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Equity trading and the allocation of market data revenue ☆

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ABSTRACT

Revenues generated from the sales of consolidated data represent a substantial source of income for U.S. stock exchanges. Until 2007, consolidated data revenue allocated in proportion to the number of reported trades. This allocation rule encouraged market participants to break up large trades and execute them in multiple pieces. Exchanges devised revenue-sharing and rebate programs that rewarded order-flow providers, and encouraged algorithmic traders to execute strategies involving large numbers of small trades. We provide evidence that data revenue allocation influenced the trading process, by examining trading activity surrounding various events that changed the marginal data revenue per trade.

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Data revenue constitutes an important source of income for securities exchanges around the globe. For example, sales of consolidated equity market data in the United States generated approximately $400 Million in 2004, representing about 10–15% of total revenues reported by the largest exchanges, and substantially more for some of the smaller exchanges. By 2008, consolidated data sales revenue had increased to approximately $450 Million.[2] In Canada, since the Toronto Stock Exchange (TSX) demutualized, revenues from market data have grown from $45 Million in 2001 to $160 Million in 2011. In Europe, the largest exchanges, including London Stock Exchange (LSE) and Deutsche Borse, have seen their market data revenue grown substantially in recent years.[3]

These figures suggest that a complete understanding of the economic forces driving the evolution of equity market structure and the competitive structure of the industry must include an analysis of market data revenues, how these revenues are allocated across exchanges, and how the allocation mechanism might favor particular market structures in equilibrium. In this paper, we take a step in this direction by documenting that the allocation of data revenue can impact investors' decisions of how and where to execute trades.

In the U.S. and Canada, the process of collecting and disseminating quote data and sharing the revenues operates under a consolidated model, while in other jurisdictions data revenues are generated by market operators. This paper focuses on the U.S. model and analyzes how the consolidated framework and the sharing arrangements affect trading activity and execution quality.

Real-time stock market data in the U.S. is sold through three different consolidated feeds. In particular, Network A (sometimes known as "Tape" A) contains quote and trade data for all stocks with primary listing on the New York Stock Exchange (NYSE), Network B contains data for stocks with primary listing on any exchange other than NYSE or NASDAQ, and Network C contains data for stocks with primary listing on NASDAQ. Networks A and

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[2] Data on aggregate consolidated data revenues are not publicly available, but were reported for 2004 and 2008 in Securities and Exchange Commission (SEC) releases. See Securities and Exchange Commission, Regulation NMS Adopting Release, No. 34-51808, June 9, 2005, and Concept Release on Equity Market Structure, No. 34-61358, April 21, 2010.

[3] For example, LSE's market data revenues increased from 105.9 million in 2007 to 184.7 million in 2011, representing almost 30% of its revenues (see London Stock Exchange Group Plc–Annual Report 2007 and 2011).

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B are managed by the exchanges through the Consolidated Tape Association (CTA), pursuant to the structure laid out in the "CTA Plan". Similarly, Network C is governed by the NASDAQ UTP Plan. These industry plans, under the regulatory oversight of the SEC, are responsible for contracting with a Securities Information Provider (SIP) to distribute the data, charging subscribers for the data, and allocating the resulting revenues back to the member exchanges.

In this paper, we show that the formulas used for allocating market data revenue across exchanges create incentives that can have a significant impact on how market participants trade stocks. Specifically, the formula used under the CTA Plan prior to April 1, 2007 allocated revenue only in proportion to the number of trades reported by each exchange. By considering only the number of trades, the allocation formula caused a distortion in trading practices, encouraging the breaking of large orders into smaller trades. For example, a trade of 1000 shares would count as a single trade, but ten trades of 100 shares each would count as ten trades and generate ten times more revenue under the formula.[4] Thus, the exchanges received more revenues when large orders were broken up and executed as multiple small trades.

During the period of our study, if a stock changed listing venues and moved from Network A to Network B, this had an immediate effect on the marginal revenue per trade. To illustrate, in 2004 the data revenues (net of expenses) distributed by the CTA to participants for calendar year 2004 amounted to $155,271,000 for Network A. These revenues were distributed to plan participants in proportion to the number of trades reported by each participant. Based on data from TAQ we estimate there were 1,028,666,115 trades reported on Network A stocks in 2004, so the tape revenue per share amounted to approximately $0.15 per trade ($155,271,000/1,028,666,115). Thus, if an exchange in 2004 were to increase the number of reported trades by breaking a larger trade into multiple smaller trades, the marginal increase in revenue to the exchange would be $0.15 for each additional trade. The same year, CTA net revenues for Network B were $99,980,000, and there were 96,989,471 trades reported in Network B. Thus, the revenue per trade on Network B was ($99,980,000/96,989,471) or approximately $1.03 per trade. If a security migrated from Network A to Network B during 2004, the marginal benefit from breaking one trade into two trades increased from $0.15 to $1.03.[5]

By examining a series of natural experiments, we demonstrate that this aspect of the revenue formula generated incentives that in certain circumstances were strong enough to influence the trading process – specifically, by leading market participants to break up larger orders into smaller pieces for reasons unrelated to execution quality, a practice known as "tape shredding". In particular, we find that average trade size is sensitive to the changes in the marginal data revenue per trade under the CTA allocation formula, especially in circumstances when revenue per trade was relatively high. In addition, we find that this sensitivity of trade size to marginal data revenue per trade is observed predominantly on those exchanges (not the primary listing exchanges) which had implemented "revenue-sharing" or "rebate" programs that created an incentive for market participants to engage in tape shredding – for example, for brokers to split their customers orders or for proprietary traders to engage in algorithmic trading designed to capture rebates. However, we find no conclusive evidence that the incentives created by the allocation formula or the practice of tape shredding had any impact on the quality of trade executions, as measured by effective spreads.

Our analysis has four prongs. First, on December 1, 2004 the NASDAQ 100 Index Tracking Stock (QQQ) moved its listing from the American Stock Exchange (AMEX) to NASDAQ. Prior to the move, QQQ accounted for more than 40% of the trades on Network B. When these trades were removed, this increased the revenue per trade for those securities remaining in Network B. This event allows us to examine the effects of a change in incentives without the possibility of contamination from other factors associated with a security changing its primary listing venue. We find that when QQQ left, average trade size decreased for those securities remaining in Network B, particularly on those exchanges that had rebate programs.

Second,we examine trading activity for a sample of 40 Exchange Traded Funds (ETFs) that switched primary listing from AMEX to NYSE on November 30, 2005. The effect of this move was immediate and striking. Comparing the three-month periods before and after the switch, we find that average trade size increased by more than a factor of five. Average trade size increased on all the exchanges but the extreme magnitude of the result was largely driven by changes in trading activity on exchanges with aggressive rebate programs. We also study the effect of this move on the stocks that remained listed on AMEX. As was the case for the QQQ migration, we again find evidence that average trading size decreased and the proportion of 100-share trades increased for the stocks remaining in Network B.

Third, between August 2005 and May 2006, six exchanges and the National Association of Securities Dealers (NASD) adopted "tape shredding" rules prohibiting brokers from breaking up customer orders into smaller pieces for any reason other than best execution. However, these rules place no restrictions on the actions of proprietary trading desks. Thus, by looking at the impact of these rules, we can evaluate the extent by which the breaking up of large orders into small orders is driven by broker agency trading, as opposed to proprietary trading. For the exchanges most involved in trading Network B securities, these rule changes went into effect in April and May of 2006. We examine whether these rules had any observable effect on average trade size. When we aggregate across securities, we find a sudden, economically large increase in average size of Network B trades on NASDAQ and NYSE Arca, both of which had rebate programs, but a decrease in average trade size on AMEX, which did not have a rebate program. This result disappears when securities are equally weighted in a paired t-test, suggesting that tape shredding activity was concentrated in a relatively small number of securities. For Network A securities, where revenue per trade was lower, we find no significant increases in average trade size when these tape-shredding rules went into effect.

Fourth, the SEC established a new allocation formula at the same time it adopted Regulation NMS, under which only one fourth of the revenue is allocated in proportion to the number of trades.[6] When the new formula went into effect on April 1, 2007, there was an immediate decrease in the marginal revenue allocated to an exchange as a result of splitting trades. However, there was no immediate change in the terms of the exchanges' rebate programs. Consistent with our earlier results for Network B securities, we find a statistically significant increase in average trade size on NYSE Arca, and a decrease on AMEX. Again, no significant increases in trade size were observed on Network A securities.

It has long been understood by industry participants and regulators that the CTA allocation formula can influence how trades are executed and reported–indeed this was the SECs motivation for

[4] Trades smaller than 100 shares are "odd lots" and are not reported to the consolidated tape, and thus generated no revenue.

[5] A similar calculation could be performed for Network C, but the calculation would be slightly different because only 50% of Network C revenue was allocated in proportion to the number of trades and the remainder was allocated in proportion to the number of shares.

[6] See SEC Release No. 34-51818, June 9, 2005.

pushing the exchanges to adopt "tape shredding" rules in 2006 and to change the allocation formula in 2007.

Our results are consistent with the findings of Kugele and Lynn (2006) and Broom et al. (2007) and confirm that the incentives created by revenue allocation can be large enough, on the margin, to have a significant impact on average trade size. Our results show that an exchange's rebate structure can have a significant impact on order execution decisions by brokers and traders, even when such decisions have no impact on trade execution quality. This finding provides perspective to the current debate on the maker-taker market structure (Cespa and Foucault, 2014), and on whether liquidity rebate fees affect order routing decisions (Battalio et al. (2014)), and if so whether order execution quality may be adversely affected.

Our results should be of interest to exchanges and regulators around the world, as they consider approaches to market data, and broader questions such as the extent to which market data should be considered a public good, whether and to what extent the distribution of market data should be consolidated across exchanges, and how property rights to market data should be assigned. Among the prior authors who have focused on these issues are Mulherin et al. (1991) and Boulatov and Dierker (2007).

The SECs policies on the distribution and pricing of market data have continued to be the focus of an active policy debate in the industry. For example, the Securities Industry and Financial Markets Association (SIFMA) in 2013 argued that the lack of transparency into costs and revenues associated with consolidated market data prevents the public from evaluating whether the level of fees is reasonable as required by securities laws, and urged the SEC to reconsider whether the SEC should consider new regulation that would eliminate what they argued was competitive advantage enjoyed by the exchanges in having access to a substantial and exclusive source of revenues. Market data distribution has been the subject of recent SEC enforcement action and private litigation (see for example, SEC Exchange Act Release 67857, Harold Lanier v. Bats Exchange et al., Southern District of New York).

Our results have implications for market design and regulation, including the question of how regulatory policy may impact the competitive structure of the industry. We show that the incentives created by market data allocation can have a direct impact on market design, as exchanges seek to develop structures to capture market data. Because data revenues are a significant source of revenues for exchanges, especially smaller exchanges that do not have primary listing revenues, policies with respect to data allocation may have a first-order impact on profitability of smaller exchanges and new entrants, and therefore on the equilibrium number of exchanges in the industry.

Our research also contributes directly or indirectly to several other areas of academic research. For example, we introduce a new dimension to the analysis of competition between exchanges, other aspects of which have been considered by authors such as Arnold et al. (1999), Santos and Scheinkman (2001), Bessembinder (2003), Foucault and Thierry (2004) and Caglio and Pescatori (2013). Our results have immediate implications for the "stealth trading" literature, which implicitly assumes the main motivation to break up larger trades into smaller trades is to camouflage informed trading (see Barclay and Jerold (1993), Chakravarty (2001), Choe and Hansch (2006)). We document a motivation for market participants to break up larger trades into smaller trades that has nothing to do with asymmetric information. While our research does not challenge the core finding of the stealth trading literature that medium-sized trades can be more informative than larger trades, it calls into question whether this finding can be interpreted as evidence for a causal connection between informed trading and trade size. We would also suggest that market data rebate programs are likely to have a direct influence on the large investor's tradeoff between block trading and "working" an order, a topic addressed by authors such as Seppi Duane (1990), Madhavan and Cheng (1997) and Back et al. (2007).

Finally, we would argue that market data revenue is an impetus contributing to the practices of payment for order flow, internalization, order preferencing, and make-or-take fees, but has largely been ignored in the literature investigating those practices. Among the many authors who have studied these topics are Chordia and Subrahmanyam (1995), Battalio et al. (1998), Bloomfield and O'Hara (1998), Battalio and Robert (2001), Parlour and Rajan (2003), Peterson et al. (2003), Chung et al. (2004) and Foucault et al. (2013).

This paper is organized as follows. In Section 1 we provide an overview of the regulatory history of the Plans that administer the dissemination of consolidated market data. We discuss the formulas used to allocate revenues, describe the revenue-sharing or rebate plans used by the exchanges to compete for trade prints, and give several examples of how revenue allocation has been influenced by trade reporting arrangements or mergers between ECNs and Exchanges.

Section 2 investigates how the migration of the NASDAQ 100 tracking stock from Network B to Network C affected the trading patterns for those stocks remaining in Network B. Section 3 contains our analysis of 40 ETFs that switched from AMEX to NYSE on November 30, 2005. Section 4 reports our analysis of the tape shredding rules implemented by the exchanges in 2005 and 2006. In Section 5 we report our results on the impact of the new revenue allocation rule that went into effect on April 1, 2007. Section 6 presents the analysis of whether order execution quality was impacted by tape shredding. Section 7 provides additional commentary and concludes the paper.

1. Institutional background

1.1. Consolidated data plans and revenue allocation

The regulatory framework for the dissemination of real-time consolidated last sale and quote data from U.S. Equity markets is set forth in three plans, the CTA Plan, the CQ Plan, and the UTP Plan.[7] These Plans are administered by their participants, who are registered National Securities Exchanges or National Securities Associations, and overseen by the SEC. As of September 2007, the parties to the CTA, CQ, and UTP Plans included eleven participants.[8]

Under these Plans, eligible securities are assigned to one of three Networks based on where the security is listed. Securities listed on NYSE are assigned to Network A, those listed on another National Securities Exchange but not NYSE or NASDAQ are assigned to Network B. Networks A and B are administered by the CTA Plan and CQ Plan. The UTP Plan administers the dissemination of market data for NASDAQ Global Market and NASDAQ Capital Market securities that are not part of Networks A and B. We will refer to this distribution channel as "Network C".

Market data revenues amount to hundreds of millions of dollars annually, and represent a nontrivial portion of the exchanges' total revenues. For example, in 2004, Networks A, B, and C generated net income of approximately $155 Million, $100 Million, and $138 Million, respectively, for a total of approximately $394 Million.[9]

[7] A separate plan governs dissemination of options data, under the Options Price Reporting Authority.

[8] American Stock Exchange (AMEX), Boston Stock Exchange (BSE), Chicago Board Options Exchange, Chicago Stock Exchange (CHX), International Securities Exchange, NASDAQ Stock Market, National Association of Securities Dealers (NASD), National Stock Exchange (NSX) (formerly Cincinnati Stock Exchange (CSE)), NYSE, NYSE Arca (formerly Pacific Exchange (PCX)), and Philadelphia Stock Exchange (PHLX).

[9] Regulation NMS Adopting Release, Securities and Exchange Commission Release No. 34-51808, June 9, 2005.

For most of the exchanges, market data revenues constitute somewhere between 10% and 20% of total revenues.

Tape Revenue is allocated across market centers according to formulas established under the regulatory jurisdiction of the SEC. Prior to April 1, 2007, revenue on Networks A and B was allocated in proportion to the number of round-lot transactions reported by the Participant. Revenue on Network C was allocated half in proportion to the number of transactions and half in proportion to share volume.

In conjunction with the adoption of Regulation NMS, the SEC in June 2005 adopted a new allocation formula for the various plans. The new formula was originally scheduled to go into effect on September 1, 2006, but was delayed to April 1, 2007. The new algorithm (1) associates revenues with individual securities in proportion to the square root of dollar trading volume, and (2) allocates revenues across exchanges one fourth in proportion to the number of trades, one fourth in proportion to dollar volume, and one half in proportion to the degree to which the exchange's quotes contribute to the National Best Bid and Offer (NBBO). The main effect of the square root transformation is to spread the revenue more evenly across securities. The effect of the weighted allocation function is to reduce the incentive for tape shredding and to create an additional incentive for exchanges to provide liquidity at the NBBO.

1.2. Revenue sharing/rebate programs

In the late 1990s, exchanges began to introduce programs to share data revenue with the specialists or member firms that generated the order flow. When an exchange shares data revenue with member firms in proportion to how much revenue they generate, this creates an incentive to execute large orders in smaller pieces.

Between 1997 and 1999, revenue sharing or rebate programs were initiated by three regional exchanges and NASDAQ. Specifically, programs were introduced by the CHX, effective January 17, 1997,[10] Cincinnati Stock Exchange, effective November 13, 1997,[11] BSE, effective October 1, 1998,[12] and NASDAQ, effective March 4, 1999.[13]

The specifics of these programs differed across exchanges. For example, on CHX, rebates were computed on a stock-by-stock basis, according to the specialist's monthly market share in that particular stock. Specialists received a rebate of 18% for all trades up to a market share of 7%, 36% for trades in excess of 7% and up to 12% market share, and 54% for trades above 12% of market share. Under the CSE's rebate program, members were credited on a pro rata basis, based upon the percentage of Network B market share in terms of transactions captured by the exchange in a given quarter, rebating 10% of revenues for stocks in which the CSE market share was below 3%, 25% when the market share was between 3% and 5%, 30% when the market share was between 5% and 7%, and 40% when the market share was at least 7%.[14] The BSE revenue sharing program rebated 50% of consolidated Tape A and Tape B market data revenue, and the NASDAQ program offered rebates from pools made of 40% of Tape A and B revenues. These descriptions apply to the revenue-sharing programs as initially designed, but the programs have been modified numerous times over the years.

On May 28, 2002, the Pacific Exchange (PCX), after its equity trading business had been taken over by Archipelago, implemented a revenue-sharing program targeted to trades executed on Archipelago. In June, 2002, PCX, NASDAQ and CSE expanded their revenue sharing programs, but the Securities and Exchange Commission abrogated these fee changes on July 2, 2002. The PCX reinstated its revenue-sharing programs through rule filings on July 9, 2002 for Network B securities, and on August 6, 2002 for Network A securities.[15] This program evolved over the years, as PCX completed its merger with Archipelago, and then was taken over by the NYSE. After the merger, NYSE Arca continued to have a rebate program. While this program had some limitations on who was eligible to receive rebates, the amount of the pool for calculation purposes was based on 50% of the gross revenues derived from market data fees. The rebate program established a 50% transaction credit on revenues generated by Network A non-ETF securities and Network B securities, while the Network C program was based on a pro rata contribution of the operating revenues generated by each participant.

1.3. Reporting arrangements and platform mergers

Trading platforms that are not National Securities Exchanges are not eligible to participate directly in the consolidated revenue plans. However, trades executed on these platforms are reported through a participant exchange, or a trade-reporting facility connected to a participant. For example, trades executed on ECNs generate market data revenue for the exchange on which the ECN chooses to report. In cases where an ECN is able to attract a significant market share, the data revenue attached to those trades make the ECN particularly attractive to the exchanges, and vice versa. This synergy created an impetus for revenue sharing arrangements between exchanges and ECNs, and increased the attractiveness of mergers between exchanges and ECNs.

For example, arrangements between Island (later iNet) and the Cincinnati Stock Exchange in 2002 generated substantial Network B and Network C revenues for that exchange, until iNet was acquired by NASDAQ in December 2005. Archipelago ECN was able to access data revenue by aligning with the Pacific Exchange. Archipelago aligned with the Pacific Exchange in 2000, registered as a stock exchange and became Arca Ex in 2001, migrated all PCX equity trading to Arca Ex in 2002, and began to report trades via PCX in stages between 2002 and 2003. Arca Ex took over the PCX completely in 2005, only to be acquired by NYSE in March 2006.

Figs. 1 and 2 illustrate the extent to which these reporting arrangements and acquisitions influenced the distribution of trade prints across exchanges. Fig. 1 graphs the market share of Network B trades (computed from TAQ data) for AMEX, CSE/NSX, PCX/Arca, and NASDAQ, from 2001 to 2006. For clarity, daily fluctuations are smoothed using a 5-day moving average. The impact of the trade-reporting arrangement between the CSE and Island ECN may be easily observed in July 2002. Likewise, market share immediately transferred from CSE (NSX) to NASDAQ in January 2006 following NASDAQ's acquisition of iNet. Particularly striking in this figure is the experience of PCX/Arca Ex, which went from almost zero to in excess of 50% market share of Network B in two years.

Fig. 2 shows a similar graph for Network C. This figure graphs the market share of Network C trades, computed from TAQ), for NASDAQ, CSE/NSX, PCX/Arca Ex, and BSE, from 2001 to 2006. CSE's Network C market share went from zero to nearly 20% overnight on March 18, 2002 when Island began reporting trades there, and jumped up again in February 2004 when Instinet moved its trade reporting from NASD's Alternative Display Facility to CSE. Likewise, the market share of trades reported by the PCX increased

[10] Securities Exchange Act Release No. 38237 (February 4, 1997), 62 FR 6592.
[11] Securities Exchange Act Release No. 39395 (December 3, 1997), 62 FR 65113.
[12] Securities Exchange Act Release No. 40591 (October 22, 1998), 63 FR 58078.
[13] Securities Exchange Act Release No. 41174 (March 16, 1999), 64 FR 14034.
[14] In 1999, the CSE modifies the previous revenue program, increasing the rebate to members to 50 percent of all Tape B revenue on a pro rata without regard to market share prerequisites.
[15] Securities Exchange Act Release No. 46293.

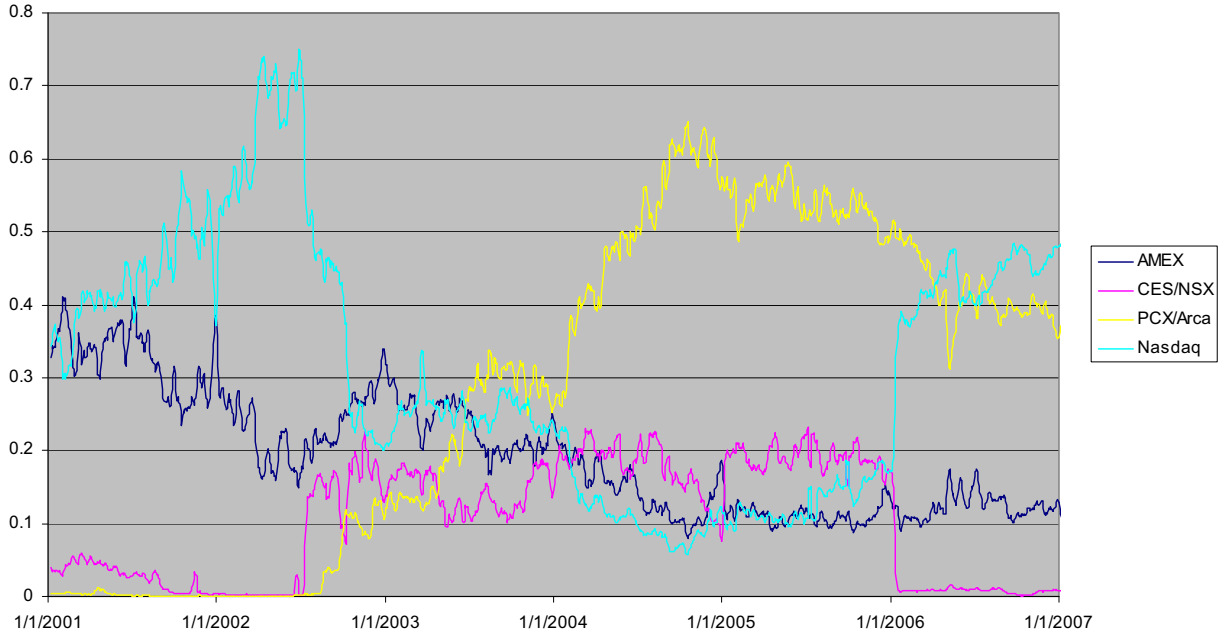

Fig. 1. Market share of Network B trades 2001–2006.

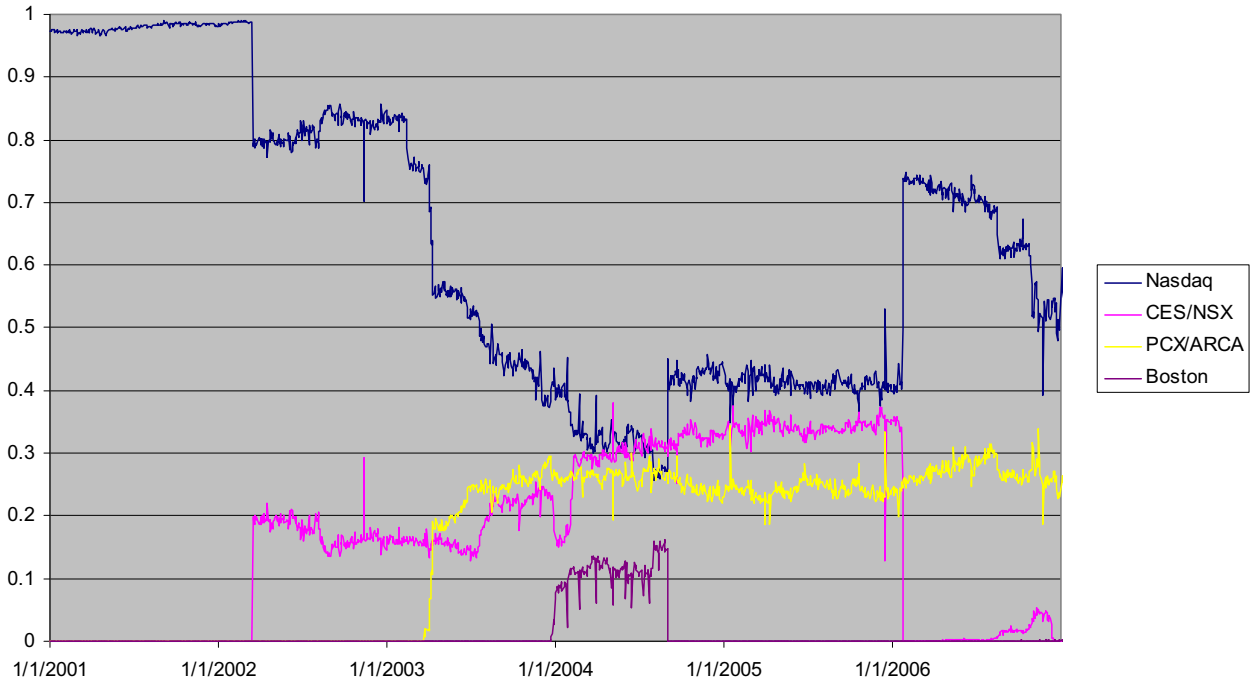

Fig. 2. Market share of Network C trades 2001–2006.

from essentially zero to nearly 20% when Arca Ex began reporting its Network C trades there in April 2003. The graphs also shows the impact of an arrangement between the BRUT ECN and the BSE in December 2003, and the acquisition of the BRUT ECN by NASDAQ in September 2004.

2. Migration of the NASDAQ-100 tracking stock

On December 1, 2004, the primary listing of the NASDAQ 100 Index Tracking Stock (QQQ) moved from AMEX to NASDAQ. Before this change, QQQ accounted for a substantial proportion of the trades on Network B. For example, based on the TAQ data, we estimate that in the three months from September through November, 2004, QQQ accounted for approximately 45.7% of trades reported on Network B.

Evidence that tape shredding was occurring on the QQQ prior to its departure from AMEX has been provided by Kugele and Lynn (2006) and Broom et al. (2007). Analysis of this event is somewhat complicated by differences in market microstructure between AMEX and NASDAQ, and by the fact that the CTA allocation formula was different from the UTP formula. For these reasons, we do not conduct of formal analysis of changes in the QQQ itself. We merely note that average trade size in the QQQ more than doubled when it migrated to NASDAQ, as illustrated by Fig. 3. Casual examination of

trading patterns on the individual exchanges surrounding December 1, 2004 indicates a particularly dramatic increase in the average trade size on Arca Ex and on the CHX.[16]

Our analysis focuses on how the departure of the QQQ affected trading in those stocks remaining in Network B. After the migration, QQQ trades no longer claimed Network B revenue, and this increased the revenue allocated to trades on the remaining securities. In the absence of any equilibrating response by market participants, this would have raised the marginal revenue per trade on the remaining Network B securities by more than 80%. If the market responded to this change in incentives, we would expect to see more tape shredding in other Network B securities after the departure of the QQQ.[17]

Tests involving direct examination of securities that switch exchanges may be influenced by other confounding effects. For example, there may be differences between the two exchanges that affect trading patterns, or the choice of the issuer to move its listing may have been influenced by endogenous factors that are also related to trading activity. Such concerns should not arise when we examine those securities that do not migrate.

In order to investigate how the departure of the QQQ affected the other Network B stocks, we extract trade data for all AMEX listed stocks from the NYSE trade and quote (TAQ) database from September 2004 to February 2005. We eliminated from consideration three stocks that moved from AMEX to NYSE during this period. We examine trading activity of Network B stocks on each exchange, only considering those stocks that continue to trade on the same exchange before and after the QQQ migration. Table 1 reports the number of trades, total volume, and average trade size for Network B stocks before and after December 1, 2004.

As indicated in the table, all the exchanges, except for BSE experienced a statistically significant increase in daily trading volume and number of trades of Network B stocks after QQQ left AMEX.[18] The average trade size declined more than 20% on NASDAQ, Arca Ex, CHX,[19] and NSX. Of particular note, the average trade size declined the most on NASDAQ (−30%) and NSX (−29%). It is important to notice that NSX had the most generous rebate programs, rebating 50% per stocks of all Tape B revenue. BSE and AMEX, which did not have rebate programs, experienced mach smaller declines in trade size or not significant changes.

Table 2 shows the distribution of trade sizes on Network B stocks on each exchange before and after the migration. It shows the percentage of reported trades in each of six size buckets, including trades of 100 shares, trades between 101 and 499 shares, trades between 500 and 999 shares, trades between 1000 and 2499 shares, and trades above 2500 shares. We find an economically important increase in the proportion of 100-shares trades on ARCA Ex and the regional exchanges. For example, the proportion of 100-share trades on the remaining Network B stocks increased from approximately 24% to 35% on NASDAQ, 74% to 84% on Arca Ex, 23% to 39% on CHX, and 25% to 58% on NSX. Moreover, the other trade size buckets experienced a significant decrease, in particular the trades with size between 101 and 2,500. The share of trades with size between 101 and 499 shares dropped from 27% to 17% on CSE and from 14% to 9% on Arca Ex. In addition, trades with size between 1000 and 2500 shares decrease from 19% to 13% on CHX, 21% to 17% on NASDAQ and 16% to 9% on NSX. This evidence confirms that the changes in mean are largely driven by the changes in the number of small trades, not by changes in the number of block trades.[20]

The results in Tables 1 and 2 provide evidence of tape shredding in Network B securities, and in particular that the amount of tape shredding is sensitive to the marginal revenue per trade. To further explore whether tape shredding is confined to a certain type of securities, we partitioned our sample in various ways and repeated our analysis. In the interest of space, we do not include numeric results here, but we find that among the securities remaining on Network B, the significant changes in average trade size are observed for both ETFs and non-ETFs.[21] The evidence of tape shredding appears to be stronger for higher-volume securities, but is not confined to only the top decile or even the top half of securities. There appears to be no obvious relation between tape shredding and price level.

Inasmuch as a relatively small number of very large block trades can have a big impact on average trade size, as a robustness check we repeated our analysis throwing out all block trades of over 10,000 shares. We found that our results were qualitatively unchanged (results not reported).

3. Securities switching from AMEX to NYSE

In the previous section, we examined changes in trading patterns surrounding the migration of the QQQ from AMEX to NASDAQ. However, we did not formally examine changes in trading patterns on the QQQ itself, in part because we believed it would be hard to disentangle the effects of tape shredding from the effects of changing the primary listing from a specialist structure to a dealership structure. It is well-known that trades are reported differently on the specialist exchanges and NASDAQ, making direct comparisons difficult. Furthermore, the analysis of the change in marginal incentive to split large trades into small trades is complicated by the fact that CTA and UTP plans used different allocation formulas.

However, securities migrating from AMEX to NYSE remain within CTA, within a specialist market structure, and the primary listing remained with an exchange that did not have a rebate program. Although there are some differences between NYSE and AMEX, we believe for the purposes of isolating the effects of a change in marginal revenue per trade, a move from AMEX to NYSE is a cleaner natural experiment than is a move from AMEX to NASDAQ.

As mentioned before, market data revenues are collected and allocated separately for NYSE-listed (“Network A”) and AMEX-listed (“Network B”) securities. Based on numbers for calendar year 2004, the aggregate data revenue was almost 50% higher for Network A than for Network B. But because the number of trades for Network A was more than ten times higher than for Network B, revenue per trade was substantially higher for stocks with their primary listing on AMEX than those with their primary listing on NYSE. As described above, in 2004 market data revenue amounted

[16] Broom et al. (2007) find that after the listing change, NASDAQ's share of the QQQ volume increased (from 12% to 36%), while AMEX's share declined from 8% to less than 2%, and NSX became the largest single venue for trading QQQ.

[17] We note that prior to the migration of the QQQ, 45.7% of the trades in Network B were on the QQQ. As of December 1, 2004 a 45.7% reduction in the number of Tape B trades, ceteris paribus, implies an increase in the revenue per trade of approximately $84\%(1/(1-.457)=1.84)$. For example, if the revenue on tape B prior to the migration was $1.03 per trade, we would expect the departure of the QQQ to increase revenue per trade for the remaining stocks to approximately $1.87, before accounting for any resulting change in trading behavior.

[18] Because of the change in listing venue, BSE (together with NYSE and PHLX) lost its UTP to trade the QQQ. However, its market share was only 3% (see Broom et al. (2007)).

[19] Even if the CHX was granted a special trading privilege to trade the QQQ after the listing change, the reported trading volume declined significantly, perhaps in part due to differences in reported trading volume between a dealer and a specialist market (see Van Ness et al. (1999)).

[20] Because the market data revenues were allocated to each exchange based on the number of trades, the rebate program were structured such that the round lot trade size (100 shares) would assure the most benefits in terms of rebates.

[21] We obtain the list of ETFs from the archived issues of ETFR on www.indexuniverse.com.

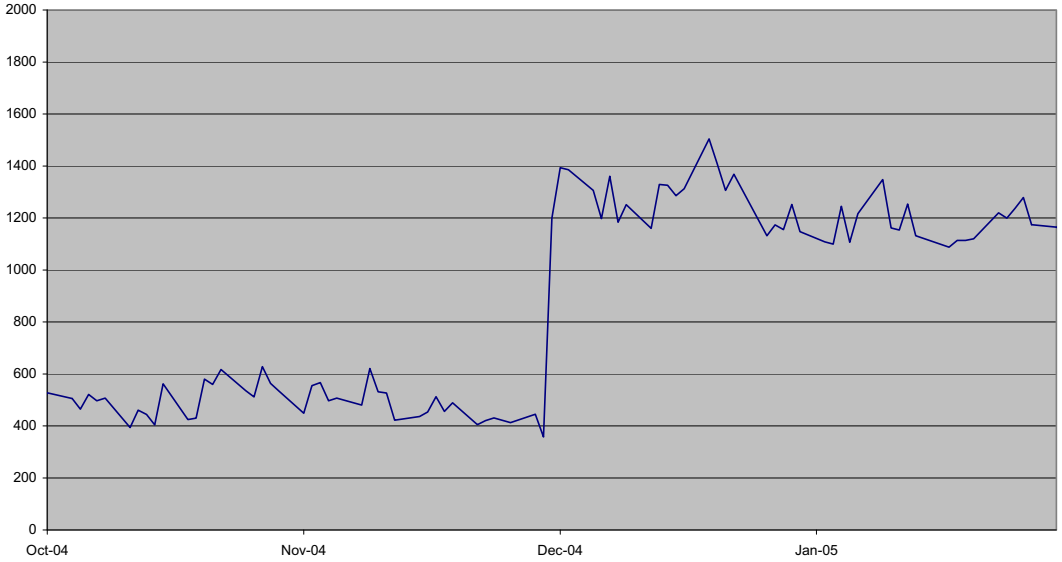

Fig. 3. Average trade size Nasdaq 100 tracking stock (QQQ/QQQQ) surrounding move from Network B to Network C.

Table 1
Impact of the QQQ migration on other Network B stocks. This table reports changes in trading volume, number of trades and average trade size for other Network B stocks surrounding the departure of the QQQ on December 1st 2004. Averages are computed for three-month windows before and after the switching date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Mean Before	Mean After	Change	% Change
AMEX	Trades	38,869	46,387	7518**	19.34%
	Volume	50,688,409	58,273,926	7,585,517**	14.96%
	Trade size	1,300.89	1,254.78	−46.11*	−3.54%
NASDAQ	Trades	25,080	40,333	15,253**	60.82%
	Volume	68,093,685	76,412,513	8,318,829**	12.22%
	Trade size	2759.87	1945.09	−814.78**	−29.52%
PCX/ Arca	Trades	122,418	214,989	92,571**	75.62%
	Volume	38,628,046	49,208,490	10,580,444**	27.39%
	Trade size	316.74	229.84	−86.90**	−27.44%
CHX	Trades	7059	10,560	3502**	49.61%
	Volume	7,417,266	8,077,599	660,333*	8.90%
	Trade size	1056.31	811.81	−244.50**	−23.15%
NSX	Trades	33,078	65,157	32,079**	96.98%
	Volume	27,531,074	33,283,341	5,752,267**	20.89%
	Trade size	837.16	593.24	−243.92**	−29.14%
Boston	Trades	1994	2109	115	5.77%
	Volume	1,865,148	1,965,893	100,746	5.40%
	Trade size	942.35	938.45	−3.90	−0.41%

to approximately $0.15 per trade on Network A and $1.03 per trade on Network B. Thus, when a security moved its primary listing from AMEX to NYSE, the marginal benefit of splitting a large trade into multiple small trades declined significantly. If market participants responded to these incentives, we would expect the average trade size to increase when the security migrated.[22]

We test this hypothesis by examining sample of 40 Exchange Traded Funds (ETFs) that switched from AMEX to NYSE on November 30, 2005. In 2005, Barclays Global Investors (BGI) announced that the primary listing for 81 iShares ETFs would move off of the American Stock Exchange, some to NYSE and some to ARCA. As a result of this move, those ETFs moving to the NYSE would change from trading in Network B to Network A, while those moving to ARCA would remain in Network B. As the first phase of this migration, BGI moved 40 iShares ETFs from AMEX to NYSE on November 30, 2005. These included ETFs tracking large-cap, mid-cap, and small-cap indexes, value and growth component indexes, sector indexes, and international equity indexes.

Analysis of this event is somewhat contaminated by a confounding event. Having been purchased by NASDAQ, iNet ECN stopped reporting its trades on NSX and began reporting them on NASDAQ during the first week of January 2006. This caused a sudden change in the composition of trades reported on those two exchanges. Accordingly, we exclude these two exchanges from our examination of three-month event windows before and after the migration. To compensate, we perform additional analysis based on one-month event windows, which are short enough to exclude the confounding event in January.[23]

Our results are reported in Table 3, with Panel A reporting events based on three-month windows and Panel B reporting results on one-month windows. Not surprisingly, NYSE gained and AMEX lost market share when the primary listing switched. Consistent with the sudden decrease in the benefit of tape shredding, we find a large increase in average trade size on all the exchanges not directly involved with the listing change. Based on the three-month window, we observe significant increases in average trade size on the CHX (27%) and a huge increase in the trade size on Arca Ex (757%).[24] As indicated in Panel B, the results based on one-month windows are essentially the same for these exchanges, but also indicate a huge increase in the average trade size on the NSX (813%), and a large increase on NASDAQ (290%). Across

[22] To get a general sense of the bounds on the elasticity of trade size with respect to revenue per trade, note that a decrease in revenue per trade of approximately 85% (from $1.03 to $0.15) corresponded to a maximum increase in the average trade size of 757% (see results on Arca Ex in panel A of Table 3). A more careful computation would require access to proprietary information on the amount of market data revenue rebates received by each exchange around each of the experiments we study in the paper.

[23] In a related paper, Boehmer and Boehmer (2003) study the effect on volume and trade size after NYSE began trading ETFs under unlisted trading privileges. Our analysis differ from them in two ways. First, NYSE was already trading the 40 ishares ETF before the change in listing venue from AMEX to NYSE; second, we also analyse the impact on trading volume and liquidity for other stocks, due to incentives in rebating data revenues.

[24] The rebate program offered by Arca Ex for Tape A stocks was limited to non-ETF. This may explain the increase in trade size for the 40 ishares ETF after they became Tape A stocks.

Table 2
Trade distribution across sizes categories for other network B stocks after the QQQ migration. This table reports the distribution of trades across different size categories for other Network B stocks surrounding the departure of the QQQ on December 1st 2004. Frequencies are computed for three-month windows before and after the switching date, based on data reported in TAQ. A t-test was performed to verify the significance of difference between the distributions for the two periods (numbers are not reported).

Share size		100	101–499	500–999	1000–2499	2500–4900	>5000
AMEX	Before	27.41%	28.53%	17.01%	16.46%	5.29%	5.3%
	After	28.24%	28.49%	16.79%	16.28%	5.16%	5.05%
NASDAQ	Before	24.18%	25.49%	17.25%	21%	4.87%	7.21%
	After	34.95%	23.28%	15.83%	16.69%	4.05%	5.19%
PCX/Arca	Before	73.75%	13.96%	6.55%	4%	1%	0.74%
	After	84.37%	8.53%	3.44%	2.58%	0.65%	0.42%
CHX	Before	22.79%	31.38%	18.34%	18.67%	5.17%	3.66%
	After	38.9%	29.16%	13.01%	12.66%	3.69%	4.73%
NSX	Before	25.04%	27.36%	26.31%	16.28%	3.07%	1.94%
	After	58.45%	17.49%	12.15%	9.21%	1.6%	1.1%
BSE	Before	18.79%	29.17%	20.83%	24.41%	4.61%	2.19%
	After	22.44%	28.15%	19.12%	23.43%	4.76%	2.10%

Table 3
Changes in trading activity for ETFs moving from AMEX to NYSE. This table reports the change in the mean number of trades, trading volume, and trade size, for 40 Exchange-Traded Funds that switched primary listing from AMEX to NYSE on November 30, 2005. Averages are computed for three-month windows (Panel A) and one-month window (Panel B) before and after the switching date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Mean Before	Mean After	Change	% Change
Panel A: Three-months window					
NYSE	Trades	420	7440	7020	1671%
	Volume	1,393,634	14,371,598	12,977,964 **	931.23%
	Trade size	3324.03	1929.76	−1394.27 **	−41.95%
AMEX	Trades	4422	774	−3648 **	−82.50%
	Volume	7,791,952	2,668,449	−5,123,503 **	−65.75%
	Trade size	1751.41	3486.00	1734.59 **	99.04%
ARCA Ex	Trades	86,215	6652	−79,563 **	−92.28%
	Volume	15,829,969	10,643,374	−5,186,595 **	−32.76%
	Trade size	185.43	1589.57	1404.14 **	757.25%
CHX	Trades	925	1115	190 **	20.50%
	Volume	500,307	748,239	247,933 **	49.56%
	Trade size	541.80	686.03	144.22 **	26.62%
Panel B: One-month window					
NYSE	Trades	459	6097	5638 **	1227.21%
	Volume	1,522,320	12,735,475	11,213,155 **	736.58%
	Trade size	3282.19	2076.60	−1205.58*	−36.73%
AMEX	Trades	4347	842	−3505 **	−80.63%
	Volume	7,758,355	2,454,860	−5,303,495 **	−68.36%
	Trade size	1777.07	2932.85	1155.78 **	65.04%
NASDAQ	Trades	13,929	4099	−9830	−70.57%
	Volume	9,738,975	11,290,020	1,551,045 **	15.93%
	Trade size	714.53	2,788.66	2,074.12 **	290.28%
ARCA Ex	Trades	94,176	5333	−88,843 **	−94.34%
	Volume	16,777,725	7,945,020	−8,832,705 **	−52.65%
	Trade size	179.88	1540.04	1360.16 **	756.13%
NSX	Trades	24,295	1227	−23,068 **	−94.95%
	Volume	3,713,590	1,505,940	−2,207,650 **	−59.45%
	Trade size	153.35	1400.52	1247.17 **	813.28%
CHX	Trades	865	791	−73	−8.46%
	Volume	474,850	630,780	155,930	32.84%
	Trade size	568.32	788.53	220.21	38.75%

all exchanges, average trade size increased by more than 500%. As shown in Fig. 4, this change did not occur gradually over the six-month period surrounding the switch, but quite suddenly, and exactly at the time of the listing switch. We also test whether the evidence of change in trade size for the 40 ETF holds after controlling for trading volume. We do so by grouping ETFs in quintiles based on the trading volume before the event on Novemebr 30, 2005, and compare the change average trade size before and after the event. In results not reported, we find that the change in trade size is significant across all the quintiles of trade size and across exchanges, with the highest changes observed for the highest volume ETFs.

As a caveat, we recognize that average trade size on particular exchanges may change for reasons other than a change in the amount of tape shredding. In particular, changes in average trade size on NYSE and AMEX are likely to be affected if the mix of large and small traders responds to the change of primary listing

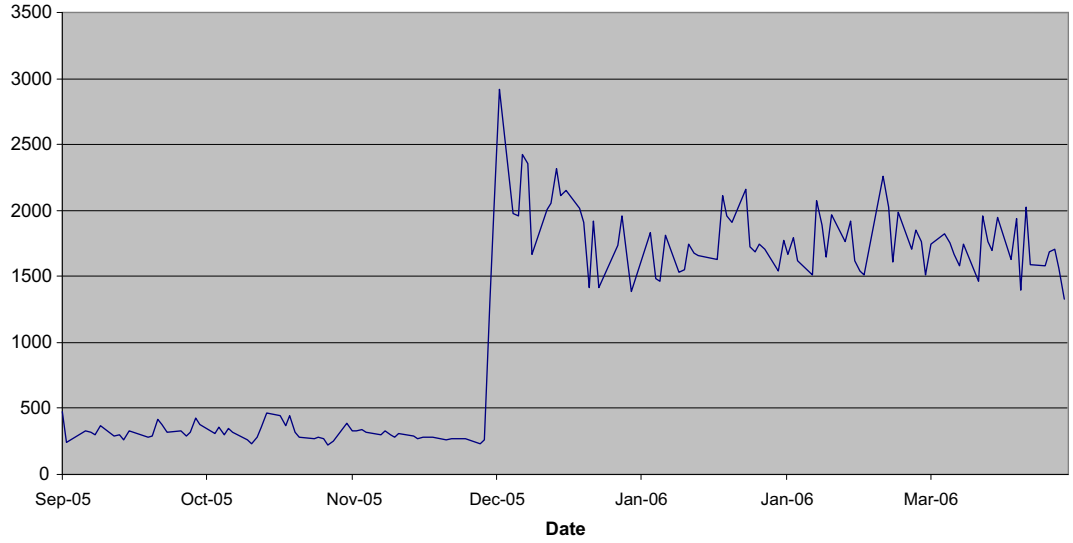

Fig. 4. Average trade size 40 iShares Exchange Traded Funds surrounding move from Network B to Network A.

Table 4
Trade distribution across sizes categories for ETFs moving from AMEX to NYSE. This table reports the distribution of trades across different size categories for 40 Exchange-Traded Funds that switched primary listing from AMEX to NYSE on November 30, 2005. Frequencies are computed for three-month (Panel A) and one-month (Panel B) windows before and after the switching date, based on data reported in TAQ. A t-test was performed to verify the significance of difference between the distributions for the two periods (numbers are not reported).

Share size		100	101–499	500–999	1000–2499	2500–4900	>5000
Panel A: Three-months window							
NYSE	Before	11.67%	19.52%	15.41%	22.41%	11.64%	19.34%
	After	25.31%	29.28%	15.08%	15.51%	6.20%	8.62%
AMEX	Before	30.21%	31.01%	14.38%	12.96%	4.34%	7.10%
	After	19.65%	21.88%	18.22%	17.69%	7.03%	15.52%
ARCA Ex	Before	95.41%	2.23%	0.73%	0.86%	0.32%	0.45%
	After	32.22%	15.43%	12.34%	24.64%	8.55%	6.82%
CHX	Before	35.38%	34.55%	17.09%	10.33%	1.71%	0.94%
	After	31.42%	35.20%	16.91%	13.00%	2.35%	1.12%
Panel B: One-month window							
NYSE	Before	12.9%	19.8%	17.93%	21.19%	9.53%	18.65%
	After	25.9%	28.19%	14.81%	15.74%	6.2%	9.14%
AMEX	Before	29.47%	31.5%	15.12%	12.56%	4.19%	7.16%
	After	23.04%	23.34%	16.2%	17.5%	6.72%	13.2%
NASDAQ	Before	79.58%	10.12%	4.11%	4.12%	0.87%	1.21%
	After	31.14%	26.5%	14.28%	17.56%	5.07%	5.45%
ARCA Ex	Before	94.48%	3.24%	0.72%	0.86%	0.32%	0.39%
	After	43.15%	15.84%	11.1%	17.22%	5.83%	6.85%
NSX	Before	95.31%	3.33%	0.39%	0.56%	0.18%	0.24%
	After	34.71%	19.51%	12.23%	17.51%	10.66%	5.38%
CHX	Before	37.12%	34.02%	16.16%	10.32%	1.6%	0.79%
	After	31.99%	34.44%	17.33%	12.62%	2.27%	1.36%

(see Boehmer and Boehmer (2003)). Also, the other exchanges experienced changes in market share of trading volume, that may be associated with a change in the mix of traders transacting on those exchanges.

Table 4 provides additional information on how the distribution of reported trade sizes changed on each exchange when the ETFs migrated. This table confirms that the change in the average trade size is largely due to changes in the number of 100-share trades relative the number of larger trades. When the ETFs were trading in Network B, we find that trades of 100 shares account for approximately 80% of all trades of these ETFs reported on NASDAQ, 95% on Arca, and 95% on the NSX. After they migrated to Network A, these numbers drop to approximately 31%, 32%, and 35%. On these three exchanges, the huge decrease in the proportion of 100 share trades is offset by increases in the each of the other five trade-size buckets. In particular, the share of trades with size between 1000 and 2500 experienced the largest surge: The percentages went from 4% to 18% on NASDAQ, 0.2% to 18% on NSX and 1% to 25% on Arca Ex.

In the three months prior to November 30, 2005, we estimate that these 40 ETFs accounted for approximately 21% of all trades printed on Network B. While this was not quite as large an event as the departure of the QQQs, it was large enough that it had an economically significant effect on the marginal revenue per trade for the securities remaining in Network B.

Table 5 reports what happened to the number of trades, trading volume, and average trade size for these securities, and Table 6

Table 5
Impact of the ETF migration from AMEX to NYSE on other Network B stocks. This table reports changes in number of trades, trading volume and average trade size for other Network B stocks when 40 Exchange-Traded Funds that switched primary listing from AMEX to NYSE on November 30, 2005. Averages are computed for three-month (Panel 1) and one-month (Panel B) windows before and after the switching date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Mean Before	Mean After	Change	% Change
Panel A: Three-months window					
NYSE	Trades	2929	3781	852**	29.08%
	Volume	5,248,523	5,145,867	−102,656	−1.96%
	Trade size	1779.06	1372.37	−406.69**	−22.86%
AMEX	Trades	52,273	63,017	10,745**	20.55%
	Volume	55,182,144	67,194,872	12,012,728**	21.77%
	Trade size	1052.86	1066.23	13.38	1.27%
ARCA Ex	Trades	237,620	293,828	56,208**	23.65%
	Volume	76,862,241	81,547,338	4,685,097	6.10%
	Trade size	322.14	280.71	−41.44**	−12.86%
CHX	Trades	6503	6888	384	5.91%
	Volume	6,947,860	7,501,587	553,727*	7.97%
	Trade size	1091.26	12.48	1.16%	
Panel B: One-month window					
NYSE	Trades	2893	3290	398*	13.74%
	Volume	4,591,530	4,900,700	309,170	6.73%
	Trade size	1594.71	1503.96	−89.75	−5.63%
AMEX	Trades	51,276	56,461	5184*	10.11%
	Volume	53,058,798	61,092,028	8,033,230**	15.14%
	Trade size	1035.20	1081.56	46.35*	4.48%
NASDAQ	Trades	78,895	83,123	4228	5.36%
	Volume	90,169,724	86,515,230	−3,654,494	−4.05%
	Trade size	1138.93	1055.94	−82.99*	−7.29%
ARCA Ex	Trades	214,337	232,102	17,765	8.29%
	Volume	70,037,935	68,024,040	−2,013,895	−2.88%
	Trade size	326.64	297.89	−28.75*	−8.80%
NSX	Trades	83,585	84,824	1239	1.48%
	Volume	31,207,780	29,639,545	−1,568,235	−5.03%
	Trade size	374.16	354.18	−19.98**	−5.34%
CHX	Trades	5862	5885	23	0.39%
	Volume	6,852,157	6,762,733	−89,424	−1.31%
	Trade size	1169.23	1142.84	−26.39	−2.26%

reports what happened to the distribution of trade sizes. As before, panel A of each table shows results based on three-month windows for all exchanges except NASDSQ and NSX and panel B shows results based on one-month windows surrounding the event. We find that when the 40 ETFs left Network B, average trade size declined significantly on Arca Ex, NASDAQ, and NSX, while no significant change is observed on CHX. We also do not find a statistically significant increase in average trade size on AMEX. This confirms our prior results that AMEX, which did not have a rebate program, does not show evidence of tape shredding. Interestingly, we also find that the average trade size for Network B securities on NYSE declines significantly on the NYSE in the three-month samples. In the one-month samples, the change on NYSE is negative but not statistically significant. It should be noted that the NYSE trades only a small number of Network B securities.[25]

The results in Table 6 indicate a modest increase in the percentage of 100-share trades on NASDAQ from 55% to 57%, on Arca Ex from 74% to 78%, and on National from 70% to 72%, for the one-month window.

[25] In results not shown, we found that the decrease in average trade size of non-migrating Network B securities on Arca Ex, NASDAQ, and NSX holds for ETFs and non-ETFs, holds across all deciles of trading volume, and does not appear to be connected exclusive to high-priced or low-priced stocks.

Table 6
Trade distribution across sizes categories for other network B stocks after the ETF migration from AMEX to NYSE. This table reports the distribution of trades across different size categories for 40 Exchange-Traded Funds that switched primary listing from AMEX to NYSE on November 30, 2005. Frequencies are computed for three-month (Panel A) and one-month (Panel B) windows before and after the switching date, based on data reported in TAQ. A t-test was performed to verify the significance of difference between the distributions for the two periods (numbers are not reported).

Share size		100	101–499	500–999	1000–2499	2500–4900	>5000
Panel A: Three-months window							
NYSE	Before	26.98%	23.75%	15.8%	19.29%	5.99%	8.19%
	After	29.88%	24.51%	16.35%	18.98%	4.61%	5.67%
AMEX	Before	32.04%	29.02%	16.39%	14.19%	4.36%	3.99%
	After	31.55%	29.06%	16.59%	14.3%	4.45%	4.05%
ARCA Ex	Before	75.18%	10.72%	7.22%	5.06%	1.12%	0.7%
	After	78.78%	9.11%	6.39%	4.39%	0.79%	0.53%
CHX	Before	22.92%	27.64%	21.34%	19.91%	5.02%	3.17%
	After	22.89%	27.84%	21.14%	19.9%	4.88%	3.35%
Panel B: One-month window							
NYSE	Before	28.66%	24.33%	14.87%	19.08%	5.43%	7.63%
	After	28.43%	25.44%	14.98%	19.84%	4.77%	6.54%
AMEX	Before	31.41%	29.86%	16.55%	13.96%	4.32%	3.9%
	After	31.27%	28.77%	16.61%	14.6%	4.6%	4.14%
NASDAQ	Before	54.77%	18.01%	11.82%	10.37%	2.55%	2.49%
	After	57.27%	16.65%	11.05%	10.16%	2.45%	2.42%
ARCA Ex	Before	73.84%	11.76%	7.44%	5.2%	1.04%	0.72%
	After	78.36%	9.38%	6.33%	4.36%	0.93%	0.64%
NSX	Before	69.64%	13.26%	8.12%	6.69%	1.33%	0.96%
	After	72.2%	11.98%	7.54%	6.24%	1.16%	0.88%
CHX	Before	21.98%	27.25%	21.98%	20.4%	5.2%	3.2%
	After	22.39%	27.22%	21.72%	20.29%	5.1%	3.27%

In a parallel exercise, not reported here, we examined whether changes in trading patterns were observed when individual stocks switch from Amex to NYSE. Using the annual NYSE Fact Books and press releases issued by the NYSE, we identified 164 stocks that switched from AMEX to NYSE between 1993 and 2005. In summary, we find a statistically significant increase in the number of trades, but no statistical evidence that moving from AMEX to NYSE was associated with a change in trade size. We find that only one exchange (NSX) experienced a significant increase in average trade size when stocks migrated from AMEX to NYSE. This evidence is consistence with the fact that NSX had one of the most aggressive rebate programs.

4. Tape shredding rules

In 2005 and 2006, the exchanges and NASD proposed (and the SEC approved) rules designed to reduce tape shredding. Specifically, these rules prohibit the unbundling of customer orders for reasons other than best execution.

In this section, we investigate whether the implementation of these rules had an appreciable effect on trading. Because these rules apply specifically to brokers who are handling customer orders on an agency basis, they would not affect order splitting by proprietary trading operations. Thus, looking at how trading activity changed when these rules became effective helps shed light on the extent to which our other results are driven by the behavior of brokers, as opposed to the activities of proprietary trading desks.

If the practice of order splitting by brokers was prevalent prior to these rules, and if these rules were effective at reducing the practice, we would expect to see an increase in average trade size

Table 7
Impact of tape-shredding rules on Network B activity. This table reports changes in trading activity for Network B stocks surrounding the implementation of Tape-Shredding Rules. Averages are computed for three-month windows before and after the switching date, based on data reported in TAQ. In Panel A, we perform a t-test on aggregate total volume, number of trades, and average trade size across all securities. A t-test is performed to verify the significance of difference between the two periods. In Panel B, we perform a paired t-test, which examines stock-by-stock the change in aggregate total volume, number of trades, and average trade size. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Mean Before	Mean After	Change	% Change
Panel A: Aggregate trading activity					
AMEX	Trades	71,618	69,424	−2194	−3.16%
	Volume	77,379,446	66,055,214	−11,324,232**	−17.14%
	Trade size	1077.47	935.80	−141.68**	−15.14%
NASDAQ	Trades	272,319	198,083	−74,237**	−37.48%
	Volume	172,830,000	172,970,000	140,000	0.08%
	Trade size	636.0211	863	227**	26.32%
NYSE ARCA	Trades	297,615	206,111	−91,505**	−44.40%
	Volume	94,047,502	124,290,000	30,242,498**	24.33%
	Trade size	319.10	598.10	279.01**	46.65%
NSX	Trades	5892	4563	−1329**	−29.13%
	Volume	7,784,495	5,222,880	−2,561,615**	−49.05%
	Trade size	1313.95	1141.92	−172.03**	−15.16%
CHX	Trades	7870	8242	372.23	4.52%
	Volume	8,515,021	8,657,447	142,426.00	1.65%
	Trade size	1082.51	1047.10	−35.41	−3.38%
NYSE	Trades	3746	4366	620**	14.20%
	Volume	6,279,232	5,725,477	−553,755	−9.67%
	Trade size	1655.38	1329.90	−325.48**	−24.47%
Panel B: Paired test (cont'd)					
AMEX	Trades	4771.3	4606.0	−165.2	−3.5%
	Volume	5,137,897	4,357,173	−780,724**	−15.2%
830	Trade size	1035.4	953.3	−82.1	−7.9%
NASDAQ	Trades	18,880.0	13,851.3	−5028.7	−26.6%
	Volume	12,050,496	12,145,774	95,278	0.8%
832	Trade size	1039.5	1136.4	96.9	9.3%
NYSE ARCA	Trades	21,255.6	14,793.6	−6462.0	−30.4%
	Volume	6,746,393	8,961,243	2,214,850	32.8%
816	Trade size	589.0	427.5	−161.5**	−27.4%
NSX	Trades	5311.3	4088.2	1223.1*	−23.0%
	Volume	7,186,970	4,741,854	−2,445,116**	−34.0%
57	Trade size	2430.5	1745.2	−685.3	−28.2%
CHX	Trades	2579.5	2576.2	−3.2	−0.1%
	Volume	2,767,431	2,713,497	53,933	−1.9%
179	Trade size	2345.3	1699.0	−646.3	−27.6%
NYSE	Trades	4253.1	4606.0	−165.2	−3.5%
	Volume	6,415,171	6,375,579	−39,592	−0.6%
48	Trade size	1648.3	1382.2	−266.1*	−16.1%

surrounding the implementation of these rules. If the response of the market to revenue allocation incentives is confined exclusively to proprietary trading operations, we would expect these tape shredding rules to have little or no effect.

In the appendix, we provide a table summarizing the date of the original proposal, the approval date and effective date for the tape shredding rules implemented by each of the Self-Regulatory Organizations. In some cases, the adopted rules reflect amendments filed after the original proposal date. In addition, we attempted to identify the date that these rules became effective, or the date that exchange members were informed of the rule. In the absence of any documentation of the effective date, we assume the effective date is the approval date.

To analyze the impact of these rules, we conduct two tests. First, we aggregate across all securities and examine whether total volume, number of trades, and average trade size were affected. Second, we perform a paired t-test, which examines stock-by-stock whether trading was affected, and then aggregates these individual comparisons into a single aggregate test statistic. If the tape shredding rules had an equal impact across all stocks, we would expect to see this reflected in both tests. On the other hand, if the impact on the highest-volume stocks is disproportionately large, we would expect to see a more significant effect in the first test. Essentially, the first test is a value-weighted test, while the second places equal weights on all stocks.

In Table 7, we report our results for trading activity on Network B securities. Panel A reports the results from the test based on aggregate trading activity. We find that when the tape shredding rule went into effect on NYSE ARCA, average trade size for Network B securities on that exchange increased by 87.4%. Likewise, trade size increased on NASDAQ by 35.7% when NASD's rule became effective. These results suggest that tape shredding by brokers was most prevalent on those exchanges prior to the rule.

In contrast, we find a significant decline in average trade size of Network B securities traded on AMEX and the NSX. It is not obvious why the implementation of a tape shredding rule should decrease average trade size.

Fig. 5 shows a graph of average trade size on Network B securities on AMEX, NASDAQ, and NYSE ARCA surrounding the

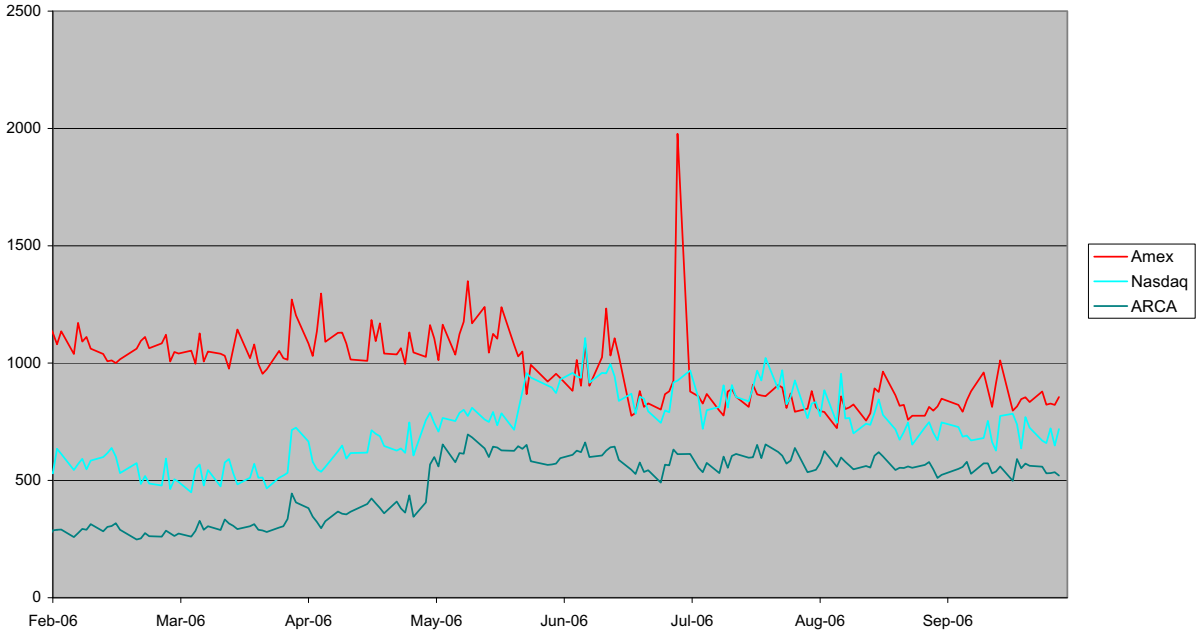

Fig. 5. Average trade size on Network B surrounding introduction of tape shredding rules.

introduction of these tape shredding rules. The graph confirms that the increase in trade size on NYSE ARCA occurred rather suddenly on May 2, 2006, the second trading day after the rule adoption notice was circulated to members. The graph also indicates a sudden increase in average trade size on NASDAQ on May 25, 2006, the effective date of the rule. The decrease of average trade size on AMEX also occurred at this time.

Panel B of Table 7 reports the results of our paired t-test. These results give quite a different picture. Based on this test, we observe no significant increases in average trade size, and even find a significant decrease on NYSE/ARCA. This suggests that the impact of the tape shredding rule was not uniform across all securities, but that the results of Panel A are driven by a relatively small number of securities. This is consistent with our earlier findings that switching from AMEX to NYSE had a significant impact on average trade size for ETFs but not for individual securities.

When we repeated both tests on Network A (NYSE-listed) securities (results not reported), we found no statistically significant increases in average trade size on any exchange. Indeed, these tests indicated a statistically significant decrease in average trade size on both NYSE ARCA and NASDAQ. That we find a different reaction in Network A and Network B reinforces our prior findings that tape shredding is more prevalent in Network B, where the revenue per trade is greater.

5. New allocation rule

In this section, we examine changes in trading activity surrounding April 1, 2007, when the new allocation formula went into effect. One of the aims of the formula change was to reduce the incentive for tape shredding. As mentioned above, the new formula allocates only 25% of the data revenue in proportion to the number of trades, with another 25% allocated in proportion to share volume and 50% in proportion to a measure of the aggressiveness with which the exchange quotes at the inside of the market. Thus, the immediate effect of the new formula was to reduce by about 75% the additional revenue allocated to the exchange when a large trade is split into multiple smaller trades.

Table 8 reports statistics summarizing the changes in trading activity surrounding the implementation of the new allocation formula. Based on a comparison of three months before and three months after April 1, 2007, we observe no increases in average trade size of Network A stocks on any exchange surrounding April 1, consistent with our prior results that trade splitting is not rampant on Network A. No changes are observed on NYSE, NYSE Arca or NASDAQ surrounding the implementation of the new formula, while there appears to have been a small but statistically significant decline in average trade size reported on NSX. We also observe significant decreases in the average size of Network A trades on some of the smaller exchanges. Given that these exchanges also experienced significant changes in total volume, it is somewhat difficult to know to extent to which these changes in average change size may be influenced by other changes in the market.

The second panel of 8 reports the same statistics for Network B. We find that average trade size on Network B stocks increased by about 5% on NYSE ARCA, and decreased by 13% on AMEX. Both of these changes are statistically significant at the 1% confidence level. Again, the allocation formula appears to be associated with trade splitting on NYSE ARCA, but not on AMEX. In Table 8, we find no significant change in the average size of Network B trades reported on NASDAQ or the National Stock Exchange. Interestingly, we do find an statistically significant increase in average trade size for Network B securities trading on NYSE.

We note that formula change on April 1, 2007 did not only decrease the incentive for tape shredding, it also increased the incentive for exchanges to quote aggressively. If some exchanges responded more than others to this incentive, those that are quoting most aggressively may have attracted more order flow, or a different kind of order flow as a result. Thus, the change in the allocation formula may have caused a change in average trade size for reasons other than changes in tape shredding.

Finally, we should note that although the changes in Network B activity reported for NYSE Arca and AMEX are statistically significant, the economic magnitude of these changes is smaller than for some of the other tests considered in this paper. Unlike some of the other events studied in this paper, where a simple visual examination of a graph reveals a sudden regime change on the event date, the effects documented in Table 8 for Network B stocks appear to have occurred gradually over time.

Table 8
Impact of new allocation formula. This table reports changes in trading activity for Network B stocks (Panel A) and Network A stocks (Panel B) surrounding the implementation of the new allocation formula that went into effect on April 1, 2007. Averages are computed for three-month windows before and after the event date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Before	After	Change	% Change
Panel A: Impact on Network A activity					
NYSE	Trades	4,095,760	4,002,172	−93,588	−2.28%
	Volume	1,556,900,000	1,515,400,000	−41,500,000	−2.67%
	Trade size	381.86	379.35	−2.50	−0.66%
NASDAQ	Trades	2,615,671	2,777,408	161,737**	6.18%
	Volume	959,040,000	1,029,700,000	70,660,000*	7.37%
	Trade size	369.84	371.66	1.82	0.49%
NYSE ARCA	Trades	1,545,748	1,620,392	74,644.00	4.83%
	Volume	311,630,000	327,770,000	16,140,000	5.18%
	Trade size	202.45	202.10	−0.35	−0.17%
NSX	Trades	34,778	68,921	34,143 **	98.17%
	Volume	7,156,666	10,655,736	3,499,070 **	48.89%
	Trade size	236.55	153.83	−82.72 **	−34.97%
BSE	Trades	15,348	18,679	3331 **	21.70%
	Volume	3,211,427	3,837,059	625,632*	19.48%
	Trade size	210.97	202.95	−8.02*	−3.80%
CHX	Trades	9087.54	6969.07	−2118.47	−23.31%
	Volume	20,439,811.00	16,566,329.00	−3,873,482.00**	−18.95%
	Trade size	8570.39	3694.48	−4875.91**	−56.89%
AMEX	Trades	744.37	792.3898	48.02	6.45%
	Volume	1,008,793.00	1,000,218.00	−8575.00	−0.85%
	Trade size	1341.36	1322.71	−18.65	−1.39%
Panel B: Impact on Network B activity					
AMEX	Trades	64,788	68,006	3218	4.97%
	Volume	40,391,182	36,955,128	−3,436,054*	−8.51%
	Trade size	626.65	544.60	−82.05 **	−13.09%
NASDAQ	Trades	293,107	336,729	43,623 **	14.88%
	Volume	164,170,000	204,050,000	39,880,000 **	24.29%
	Trade size	532.98	604.61	71.63 **	13.44%
NYSE ARCA	Trades	214,281	222,196	−11,815	−5.51%
	Volume	100,620,000	108,800,000	8,180,000	8.13%
	Trade size	463.02	487.18	24.16 **	5.22%
NSX	Trades	4569	3626	−943*	−20.65%
	Volume	2,200,066	1,727,573	−472,493*	−21.48%
	Trade size	457.67	472.76	15.09	3.30%
NYSE	Trades	6769	4254	−2515 **	−37.15%
	Volume	3,402,256	2,623,261	−778,995 **	−22.90%
	Trade size	510.03	620.80	110.77 **	21.72%

In this respect, our evidence in this section is somewhat weaker than in other sections. One possible reason for this is that when the new formula went into effect, the exchanges did not immediately alter their rebate programs, but continued to share revenue in proportion to the number of trades. To the extent that rebate programs are the key mechanism through which the allocation formula affects markets, we might expect the main impact of the new formula to occur only after the terms of these programs are modified to align the incentives of order flow providers with those of the exchange.

6. Analysis of market quality

In the first part of this article we explored the extent to which the market data revenue rebates created an incentive for traders to modify their trading behavior by changing the size of their trades. In this section we explore whether such behaviors have an impact on market quality in the market centers that offered such rebate programs.

Recent work on liquidity rebates offered by exchanges under the maker/taker pricing model suggests that liquidity rebates can influence the routing decision, and potentially may have an impact on order execution quality (see, for example, Battalio et al. (2014)). From a policy perspective it may be interesting to evaluate whether there is any evidence that a change in the degree of tape shredding, another type of response to rebates, has any implications for order execution quality.

Another hypothesis is that market data revenue rebates can have an impact on market quality through the increased fragmentation in order flow. To the extent that fragmentation is driven by competition, one might expect fragmentation to be associated with lower execution costs. However, if fragmentation is driven by trading venues seeking to increase their profits by offering rebates without improving market quality, fragmentation may be associated with no change in market quality. To the extent that brokers sacrifice best execution in order to capture larger rebates, fragmentation may be associated with inferior market quality. Among the papers that have looked at this issue, Nguyen et al. (2007) directly study the long- and short-term effects of multimarket trading for three large ETFs (DIA, QQQ, and SPY) and conclude that the competition effect dominates the fragmentation effect over the long horizon. In other recent empirical work O'Hara and Ye (2011) show that fragmented stocks have lower execution costs. We study the same question from another direction, by examining whether tape shredding appears to be associated with market quality.

We focus our market quality analysis on those events where we document the most clear, economically significant changes in the degree of tape shredding. Specifically, we focus on the execution

Table 9
Impact of the QQQ migration on other Network B stocks liquidity and execution quality. This table reports changes in average daily quoted spread and average daily effective spread, for other Network B stocks surrounding the departure of the QQQ on December 1st 2004. Averages are computed for three-month windows before and after the switching date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Before	After	% Change
AMEX	Quoted Spread	0.1657	0.1387	−16.29%**
	Effective Spread	0.0295	0.0227	−23.05%**
NASDAQ	Quoted Spread	0.066	0.0549	−16.82%**
	Effective Spread	0.0385	0.0202	−47.53%**
PCX/Arca	Quoted Spread	0.0239	0.0232	−2.93%
	Effective Spread	0.0044	0.0021	−52.27%**
CHX	Quoted Spread	0.0777	0.065	−16.34%**
	Effective Spread	0.021	0.0147	−30.00%**
NSX	Quoted Spread	0.0169	0.0172	1.78%
	Effective Spread	0.0041	0.0026	78.05%
BSE	Quoted Spread	0.0366	0.0346	−5.46%
	Effective Spread	0.0022	0.002	−9.09%

Table 10
Impact of the 40 ETF migration on liquidity and execution quality. This table reports changes in average daily quoted spread, average daily effective spread, for 40 Exchange-Traded Funds that switched primary listing from AMEX to NYSE on November 30, 2005. Averages are computed for three-month windows (Panel A) and one-month window (Panel B) before and after the switching date, based on data reported in TAQ. A t-test is performed to verify the significance of difference between the two periods. * denotes significance at the 5% level, ** denotes significance at the 1% level.

		Before	After	% Change
Panel A: Three-month window				
NYSE	Quoted spread	0.019	0.019	−0.02%
	Effective spread	0.001	0.001	−0.33%**
AMEX	Quoted spread	0.021	0.020	−0.05%
	Effective spread	0.001	0.001	0.00%
CHX	Quoted spread	0.029	0.020	−0.31%**
	Effective spread	0.001	0.001	−0.11%
ARCA Ex	Quoted spread	0.015	0.015	0.03%
	Effective spread	0.001	0.001	−0.36%
Panel B: One-month window				
NYSE	Quoted spread	0.020	0.018	−7.69%
	Effective spread	0.001	0.001	−27.27%**
AMEX	Quoted spread	0.021	0.020	−5.16%
	Effective spread	0.001	0.001	0.00%
CHX	Quoted spread	0.028	0.021	−25.18%**
	Effective spread	0.001	0.001	−11.11%
ARCA Ex	Quoted spread	0.015	0.016	8.97%**
	Effective spread	0.002	0.001	−53.33%
NASDAQ	Quoted spread	0.022	0.020	−9.05%
	Effective spread	0.001	0.001	0.00%
NSX	Quoted spread	0.012	0.015	22.88%**
	Effective spread	0.001	0.001	0.00%

quality of stocks remaining on Network B with the migration of QQQ and the 40 ETFs, and the implications of a reduction in "trade shredding" when the 40 ETFs migrated to the NYSE.

We use two measures for market quality: the quoted spread, defined as the difference between the best ask and bid price available at the time of the trade, and the effective spread, defined as twice the absolute value of the difference between the trade price and the midquote prevailing at the time of the trade. We calculate the average time-weighted quoted spread and the trade-weighted effective spread on a given exchange for each stock for the period before and after the event. We then test for significant changes in the mean daily quoted spread and effective spread.

Table 9 reports the changes in market quality for Network B stocks surrounding the move of the QQQ to NASDAQ in December 2004.[26] As described above, when QQQ migrated off of Network B, it increased the net revenue per trade for the stocks remaining in Network B, and these stocks experienced a significant decrease in average trade size on the NASDAQ, Arca Ex, CHX, and NSX, suggesting an increase in tape shredding. The results in Table 9 indicate that the execution quality for these stocks did not deteriorate, and in fact improved on some exchanges. In particular, AMEX, NASDAQ and CHX registered a drop in quoted spread of about 16%, while the effective spread decreased the most for NASDAQ (47%) and ARCA Ex (52%). The evidence suggests that the tape shredding documented in the first part of the paper did not negatively impact the market quality of these stocks.

Table 10, panel A (3-month window) and panel B (1-month window) show the results of changes in market quality for the 40 Exchange Traded Funds after they switched primary listing from AMEX to NYSE on November 30, 2005. As described above, this move corresponded to significant increase in average trade size on the NASDAQ, Arca Ex, NSX, and CHX, indicating a significant decrease in the amount of tape shredding on those exchanges. As the table indicates, there is no consistent evidence of improvement in market quality on those exchanges at this time.[27] In results not reported, we conducted a similar analysis for the other TAPE B stocks after the 40 ETF left the Tape B, but we found no significant changes in market quality.

In summary, we find no evidence to suggest that tape shredding had a significant negative impact on market quality, as reflected in quoted and effective spreads.

7. Conclusions

In this paper, we have explored several facets of how the trading process is affected by the formulas used for allocating data revenue in proportion to the number of trades. Our results indicate that the old, proportional allocation rule used by the U.S. equity exchanges had a strong influence under certain circumstances, but in other cases appears to have a minimal impact. The effect has been most severe where the revenue per trade is greatest (Network B), and on those exchanges that have developed mechanisms to exploit the formula. Moreover, our evidence indicates that the effects of the allocation rule are particularly concentrated in certain securities, such as certain Exchange Traded Funds. Our analysis shows that ETFs were particulary attractive for tape shredding and that the more significant results are for the high volume ETFs.

We hope that by demonstrating that data revenue allocation has had an important influence on the trading process, this paper will stimulate further research on the nature of competition between exchanges. Three significant sources of revenues for the exchanges are listing fees, transaction fees, and data revenues. We would suggest that in the distant past, it was largely the case that these three revenue sources were closely tied to listing. That is, whichever exchange obtained the primary listing would also attract the dominant market share of transaction volume, and trades were reported where they were executed, so transaction fees and market data revenue were determined mostly by listing. But this has changed significantly since the mid 1990s, partially as a result of the economic forces and institutional developments explored in this paper. Today, there is vigorous competition for

[26] See Broom et al. (2007) for a detailed analysis of the changes in trading volume and execution quality across exchanges after NASDAQ QQQ migrated to NASDAQ.

[27] Tang et al. (2011) found that the major decline in quote competitiveness observed after decimalization is primary due to a decline in 100-share quotes. In results not reported, we test if the change in execution quality as driven by a reduction in tape shredding after the 40 ETF moved to NYSE is positive for the small size trades.

transaction volume, to the point that it appears to have become largely irrelevant where the stock has its primary listing. Apparently, primary listing no longer gives the listing exchange a significant advantage in the competition for order flow.

Similarly, we should note that a significant portion of all trading volume is either executed off exchange, such volume traded on Alternative Trading Systems, and orders that are preferenced or internalized and executed by an off-exchange market maker. However, this trading activity can only generate data revenue through a reporting channel. The research community should recognize that there is an important distinction between competition among trading venues to execute trades and competition among plan participants to report trades that are executed off of the exchanges. The examples depicted in Figs. 1 and 2 illustrate that this becomes particularly important when an ECN that is unaffiliated with an exchange gains significant market share.

Another interesting topic that we do not address here is the extent to which the new allocation formula has led to greater depth at the NBBO. By assigning 50% of the revenue on the basis of quoting activity, the new formula should encourage more aggressive quoting. Further research in this area could shed light on whether the new formula succeeded in this regard, and perhaps reveal other ways that the exchanges have responded in the face of this new incentive.

Other interesting research questions relating to equity markets have emerged in recent years. The equity trading industry recently went through a period of rapid structural change, as a result of a confluence of many inter-related forces and trends. Among these are the demutualization of exchanges, the separation of the regulatory function from the exchanges, national and international consolidation, Regulation NMS, new trading technologies that have significantly decreased the role of a physical trading floor, the emergence of the maker-taker fee structure, the increasing prevalence of "high frequency" and "low latency" trading, and the increased use of Alternative Trading Systems. Research on these other topics may wish to consider how market data revenue may be influencing other aspects of the trading process. To the extent that it continues to be a major revenue source for exchanges, it is likely that market data revenue will continue to play a significant role in shaping the industry.

Appendix A. Implementation dates of tape shredding rules

Exchange	Proposed	Approved	Effective
Boston Stock Exchange	June 23, 2005	August 26, 2005	August 26, 2005
New York Stock Exchange	September 9, 2005	October 26, 2005	November 10, 2005
American Stock Exchange	November 1, 2005	May 12, 2006	May 12, 2006
NASD	December 8, 2005	February 24, 2006	May 25, 2006
Chicago Stock Exchange	January 24, 2006	April 17, 2006	April 17, 2006
NYSE Arca	February 3, 2006	April 24, 2006	April 28, 2006
National Stock Exchange	April 4, 2006	May 24, 2006	May 24, 2006

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