolidate-Fragment**	**p-value**	**Consolidate-Fragment**	**p-value**
T-test	Mean	-0.06	0.42	0.00	0.50
Wilcoxon Signed Rank Test	Median	0.00	0.49	0.10	0.21
Realized Spread					
T-test	Mean	0.57**	0.02	-0.06	0.41
Wilcoxon Signed Rank Test	Median	0.18**	0.03	0.05	0.38
Average Speed					
T-test	Mean	3.65	0.25	3.16	0.37
Wilcoxon Signed Rank Test	Median	1.14	0.48	0.98	0.50

Table 6: Execution Quality for Large and Small Stocks by Market based on TRF Volumes

The table contains the pair-wise difference of execution quality statistics of in each market based on market cap. Panel A has 112 pairs of NYSE stocks and Panel has 150 pairs of NASDAQ stocks. The NYSE and NASDAQ samples are divided into large and small stocks based on the market cap on January 2, 2008. We consider marketable limit order of all sizes executed in all market centers. Effective spread and realized spread are in cents and average speed is in seconds. All three variables are calculated using weighted averages based on executed shares across different sizes and market centers in SEC 605 data. The sample period for execution quality is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

		Large Stocks		**Small Stocks**	
Panel A: NYSE Stocks					
Effective spread		**Consolidate-Fragment**	**p-value**	**Consolidate-Fragment**	**p-value**
T-test	Mean	0.21	0.11	0.16	0.33
Wilcoxon Signed Rank Test	Median	0.08	0.14	0.08	0.45
Realized Spread					
T-test	Mean	0.12	0.35	-0.02	0.47
Wilcoxon Signed Rank Test	Median	-0.03	0.47	-0.27	0.34
Average Speed					
T-test	Mean	7.14	0.13	7.96	0.23
Wilcoxon Signed Rank Test	Median	1.02	0.30	6.92*	0.08
Panel B: NASDAQ Stocks					
		Large Stocks		**Small Stocks**	
Effective Spread		**Consolidate-Fragment**	**p-value**	**Consolidate-Fragment**	**p-value**
T-test	Mean	-0.05	0.46	0.78**	0.04
Wilcoxon Signed Rank Test	Median	0.01	0.48	0.29**	0.02
Realized Spread					
T-test	Mean	-0.15	0.36	-0.25	0.25
Wilcoxon Signed Rank Test	Median	-0.23	0.28	0.10	0.39
Average Speed					
T-test	Mean	5.77	0.28	8.80	0.25
Wilcoxon Signed Rank Test	Median	5.58	0.24	6.34	0.31

Table 7: Price Efficiency for Consolidated and Fragmented Samples

The table contains the pair-wise difference of price efficiency statistics of all 112 NYSE pairs and 150 NASDAQ pairs in our sample. Those pairs are matched based on market capitalization and closing price on January 2, 2008. We divide the regular daily trading hour into 26 15-minute intervals and also consider the time between today's close and tomorrow's open as an interval. Short term volatility measures the standard deviation of return for the interval. Variance ratio is the absolute value of 1 minus the ratio of variance of one interval log return to one half of the variance of two interval log return. Autocorrelation means the absolute value of first order autocorrelation of each interval. Because of our standardization, small numbers in all three measures mean more efficiency. Panel A divides stocks into consolidated and fragmented samples based on TRF volumes. Panel B divides stocks into consolidated and fragmented samples based on Off-Primary Listing Exchange volumes. The sample period for execution quality is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

A. TRF Sample		**Consolidate**	**Fragment**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	0.728	0.749	-0.021	0.11
Wilcoxon Signed Rank Test	Median	0.642	0.716	-0.030**	0.05
Variance Ratio					
T-test	Mean	0.179	0.163	0.017***	0.01
Wilcoxon Signed Rank Test	Median	0.166	0.153	0.014***	0.01
Return Autocorrelation					
T-test	Mean	0.181	0.164	0.016***	0.01
Wilcoxon Signed Rank Test	Median	0.169	0.154	0.014***	0.01

B. OEX Sample		**Consolidate**	**Fragment**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	0.714	0.763	-0.049***	0.00
Wilcoxon Signed Rank Test	Median	0.644	0.715	-0.046***	0.00
Variance Ratio					
T-test	Mean	0.174	0.168	0.006	0.20
Wilcoxon Signed Rank Test	Median	0.162	0.158	0.009	0.13
Return Autocorrelation					
T-test	Mean	0.175	0.169	0.006	0.21
Wilcoxon Signed Rank Test	Median	0.163	0.159	0.008	0.15

Table 8: Price Efficiency for NYSE and NASDAQ Stocks

The table contains the pair-wise difference of price efficiency for stocks listed in different markets. Panel A is based on TRF volumes, while Panel B is based on volumes off of the listing exchange. The NYSE sample has 112 pairs and the NASDAQ sample has 150 pairs. We divide the regular daily trading hour into 26 15-minute intervals and also consider the time between today's close and tomorrow's open as an interval. Short term volatility measures the standard deviation of return for the interval. Variance ratio is the absolute value of 1 minus the ratio of variance of one interval log return to one half of the variance of two interval log return. Autocorrelation means the absolute value of first order autocorrelation of each interval. Because of our standardization, small numbers in all three measures mean more efficiency. The sample period for execution quality is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

TRF Sample		**NASDAQ**		**NYSE**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	0.024	0.16	-0.081***	0.00
Wilcoxon Signed Rank Test	Median	0.005	0.25	-0.061***	0.00
Variance Ratio					
T-test	Mean	0.019**	0.02	0.014	0.11
Wilcoxon Signed Rank Test	Median	0.016**	0.02	0.009	0.12
Return Autocorrelation					
T-test	Mean	0.019**	0.02	0.013	0.12
Wilcoxon Signed Rank Test	Median	0.014**	0.02	0.007	0.13

OEX Sample		**NASDAQ**		**NYSE**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	-0.019	0.21	-0.089***	0.00
Wilcoxon Signed Rank Test	Median	-0.034*	0.08	-0.054***	0.00
Variance Ratio					
T-test	Mean	0.004	0.32	0.009	0.22
Wilcoxon Signed Rank Test	Median	0.004	0.30	0.016	0.11
Return Autocorrelation					
T-test	Mean	0.004	0.33	0.008	0.23
Wilcoxon Signed Rank Test	Median	0.006	0.33	0.015	0.13

Table 9: Price Efficiency for Large and Small Stocks in Each Market based on TRF volumes

The table contains the pair-wise difference of price efficiency in each market based on market cap. The 112 NYSE pairs and 150 NASDAQ pairs are both divided into large and small stocks based on the market cap on January 2, 2008. Each category has one half of the observations. We divide the regular daily trading hour into 26 15-minute intervals and also consider the time between today's close and tomorrow's open as an interval. Short term volatility measures the standard deviation of return for the interval. Variance ratio is the absolute value of 1 minus the ratio of variance of one interval log return to one half of the variance of two interval log return. Autocorrelation means the absolute value of first order autocorrelation of each interval. Because of our standardization, small numbers in all three measures mean more efficiency. The sample period for execution quality is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent

Panel A: NYSE Stocks

		Large Stocks		**Small Stocks**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	-0.052**	0.02	-0.11***	0.00
Wilcoxon Signed Rank Test	Median	-0.037**	0.03	-0.10***	0.00
Variance Ratio					
T-test	Mean	0.008	0.31	0.019*	0.10
Wilcoxon Signed Rank Test	Median	0.016	0.20	0.009	0.17
Return Autocorrelation					
T-test	Mean	0.009	0.30	0.017	0.12
Wilcoxon Signed Rank Test	Median	0.016	0.21	0.004	0.19

Panel B: NASDAQ Stocks

		Large Stocks		**Small Stocks**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**P-value**
Short-term Volatility (in Percent)					
T-test	Mean	-0.026	0.19	0.074**	0.02
Wilcoxon Signed Rank Test	Median	-0.031	0.14	0.055**	0.03
Variance Ratio					
T-test	Mean	0.012	0.15	0.026**	0.05
Wilcoxon Signed Rank Test	Median	0.013	0.13	0.032**	0.04
Return Autocorrelation					
T-test	Mean	0.012	0.14	0.025**	0.05
Wilcoxon Signed Rank Test	Median	0.012	0.13	0.023**	0.04

Table 10: Price Efficiency for Large and Small Stocks in Each Market Based on Off Primary Market Volume

The table contains the pair-wise difference of price efficiency in each market based on market cap. The 112 NYSE pairs and 150 NASDAQ pairs are both divided into large and small stocks based on the market cap on January 2, 2008. We divide the regular daily trading hour into 26 15-minute intervals and also consider the time between today's close and tomorrow's open as an interval. Short term volatility measures the standard deviation of return for the interval. Variance ratio is the absolute value of 1 minus the ratio of variance of one interval log return to one half of the variance of two interval log return. Autocorrelation means the absolute value of first order autocorrelation of each interval. Because of our standardization, small numbers in all three measures mean more efficiency. The sample period for execution quality is from April 2008 to June 2008. The asterisks ***, **, and * indicate significance level of one percent, five percent or ten percent.

Panel A: NYSE Stocks

		Large Stocks		**Small Stocks**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**p-value**
Short-term Volatility (in Percent)					
T-test	Mean	-0.079***	0.00	-0.098***	0.01
Wilcoxon Signed Rank Test	Median	-0.039***	0.00	-0.077***	0.01
Variance Ratio					
T-test	Mean	0.017	0.16	0.000	0.49
Wilcoxon Signed Rank Test	Median	0.032*	0.08	0.008	0.37
Return Autocorrelation					
T-test	Mean	0.017	0.16	-0.001	0.48
Wilcoxon Signed Rank Test	Median	0.029*	0.09	0.004	0.40

Panel B: NASDAQ Stocks

		Large Stocks		**Small Stocks**	
		Consolidate-Fragment	**p-value**	**Consolidate-Fragment**	**P-value**
Short-term Volatility (in Percent)					
T-test	Mean	-0.040*	0.09	0.001	0.49
Wilcoxon Signed Rank Test	Median	-0.046**	0.05	-0.021	0.35
Variance Ratio					
T-test	Mean	0.012	0.14	-0.003	0.42
Wilcoxon Signed Rank Test	Median	0.009	0.14	0.003	0.41
Return Autocorrelation					
T-test	Mean	0.011	0.16	-0.003	0.43
Wilcoxon Signed Rank Test	Median	0.008	0.17	0.002	0.43

References

Battalio, R. H., 1997, Third market broker-dealers: Cost Competition or cream skimmers?" *Journal of Finance*, 52(1), 341-352.

Bennett, P. and L. Wei, 2006, Market structure, fragmentation, and market quality, *Journal of Financial Markets*, 9, 49-78.

Boehmer, E., 2005, Dimensions of execution quality: Recent evidence for U.S. equity markets, *Journal of Financial Economics*, 533-582.

Boehmer, E., and B. Boehmer, 2003, Trading our neighbor's ETF': Competition or fragmentation?, *Journal of Banking and Finance*.

Chowdry, B., and V. Nanda, 1991, Multimarket trading and market liquidity, *Review of Financial Studies*, 4(3), 483-511.

Davies, R. J. and S. S. Kim, 2008, Using matched samples to test for differences in trade execution costs, *Journal of Financial Markets*.

Domowitz, I., Finkelshteyn, I., and H. Yegerman, 2009, Cul de sacs and highways: An optical tour of dark pool trading performance, *Journal of Trading*, forthcoming.

Economides, N., 1996, The economics of networks, *International Journal of Industrial Organization*, 14, 673-699.

Fong, K., A. Madhavan, and P. L. Swan, 2001, Why do markets fragment? A panel-data analysis of off-exchange trading, Working Paper, University of Sydney.

Foucault, T. and A. Menkveld, 2008, Competition for order flow and smart order routing systems, *Journal of Finance*, 63(1), 119-158.

Gajewski, J-F, and C. Gresse, 2007, Centralised order books versus hybrid order books: A paired comparison of trading costs, *Journal of Banking and Finance*, 31(9), 2906-2924.

Goldstein, M., Shkillo, A., Van Ness, B., and R. Van Ness, 2008, Competition in the market for NASDAQ securities, *Journal of Financial Markets*, 11, 113-143.

Harris, L., 1993, Consolidation, Fragmentation, Segmentation, and Regulation, *Financial Markets, Institutions & Instruments*, 2 (5), 1-28.

Hasbrouck, J., 1993, Assessing the Quality of a Security Market: A New Approach to Transaction- Cost Measurement, *The Review of Financial Studies* 6, 191-212.

Hendershott, T., and H. Mendelson, 2000, Crossing Networks and Dealer Markets: Competition and Performance, *Journal of Finance*, 55 (5), 2071-2115.

Lo, A., and C. MacKinlay, 1988, Stock market prices do not follow random walks: Evidence from a simple specification test, *Review of Financial Studies*, 1(1), 41-66.

Macey, J., and M. O'Hara, 1999, The regulation of exchanges and alternative trading systems: A law and economics perspective, *Journal of Legal Studies*, 28(1), 17-54.

Macey, J., O'Hara, M. and D. Pompilio, 2009, Down and out in the stock market: The law and economics of the delisting process, *Journal of Law and Economics*, 51,683-713.

Madhavan, A., 1995, Consolidation, fragmentation, and the disclosure of trading information, *Review of Financial Studies*, 8(3), 579-603.

Mendelson, H., 1987, Consolidation, fragmentation, and market performance, *Journal of Financial and Quantitative Analysis*, 22(2), 189-208.

Pagano, M., 1989, Trading volume and asset liquidity, *Quarterly Journal of Economics*, 104(2), 255-274.

Securities and Exchange Commission, 2001, *Report on the Comparison of Order Execution Across Equity Market Structures*.