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Marios Panayides, Barbara Rindi and Ingrid M. Werner

Trading Fees and Intermarket Competition

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Trading Fees and Intermarket Competition

Marios Panayides
University of Pittsburgh
mpanayides@katz.pitt.edu

Barbara Rindi
Bocconi University, Carefin and Igier
barbara.rindi@unibocconi.it

Ingrid M. Werner
Fisher College of Business, The Ohio State University
werner@fisher.osu.edu

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Abstract

We model an order book with liquidity rebates (make fees) and trading fees (take fees) that faces intermarket competition, and use the model's insights to explain changes in market quality and market shares following changes in make-take fees. As predicted by our model, we document that fee changes by one venue affect market quality and market shares for all venues that compete for order flow. Furthermore, we document cross-sectional differences in changes in market quality and market shares following a simultaneous decrease in both make and take fees consistent with traders in large (small) capitalization stocks being more sensitive to the change in make (take) fees.

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Keywords: Trading Fees, Maker-Taker Pricing, Intermarket Competition, Limit Order Book

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1 Introduction

In today's fragmented equity trading environment, venues use trading fees to compete for order flow. Most venues operate limit orders books, and rely almost exclusively on endogenous provision of liquidity. As a result, venues have an incentive to subsidize liquidity supply by offering a rebate (make fee) to traders submitting limit orders. However, venues have to generate revenues to cover their costs and therefore impose a higher positive fee (take fee) on market orders.[1] This type of pricing, called maker-taker pricing, is actively debated among academics, practitioners, market operators, and is currently under review by U.S. and European regulators. Maker-taker pricing is an important competitive tool for exchanges in today's fragmented markets, and may benefit retail investors to the extent that it contributes to narrower posted spreads. However, maker-taker pricing has recently been criticized for potentially exacerbating conflicts of interest between brokers and their customers, for contributing to market fragmentation and market complexity, and for undermining price transparency.[2]

This paper studies the effects of changes in trading fees in standard limit order books that have a price grid based on tick size, and that at the same time face competition from other trading venues. It adds to the theoretical literature by simultaneously taking into account both a pricing grid and intermarket competition when drawing predictions on the effects of fee changes on market quality and market shares. It adds to the empirical literature by documenting significant changes in market shares and market quality following fee changes, both for the venues implementing the changes and for competing venues. Finally, it adds to the literature by documenting significant cross-sectional differences which suggests that traders in large capitalization stocks are more sensitive to make-fee changes whereas traders in small capitalization stocks are more sensitive to take-fee changes.

Maker-taker pricing in the U.S. equity market was first adopted by the electronic trading platform Island ECN in the late 1990s in order to compete with exchanges. In response, other Alternative Trading Systems (ATSs) and exchanges also adopted maker-taker pricing. By the mid-2000s, maker-taker pricing was the standard pricing model in U.S. equity markets. Concerned about escalating access (taker) fees, the U.S. Securities and Exchange Commission (SEC) imposed an access fee cap of 30 cents per 100 shares by adopting Rule 610 of Regulation NMS in 2005.[3] The 2007 MiFID I opened the European equity markets and allowed new

[1]According to the OICU-IOSCO (2013) report, there exists at least four types of fee structures: the symmetrical pricing model, with both the active and passive side of a trade paying the same fee; the asymmetrical pricing model, with both the active and the passive side of a trade paying a fee, but the fee paid is not the same; the maker-taker pricing model, with the provider of liquidity (maker) receiving a rebate and the taker of liquidity (taker) paying a fee; and the inverted maker-taker pricing model, with the provider of liquidity (maker) paying a fee and the taker of liquidity (taker) receiving the rebate.

[2]For extensive background and critical review on access fees, see the SEC Market Structure Advisory Committee's October 20, 2015, Memorandum "Maker-Taker Fees on Equities Exchanges."

[3]Securities Exchange Act Release No. 51808 (Jun. 9, 2005), 70 FR 37496, 3745 (Jun. 29, 2005) (File No.

trading platforms called Multilateral Trading Facilities (MTFs) to compete with exchanges by also adopting the maker-taker pricing.

In the ensuing decade, trading venues have frequently tweaked their maker-taker pricing models primarily to attract certain types of order flow. The liquidity rebates are particularly attractive to High Frequency Traders (HFTs) who have developed rebate harvesting strategies by acting as two-sided liquidity providers. Menkveld (2013) shows that the liquidity rebates can represent a significant fraction of a HFT trading firm's profits. As HFTs share of trading volume in both U.S. and European markets grew rapidly reaching close to 70% in the U.S. and 30% in Europe, the incentive to cater to this particular group of traders motivated even more aggressive competition for order flow using maker-taker pricing, often with added volume-based incentives.[4]

While maker-taker pricing has enabled new entrants to compete effectively with incumbent exchanges, potentially leading to narrower quoted spreads, the practice has been also criticized. Angel, Harris and Spatt (2013) argue that maker-taker pricing obfuscates true spreads; that it distorts order routing decisions;[5] and that it hurts both internalizing dealers and venues that do not use maker-taker pricing. Harris (2013) further argues that rebates allow traders to circumvent the minimum price variation (tick size), thus by-passing Regulation NMS order protection rules. Angel et al (2013) recommend that the SEC either require that all brokers pass through access fees and liquidity rebates to their clients and clarify that best execution obligations apply to net prices instead of quoted prices, or prohibit maker-taker pricing altogether.

On the other hand, Malinova, Park and Riordan (20162) see no reason to abolish maker-taker pricing as academic evidence suggest that HFTs and other traders pass through a significant fraction of the rebates to active traders.[6] Instead, they support initiatives to provide investors with better information about execution quality that includes maker-taker fees. Foucault (2013) shows that the make-take fee breakdown can affect the mix of market and limit orders and may even increase market participants' welfare. Consequently, he advocates that exchanges and regulators conduct pilot experiments to assess the effect of maker-taker fees on the composition of order flow (market vs. limit orders) before contemplating any changes to the current rules.

Not surprisingly, industry participants and exchanges and even members of Congress have

S7-10-04).

[4]Brogaard (2010) documents that HFTs represent 68% of Nasdaq trade volume, and Jarnecic and Snape (2010) document that HFTs represent 28% of total LSE volume.

[5]This concern has been validated using options market data, Battalio, Corwin, and Jennings (2015) who show that retail brokers appear to route orders to maximize order flow payments: selling market orders and sending limit orders to the venues paying large liquidity rebates, and that retail traders' limit order execution quality is negatively related to the level of the liquidity rebates.

[6]Hendershott and Riordan (2011) also show that HFT market makers pass through some of the rebates to active traders.

also weighed in on the maker-taker pricing debate. The Intercontinental Exchange Group, Inc. (ICE) and the Securities Industry Financial Markets Association (SIFMA) argue that the maker-taker pricing contributes to market complexity and advocate that the SEC reduce or eliminate maker-taker pricing and lower the cap on access fees from $0.003 per share to $0.0005 per share. BATS agrees that access fees should be lowered for the most liquid stocks, but argues that a tiered approach based on securities' characteristics should be applied for less liquid stocks. On March 3, 2015, Congressman Stephen F. Lynch introduced The Maker-Taker Conflict of Interest Reform Act of 2015 (H.R. 1216) which would require the SEC to carry out a pilot program to assess the impact of an alternative maker-taker pricing model.[7] A year later, the bill still pending, a proposal for an Access Fee Pilot that would reduce the access fee cap (and corresponding liquidity rebates) was forwarded by a sub-committee to the SEC's Equity Market Structure Advisory Committee.[8]

The markets we study empirically in this paper are fragmented with several competing venues operating electronic limit order books with discrete prices, while the existing theoretical literature focuses either on a single venue with discrete prices (Foucault, Kadan, and Kandel (2005)) or on competing venues without price discreteness (Colliard and Foucault (2012)). To help us frame the empirical analysis, we therefore develop a model of a dynamic limit order book with a discrete pricing grid that faces competition from another venue. We build our model on Parlour (1998) and Degryse, Van Achter and Wuyts (2009) and we extend their models to include two price levels on each side of the market, a competing venue and different trading fees. We use the model to derive predictions on the effects of a change in fees on spread, depth and volume, both in a setting without intermarket competition and in a fragmented market. The new feature of our model is that it includes both frictions (tick size) and a competing venue. So it complements both the Colliard and Foucault (2012) model in that it has a tick size, and the Foucault, Kadan, and Kandel (2005) model in that it includes a competing market.

Colliard and Foucault (2012) show that in a competitive market without tick size traders perfectly neutralize a change in fees so that such a change has no effects on the spread net of fees (cum-fee spread). Foucault, Kadan, and Kandel (2005) instead show that in a single market limit order book the make take fee breakdown matters for spreads. By contrast, we show that the effects of fee changes may be very different in a setting with intermarket competition compared to what they would be in a concentrated market. Furthermore, we show that fee changes do affect quoted spread, and in addition, they affect depth and volume.

The intuition is straightforward. Suppose that in a single market framework the take fee is

[7]The Maker-Taker Conflict of Interest Reform Act of 2015 would require the SEC to identify a random sample of 50 of the 100 most heavily traded US stocks, and prohibit the payment of rebates market-wide for those stocks for six months.

[8]EMSAC Regulation Subcommittee Memorandum addressed to EMSAC, April 19, 2016. https://www.sec.gov/spotlight/emsac/emsac-regulation-nms-subcommittee-recommendation-041916.pdf

increased. This induces traders to switch to less aggressive strategies thus reducing liquidity demand (and hence volume) and generating an improvement in spread and depth. The single market model however does not take into account the effects that the migration of orders may have on market quality. Specifically, if the same fee change is implemented in a framework with intermarket competition, an increase in the take fees reduces the attractiveness of the trading platform; this induces order flows to migrate away to alternative trading venues and has a detrimental effects on market quality. Our model shows that if the migration is substantial, the final effect of an increase in take fee on market quality may reverse compared to the single market framework, and market quality may deteriorate rather than improve. Similarly, in a single market framework an increase in the rebate generates a switch from market to limit orders which leads to an improvement in market quality and a deterioration of volume. However our model shows that in a framework with intermarket competition an increase in the rebate generates an inflow of orders migrating away from competing trading platforms which attenuates the negative effects on volume. Moreover, our model allows us to generate predictions for market depth which the prior literature is silent on.

We then use the model to frame our empirical analysis of the effects of changes in make-take fees implemented in January 2013 by BATS Europe (BATS) on its two lit venues – BXE and CXE. Specifically, CXE reduced its make-fee while leaving its take fee constant and BXE eliminated the make-fee entirely and cut its take fee in half. In both cases, the total fee captured by BATS increased by fifty percent. BATS' venues face competition not just from the primary exchange in each market but also from other non-exchange venues such as Turquoise (TQ). Therefore we also study changes in TQ's market quality and market share following the BATS' fee changes.

Our model predicts that a make fee reduction will have the opposite effect on market quality and market share to that of a take fee reduction. Therefore, the predicted effects on BXE market quality and market shares depend on whether traders are more sensitive to changes in make fees or take fees. On average, we find a decline in market share and depth, but no significant change in spreads following the fee changes. More importantly, we find that the effect of BXE's fee changes differs significantly in the cross-section. Specifically, the evidence is consistent with traders in large capitalization stocks being primarily focused on rebates whereas traders in small capitalization stocks are more focused on take fees. As a result, we find that the same fee changes are associated with deteriorating market quality and market share for large capitalization stocks while market quality and market shares improve for small capitalization stocks. We cannot observe HFT activity for our stocks directly, but our results are consistent with large capitalization stocks attracting more rebate seeking HFTs than small stocks.

In our setting, it is the relative fees that matter for traders' order selection and order routing decisions. Hence, even though CXE reduces its make fee, the new fee is still much more attractive relative to the now non-existent rebates on BXE. Similarly, although CXE does not change its take fee, it is now competing against a fifty percent lower take fee on BXE. It follows that CXE's make fee and take fee both increase relative to BXE and our model again suggests that the consequences for market quality and market share depend on the prevalence of rebate-seeking traders compared to take-fee sensitive traders. In addition, CXEs make fee falls relative to TQs which gives limit order traders an incentive to route orders away from CXE to TQ resulting in lower CXE depth. Our empirical results suggest that the relative increase in the CXE take fee and/or the loss of limit orders to TQ are the most important driving forces. As a result, CXE market quality and market share deteriorate significantly following the BATS fee changes, and this is true both for large and small capitalization stocks.

Finally, TQ's make-fee improves while its take-fee deteriorates relative to BXE following BATS' fee changes and our model therefore suggests that the consequences for market quality and market share depend on the composition of traders. Moreover, as noted above, TQ may attract more limit orders from CXE. Our results again suggest that there are more rebate seeking traders for large capitalization stocks while traders in small capitalization stocks are more concerned about take-fees. As a result, we find that TQ market quality and market shares improve for large capitalization stocks and deteriorate for small capitalization stocks following the BATS fee changes.

The first contribution to the empirical literature is that we take intermarket competition into account when studying the effects of make-take fee changes empirically. The second contribution is that we show that an elimination of the make fee coupled with a reduction in the take fee has a different effect for large capitalization stocks compared to small capitalizaiton stocks. The third contribution is that our sample is drawn from a recent time period, which is important as market structure and the ecosystem of traders has changed significantly over time.[9]

The paper is organized as follows. In Section 2 we briefly review the existing literature and in Section 3 we present the theoretical model and discussion of our empirical predictions. We present our datasets and the methodology in Section 4. In Section 5 we discuss our empirical results, and in Section 6 we provide a series of robustness checks. Finally, in Section 7 we present our conclusions and the policy implications of our findings.

2 Literature review

Theoretical models of make-take fees have primarily focused on whether the breakdown of the total fee charged by a venue into rebate and take fee matters for order flow composition, market

[9]We also study the introduction of fee schedules that depend on the value traded as in Malinova and Park (2015), but this analysis is relegated to Appendix 2.

quality, and welfare. Colliard and Foucault (2012) model a dealer market that competes with a limit order book with no frictions and a zero tick size to show that the breakdown does not affect the order flow composition, the trading rate, or welfare. Foucault, Kadan and Kandel (2013) model of a limit order book with a positive tick size populated by two distinct groups of traders – market makers and market takers – to show that the total fee breakdown matters because trading platforms have an incentive to change the fee breakdown so as to balance the speed of reaction of makers and takers. Brolley and Malinova (2013) model a dealer market with informed limit order traders to show that the breakdown of the total fee matters when investors pay a flat fee while liquidity providers incur take fees and receive rebates. Finally, Chao, Yao, and Ye (2015) model a limit order book with one price level and traders that cannot choose order type to show that the total fee breakdown matters because of the tick size.

To date, empirical work on make-take fees is relatively limited. Lutat (2010) studies the October 2008 introduction of a maker-taker pricing model on the Swiss exchange and find a decrease in depth but no significant effect on spreads. Malinova and Park (2015) study the 2005 switch by the Toronto Stock Exchange from a value-based to a volume based make-take fee schedule that was accompanied by an increase both in the rebate and the take fee, and they find that for the stocks that did not experience a change in total fee, quoted spread declined but cum-fee spreads (quoted spread plus twice the take fee) remained unaffected supporting Colliard and Foucault (2010). Skjeltorp, Sojli and Tham (2014) using data from the Nasdaq OMX BX and exogenous changes in make-take fees and a technological shock to liquidity takers to show that cross-side liquidity externalities exist and conclude that the reason is that an increase in market makers' monitoring benefits market takers as predicted by Foucault, Kadan, and Kandel (2013). Cardella, Hao and Kalcheva (2013) investigate 108 instances of fee changes for U.S. exchanges in 2008-2010 and find that an increase in total fees is associated with a decrease in trading volume and an increase in spreads and that an increase in take fees has a larger impact on trading activity than an increase in make fees. Finally, He, Jarnecic, and Liu (2015) study the entry of Chi-X in Europe, Australia, and Japan and find that Chi-X's market share is higher the more competitive its total fee relative to the total fee by the primary market is.

3 Theoretical Background and Empirical Predictions

3.1 The Model

Our model of a limit order book extends Parlour's (1998) and Degryse, Van Achter and Wuyts' (2009) frameworks to include a grid of four prices $P_i = \{S_2, S_1, B_1 B_2\}$, two on the ask and two on the bid side of the market around the asset value AV and a tick size τ. The ask prices are equal to $S_2 = AV + \frac{1}{2}\tau$, $S_1 = AV + \frac{3}{2}\tau$ respectively, and symmetrically the bid prices are equal to $B_2 = AV - \frac{1}{2}\tau$ and $B_1 = AV - \frac{3}{2}\tau$. The trading game lasts three periods and at each trading round $t = \{t_1, t_2, t_3\}$ a risk-neutral trader arrives to the market with a private evaluation equal to γAV. γ is drawn from a normal distribution, $\gamma \sim N(\mu, \sigma^2)$, and lies within the interval $\gamma \in (0, 2)$ so that conditional on $0 < \gamma < 2$, γ has a truncated normal distribution where σ indicates the dispersion of traders' beliefs around the mean µ. Traders coming to the market with extreme values of γ are more eager to trade, whereas traders arriving with γ values next to 1 are more patient. Trade size is unitary.

The limit order book opens empty at t_1 and the only liquidity available at S_2 and B_2 is offered by a liquidity provider who absorbs any buy (or sell) order submitted at the highest (lowest) level of the book. Consistent with the nature of liquidity providers in limit order books, we can think of the liquidity provider as a high frequency market maker. As such, the liquidity provider does not yield time priority to other market participants who must queue behind him when willing to supply liquidity at S_2 or B_2.

When dealing with trading fees it is crucial to take into account the effects of competition across trading venues.[10] For this reason, we consider two versions of the model. A single market framework (SM) whereby traders can only post orders to a limit order book (LOB) like the one described above, and a dual market framework (DM) that embeds competition from a crossing network (CN). In the DM traders can choose the trading venue where to post orders, be it the LOB or the CN. The owner of the LOB imposes a maker-taker pricing structure. When trading on the LOB market participants opting for a market order have to pay a take fee (TF) to the trading platform. The take fee is paid by the trader whenever a market order is executed. Traders opting instead for a limit order will receive a rebate or make fee (MF) whenever the limit order is executed. So the make fee is a reward that traders receive when they supply liquidity to the limit order book. The owner of the CN can also impose make and take fees (*mf* and *tf* respectively). In the SM framework at each trading round one trader comes to the market and chooses to post a limit order (LO), a market order (MO) or not to trade (NT). In the DM framework the incoming trader can also choose to post a limit order or a market order to the CN (LOS_{CN} or LOB_{CN}).

Table 1 reports the payoffs from the different orders that a trader can choose when arriving at the market at time t either in the SM or in the DM. When choosing their order submission strategies traders face a trade-off between non-execution costs and price opportunity costs. If they post a MO to the LOB, they get immediate execution at the best ask price, $S_i^b = min\{S_i | l_i > 0\}$ or at the best bid price, $B_i^b = max\{B_i | l_i > 0\}$,where l_i is the number of shares available at the $i - th$ price level. If instead they choose a LO, they face execution uncertainty but they will get a better price upon execution. In the DM framework traders also have the option to post an even more aggressive LOs to the CN that will execute at

[10] We thank Tito Bastianello for thorough discussions and suggestions on this aspect.

the midquote of the LOB best bid-offer, $mid_i = \frac{1}{2}(S_i^b + B_i^b)$. When a LO with opposite sign already exists in the CN, traders have the additional option to post a MO that will execute immediately at the midquote. Clearly a MO posted to the CN always dominates a MO posted to the LOB as both orders bear zero non-execution costs whilst the MO executed at the midquote in the CN does not pay the half-spread. Conditional of their γ, traders opt not to trade (NT) when the payoff of the avaliable LOs and MOs is not positive.

[Insert Table 1 about here]

In equilibrium the trader will choose a MO if the non-execution costs associated with the LO is higher than the price opportunity cost associated with the MO. Formally, at each period t a trader will choose the order submission strategy (ST^*) that maximizes the expected payoff (π^e) conditional on his personal evaluation of the asset, γ. In the SM the trader's expected payoff will be conditional on the state of the LOB, $lob_t = \{P_i, l_i\}$, and in the DM it will be conditional on both the state of the LOB and the state of the CN, $cn_{t.} = \{mid_i, l_i^{cn}\}$:

$$SM : \ max_{ST_t^*} \pi_t^e \left\{ ST_{MO}(1, P_i^b),\, ST_{LO}(1, P_i),\, ST_{NT}(0) \mid \gamma,\, lob_t \right\} \tag{1}$$

$$DM : \ max_{ST_t^*} \pi_t^e \left\{ ST_{MO}(1, P_i^b),\, ST_{MO,LO_{CN}}(1, mid_i),\, ST_{LO}(1, P_i),\, ST_{NT}(0) \mid \gamma,\, lob_t, cn_t \right\} \tag{2}$$

The model is solved by backward induction. We start from the end of the trading game (t_3) when traders rationally submit MOs only, and solve the model for the equilibrium market buy and market sell orders. As the equilibrium probability of market buy and market sell orders at t_3 are the execution probabilities of LOs (to sell and to buy respectively) at t_2, the model can then be solved at t_2, and recursively at t_1. We refer to the Appendix 1 for a more extensive discussion on the model's solution. For our numerical simulations we hold the values of $AV = 1$, $\mu = 1$, $\sigma = 1$, $\tau = 0.1$ constant and change the values of the make and the take fees only. This allows us to show how a change in trading fees affects traders' strategies, and in turn the equilibrium order flows and the quality of the LOB. To this end, we build measures of spread and depth based on the equilibrium order submission strategies. We mainly focus on the first two periods of the trading game and provide results for the average of periods t_1 and t_2.[11]

[11] Clearly to solve the model for period t_2 and t_1 we have to solve it for t_3 first. However, we do not include results from period t_3 in the average as this is the last period of the trading game when traders only post market orders, and therefore the measures of volume, spread and depth for that period would be affected by the end of the game effects.

3.2 Empirical Predictions

In this section we discuss the model's predictions, and in particular what we expect to happen to the LOB spread, depth, and order flows when the LOB changes its make and/or take fee. To clarify the mechanism at work when a trading fee changes, we first consider the trade-off that traders face when choosing their optimal order submission strategy and then discuss how this trade-off depends on trading fees. Specifically, we first illustrate how this trade-off is affected by fees at t_1 in Figure 1 and then discuss the general results reported in Figures 2 and 3 for the average of periods t_1 and t_2.

[Insert Figures 1, 2, and 3 about here]

Panel A of Figure 1 reports the payoffs and the γ-thresholds at t_1 which derive from our simulations of increases in make and take fees for the SM model, whereas Panel B reports the results of the same exercise for the DM model. The piecewise linear function (red dotted line) reported in Figure 1.1A shows the payoffs from the traders' optimal strategies associated with each possible value of γ for the SM and no fees. The benchmark case for the DM with no fees is reported in Figure 1.1B.

The effects on traders' equilibrium strategies of an increase in the make fee are shown in Figure 1.2A for the SM and in Figure 1.2B for the DM. In a SM, an increase in the rebate (a more negative make fee) makes liquidity supply more attractive so that traders switch from MO to LO. Hence, in equilibrium the γ-supports of LO increase symmetrically for both buyers and sellers. The resulting increase in liquidity supply and reduction in liquidity demand (volume) positively affects market quality so that in Figure 2.4A and 2.5A we observe that spread narrows and depth increases following an increase in the rebate.

In the DM the effects of a make fee increase are different. The reason is that once liquidity is subsidized on the LOB, traders who in absence of rebate would post limit orders to the CN switch to the LOB.[12] Consequently, order flows migrate from the CN to the LOB and the positive effects on depth of an increase in the rebate are reinforced (Figure 2, Panel B). As limit orders migrate from the CN to the LOB they attract additional market orders so that the overall effect on LOB volume may be positive rather than negative.

In the DM setting we discuss above, the alternative market is a CN for tractability. However, the conclusion that it is the relative make-take fees that dictate the direction of order flow between competing markets should hold more generally as does the insight that it is always a

[12]For illustration in Figure 1.2B we report simulations at t_1 for an increase in rebate which is very large and makes liquidity supply in the LOB so attractive to crowd out all LO_CN. Further unreported simulations show that for smaller increases in rebate LO_CN only partially migrate to the LOB. Note also that at t_1, when the CN opens empty, only LO_CN migrate to the LOB (Figure 1.2B), whereas at t_2 also MO_CN migrate to the LOB attracted by the virtuous liquidity cycle (Figure 2 which reports the average of t_1 and t_2).

mixture of market and limit orders that migrate from one market to the other in response to fee changes. This insight allows us to draw our first empirical prediction.

Prediction 1.

If a market's make fee increases (decreases) relative to competing venues, within the venue traders will switch from market to limit orders (limit to market orders), and orders will migrate into (out of) the market causing market quality to improve (deteriorate) and volume to increase (decrease).

We now move to study the effects of an increase in the take fee. Figure 1.3A and 1.3B show how the trade-off between order types changes after an increase in the take fee. In the SM following an increase in the take fee liquidity demand becomes more expensive and the payoff thresholds between market and limit orders change so that the equilibrium supports for LO increase. Consequently, in equilibrium, attracting LO by subsidizing limit orders or discouraging MO by taxing market orders have the same qualitative effects of increasing liquidity supply and decreasing liquidity demand with the result that market quality improves. Figure 3, Panel A shows evidence of that.[13]

The effects of a change in the take fee in the DM are different. Following an increase in the take fee, traders now have the opportunity to move to the CN and therefore they start routing MO away from the LOB to the CN, and limit orders follow suit seeking out the higher execution probability in the CN. Hence, the increase in the take fee in the DM generates a migration of orders to the CN and this may result in a deterioration of market quality (Figure 3, Panel B). It also generates a stronger reduction in volume. This leads to our second empirical prediction.

Prediction 2.

If a market's take fee increases (decreases) relative to competing venues, traders within the venue will switch from market to limit orders (limit to market orders), and orders will flow out of (into) the market causing market quality to deteriorate (improve) and volume to decrease (increase).

Note that our results for a market with a competing venue are new in the literature and show how important the effects of competition are when studying trading fees in a market with discrete prices. Colliard and Foucault (2012) have competition from a CN but they do not have frictions (no tick size). This means that in their model following a change in fees traders accommodate their strategies and the cum-fee spread does not change. Foucault, Kadan, and Kandel (2013) do have a tick size so that the breakdown between make and take fee affects the spread; however they do not have a competing market and therefore they cannot show the effects that a migration of order flow may have on the quality of the LOB following a change in trading fees.

[13] Our results for how spread responds to either a make fee or a take fee increase in a single market framework are consistent with Colliard and Foucault (2012) and with Foucault, Kadan, and Kandel (2013).

We can also use our model's result to infer what happens when a market changes both its relative make and its relative take fees simultaneously, and this leads to our third empirical prediction.

Prediction 3.

If both the make fee and the take fee increase (decrease) in a market relative to competing venues, the effect on market quality and volume depends on the composition of traders. If rebate seeking traders are more prevalent, the effects of the make fee increase will prevail, market quality will improve (deteriorate) and volume increase (decrease). If take-fee sensitive traders are more prevalent, the effects of the take fee increase will prevail with the consequence that market quality will deteriorate (improve) and volume decrease (increase).

For economic reasons, it is difficult for a market to raise its make-fees without also raising it's take-fees. However, in principle the change in the relative make-take fees can either go in the same or the opposite directions, leading to our final empirical prediction.

Prediction 4.

If a market's make fee increases (decreases) and the take fee decreases (increases) relative to competing venues, market and limit orders will flow into (out of) the market causing market quality to improve (deteriorate) and volume to increase (decrease).

In the following sections we use our empirical predictions to investigate the effects of the change in BATS trading fees that took place in January 2013.[14]

4 Data Description and Methodology

4.1 Market Structure and Intermarket Competition

We study the January 1, 2013, changes in BATS make-take fees based on two stratified samples (LSE listed and Pan-European) each consisting of 120 stocks.[15] During our sample period, November 2012 - February 2013, BATS operated two European lit venues, BXE and CXE, and each platform featured a continuous order book executing orders based on price, display, and time priority, and both offered very similar maker-taker pricing at the end of 2012. Table 2 illustrates the trading fee schedules in basis points (bps) that apply for LSE listed stocks in each venue in our sample as of December, 2012. It shows that the take fee was 0.28 bps (0.30 bps) and the rebate was 0.18 bps (0.20 bps) on BXE (CXE).[16]

[14] BATS continued its fee-experimentation after the 2013 event, and we use the model's predictions to discuss fee changes in 2014 and 2015 in Appendix 2.

[15] The details of sample construction are provided in Section 5.1. BATS Europe is a subsidiary of the U.S. exchange BATS.

[16] Trading fees for other Primary/Listing exchanges in our sample are similar to those used by the LSE, and the MTF trading fees are Pan-European with the exception of short promotions that do not conflict with our sampling windows.

[Insert Table 2 about here]

BXE and CXE faced competition from the transparent primary exchange in each market. The European primary exchanges all operate continuous order books executing orders based on price, display, and time priority. LSE charged trading fees based on the value-traded using a scale ranging from 0.45 bps to 0.20 bps for orders beyond £10bn of value traded (Table 2).[17]Value-tiers are typically determined based on monthly value traded, and rebates are distributed and fees collected ex post on a monthly basis. Furthermore, BATS faced competition from the transparent MTF Turquoise (TQ) which also operated a continuous order book executing orders based on price, display, and time priority.[18] TQ charged takers 0.30 bps and used a value-based maker fee ranging from -0.14 bps to -0.28 bps for monthly value traded above €2.5bn.

Several dark venues were also actively trading European stocks during our sample period, including: two venues operated by BATS - BXE-Dark and CXE-Dark - both operated as dark midpoint order books; a venue operated by the LSE - TQ-Dark - a dark midpoint order book with both continuous and uncross trading which executed orders based on size followed by time priority; and a venue operated by the broker UBS - UBS-MTF.[19] BXE-Dark charged 0.15 bps for executed orders, while CXE-Dark charged 0.15 bps for executed Non Immediate or Cancel (IOC) orders and 0.30 bps for executed IOC orders. TQ-Dark charged 0.30 bps for executed orders. The UBS-MTF operates as a continuous midpoint order book with price followed by time priority and it charged 0.10 bps for executed orders.

To illustrate the degree of intermarket competition in or sample of stocks, we manually collect daily data from Fidessa (Fragulator) on share volume reported by each venue, and use it to compute the distribution of market shares across venues based on our sample of stocks. Figure 4, Panels A and B (column 1) report the distribution of market share across our covered venues for our sample of LSE and Pan-European samples, respectively, for November and December, 2012. Figure 4, Panel A shows that LSE trades (continuous and auction) represent 67.00%, CXE Lit 16.63%, BXE Lit 4.96%, TQ Lit 6.25%, CXE Dark 179%, BXE Dark 1.08%, TQ Dark 0.88%, and UBS Dark 1.42% of share volume.[20] In other words, lit MTFs together capture 27.8% of share volume while dark MTFs capture 5.17% of share volume for UK stocks.

[17]The LSE briefly experimenting with maker-taker pricing in 2009.

[18]TQ was originally launched by a consortium of investment banks on August 15, 2008, but was acquired by the LSE on December 21, 2009. See Gresse (2016) for a discussion of the fragmentation of European equity trading.

[19]BXE Dark, CXE Dark, and TQ Dark all use the midpoint from the Listing (Primary) market as their reference price.

[20]We exclude off-market trades, which represented 56.5% of share volume for LSE listed stocks during November and December 2012, when calculate market shares.

BATS lit venues' market share is 21.59% and BATS overall market share is 24.46%. Figure 4, Panel B shows a similar distribution of market share across the covered venues for our Pan-European sample. As the figure shows, primary markets' trades represent 67.1%, whereas lit MTFs capture 29.5%, and dark MTFs capture 3.37% of total volume.

[Insert Figure 4 about here]

4.2 Data and Sample

We rely on two universes of stocks: a LSE and a Pan-European sample, each consisting of 120 stocks, to study the effect of BATS' January 2103 fee changes on market share and market quality.[21] The LSE sample is constructed using the following stratification methodology. We begin with a sample of all publicly traded companies on the LSE that are also traded on either BXE or CXE (using information provided on the BATS website). The reason we screen on existing BATS trading activity is that we cannot measure changes in market quality and market share at the venue-level unless the stock was traded on BATS both before and after the fee change. For these firms we acquire information on daily average market capitalization and daily price for the month of January 2012 using COMPUSTAT Global and Bloomberg. This initial sample consists of 355 firms. We then only focus on firms where market captialization is greater than £500m in order to have sufficient liquidity when we calculate our measures of market quality. From this set of 258 firms, we sample 12 firms (with 6 firms above the median price and six below) within each market capitalization decile and end up with a representative final sample of 120 LSE firms that also traded on BATS.

In a similar manner, our Pan-European sample was constructed from the universe of publicly traded companies in Europe that are also traded on either BXE or CXE.[22] We again collect information on market capitalization and price (from COMPUSTAT Global and Bloomberg) for January 2012. This initial European sample consists of 949 firms. Furthermore, we impose a market capitalization screen of €500m. We group stocks according to their primary market and sample 120 firms so as to match each country's frequency of firms traded in the January 2012 population of firms. Within each country we use stratified sampling with respect to market capitalization and price, similarly to the LSE sample. Our final sample for the January 2013 event covers 13 primary market centers with the following distribution of firms: Amsterdam (5 firms), Brussels (2 firms), Copenhagen (3 firms), Frankfurt (10 firms), Helsinki (8 firms), Lisbon (3 firms), London (45 firms), Madrid (4 firms), Milan (5 firms), Oslo (4 firms), Paris (15 firms), Zurich (4 firms), and Stockholm (12 firms).

[21] We follow the same sampling procedure to create samples around maker-taker pricing changes in 2014 and 2015 respectively. These are discussed in Appendix 2.

[22] Note that this sample also includes LSE listed stocks.

For each of our sample stock-venue combination, we calculate our daily market quality and volume measures (to compute market shares) using Thompson Reuters Tick History (TRTH) cash equities market data. The data includes all intraday best bid and ask prices and associated depth, as well as all trades (price and size) for each covered venue (exchanges and transparent MTFs), time-stamped to the microsecond. We also use TRTH end-of-day data to obtain volume, high, low and closing prices.

4.3 Descriptive Statistics

Our model generates predictions for how the LOB market quality and market share is affected by a change in make fees and/or take fees. Note that the model speaks to market quality at the venue level. We calculate five different measures of market quality for each universe-venue combination as follows: Volume is the daily number of shares (in 000s) traded using the end-of-day files from TRTH; Depth is the daily average of the intraday quoted depth in shares at the ask-side and the bid-side of each quote respectively; Spread is the time-weighted average of the intraday difference between the ask price and the bid price of each quote in units of currency (£ or €); %Spread is the time-weighted average of the intraday ask price minus the bid price of each quote divided by the midquote (average of the ask and bid prices); Volatility is the difference between the high and low trading price each trading day (using the end-of-day files from TRTH) divided by the high price.

Table 3 reports summary statistics across stocks based on average daily values for each market quality measure at the primary exchange during December 2012 for both the LSE (Panel A) and Pan-European samples (Panel B). We also report summary statistics for the distribution of market capitalization in millions as well as price levels (£ for Panel A and € for Panel B, respectively). For reference, the average December 2012 exchange rate was £0.813/€. We report summary statistics Overall and for the subsamples of the highest (Large) and lowest (Small) market capitalization terciles.

[Insert Table 3 about here]

As can be seen in Table 3, Panel A, the average (median) market capitalization of our LSE sample firms is £7.62bn (£1.68bn) and the stratified sampling generates a wide distribution of firms along the size dimension (interquartile range is £3.36bn). Similarly, the average (median)stock price is £6.91 (£4.11) and the distribution across stocks in terms of price is significant (interquartile range is £7.56). In terms of market quality measures for our LSE sample stocks, the average (median) share volume is 4.5mn (0.793mn), depth 7,421 (3,172) shares, spread 1.667 (0.889) pence, %spread 0.228% (0.146%), and volatility is 1.189% (1.575%). Hence, our sampling methodology ensures that we have a significant dispersion in market quality measures across firms. As expected, size and price are higher and market quality better for Large than for Small firms.

Panel B of Table 3 illustrates that the Pan-European sampling methodology also generates a significant distribution across firms in terms of size, price, and market quality. The average market capitalization is slightly larger for the Pan-European sample (€12,870*£0.813/€ = £10,463mn) compared to the LSE sample, but the average stock price is considerably higher (€24.52*£0.813/€ = £19.93). Given the much higher average stock price, it is not surprising that average depth is smaller for the Pan-European sample (5,108 shares) than for the LSE sample. Note also that the average %spread for the Pan-European sample (0.137%) is 40 percent lower than the LSE sample %spread (0.228%).

We compare market quality measures for each venue, BXE, CXE, and TQ, to the primary market for each sample and subsamples by size in Figure 5. For each venue, we report the average market quality measure for the pre-event period. Filled bars indicate that a venue mean is significantly different from the primary market mean based on a simple differences in group means test.[23] As we already highlighted in Section 4.1, the primary market is the dominant venue in terms of share volume both for LSE stocks (Panel A) and Pan-European stocks (Panel B), and this is true both Overall, and for Large and Small stocks. CXE captures the second largest fraction of share of volume both for LSE and Pan-European stocks overall, and its share of average volume is higher for Large than for Small stocks. By comparison, both TQ and BXE are smaller players in terms of market share.

The distribution of average depth is also skewed towards the primary market for both universes, but much less so than share volume. For LSE stocks, MTFs depth relative to the primary market depth is higher for Large stocks than for Small stocks. The situation is the opposite for Pan-European stocks; MTF depth relative to the depth on the primary market is higher for Small than for Large stocks.

[Insert Figure 5 about here]

By comparison, the differences in average relative spreads across venues trading LSE stocks is smaller. Quoted relative spreads for both universes are on average lowest on the primary markets, followed by CXE and TQ, while BXE has the widest relative quoted spreads. For Large LSE stocks, the MTF, are much more competitive relative to the primary market. By contrast, for Small LSE stocks, the MTFs all have at least fifty percent wider spreads than the primary market. For Large Pan-European stocks MTF spreads aree consistently wider than the spreads on the primary market. The situation is even worse for Small Pan-European stocks where MTF spreads are more than double the spread on the primary market.

[23]Based on pair-wise t-tests, all differences in Figure 5 are statistically significant.

Finally, the differences in volatility measured as (High-Low)/High for each venue for each universe and subsample. Volatility is significantly lower on the MTFs compared to the primary market for LSE and Pan-European stocks Overall. Volatility is also more muted on the MTFs for Small than for Large stocks for both universes.

4.4 Methodology

In order to examine whether the fee changes have a significant effect on market quality and market share for BATS' and its competitors, we conduct an event study using an event window of two months centered on the fee-change event. We face the usual trade-off when selecting the event window. Using a longer time series would enable us to more precisely measure variables pre- and post-event and also capture longer term effects of the pricing changes. However, a narrower window would allow us to minimize the potential effects of confounding factors.[24]

We compute daily average depth, spread (quoted and %) and volume based on TRTH data for each stock-venue combination for each of our universes (LSE stocks and Pan-European stocks). Stocks in the Pan-European sample trade in different currencies, and it is tempting to simply convert all prices into a common currency. However, doing so would inevitably add more noise to our estimates of trading costs. Moreover, stock price levels are very different across markets, and this is true even after correcting for the exchange rate. We deal with the cross-sectional heterogeneity arising from currencies and different nominal price levels by standardizing our variables as follows. We divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where the total and averages are taken over all four venues (BXE, CXE, primary exchange, and TQ) for that stock-day. For ease of exposition, we will call these measures relative volume, relative depth, and relative spread respectively.

We start by collapsing the panel into a time-series of average daily standardized market quality measures. Specifically, for each universe, we compute equal-weighted daily means across stocks for each venue both for the overall sample (120 firms) and for subsamples based on size terciles. Firms are classified into size terciles based on market capitalization of the firms for each universe one year before the first month of the event (i.e., January 2012).[25] The result is four time-series (Overall, Large, Medium, and Small) of roughly fourty-two daily observations (trading days) for each venue (BXE, CXE, TQ and primary exchange), and universe (LSE and Pan-European).[26] As a first pass, we evaluate the change in market share, relative depth,

[24]Our results are qualitatively robust for longer windows (four months before and four months after the fee changes), but the statistical significance is as expected lower.

[25]Similarly, in unreported results we examine subsamples based on the median price level (low and high priced stocks).

[26]We exclude the week of Christmas in December, and instead add the last week of November for the 2013 and 2015 events. We winsorize extreme values of the dependent variable at the 1% level for the Overall samples, to reduce the influence of extreme observations.

and relative spread for each universe, venue, and sample following the fee changes based on a time-series regression:

$$y_t^V = \mu + \delta \cdot Event_t + \varepsilon_t \tag{3}$$

where y_t^V is the standardized measure of market quality for venue V and $Event_t$ is a dummy variable that takes on a value of one for days in the post-event period and zero otherwise. Standard errors are computed using the Newey-West correction for autocorrelation with ten lags.

Recall from the model that the fee changes affect traders' order choice and order routing decisions, and this in equilibrium produces market outcomes that we can measure such as venue market share, depth and spreads. In our empirical setting, all orders routed to a particular venue experience the same fee change so we do not have any within-venue variation across stocks in terms of the fees to exploit for the creation of a control sample (e.g., matching stocks on pre-event characteristics). By contrast, we do have variation in terms of fees across venues trading the same stocks - e.g., BATS changes its fees but fees on the primary exchange and other MTFs remain unchanged. It is therefore tempting to use market quality on competing platforms as a control sample. However, our model shows that traders' response to fee changes affects not just their order choice on the venue which changes its fees, but also affects order inflow from, and order outflow to, competing venues. As a result, market quality on competing venues are likely to be indirectly affected by the BATS fee changes which violates the exclusion restriction for difference in difference analysis (Boehmer, Jones, and Zhang (2015)).[27]

Therefore, we resort to a regression framework where we use relative market quality on the primary exchange as an explanatory variable in an attempt to control for the variation in relative market quality for the venue experiencing fee changes that can be explained by the normal day-to-day competitive interaction with the primary exchange. Specifically, to evaluate if the changes in trading fees are associated with changes in standardized venue market quality, we run the following time-series regressions:

$$y_t^V = \mu + \beta \cdot y_t^{PE} + \delta \cdot Event_t + \gamma \cdot VIX_t + \eta_t \tag{4}$$

where y_t^V is the standardized measure of market quality for venue V , y_t^{PE} is the standardized measure of market quality for the primary exchange, t denotes time in days, and $Event_t$ is a dummy variable that takes on a value of one for days in the post-event period and zero otherwise. Standard errors are computed using the Newey-West correction for autocorrelation

[27]We conducted a difference in difference estimation where we regressed the difference between the venue and primary market relative market quality on an event dummy in an earlier draft of this paper. The results from this estimation are available from the authors on request and are qualitatively the same as those presented in the paper.

with ten lags. The estimated coefficient $\hat{\delta}$ measures the change in market quality associated with the change in trading fees that cannot be explained by the normal day-to-day variation in standardized market quality for the primary exchange.

Furthermore, we estimate a panel version of the relationship between relative market quality and the fee changes controlling for relative market quality on the primary exchange to evaluate the robustness of our results. Specifically, we estimate the following regressions:

$$y_{i,t}^{V} = \mu_i + \beta \cdot y_{i,t}^{PE} + \delta \cdot Event_t + \gamma \cdot VIX_t + \eta_{i,t} \tag{5}$$

where the subscript i indicates an individual stock. For this analysis, we account for firm fixed effects and cluster standard errors by firm. We acknowledge that we cannot claim causality using our regression analysis. Nevertheless, we believe that we can learn from comparing the empirical results to our model predictions to better understand the changes in market outcomes that we observe following changes of trading fees in a market with significant intermarket competition.

5 Empirical Results

In this section, we estimate the changes in volume and market quality on CXE, BXE, and TQ associated with the BATS fee changes for each universe of stocks, and sub-sample and compare these to our model predictions. We start by discussing the model predictions and the results based on the time-series event-study methodology for each MTF: BXE, CXE, and TQ. We then report the results using panel regressions in a separate subsection to confirm that our results are robust.

5.1 Fee Change

In late 2012, BATS announced a plan to change its pricing effective January 1, 2013, to better differentiate the services provided by its two transparent trading venues. Specifically, as reported in the second sets of columns in Table 2, BATS reduced the CXE liquidity rebate from 0.20 bps to 0.15 bps while leaving the take fee at 0.30 bps. Thus, CXE became less attractive for liquidity providers such as High Frequency Traders (HFTs) seeking to harvest rebates. Furthermore, BATS eliminated the liquidity rebate from its BXE venue completely, and reduced the take fee from 0.28 bps to 0.15 bps. This move clearly made BXE unattractive for traders such as HFTs seeking to harvest rebates, but at the same time making the venue more attractive to traders relying more heavily on marketable orders. Table 4 summarizes our model predictions for the relative change in fees, as they apply to the 2013 event, and we refer to these predicitons in our discussion below.

[Insert Table 4 about here]

Finally, note that the total fee became 0.15 bps for both BATS' platforms after the pricing change, an increase of 50% (from 0.10 bps). This means that traders using mixed limit and market order strategies all else equal would find it more expensive to trade on BATS' venues after the fee changes and may have decided to route their orders elsewhere.

5.2 BXE

The January 2013 BXE fee changes were significant: the rebates were completely eliminated and the take fee cut in half. Both the BXE make and the take fees are lower than the corresponding make and take fees on CXE and TQ following the fee change. Referring to Prediction 3 (in Section 3) and our Table 4, the simultaneous reduction of make and take fees will cause traders on BXE to switch from limit to market orders. Furthermore, the reduction of the BXE rebate induces limit orders (chasing rebates) to migrate away from BXE to competing venues, thus causing spreads to widen and depth at the BBO to decline. The anticipated worsening market quality on BXE encourages market orders to follow limit orders to competing venues, dampening the adverse effects on market quality and causing volume to decline. In addition, the reduction of the take fee attracts market orders (seeking lower take fees) to BXE from competing venues, thus increasing limit orders' execution probability and therefore potentially attracting limit order submitters. This would improve market quality and boost volume.

As a result of these opposing forces, the overall effect on market quality and volume will depend on the sensitivity of traders to the rebate elimination (spreads widen, depth and volume declines) relative to the take-fee reduction (spreads narrow, depth and volume increases), and therefore on the composition of market participants. If liquidity suppliers take the lead and drive order flows away from BXE in search of better rebates, then we expect market quality to deteriorate and volume to decrease. If instead liquidity takers take the lead and, attracted by the lower cost to consume liquidity, migrate to BXE, then we expect market quality to improve and volume to increase.

We first examine the changes in relative volume, depth, and spread based on a simple collapsed time-series regression with an Event dummy that takes on a value of one following the fee change and 0 otherwise. The results in Table 5, Panel A show that for the Overall LSE sample, BXE relative volume increases significantly by 0.80%, relative depth decreases significantly by 2.41%, while relative spreads do not change significantly. For Large stocks, BXE market quality clearly deteriorates (depth declines by 4.92% and spreads widen by 3.74%)

while relative volume does not change significantly. By contrast, for Small stocks, BXE market quality improves significantly (spreads narrow by 7.57%) while volume increases by 1.40%. This suggests that there are significant cross-sectional differences in terms of traders' sensitivities to make fees versus take fees. We explore this conjecture further in our multivariate time-series and panel regressions below.

[Insert Table 5 about here]

Table 6 reports the results from our collapsed time-series regressions of relative volume, depth, and spread respectively on a dummy that takes on a value of one following the fee change and 0 otherwise. We also include VIX to control for market-wide changes that may affect market shares and relative market quality independently of the fee changes, and the primary market relative volume, relative depth, and relative spread respectively to control for the normal day-to-day competitive interaction between the MTFs we study and the primary market.

[Insert Table 6 about here]

The coefficients on our Event dummy reported in Table 6, Panel A show that for LSE stocks Overall BXE relative volume increases significantly by 0.49%, while relative depth declines significantly by 2.25%, and relative spreads narrow albeit not quite significantly following BXEs fee changes. To understand these results, it is helpful to study the corresponding coefficients for our LSE subsamples by market capitalization. For Large stocks, relative volume decreases significantly by 0.27%, relative depth declines by 5.31% while relative spreads widen by 2.97%. This outcome is what our model predicts will happen if BXE traders in Large capitalization stocks are primarily focused on the rebate reduction. By contrast, for Small stocks relative volume increases significantly by 1.45%, relative depth increases albeit insignificantly by 1.47% and relative spread narrows significantly by 6.58%. This is the outcome we would predict if BXE traders in Small capitalization stocks are primarily focused on the take fee reduction. Hence, the results we observe for LSE stocks Overall mask significant cross-sectional differences between Large stocks where the make fee reduction appears to be the primary concern for traders and Small stocks for which the take fee reduction appears to be the primary concern.

5.3 CXE

The January 2013 BATS trading fee change implied that the CXE rebate was reduced by 0.05 bps, keeping the take fee constant. Relative to BXE, CXE has a higher rebate but also a higher take fee following the fee changes. Relative to TQ, CXE has a lower rebate than before but it is still marginally higher than the base TQ rebate of 0.14 bps and there is no change in the relative take fees. How our model predicts that these different changes will affect market quality and market shares is summarized in Table 4 above.

Consider first the new CXE take fee which is now higher than the take fee on BXE. Our model predicts that this would cause market orders to leave CXE for BXE, and limit orders would follow causing CXE spreads to widen, and depth and volume to decline. However, the new CXE make fee is more attractive than the non-existent make fee on BXE for liquidity providers. According to our model, this would cause limit orders to migrate from the BXE to the CXE, and this may encourage market orders to follow causing CXE spreads to narrow and depth and volume to increase. At the same time, the CXE rebate falls to a level very close to the rebate TQ, and our model predicts that fewer limit orders than before would be routed to CXE possibly also causing a seepage of market orders, leading CXE spreads to widen, and depth and volume to decline. Hence, we have to consider multiple dimensions: a) whether or not CXE traders are more affected by the higher liquidity rebates (narrower spread and an increase in depth and volume) or the higher take fees (wider spreads, and a decline in depth and volume), and b) whether the competition for liquidity provision from BXE (narrower spreads and an increase in depth and volume) or TQ (wider spreads and a decrease in depth and volume) is the dominant force.

Consider first the results based on the simple collapsed time-series regression of relative volume, depth, and spreads respectively on an Event dummy reported in Table 5, Panel A. Overall, we find no change in CXE relative volume, while relative depth declines by 1.65% and relative spreads widen significantly by 2.59%. Broken down by sub-samples, the results show that for Large stocks CXE relative depth declines significantly by 3.55% without a significant change in relative spreads or volume while for Small stocks CXE relative spreads widen significantly by 5.59% and volume declines significantly by 1.00%.

Table 6, Panel B reports the estimated coefficients on the Event dummy after controlling for the corresponding relative variables for the primary exchange and VIX. CXE relative volume decreases significantly by 0.77%, relative depth declines significantly by 1.61%, and relative spread increases significantly by 2.46% for the Overall LSE sample. This is what our model suggests that we should expect to see if the relative increase in the CXE take fee and/or the loss of attractiveness of the CXE make fee relative to TQ was the most important driving forces for changes in CXE market quality and market share. Furthermore, the results are similar both for Large and Small LSE stocks, albeit with insigificant coefficients for relative spreads for Large capitalization stocks and for relative depth for Small capitalization stocks.

Hence, although CXE did not change its take fee in 2013, its take fee became relatively less attractive due to the simultaneous cut of the BXE take fee. As a result, market orders that would otherwise have been routed to CXE were now redirected to BXE and limit orders seeking execution would have followed suit. Furthermore, the lower rebates meant that limit orders that were previously routed to the CXE were now to a larger extent redirected to TQ with more attractive rebates.

5.4 Turquoise

As we already have discussed, the BATS fee changes also affected the relative attractiveness of TQ. Specifically, TQ's rebate schedule became more attractive relative to the rebates offered by BXE and CXE while its take-fee became less attractive than the one offered by BXE. We can use our model to predict what should happen to market quality and market share on TQ following BATS' fee changes. The relative increase in rebates should cause limit orders to migrate from BXE and CXE to TQ, and as long as market orders follow suit we expect spreads to decline, and depth and volume to increase. At the same time, the relatively higher TQ take fee would prompt market orders to be routed away from TQ, and limit orders would follow suit resulting in wider spreads, narrower depth and lower volume. Our predictions are again summarized in Table 4 above.

Overall, Table 5 Panel A shows that TQ relative volume and depth increased significantly by 2.19% and 3.69% respectively while there was no significant change in relative spreads following the BATS fee changes. TQ relative spreads do not change significantly for either subsample by market capitalization. However, TQ relative volume and depth increases significantly for Large stocks by 3.88% and 4.47% respectively, while TQ relative depth declines significantly by 7.90% and volume remained unchanged for Small stocks. In other words, we again observe significant cross-sectional differences that we will return to after presenting the multivariate regressions.

Table 6, Panel C reports the Event dummy and the results show that TQ relative volume and relative depth increased significantly by 0.24% and 3.80% respectively while relative spreads declined albeit not significantly for LSE stocks Overall following the BATS fee changes. Hence, Overall the effect of the relatively more attractive TQ make-fee schedule dominated the routing of orders post fee changes. Note also that there are significant differences across sub-samples. As was the case for BXE, we clearly see that the effect of the relatively more attractive TQ make-fee dominates for Large stocks (spreads decline significantly and depth and volume increase significantly) while the relatively less attractive TQ take-fee dominates for Small stocks (spreads increase and depth and volume decline significantly).

5.5 Panel Regressions

We repeat the analysis of the effects of the BATS fee changes on relative volume, depth, and spreads on an event dummy and the same control variables but now using a panel regression with stock fixed effects and standard errors clustered by firm. Table 7, Panel A reports the results for BXE. These results support our earlier conclusion that the BXE make fee elimination was the driving force for traders of Large LSE stocks causing market quality deteriorate and market share to decline. Similarly, the BXE take fee reduction was the driving force for traders for Small LSE stocks and we document an improvement in spreads (while the change depth is not significant) and an increase in market share. For the overall LSE sample, the results for the panel regression are consistent with the fact that they are a combination of the effects for Large stocks driven by traders concerned about rebates and Small stocks driven by traders concerned about take fees.

[Insert Table 7 about here]

We report the results for CXE in Panel B and also here the results confirm our findings based on the time-series analysis. Specifically, both the higher take fee relative to BXE and the relatively less attractive make fee relative to TQ cause an outflow of market and limit orders from CXE after the fee changes. As a result, we document a deterioration in market quality and a decrease in market share for the CXE following the BATS fee changes and this is true both for the Overall sample, and for subsamples by market capitalization.

Finally, we report the results for our event study using panel regressions to evaluate the changes in market quality and market share for TQ in Panel C. In terms of signs and significance, the results are very similar to those reported in Table 6, Panel C. Hence, we conclude that TQ market quality overall improved and its market share increased following the fee changes suggesting that the elimination of the rebates on BXE and reduction of CXE rebates benefited TQ through the intermarket competition channel. We again document significant differences for stocks in the cross section. The effect of relatively more attractive rebates drive the outcome for Large stocks causing market quality and market share to improve while the effect of relatively less attractive take fees drives the outcome for Small stocks causing market quality and market share to deteriorate.

6 Robustness

6.1 Normalization

In our main analysis, we normalize each daily observation for a venue by the contemporaneous market-wide total/average in order to control for cross-sectional heterogeneity in currency denomination of prices as well as differences in nominal price levels across countries. An alternative is to use the same denominator for the pre- and the post-periods. The advantage of a constant denominator is that the entire effect on market quality arising from changes in the make-take fees comes from the numerator, i.e., the change in volume, depth, and spreads. However, the drawback of this approach is that we would observe changes in for example market share even if the venue did not capture a larger or smaller market share than it had in the pre-period. Nevertheless, for robustness we repeat our time-series regressions with variables normalized by a constant denominator and find that our results are qualitatively unchanged.[28]

6.2 Pan-European Sample

As a further robustness check, we repeat both the time-series and the panel regressions for the stratified sample of Pan-European stocks we described in Section 4 above. Table 5, Panel B reports the simple collapsed time series regression in an event dummy for the three MTFs for Pan-European stocks.

The results for the multivariate time-series regressions are reported in Table 8 and the results for the panel-regressions in Table 9. While at times slightly weaker statistically, the results are qualitatively the same as those reported earlier for the LSE sample. We find strong evidence that the elimination of the make fee on BXE was the driving force for Large Pan-European stocks, resulting in poorer market quality and loss of market share. By contrast, the more attractive BXE take-fee resulted in narrower spreads and improved market share (but no significant change in depth) for Small Pan-European stocks. The effects of the fee changes on CXE depth and market share remain negative also for the Pan-European sample overall and the effects on Small stock market quality and market shares echo those from the LSE sample. By contrast, the results for Large Pan-European stocks are weaker. This is most likely due to the opposite effects of the make-fee changes arising from competition from BXE and TQ respectively. Finally, it appears that TQ also benefited from BATS' reduction in make-fees for Large Pan-European stocks. Specifically, TQ market quality and market share both improved for Large Pan-European stocks following BATS' fee changes. By contrast, TQ market quality deteriorated (albeit not significantly) and market share declined for Small Pan-European stocks.

[Insert Tables 8 and 9 about here]

7 Conclusions and Policy Implications

Maker-taker pricing is actively debated among academics, practitioners, market operators, and is currently under review by U.S. and European regulators. Proposals are being considered that would mandate a reduction or elimination of rebates (make fees) and a significant reduction in the cap for take fees. We shed light on this debate by studying the effects on venue market quality and market shares of a reduction of liquidity rebates and take fees in fragmented markets in which intermarket competition plays an important role.

[28]Tables reporting these results are available from the authors on request.

We first develop a theoretical model of a limit order book facing competition from a crossing network. It shows that order flow between venues significantly influences the model's predictions of what will happen to the venue's market quality and market share when it changes its maker-taker pricing structure. We then empirically examine the effects on market quality and market shares of changes in make-take fees implemented by BATS on its two lit European venues—BXE and CXE—in 2013 and compare the outcomes to the model's predictions.

We find that when BXE eliminates its rebates and reduce the take fee by 50 percent, BXE market quality deteriorates and the venue loses market share for Large stocks. By contrast, BXE market quality improves and its market share increases for Small stocks. These results are what our model predicts we should see when rebates are relatively more important for traders in large capitalization stocks while take fees are relatively more important for traders in small capitalization stocks. Our findings are consistent with traders like HFT that pursue rebate-capture strategies and are active in Large stocks, but much less so in Small stocks. In other words, the composition of traders and their relative sensitivity to fee changes varies significantly for stocks with different characteristics.

Market quality worsens but there is no change in volume (market share) following CXE's rebate reduction that leaves the take fee unchanged. The reason is instructive as it illustrates the role of intermarket competition. The contemporaneous elimination of rebates and reduction of take fees by BXE implied that CXE's rebate becomes more attractive and the take fee less attractive relative to BXE. These relative fee changes have opposite effects on market quality and market share. However, in addition CXE's rebate becomes less attractive relative to the one offered by TQ. This helps explain why orders flow out of CXE to TQ and BXE causing market quality to deteriorate.

To further highlight intermarket competition, we also study TQ which does not change its fees during our sample. Relative to BXE, both the make and the take fee increased. Our results show that the fee changes are associated with an increase in depth and volume for large capitalization stocks. By contrast, depth deteriorates significantly and volume falls significantly for small capitalization stocks. These results are again consistent with traders in large capitalization stocks being more sensitive to the make fee while traders in small capitalization stocks are more influenced by the take fee.

In Appendix 2, we also examine introductions by BATS of value-tiers which imply that HFTs that execute significant volume on BATS venues enjoy a higher rebate (2014, CXE) and a lower take fee (2015, CXE). BATS was hoping to create a virtuous cycle where both limit and market orders from HFTs were attracted to their venues. Their experimentation illustrates how difficult it is to achieve a virtuous cycle in a market with significant intermarket competition. Traders easily shift their order flow across venues in response to fees, and the composition of traders is ever changing.

Based on our empirical results, we conclude that the effects on market quality and the distribution of volume of a proposal such as the one put forth by ICE and SIFMA are likely to differ across stocks. Specifically, our evidence suggests that an elimination of the make fee and a reduced take fee cap would result in worse market quality for large capitalization stocks but better market quality for small capitalization stocks. This suggests that the elimination of make-fees are going to be particularly detrimental for liquid stocks. In light of our findings, BATS' proposal to eliminate rebates and reduce take fees for the most liquid stocks, while allowing higher rebates and take fees for less liquid stocks is, may be ill advised.

We caution that our empirical setting is one where fees are changed by a subset of the market operators, and hence traders can shop across venues for the combination of fees that best fit their trading strategies. If a regulator like the SEC mandates an elimination of rebates for all market operators in a particular stock, our single market model predicts that market quality will deteriorate and will volume increase. However, note that even if the fee structure is mandated to be the same for all venues trading a particular stock, traders will likely substitute across stocks focusing their rebate strategies in stocks with the most attractive rebates and their more aggressive strategies in those with low take fees. This means that it is going to be challenging to use the SEC Equity Market Structure Advisory Committee's Access Fee Pilot to infer what would happen to market quality following a universally lower cap on fees.

Documenting cross-sectional differences of the effect of fee changes on market quality and volume leads naturally to the following question: was the BATS fee fight successful? This is a challenging question to answer as we are unable to observe the counterfactual, what would have happened had BATS not changed their fees. However, we can use our data to illustrate what happened to BATS market share in our sample of LSE listed stocks between 2012 and 2015. Figure 4 shows that BATS combined market share in LSE listed stocks declined from 24.6% in November and December 2012 to 22.4% in February and March 2015. Similarly, BATS combined market share for the Pan-European sample declined from 26.51% to 25.15%, but BXE's market share increased. The distribution across BATS venues also shows that the loss of market share was primarily caused by traders leaving CXE which is where the bulk of the fee experimentation took place. By contrast, BXE actually gained market share suggesting that there is a role for a venue without liquidity rebates and low take fees.

We close by highlighting our contributions to the literature. First, we take intermarket competition between transparent limit order books and alternative venues into account in both our theoretical and empirical analyses of maker-taker fee changes. Given the significant fragmentation of today's equity markets, this is clearly an important consideration. We show empirically that the spillover effects on competing venues are significant. Our evidence is corroborated by recent fee experiments conducted by both the Nasdaq and the TSX which lost market share after reducing liquidity rebates (Appendix 3).

Second, we study a multi-platform reduction in rebates which are only partially subsidized by reductions in take fee, hence leading to an increase in total fees. The previous literature has mainly studied the elimination of a charge for liquidity provision (Lutat, 2010) and increases in the make and take fees (Malinova and Park, 2015). The current policy debate is focused on reducing rather than increasing make-take fees, and our evidence is therefore directly relevant to current proposals considered by the SEC.

Third, we document significant cross-sectional differences in the response to changes in maker-taker fees. Specifically, our evidence suggests that traders in large capitalization stocks are relatively more sensitive to make fees, while traders in small capitalization stocks are more concerned about take fees. We conjecture that the reason for this is that HFTs concentrate their trading in liquid large capitalization stocks, and it is well known that they pursue rebate-capture strategies and engage in voluntary market making activities.

Lastly, we study changes in fees that took place in 2013 (and 2014 and 2015 in Appendix 2) while the previous empirical work on the topic of maker-taker pricing has evaluated this type of pricing based on data from 2008-2010. Given how fast market structure and the ecosystem of traders are changing, it is important to evaluate fee changes in recent years when regulators consider mandating a reduction in liquidity rebates.

Appendix 1: The Dual Market Model

To economize space, we only sketch the solution to the model with intermarket competition. The solution to the benchmark model without a CN can be easily derived by removing from the set of the strategies available to traders the orders posted to the CN, $ST_{MO_{CN}}(1, mid_i)$ and $ST_{LO_{CN}}(1, mid_i)$.

At each period t, a trader uses the information from the state of the book and the CN to rationally compute and compare the payoffs from the available strategies (Table 1). However, to compare the payoffs across these strategies, the trader has to compute the execution probabilities of limit orders, which are uncertain as they depend on the probability of the $t+1$ market order submissions. To overcome this issue, the model is solved by backward induction starting from the last period of the trading game, t_3. At t_3 the execution probabilities of limit orders, $ST_{LO}(1, P_i)$, are equal to zero and the trader can solve problem (6) by choosing between $ST_{MO}(1, P_i^b)$, $ST_{MO_{CN}}(1, mid_i)$, and $ST_{NT}(0)$:

$$max_{ST^*_{\bullet}} \pi^e_{t_3} \left\{ ST_{MO}(1, P_i^b), ST_{MO_{CN}}(1, mid_i),\ ST_{NT}(0) \mid \gamma,\, lob_{t_3} \right\} \tag{6}$$

Table 1 shows that the non-zero traders' payoffs are a function of $\gamma \in (0, 2)$. We can therefore rank (in terms of γ) the payoffs of adjacent optimal strategies and equate them to determine the t_3 equilibrium γ thresholds in the following way:

$$\gamma_{t_3}^{ST^*_n, ST^*_{n-1}} = \left\{ \gamma \in \mathbb{R} \,:\, \pi^e_{t_3} \left(ST^*_{\text{n}} \,|\, lob_{t_3}, cn_{t_3} \right) - \pi^e_{t_3} \left(ST^*_{n-1} \,|\, lob_{t_3}, cn_{t_3} \right) = 0 \right\} \tag{7}$$

By using the γ thresholds together with the cumulative distribution function (CDF) of γ, $F(\bullet)$, we can now derive the probability of each equilibrium order submission strategy, $ST^*_{\bullet}$, conditional on all the possible combinations of the t_3 states of the book and of the CN:

$$Pr[ST^*_{\text{n}} \,|\, lob_{t_3}, cn_{t_3}] = F(\gamma_{t_3}^{ST^*_{n+1}, ST^*_n} \,|\, lob_{t_3}, cn_{t_3}) - F(\gamma_{t_3}^{ST^*_n, ST^*_{n-1}} \,|\, lob_{t_3}, cn_{t_3}) \tag{8}$$

Clearly, the probability to observe a $ST_{MO}(1, P_i^b)$ at t_3 is the execution probability of a $ST_{LO}(1, P_i)$ at t_2, therefore, we can now compute and compare the t_2 payoffs to determine the equilibrium γ thresholds and therefore the equilibrium order submission probabilities conditional on each possible combination of state of the LOB and of the CN at t_2. The t_1 equilibrium order submission strategies can then be recursively obtained, as the t_2 market orders' equilibrium probabilities are the execution probabilities of the limit orders posted at t_1. As an example, consider a case at t_3 with the book that opens empty and with one buy order standing in the CN. This means that as long as the difference between mid_i and B_i^b is greater than the difference in the fees, i.e., $mid_i - B_i^b > TF - mf$, on the sell side $ST_{MOS_{CN}}(1, mid_i)$ will dominate $ST_{MOS}(1, S_i^b)$. The payoffs from the t_3 strategies are:

$$\pi^e_{t_3}(ST_{MOS_{CN}}(1, mid_2) \,|\, lob_{t_3}, cn_{t_3}) = mid_2 - \gamma AV - mf$$
$$\pi^e_{t_3}(ST_{NT}(0) \,|\, lob_{t_3}, cn_{t_3}) = 0 \tag{9}$$
$$\pi^e_{t_3}(ST_{MOB}(1, S_2) \,|\, lob_{t_3}, cn_{t_3}) = \gamma AV - S_2 - TF$$

Hence the t_3 equilibrium strategies are:

$$ST^*_{(\bullet)} = \begin{cases} ST_{MOS_{CN}}(1, mid_2) & \text{if } \gamma \in [0, \frac{mid_2 - mf}{AV}) \\ ST_{NT}(0) & \text{if } \gamma \in [\frac{mid_2 - mf}{AV}, \frac{S_2 + TF}{AV}) \\ ST_{MOB}(1, S_2) & \text{if } \gamma \in (\frac{S_2 + TF}{AV}, 2] \end{cases} \tag{10}$$

and the t_3 equilibrium order submission probabilities are:

$$Pr[ST^*_{(\bullet)} \,|\, lob_{t_3}, cn_{t_3}] = \begin{cases} \int_{\gamma \in \left\{\gamma \,:\, ST^*_{(\bullet)} = ST_{MOS_{CN}}(1, mid_2)\right\}} g(\gamma)\, d\gamma \\ \int_{\gamma \in \left\{\gamma \,:\, ST^*_{(\bullet)} = ST_{NT}(0)\right\}} g(\gamma)\, d\gamma \\ \int_{\gamma \in \left\{\gamma \,:\, ST^*_{(\bullet)} = ST_{MOB}(1, S_2)\right\}} g(\gamma)\, d\gamma \end{cases} \tag{11}$$

where $g(\gamma)$ is the probability density function (PDF) of γ.
Note that $Pr[ST^*_{MOS_{CN}}(1, mid_2) \,|\, lob_{t_3}, cn_{t_3}]$ and $Pr[ST^*_{MOB}(1, S_2) \,|\, lob_{t_3}, cn_{t_3}]$ correspond to the execution probabilities of the previous period (t_2) limit orders respectively posted to the CN and to the LOB, i.e., $ST_{LOB_{CN}}[(1, mid_2) \,|\, lob_{t_2}, cn_{t_2}]$ and $ST_{LOS}[(1, S_2) \,|\, lob_{t_2}, cn_{t_2}]$, which are the dynamic link between periods t_3 and t_2.

Appendix 2: BATS fee changes 2014 and 2015

On April 3, 2014, BATS announced a new pricing model for CXE that was designed specifically to attract traders that routinely supply a large amount of liquidity (effective retroactively as of April 1, 2014). CXE introduced rebate pricing tiers, ranging from 0.15 bps to 0.25 bps for monthly value exceeding £4bn. Compared to the rebate schedule offered by TQ , CXE introduced more tiers, but the increase in the rebate was less aggressive.[29] The take fee remained at 0.30 bps as a default, but an optional Removal Package was also introduced where a broker could pay a fixed £25,000 (€25,000) fee per calendar month in order to enjoy a lower take fee of 0.20 bps. The new pricing scheme applied only to the CXE platform (there were no changes to BXE Lit or BATS two Dark platforms) for UK & Irish stocks (LSE Listed) and French, Dutch, Belgian, and Portuguese stocks (Euronext listed). We use the same stratified methodology described in Section 4.2 to contrsuct our samples and study the 2014 BATS fee changes.

The April 2014 introduction of CXE value tiers for determining the rebate rate combined

[29] The rebates were 0.15 bps for monthly value traded below £1.5bn, .175 between £1.5 and £2bn, 0.20 bps between £2.0 and £3, 0.225 between £2.0 and £3.0bn, and 0.25 bps for value traded above £4bn.

with a Removal Package targeted HFTs and was intended to create a virtuous cycle. The Removal Package would encourage HFTs to route more aggressive orders to CXE to meet the value tiers, and as a reward they would obtain a higher rebate and therefore route also more passive orders to the CXE platform. This would in theory improve market quality, encouraging also other traders to route their aggressive and passive orders to CXE. A rebate increase on its own should result in an improvement in market quality as it encourages liquidity provision, but also a decrease in volume as traders switch from active to passive strategies. However, BATS' hope was that the Removal package would entice traders seeking better liquidity and the high volume traders already on CXE seeking to meet value-tiers would be sufficient to cause volume to instead increase. If successful, the virtuous cycle would also strenghten the positive effect on market quality. So we would expect an improvement in CXE market quality and an increase in CXE market share.

Table A1 Panels A and B report the estimated changes in volume and market quality measures for the 2014 CXE fee change. CXE market shares for LSE and Pan-European stocks decrease, but the change is not statistically significant. Similarly, depth tends to decline but the change is not statistically signifcant but spreads for LSE stocks widen significantly by 3.62% Overall, and by 2.11% for Large stocks. Spreads also widen by a significant 2.04% for Pan-European stocks Overall. In other words, the 2014 CXE fee-change was unsuccessful in terms of generating the desired increase in market share and the associated increase in fee revenue. Moreover, the fee change did not entice rebate seeking HFTs, and hence it did not result in consistently better market quality.

[Insert Table A1 about here]

Evidence suggesting that it was even worse can be seen from examining the effect of the CXE fee change on BXE and TQ. Note that neither BXE nor TQ changed its make-take fees in the event window surrounding April 3, 2014. Table A1 , Panel A shows that BXE market share for LSE stocks increases significantly both Overall and for Large and Small stocks. At the same time, BXE depth increases significantly for Large stocks and spread decreases Overalll. For Pan-European stocks in Panel B, we see similar effects: market share increases significantly Overall and for Large stocks, depth increases significantly for Large stocks and spread decreases Overall. TQ does not gain markets share (it even loses market share and depth for Small stocks) for LSE stocks, but market quality improves significantly for Large stocks and Overall depth increases significantly. For the Pan-European sample, TQ gains market share and market quality improves significantly for Large stocks. Hence, it appears that the April 2014 fee change instead of attracting more volume and improving market quality on CXE resulted in more aggressive orders being routed to BXE and more passive orders particularly in Large stocks being routed to TQ.

On November 24, 2014, BATS announced yet another update to its pricing model, to be effective January 1, 2015, on CXE . The main innovation was to allow a participant's total notional value traded across all BATS Europe's four platforms, dark and lit, to be combined to determine the value traded for the purposes of meeting the new volume tiers on CXE. However, note that the rate at which the new rebates rose with increased value traded is much flatter than before, ranging from a rebate of 0.15 bps to a rebate of 0.225 bps for monthly value traded in excess of £16bn. In addition, CXE take fee tiers were introduced, ranging from 0.30 bps to 0.24 bps for monthly value traded exceeding £16bn. This new pricing model applied to all CXE order books throughout Europe.[30]

The January 2015, CXE fee structure was specifically designed to entice HFTs. The hope was that the take-fee tiers would result in more active orders being routed to CXE, which inturn would ideally entice rebate-seeking HFTs to route even more passive orders to CXE, starting a virtuous cycle. However, the fact that orders executed on any platform counts toward both the value-tiers means that traders will send fewer market orders to CXE and instead remain on BXE to enjoy the lower take fee or stay dark. In other words, fee sensitive HFT traders could essentially separate the order flow and send passive orders to CXE (to capture rebates) and active orders to BXE (which has lower take fees) or to one of the two BATS dark venues. As a result, it is unclear if the take-fee tiers would be sufficient to start a virtuous cycle.

Panela C and D of Table A1 report the estimated changes in market share and market quality measures for CXE. Market share does not change significantly for either universe or subsample. However, depth declines significantly both Overall and for Large stocks for both LSE and Pan-European samples following the fee change. CXE depth falls significantly both Overall and for Large LSE and Large Pan-European stocks. CXE spreads widen significantly for Large LSE stocks Overall and for Large stocks, and also for Large Pan-European stocks Overall. In other words, CXE market quality deteriorates without an increase in market share suggesting that the 2015 fee changes failed to ignite a virtuous cycle for Large stocks. By contrast, while CXE market share did not change significantly, both spreads and depth declined for Small stocks for both universes.

Evidence that aggressie orders migrated to BXE both in search of lower take-fees and to meet CXE value-tiers can be seen in Panels C and D of Table A1. BXE volume increases significantly Overall and for Large stocks regardless of universe. At the same time, BXE market quality for Large stocks improves significantly, depth increases and spreads decline . Hence, the inflow of market orders from CXE also enticed traders to route more limit orders to BXE in spite of the fact that they would receive no rebates. Although there is only evidence of

[30] The rebate (take-fee) tiers were 0.15 bps (0.30 bps) for monthly value traded below £8.0bn, .175 (0.28 bps) between £8.0 and £12bn, 0.20 bps (0.26 bps) between £12.0 and £16.0, 0.225 bps (0.24 bps) for value traded above £16.0bn.

a significant increase in TQ market share for Large Pan-European stocks, TQ depth increases and spreads widen significantly both Overall and for most subsamples by size. This result suggests that limit orders leaving TQ in search of more attractive rebates schedules on CXE.

Appendix 3: Nasdaq and TSX fee experiments

Nasdaq Fee Pilot

To provide initial empirical evidence on the likely effects of imposing a lower cap on access fees, Nasdaq on November 4, 2014, announced a fee pilot experiment which lowered the Nasdaq take fee to $0.0005/share and the liquidity rebate to $0.0004/share for fourteen stocks..[31]

Hatheway (2015) shows that the pilot resulted in a reduction in Nasdaq's time and size at the National Best Bid Offer (NBBO) and also a reduction in Nasdaq's market share. However, there were no significant difference in changes in Nasdaq quote quality between pilot and control stocks. Hatheway concludes that more rebate sensitive traders, such as HFT market makers, left Nasdaq but that other liquidity providers (both market makers and algorithmic traders) replenished some of the lost liquidity.[32]

Based on these results, several market participants advocated that the SEC should require NYSE-ARCA and BATS-Direct Edge to participate in any new access fee pilot to avoid the prisoner dilemma introduced by the fee cap, and also proposed that the new access fee pilot should cover a broader cross-section of stocks.[33]

TSX Maker-Taker Reduction Program

In response to industry concerns about maker-taker pricing, TSX implemented a phased program of reductions to its maker-taker fees. TSX encouraged competing platforms to follow their example with limited success. Only minor changes were undertaken by Aequitas (non-interlisted and ETFs) and Chi-X Canada (ETFs). Hence, no competing market changed its fees for interlisted stocks in June, 2015.

The first phase of the program entailed a TSX reduction of both maker and taker fees for interlisted stocks priced above $1 of 5 bps (to 30/-26) and for ETFs by 7 bps (to 23/-19). For non-interlisted stocks above $1, the TSX take fee was reduced 7 bps (35 to 28) while the make fee was reduced 12 bps (-31 to -19). As a result, the total fee became 4 bps for all segments of the market. At the same time, TSX introduced reductions to the maker-taker fees for its TSX

[31] For information on the Nasdaq Fee Pilot, and access to the Nasdaq reports, please see: http://www.nasdaqomx.com/transactions/trading/access-fee-experiment.

[32] Pearson (2015) commented that the Nasdaq Fee Pilot allowed ITG to achieve higher queue positions on Nasdaq to the benefit of their clients.

[33] For example, Bloomberg and Themis Trading, LLC

Alpha (TSX-A) platform to a take fee of 18 bps and a make fee of 14 bps for all segments, resulting in a total fee of 4 bps.

The TSX impact report for the three months following the 2015 fee changes (June, July, and August) shows that quoted and effective spreads increased significantly (19%) both market-wide (Canadian Best Bid Offer (CBBO)) and for TSX following the fee change. While there was no significant change in CBBO depth overall, both CBBO and TSX depth declined significantly (11% and 18% respectively) for highly liquid, low-priced ($1 to $5) interlisted stocks. There were also changes in market shares associated with the fee changes. TSX-A particularly lost market share relative to TSX, which suggests that rebate sensitive HFTs shifted away from TSX-A which had lower rebates (14 bps) than TSX (19 to 26 bps) following the fee change. The TSX impact report highlights that there were significant macro even during this time period, and that a major market structure event took place in September. Therefore, they recommend caution in terms of extrapolating from these findings.

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Table 1: **Order Submission Strategies**

This Table reports the payoffs of the order submission strategies reported in column 1. In column 2 it reports the payoffs of the Single Market model (SM) and in column 3 the payoffs of the Dual Market model (DM). Market orders posted to the LOB always execute against the the best bid price,$B_i^b = max\{B_i|l_i > 0\}$or the best ask price, $S_i^b = min\{S_i|l_i > 0\}$ of the LOB, where$l_i$is the number of oders (shares) available at the i-th price level of the LOB. Limit orders posted to the LOB execute at the limit price but have uncertain execution, which depends on the probability that a market order arrives with opposite direction, given the state of the book, $lob_t = \{P_i, l_i\}$. Market orders posted to the CN execute at the midquote of the best bid and ask prices of the LOB, i.e., $mid_i = \frac{S_{i,b}+B_{i,b}}{2}$; whereas limit orders posted to the CN execute at the midquote, conditional both on the arrival to the CN of a limit or a market order with opposite direction, and on both the state of the LOB, and the state of the CN, i.e.,$cn_{t.} = \{mid_i, l_i^{cn}\}$, where $l_i^{cn}$is the number of shares posted to the CN.

Strategy (ST)	Payoffs: Single Market (SM)	Payoffs: Dual Market (DM)
Market Order to Sell (MOS)	$B_i^b - \gamma AV - TF$	$B_i^b - \gamma AV - TF$
MarketOrder to Sell in CN (MOS_{CN})		$mid_i - \gamma AV - tf$
Limit Order to Sell in CN (LOS_{CN})		$(mid_i - \gamma AV + mf)\, Pr(mid_i|lob_t, cn_t)$
Limit Order to Sell (LOS)	$(S_i - \gamma AV + MF)\, Pr_t(S_i|lob_t)$	$(S_i - \gamma AV + MF)\, Pr(S_i|lob_t, cn_t)$
No Trade (NT)	0	0
Limit Order to Buy (LOB)	$(\gamma AV - B_i + MF)\, Pr_t(B_i|lob_t)$	$(\gamma AV - B_i + MF)\, Pr(B_i|lob_t, cn_t)$
Limit Order to Buy in CN (LOB_{CN})		$(\gamma AV - mid_i + mf)\, Pr(mid_i|lob_t, cn_t)$
MarketOrder to Buy in CN (MOB_{CN})		$\gamma AV - mid_i - tf$
Market Order to Buy (MOB)	$\gamma AV - S_i^b - TF$	$\gamma AV - S_i^b - TF$

Table 2: Trading Fee Schedules for UK and Irish Listed Stocks

The table reports the trading fee schedules that apply for the LSE-listed stocks during our sample period right before December 31st, 2012 to the period right after January 1st, 2013. The venues that we examine are: BXE-Lit, CXE-Lit, TQ-Lit, LSE-Lit, BXE-Dark, CXE-Dark, TQ-Dark and UBS-Dark. Our study focuses on the fee changes for the BXE-Lit and CXE-Lit markets implemented on January 1st, 2013. No other venue incurred any changes in fees. The fee changes are highlighted in the table.

		Effective December 31, 2012			Effective January 1, 2013		
	Tiers/Order Type	Maker fee (bps)	Taker Fee (bps)	Total Fee (bps)	Maker fee (bps)	Taker Fee (bps)	Total Fee (bps)
A. Transparent MTFs							
BXE-Lit		-0.18	0.28	0.10	0.00	0.15	0.15
CXE-Lit		-0.20	0.30	0.10	-0.15	0.30	0.15
TQ-Lit	< €1.5bn	-0.14	0.30	0.16	-0.14	0.30	0.16
	€1.5 - €2.5bn	-0.24	0.30	0.06	-0.24	0.30	0.06
	> €2.5bn	-0.28	0.30	0.02	-0.28	0.30	0.02
B. Primary/Listing Exchange							
LSE-Lit*	< £2.5bn	0.00	0.45	0.45	0.00	0.45	0.45
	£2.5 - £5.0bn	0.00	0.40	0.40	0.00	0.40	0.40
	£5.0 - £10.0bn	0.00	0.30	0.30	0.00	0.30	0.30
	> £10.0bn	0.00	0.20	0.20	0.00	0.20	0.20
C. Dark Venues							
BXE-Dark		0.15	0.15	0.30	0.15	0.15	0.30
CXE-Dark	Non-IOC Orders	0.15	0.15	0.30	0.15	0.15	0.30
	IOC Orders	0.30	0.30	0.60	0.30	0.30	0.60
TQ-Dark		0.30	0.30	0.60	0.30	0.30	0.60
UBS-Dark		0.10	0.10	0.20	0.10	0.10	0.20

Notes: * LSE enforced a minimum per order charge of £0.10. Furthermore, LSE offered two Liquidity Taker Scheme Packages for Equities: 1) for a monthly fee of £50,000 the taker fee is 0.15 bps; 2) for a monthly fee of £5,000 the taker fee is 0.28 bps. Effective June 3, 2013, the hurdles for these packages were reduced to £40,000 and £4,000 respectively.

Table 3: Descriptive Statistics

This table reports summary statistics for our main variables. Panel A reports statistics for the 2013 Event LSE sample and Panel B reports similar statistics for the 2013 Event Pan-European sample. In particular, the 120 LSE stocks sample is stratified by price and market capitalization, based on daily average numbers for the month of Jan 2012. The 120 European stocks sample is a similar stratified sample from 13 different listed market venues according to their frequency of BATS market venue traded symbols. All variables reported in the table are measured at the stock level for the primary markets only. *Volume* is defined as the daily number of shares (in 000s) at the end-of-day files from Thomson Reuters Tick History (TRTH). *Depth* is defined as the daily average of the intraday quoted depth at the ask-side and the bid of each quote respectively. *Spread* is defined as the time weighted average of the intraday difference between the ask price and the bid price of the quotes. *%Spread* is defined time weighted average of the intraday ask price minus the bid price divided by the midquote. *Volatility* is defined as the difference between the high and low trading prices each trading day (from the end-of-day files from TRTH) divided by the high price of that day. The four measures of market quality are based on daily numbers for each stock in the one-month pre-period (Dec 2012). We also report *market capitalization* in millions of the local currency (GBP and Euro respectively) and *price* levels both measured at the daily level for the month of Jan 2012. In addition to the *overall* samples, for all of our variables we also report summary statistics for the subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles.

Panel A: 2013 Event, LSE Sample

Market Quality Measures		Mean	Median	ST dev	Q1	Q3
Volume (000s)	Large	10,980	3,352	23,692	1,478	7,718
	Small	767	329	1,140	119	910
	Overall	4,457	931	14,560	307	2,854
Depth	Large	11,500	7,082	16,730	4,094	11,080
	Small	6,211	1,922	14,336	867	4,882
	Overall	7,421	3,172	13,899	1,403	7,271
Spread	Large	0.898	0.722	0.812	0.215	1.486
	Small	2.050	0.891	2.748	0.369	2.658
	Overall	1.667	0.889	3.576	0.310	1.717
% Spread	Large	0.092%	0.096%	0.038%	0.060%	0.120%
	Small	0.357%	0.264%	0.330%	0.182%	0.435%
	Overall	0.228%	0.146%	0.276%	0.108%	0.246%
Volatility (High-Low)/High	Large	1.602%	1.402%	0.819%	1.101%	1.899%
	Small	2.068%	1.706%	1.387%	1.207%	2.552%
	Overall	1.886%	1.575%	1.284%	1.163%	2.211%
Market Capitalization (£ Mill)	Large	20,290	8,896	24,684	4,373	25,200
	Small	789	792	169	634	926
	Overall	7,622	1,676	16,835	931	4,289
Price	Large	9.280	5.620	8.633	2.502	14.180
	Small	4.970	2.910	4.994	1.195	5.768
	Overall	6.909	4.115	6.932	2.148	9.705

Panel B: 2013 Event, Pan-European Sample

Market Quality Measures		Mean	Median	ST dev	Q1	Q3
Volume (000s)	Large	9,037	2,586	21,052	816	7,102
	Small	509	233	738	64	605
	Overall	3,791	674	12,893	198	2,351
Depth	Large	9,254	3,804	16,984	1,248	8,367
	Small	1,786	981	2,079	452	2,045
	Overall	5,108	1,851	12,542	681	4,529
Spread	Large	0.171	0.022	0.345	0.012	0.130
	Small	0.741	0.231	1.701	0.041	0.526
	Overall	0.439	0.084	1.122	0.022	0.332
% Spread	Large	0.068%	0.063%	0.030%	0.047%	0.080%
	Small	0.219%	0.180%	0.133%	0.132%	0.246%
	Overall	0.137%	0.108%	0.107%	0.070%	0.164%
Volatility (High-Low)/High	Large	1.577%	1.385%	0.809%	1.068%	1.879%
	Small	2.072%	1.675%	3.312%	1.227%	2.451%
	Overall	1.813%	1.675%	2.056%	1.152%	2.150%
Market Capitalization (€ Mill)	Large	34,310	18,090	52,253	9,226	36,860
	Small	1,055	1,015	348	811	1,286
	Overall	12,870	2,894	33,772	1,296	8,494
Price	Large	38.100	16.200	61.014	6.281	43.230
	Small	12.950	8.322	12.242	3.810	17.640
	Overall	24.520	12.070	40.540	4.227	26.440

Table 4: Model Predictions

The table shows the empirical predictions of the effects of the changes in the two BATS make venues (CXE and BXE) trading fees that took place in January 2013 on measures of market quality (Spread, Depth and Volume). These predictions are derived from our model in Section 3. They are based on the relative change in make and take fees among three market venues: CXE, BXE, and TQ which is the competitive venue. We show separate predictions for the scenario when there is no market competition (Single Market) and under the scenario when there is intermarket competition. The symbols ↓, ↑, and, = represent the following direction of changes: increase, decrease, and no change, respectively.

Market relative to Competitor	Relative Fees			Single Market			Predictions with Intermarket Competition			
	Make/Take	Change	Within Venue	Spread	Depth	Volume	Orderflow	Spread	Depth	Volume
BXE rel to CXE	Make Fee	↓	LO →MO	↑	↓	↑	Outflow	↑	↓	↓
	Take Fee	↓	LO →MO	↑	↓	↑	Inflow	↓	↑	↑
BXE rel to TQ	Make Fee	↓	LO →MO	↑	↓	↑	Outflow	↑	↓	↓
	Take Fee	↓	LO →MO	↑	↓	↑	Inflow	↓	↑	↑
CXE rel to BXE	Make Fee	↑	LO ←MO	↓	↑	↓	Inflow	↓	↑	↑
	Take Fee	↑	LO ←MO	↓	↑	↓	Outflow	↑	↓	↓
CXE rel to TQ	Make Fee	↓	LO →MO	↑	↓	↑	Outflow	↑	↓	↓
	Take Fee	=								
TQ rel to CXE	Make Fee	↑	LO ←MO	↓	↑	↓	Inflow	↓	↑	↑
	Take Fee	=								
TQ rel to BXE	Make Fee	↑	LO ←MO	↓	↑	↓	Inflow	↓	↑	↑
	Take Fee	↑	LO ←MO	↓	↑	↓	Outflow	↑	↓	↓

Table 5: Measures of Market Quality – Time-Series Changes for the 2013 Event

This table reports the changes in market quality measures (Volume, Depth, and Spread) for the 2013 event using a one-month pre- and one-month post-event window. We investigate three market venues: Chi-X (CXE) and BATS (BXE) and Turquoise (TQ). To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, primary exchange and TQ). Our post minus pre (diff) estimation methodology is based on running daily time-series regressions of the mean values of each measure of market quality on a dummy variable *Event* to indicate post-event period. We run regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panel A reports estimated coefficients and t-statistics (in parentheses) for the LSE sample and Panel B reports similar statistics for the Pan-European sample. For all specifications we employ the Newey-West correction for autocorrelation in the error terms using 10 day lags. ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2013 Event for LSE Sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	0.0012	0.0140***	0.0080**	-0.0492***	-0.0097	-0.0241***	0.0374***	-0.0757**	-0.0136
(t-statistic)	(0.79)	(3.51)	(3.53)	(-4.93)	(-0.84)	(-3.20)	(7.57)	(-2.52)	(-0.80)
CXE									
Event	0.0048	-0.0100**	-0.0007	-0.0355**	-0.0068	-0.0165	-0.0013	0.0559***	0.0259***
(t-statistic)	(1.33)	(-2.63)	(-0.15)	(-2.05)	(-0.77)	(-1.98)	(-0.19)	(3.67)	(2.81)
TQ									
Event	0.0388***	-0.0053	0.0219***	0.1494***	-0.079***	0.0369**	-0.0130	-0.0076	0.0051
(t-statistic)	(5.59)	(-0.75)	(3.40)	(4.47)	(-2.68)	(2.50)	(-0.88)	(-0.31)	(0.30)

Panel B: 2013 Event for Pan-European Sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	-0.0011	0.0079***	0.0026***	-0.0142	-0.0246	-0.0070	0.0597***	-0.0424***	0.0165***
(t-statistic)	(-0.88)	(6.14)	(3.56)	(-1.41)	(-1.43)	(-0.69)	(4.86)	(-2.99)	(3.11)
CXE									
Event	0.0013	-0.0037	-0.0009	-0.0062	-0.0067	-0.0178***	-0.0235***	0.0282**	-0.0032
(t-statistic)	(0.29)	(-0.91)	(-0.24)	(-0.72)	(-1.26)	(-3.85)	(-3.64)	(2.12)	(-0.65)
TQ									
Event	0.0085	-0.0008	0.0072	0.0166	-0.0323	0.0177	-0.0314**	-0.0041	-0.0162
(t-statistic)	(1.49)	(-0.12)	(1.57)	(1.01)	(-0.84)	(0.96)	(-2.29)	(-0.27)	(-1.51)

Table 6: Measures of Market Quality – Time-Series Multivariate Regressions of the 2013 Event for the LSE Sample

This table reports the changes in market quality measures (Volume, Depth, and Spread) using time-series multivariate regressions for the 2013 event using a one-month pre- and one-month post-event window for the LSE sample. Following Boehmer Jones and Zhang (2015), we use a regression framework to run daily time-series regressions of the mean values of each measure of market quality on a dummy variable *Event* to indicate post-event period where we also control for market quality in competing venues (using the primary exchange market quality measures) and volatility index VIX (using the FTSE 100 volatility index). To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, primary exchange and TQ). We run regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panel A reports estimated coefficients and t-statistics (in parentheses) for the BXE market, whereas Panels B and C reports similar statistics for the CXE and TQ markets, respectively. For all specifications we employ the Newey-West correction for autocorrelation in the error terms using 10 day lags. ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2013 Event for LSE sample -- Time Series Regression Results for BXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1766***	0.2473***	0.2090***	0.7249***	1.5134***	1.0706***	1.6974***	2.0009***	1.7989***
(t-statistic)	(9.72)	(8.98)	(11.56)	(13.53)	(15.94)	(12.86)	(38.42)	(18.57)	(22.73)
Event	-0.0027***	0.0145***	0.0049**	-0.0531***	0.0147	-0.0225***	0.0297***	-0.0658***	-0.0201
(t-statistic)	(-3.67)	(4.06)	(2.22)	(-6.62)	(1.74)	(-2.97)	(10.05)	(-3.58)	(-1.89)
Primary Market	-0.1811***	-0.2637***	-0.2208***	-0.1825***	-0.4699***	-0.2881***	-0.5538***	-0.89178***	-0.6428***
(t-statistic)	(-7.40)	(-7.54)	(-9.74)	(-7.97)	(-6.30)	(-6.52)	(-15.57)	(-7.59)	(-7.08)
VIX	0.0003	0.0008	0.0003	0.0057***	0.0055	0.0030	-0.0034***	-0.0064	-0.0040
(t-statistic)	(0.99)	(1.69)	(1.20)	(3.92)	(1.11)	(1.05)	(-3.27)	(-1.84)	(-1.33)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.67	0.58	0.63	0.71	0.55	0.48	0.83	0.6	0.48

Panel B: 2013 Event for LSE sample -- Time Series Regression Results for CXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.6095***	0.4676***	0.5145***	2.3467***	1.2921***	1.8839***	0.8184***	0.9655***	0.9975***
(t-statistic)	(39.55)	(23.17)	(27.41)	(35.89)	(17.15)	(22.39)	(18.38)	(13.63)	(18.50)
Event	-0.0081***	-0.0093***	-0.0077***	-0.0553***	0.0039	-0.0161***	0.0001	0.0553***	0.0246**
(t-statistic)	(-4.19)	(-3.76)	(-2.80)	(-8.94)	(0.56)	(-3.22)	(0.02)	(3.83)	(2.63)
Primary Market	-0.5919***	-0.4797***	-0.5061***	-0.5709***	-0.2489***	-0.0032***	-0.0083	-0.0094	-0.1121
(t-statistic)	(-27.94)	(-18.63)	(-21.93)	(-14.57)	(-4.01)	(-11.87)	(-0.20)	(-0.09)	(-1.42)
VIX	0.0008**	0.0010***	0.0013***	-0.0036***	-0.0032	-0.0010	0.0041**	-0.0020	-0.0013
(t-statistic)	(2.16)	(3.30)	(3.85)	(-4.45)	(-0.79)	(-0.45)	(2.38)	(-0.59)	(-0.46)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.91	0.82	0.83	0.85	0.37	0.57	0.08	0.32	0.27

Panel C: 2013 Event for LSE sample -- Time Series Regression Results for TQ

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.2139***	0.2851***	0.2757***	0.9284***	1.1945***	1.0370***	1.4800***	1.0336***	1.2407***
(t-statistic)	(25.19)	(19.54)	(29.62)	(25.29)	(20.48)	(24.34)	(40.79)	(17.36)	(24.08)
Event	0.0109***	-0.0052***	0.0024**	0.1083***	-0.0187***	0.0380***	-0.0300***	0.0105	-0.0037
(t-statistic)	(7.51)	(-3.62)	(2.21)	(20.90)	(-3.97)	(10.16)	(-11.85)	(1.40)	(-0.72)
Primary Market	-0.2270***	-0.2567***	-0.2743***	-0.2466***	-0.2812***	-0.2431***	-0.4323***	-0.0988	-0.2881***
(t-statistic)	(-19.73)	(-14.60)	(-22.51)	(-9.98)	(-7.92)	(-10.49)	(-11.85)	(-1.82)	(-5.70)
VIX	-0.0011***	-0.0018***	-0.0016***	-0.0021	-0.0023	-0.0020**	-0.0008	0.0084***	0.0045***
(t-statistic)	(-3.95)	(-4.01)	(-6.45)	(-1.43)	(-1.23)	(-2.01)	(-0.70)	(3.82)	(3.78)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.90	0.59	0.78	0.93	0.69	0.75	0.66	0.08	0.28

Table 7: Measures of Market Quality – Panel Regressions of the 2013 Event for the LSE Sample

This table reports the changes in market quality measures (Volume, Depth, and Spread) using panel regressions for the 2013 event using a one-month pre- and one-month post-event window for the LSE sample. Following Boehmer Jones and Zhang (2015), we use a regression framework to run panel regressions of each stocks daily values of each market quality measure on a dummy variable *Event* to indicate post-event period where we also control for market quality in competing venues (using the primary exchange market quality measures) and volatility index VIX (using the FTSE 100 volatility index). To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, primary exchange and TQ). We run panel regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panel A reports estimated coefficients and t-statistics (in parentheses) for the BXE market, whereas Panels B and C reports similar statistics for the CXE and TQ markets, respectively. For all specifications we account for stock fixed effects and clustered standard errors by date (time clusters). ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2013 Event for LSE sample -- Panel Regression Results for BXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1792***	0.21512***	0.2021***	0.7459***	1.1525***	0.9086***	1.6128***	1.8823***	1.5819***
(t-statistic)	(23.26)	(19.98)	(28.15)	(25.03)	(18.62)	(23.02)	(79.16)	(30.19)	(48.35)
Event	-0.0028***	0.0145***	0.0050***	-0.0539***	0.0076	-0.0223***	0.0303***	-0.0731***	-0.0209**
(t-statistic)	(-3.09)	(6.45)	(3.71)	(-9.25)	(0.92)	(-4.20)	(8.56)	(-4.34)	(-2.31)
Primary Market	-0.1850***	-0.2819***	-0.2333***	-0.2053***	-0.3362***	-0.2855***	-0.5175***	-0.4498***	-0.4357***
(t-statistic)	(-24.39)	(-24.33)	(-27.46)	(-28.41)	(-19.71)	(-31.17)	(-38.83)	(-13.92)	(-28.15)
VIX	0.0003	0.0008	0.0004	0.0055***	0.0035	0.0029	-0.0033***	-0.0099**	-0.0057**
(t-statistic)	(0.62)	(1.27)	(0.87)	(2.84)	(0.78)	(1.05)	(-3.14)	(-2.43)	(-2.42)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.65	0.76	0.70	0.74	0.68	0.80	0.85	0.66	0.73

Panel B: 2013 Event for LSE sample -- Panel Regression Results for CXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.6267***	0.4694***	0.5425***	2.3152***	1.5935***	2.0420***	1.0280***	0.9356***	1.139***
(t-statistic)	(82.06)	(55.07)	(72.76)	(81.98)	(29.92)	(52.83)	(41.74)	(22.30)	(49.03)
Event	-0.0088***	-0.0093***	-0.0072***	-0.0544***	0.0098	-0.0160***	-0.0016	0.0596***	0.0251***
(t-statistic)	(-6.76)	(-5.69)	(-5.19)	(-8.97)	(1.35)	(-3.11)	(-0.37)	(4.76)	(3.62)
Primary Market	-0.6192***	-0.4124***	-0.4865***	-0.5467***	-0.3587***	-0.4217***	-0.1662***	-0.2707***	-0.2486***
(t-statistic)	(-78.61)	(-35.26)	(-53.05)	(-58.83)	(-22.96)	(-45.56)	(-9.86)	(-10.14)	(-20.51)
VIX	0.0007	0.0010***	0.0013***	-0.0034**	-0.0016	-0.0014	0.0039***	0.0000	0.0010
(t-statistic)	(1.75)	(2.97)	(4.22)	(-2.31)	(-0.42)	(-0.62)	(2.85)	(0.01)	(0.57)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.86	0.90	0.93	0.82	0.74	0.87	0.74	0.63	0.67

Panel C: 2013 Event for LSE sample -- Panel Regression Results for TQ

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1941***	0.3155***	0.2554***	0.9389***	1.2541***	1.0494***	1.3600***	1.1821***	1.2810***
(t-statistic)	(34.47)	(31.32)	(36.91)	(36.95)	(39.63)	(38.17)	(52.19)	(27.98)	(64.59)
Event	0.0116***	-0.0052***	0.0022**	0.1083***	-0.0174***	0.0383***	-0.0287***	0.0135	-0.0043
(t-statistic)	(10.88)	(-3.38)	(2.04)	(20.17)	(-3.60)	(9.57)	(-7.59)	(1.45)	(-0.86)
Primary Market	-0.1958***	-0.3057***	-0.2803***	-0.2479***	-0.3051***	-0.2927***	-0.3166***	-0.2795***	-0.3157***
(t-statistic)	(-32.99)	(-28.00)	(-38.14)	(-30.62)	(-30.26)	(-36.99)	(-20.96)	(-16.65)	(-41.66)
VIX	-0.0010***	-0.0018***	-0.0016***	-0.0021	-0.0019	-0.0016	-0.0006	0.0099***	0.0046***
(t-statistic)	(-3.44)	(-3.11)	(-4.27)	(-1.16)	(-1.21)	(-0.95)	(-0.50)	(3.96)	(3.48)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.72	0.77	0.72	0.84	0.73	0.75	0.73	0.58	0.66

Table 8: Measures of Market Quality – Time-Series Multivariate Regressions of the 2013 Event for the Pan-European Sample

This table reports the changes in market quality measures (Volume, Depth, and Spread) using time-series multivariate regressions for the 2013 event using a one-month pre- and one-month post-event window for the Pan-European sample. Following Boehmer Jones and Zhang (2015), we use a regression framework to run daily time-series regressions of the mean values of each measure of market quality on a dummy variable *Event* to indicate post-event period where we also control for market quality in competing venues (using the primary exchange market quality measures) and volatility index VIX (using the FTSE 100 volatility index). To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, primary exchange and TQ). We run regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panel A reports estimated coefficients and t-statistics (in parentheses) for the BXE market, whereas Panels B and C reports similar statistics for the CXE and TQ markets, respectively. For all specifications we employ the Newey-West correction for autocorrelation in the error terms using 10 day lags. ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2013 Event for Pan-European sample -- Time Series Regression Results for BXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1825***	0.1587***	0.1588***	1.4419***	1.4339***	1.4302***	1.5858***	1.8113***	1.7509***
(t-statistic)	(17.98)	(6.30)	(11.64)	(7.29)	(13.72)	(15.99)	(4.87)	(11.33)	(17.46)
Event	-0.0018***	0.0077***	0.0020**	-0.0136**	-0.0097	-0.0053	0.0567***	-0.0382**	0.0151***
(t-statistic)	(-5.40)	(4.40)	(2.15)	(-2.40)	(-1.50)	(-0.93)	(6.35)	(-2.59)	(3.93)
Primary Market	-0.1867***	-0.1560***	-0.1587***	-0.4647***	-0.4338***	-0.4561***	-0.3685	-0.7240***	-0.6074***
(t-statistic)	(-14.49)	(-5.61)	(-9.85)	(-5.25)	(-6.24)	(-9.97)	(-0.82)	(-2.64)	(-4.47)
VIX	0.0002	0.0003	0.0003	-0.0007	0.0030	0.0017	-0.0053	-0.0052	-0.0030***
(t-statistic)	(0.91)	(0.79)	(1.95)	(-0.37)	(0.73)	(0.87)	(-1.22)	(-1.36)	(-2.83)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.70	0.52	0.57	0.49	0.64	0.59	0.55	0.31	0.36

Panel B: 2013 Event for Pan-European sample -- Time Series RegressionResults for CXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.6100***	0.5471***	0.5930***	1.4793***	1.1455***	1.3143***	0.4897***	0.9119***	0.6139***
(t-statistic)	(53.10)	(21.71)	(30.92)	(9.49)	(17.53)	(16.67)	(6.50)	(6.35)	(6.17)
Event	-0.0010	-0.0042***	-0.0031	-0.0034	-0.0008	-0.0160***	-0.0211***	0.0278**	-0.0033
(t-statistic)	(-0.92)	(-2.69)	(-1.87)	(-0.68)	(-0.12)	(-5.27)	(-7.34)	(2.07)	(-0.84)
Primary Market	-0.6075***	-0.5615***	-0.5975***	-0.2924***	-0.1799***	-0.2278***	0.4305***	0.0248	0.3715**
(t-statistic)	(-36.17)	(-16.81)	(-21.14)	(-3.92)	(-6.68)	(-5.81)	(4.15)	(0.09)	(2.55)
VIX	0.0009***	0.0012***	0.0010***	0.0060***	0.0004	0.0034***	0.0030	-0.0006	-0.0009
(t-statistic)	(3.85)	(4.07)	(3.62)	(2.73)	(0.12)	(4.71)	(1.53)	(-0.18)	(-0.57)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.92	0.79	0.85	0.38	0.27	0.51	0.55	0.14	0.15

Panel C: 2013 Event for Pan-European sample -- Time Series Regression Results for TQ

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.2075***	0.2942***	0.2402***	1.0788***	1.4206***	1.1973***	1.9166***	1.3070***	1.6151***
(t-statistic)	(20.85)	(26.05)	(12.62)	(8.59)	(12.16)	(13.25)	(5.26)	(11.80)	(9.42)
Event	0.0028***	-0.0035***	0.0012	0.0170**	0.0105	0.0210***	-0.0340***	0.0110	-0.0107**
(t-statistic)	(2.61)	(-3.11)	(1.23)	(2.17)	(1.68)	(4.61)	(-3.95)	(1.33)	(-2.77)
Primary Market	-0.2058***	-0.2825***	-0.2355***	-0.2429***	-0.3863***	-0.3006***	-1.0465**	-0.3475**	-0.7434***
(t-statistic)	(-12.37)	(-18.52)	(-8.16)	(-4.24)	(-5.24)	(-5.76)	(-2.03)	(-2.28)	(-3.05)
VIX	-0.0011***	-0.0014***	-0.0012***	-0.0053**	-0.0033**	-0.0035**	0.0018	0.0060	0.0034**
(t-statistic)	(-4.63)	(-4.04)	(-5.94)	(-2.28)	(-2.15)	(-2.57)	(0.41)	(1.85)	(2.09)
Nobs	41	41	41	41	41	41	41	41	41
Adj R^2	0.61	0.54	0.56	0.32	0.56	0.60	0.45	0.02	0.27

Table 9: Measures of Market Quality – Panel Regressions of the 2013 Event for the Pan-European Sample

This table reports the changes in market quality measures (Volume, Depth, and Spread) using panel regressions for the 2013 event using a one-month pre- and one-month post-event window for the Pan-European sample. Following Boehmer Jones and Zhang (2015), we use a regression framework to run panel regressions of each stocks daily values of each market quality measure on a dummy variable *Event* to indicate post-event period where we also control for market quality in competing venues (using the primary exchange market quality measures) and volatility index VIX (using the FTSE 100 volatility index). To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, primary exchange and TQ). We run panel regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panel A reports estimated coefficients and t-statistics (in parentheses) for the BXE market, whereas Panels B and C reports similar statistics for the CXE and TQ markets, respectively. For all specifications we account for stock fixed effects and clustered standard errors by date (time clusters). ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2013 Event for Pan-European sample -- Panel Regression Results for BXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1955***	0.2208***	0.1983***	1.2133***	1.3171***	1.1162***	1.9197***	1.7322***	1.7536***
(t-statistic)	(31.28)	(15.24)	(29.45)	(18.28)	(23.14)	(35.51)	(10.07)	(31.31)	(26.19)
Event	-0.0099***	0.0076***	0.0018**	-0.0134**	-0.0121	-0.0054	0.0558***	-0.0398***	0.0166***
(t-statistic)	(-2.66)	(5.27)	(2.36)	(-2.24)	(-1.63)	(-1.18)	(5.93)	(-3.51)	(2.84)
Primary Market	-0.1986***	-0.2424***	-0.2066***	-0.3714***	-0.3330***	-0.3376***	-0.8934***	-0.4930***	-0.6857***
(t-statistic)	(-32.89)	(-16.53)	(-26.61)	(-14.67)	(-20.59)	(-29.26)	(-4.11)	(-9.30)	(-10.04)
VIX	0.0001	0.0002	0.0002	-0.0003	0.0037	0.0014	-0.0020	-0.0058	-0.0031
(t-statistic)	(0.42)	(0.50)	(0.79)	(-0.14)	(0.94)	(0.82)	(-0.55)	(-1.67)	(-1.55)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.81	0.68	0.74	0.72	0.72	0.79	0.75	0.72	0.76

Panel B: 2013 Event for Pan-European sample -- Panel Regression Results for CXE

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.6131***	0.4907***	0.5632***	1.5609***	1.1295***	1.5157***	0.6397***	0.9680***	0.9696***
(t-statistic)	(67.39)	(39.11)	(64.93)	(33.47)	(19.93)	(47.10)	(8.47)	(22.97)	(20.34)
Event	-0.0010	-0.0042***	-0.0026**	-0.0032	0.0003	-0.0161***	-0.0212***	0.0316***	-0.0025
(t-statistic)	(-0.99)	(-2.71)	(-2.22)	(-0.53)	(0.06)	(-4.04)	(-4.63)	(3.46)	(-0.51)
Primary Market	-0.6115***	-0.4726***	-0.5391***	-0.3122***	-0.2145***	-0.2706***	0.2657***	-0.2950***	-0.0539
(t-statistic)	(-58.16)	(-46.60)	(-70.81)	(-18.44)	(-13.29)	(-24.18)	(-3.48)	(-5.15)	(-1.07)
VIX	0.0009**	0.0012**	0.0011**	0.0060***	0.0001	0.0030**	0.0040	0.0002	0.0015
(t-statistic)	(2.44)	(2.50)	(2.56)	(2.77)	(0.05)	(2.53)	(1.82)	(0.06)	(0.91)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.95	0.89	0.94	0.88	0.55	0.79	0.55	0.69	0.65

Panel C: 2013 Event for Pan-European sample -- Panel Regression Results for TQ

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	0.1913***	0.2885***	0.2386***	1.2259***	1.5534***	1.3681***	1.4449***	1.2252***	1.2772***
(t-statistic)	(28.90)	(21.87)	(33.40)	(26.70)	(34.20)	(59.10)	(6.73)	(28.53)	(16.16)
Event	0.0029***	-0.0034**	0.0009	0.0165**	0.0118	0.0215***	-0.0315***	0.0089	-0.0098
(t-statistic)	(3.01)	(-2.52)	(0.88)	(2.65)	(1.66)	(4.92)	(-3.36)	(0.87)	(-1.47)
Primary Market	-0.1899***	-0.2850***	-0.2543***	-0.3164***	-0.4525***	-0.3918***	-0.3789	-0.2139***	-0.2670***
(t-statistic)	(-23.42)	(-22.32)	(-35.00)	(-17.98)	(-31.71)	(-47.61)	(-1.49)	(-4.26)	(-2.94)
VIX	-0.0011***	-0.0014***	-0.0013***	-0.0057**	-0.0039	-0.0044***	-0.0020	0.0056	0.0019
(t-statistic)	(-3.59)	(-4.36)	(-4.48)	(-2.55)	(-1.56)	(-2.90)	(-0.58)	(1.83)	(0.91)
Nobs	1640	1640	4920	1640	1640	4920	1640	1640	4920
Adj R^2	0.80	0.78	0.77	0.70	0.63	0.71	0.59	0.74	0.69

Figure 1: **Effects of Increase in Make and Take Fees**

These figures reports results for payoffs and γ-thresholds from simulations on changes in make and take fees at t_1. Panel A refers to the Single Market framework (SM) and Panel B to the Dual Market (DM). In both frameworks traders have a personal evaluation of the asset which is truncated Normal, $\gamma \sim N(\mu, \sigma^2)$ and lies in the domain $\gamma \in (0, 2)$, $-\infty \leq 0 < 2 \leq \infty$. In the SM traders can choose between market/limit orders to sell (MOS or LOS) or market/limit orders to buy (MOB or LOB); in the DM traders can also choose a limit order to buy or to sell in the crossing network (LOB_CN or LOB_CN). Figure 1A shows the piecewise linear funtion (red dotted line) of the optimal traders' strategies at $t_1$for the SM and no fees. On the vertical axes the figure reports the payoffs from the traders' optimal strategy associated with any possible value of γ in its domain. For example, if a trader comes to the market with an extreme value of gamma he will choose a MO, whereas if he has a gamma next to 1 he will choose a LO, either to sell or to buy. The vertical red lines indicate the gamma-threshold associated with changes in optimal strategies. Figure 2A reports two piecewise functions, one from the benchmark case with no fees (Figure1A) and one (solid gray line) for the case with a make fee equal to MF=0.9τ and no change in the take fee. Figure 3A reports the piecewise functions for both the benchmark case with no fees and the case with a take fee equal to TF=0.9τ. Figures 1B-3B reports the same simulation results for the DM. For our numerical simulations we set the parameters as AV=μ=$\sigma^2 = 1$.

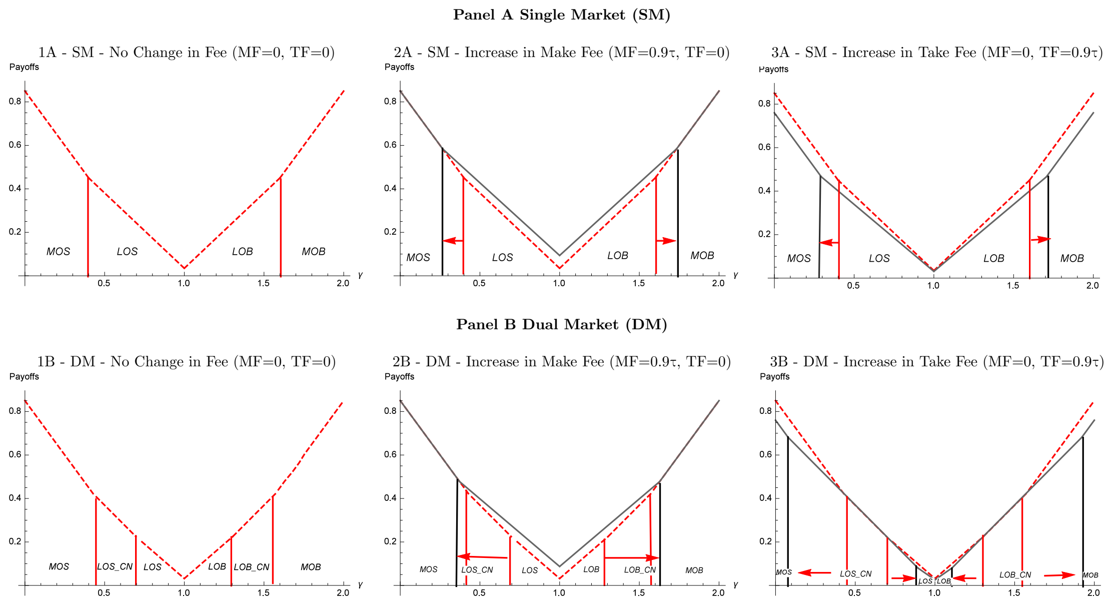


Figure 2: **Order Submission Strategies and Market Quality: Change in the Make Fee**

These figures reports on the vertical axes the average of the equilibrium order submission probabilities of order flows (LO, MO, NT, LO_{CN} and MO_{CN}) and the average of the derived measures of market quality (Spread and Depth) over periods t_1 and t_2. Panel A reports results for the SM and Panel B for the DM. The model is solved holding all the parameters constant at AV=μ=$\sigma^2 = 1$ and changing the make fee from $0.0\,bps$ to $0,009\,bps$ in steps of $0,001\,bps$ (horizontal axis). The take fee is held constant at $0.0\,bps$. In both frameworks traders have a personal evaluation of the asset which is truncated Normal,$\gamma \sim N(\mu, \sigma^2)$ and lies in the domain $\gamma \in (0, 2)$, $-\infty \leq 0 < 2 \leq \infty$.

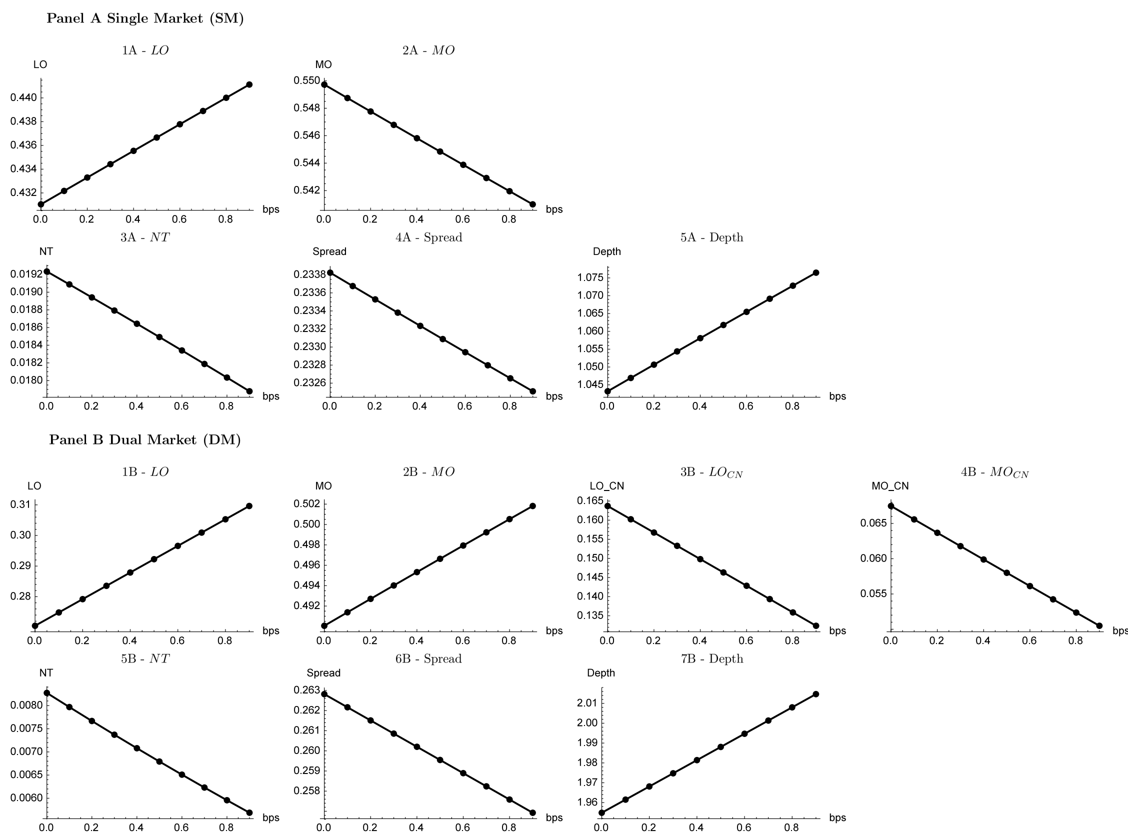


Figure 3: **Order Submission Strategirs and Market Quality: Change in the Take Fee**

These figures reports on the vertical axes the average of the equilibrium order submission probabilities of order flows (LO, MO, NT, LO_{CN} and MO_{CN}) and the average of the derived measures of market quality (Spread and Depth) over periods t_1 and t_2. Panel A reports results for the SM and Panel B for the DM. The model is solved holding all the parameters constant at AV=μ=$\sigma^2 = 1$ and changing the take fee from $0.0\,bps$ to $0,009\,bps$ in steps of $0,001\,bps$ (horizontal axis). The make fee is held constant at $0.0\,bps$. In both frameworks traders have a personal evaluation of the asset which is truncated Normal,$\gamma \sim N(\mu, \sigma^2)$ and lies in the domain $\gamma \in (0,2)$, $-\infty \leq 0 < 2 \leq \infty$.

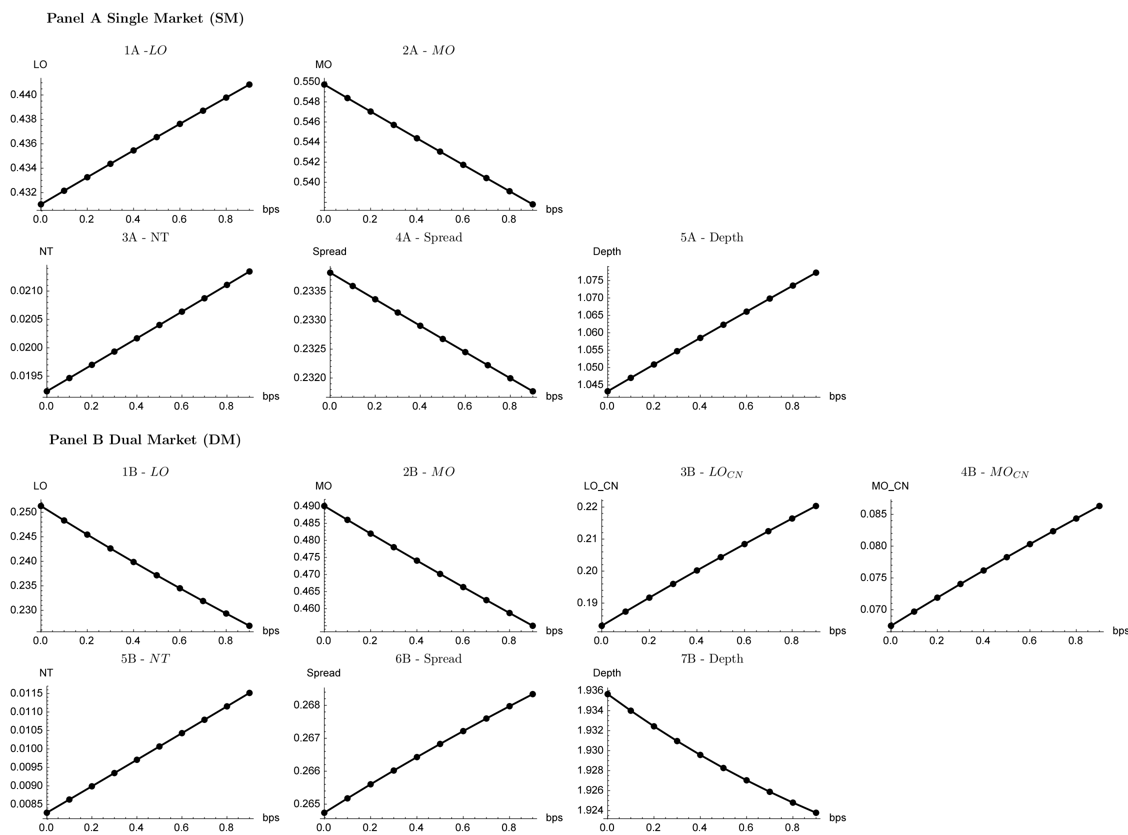
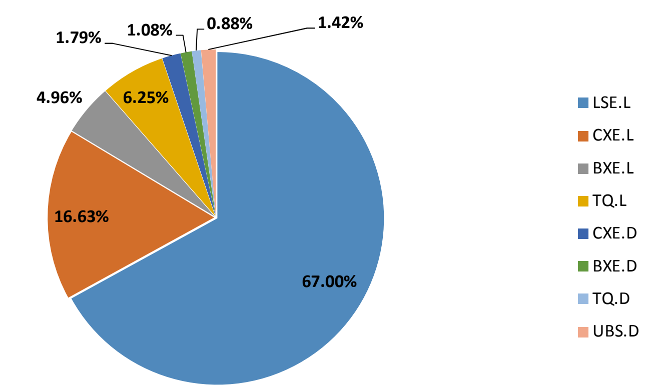


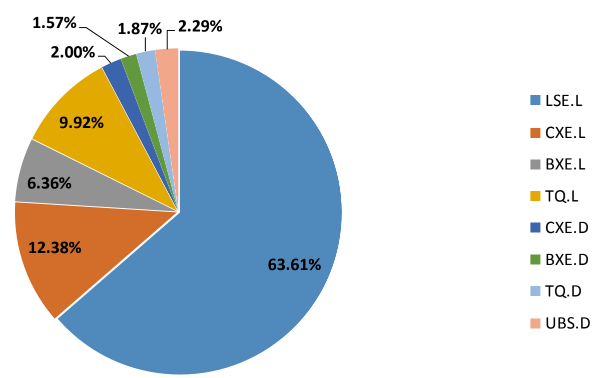
Figure 4: Market Share Pie-Charts of both the LSE and Pan-European samples in 2012 (Pre-Event) and 2015 (Post-Event)

The pie-chart figures show average daily market share of each market venue used in the analysis for the LSE and Pan-European samples in the pre-period of the 2013 event (November and December 2012) and in the period after the 2015 event (February and March 2015). In particular, we look at both lit markets (LSE.L, CXE.L, BXE.L, and TQ.L) and dark pool venues (CXE.D, BXE.D, TQ.D, and UBS.D) market share. We exclude other trading venues and off-market trades for the pie-charts. Market share data were collected from Fidessa (Fragulator).

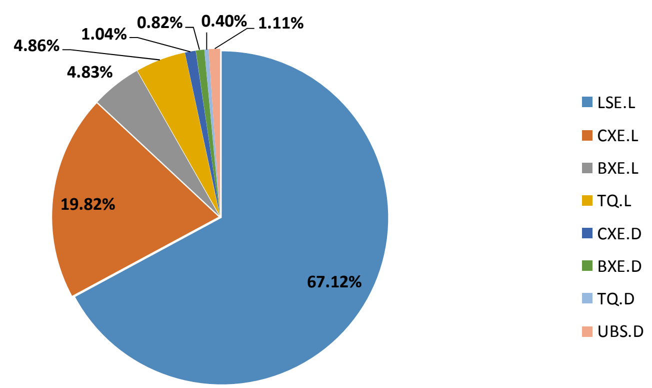
2013 Event Pre-Period (November and December 2012) | **2015 Event Post-Period (February and March 2015)**

Panel A: LSE Sample





Panel B: Pan-European Sample



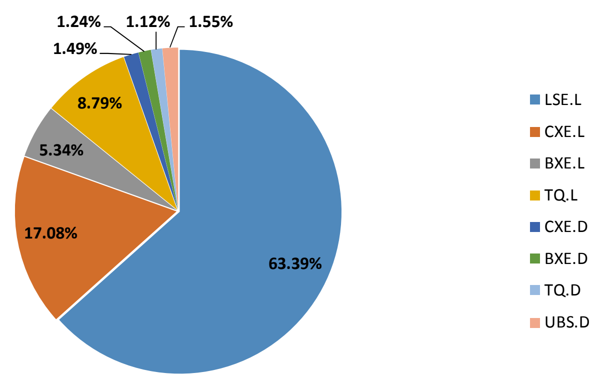
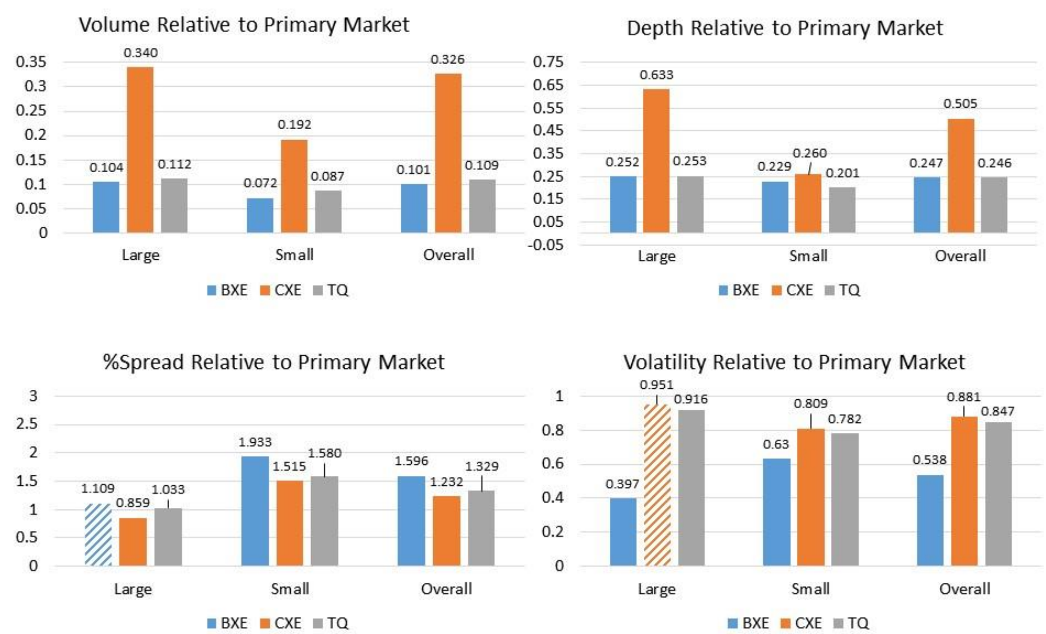


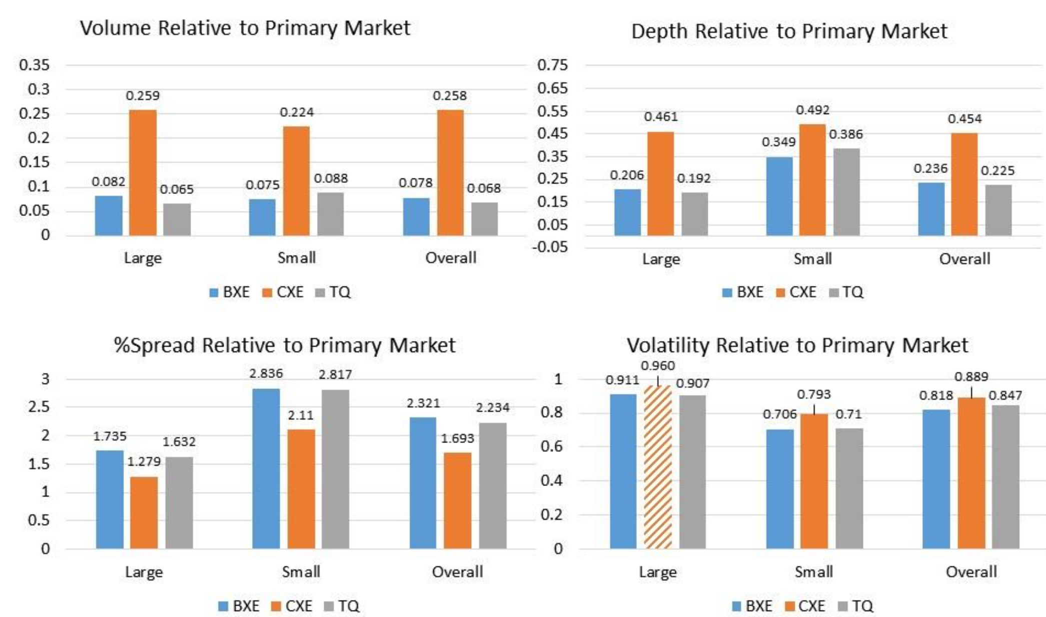
Figure 5: Market Quality Measures across Markets

The figures show average daily market quality measures (Volume, Depth, %Spread, and Volatility) of the three market venues (BXE, CXE, TQ) relative to the Primary market in the pre-period (Nov/Dec 2012) of the 2013 Event. Panel A reports results for the LSE sample and Panel B for the Pan-European sample. The figures depict relative market quality measures for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Filled bars indicate that a venue mean is significantly different from the primary market mean based on a simple differences-in-group-means test.

Panel A: LSE Stocks November-December 2012



Panel B: Pan-European Stocks November – December 2012



Appendix Table 1: Measures of Market Quality – Time-Series Changes for the 2014 and 2015 Events

This table reports the changes in market quality measures (Volume, Depth, and Spread) for the 2014 and the 2015 events using a one-month pre- and one-month post-event window. We investigate three market venues: CXE, BXE and TQ. To deal with cross-sectional heterogeneity in each of the three market quality measures we standardize them as follows: we divide venue-stock-day volume by total daily volume, depth by average depth, and quoted spread by average quoted spread where total and averages are taken over all four venues (BXE, CXE, Primary exchange and TQ). Our post minus pre (diff) estimation methodology is based on running daily time-series regressions of the mean values of each measure of market quality on a dummy variable *Event* to indicate post-event period. We run regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. Panels A and B report estimated coefficients and t-statistics (in parentheses) of the LSE and the Pan-European sample, respectively, for the 2014 event. Panels C and D report similar statistics for the 2015 event. For all specifications we employ the Newey-West correction for autocorrelation in the error terms using 10 day lags. ** and *** indicate significance at the 5% and 1% levels, respectively.

Panel A: 2014 Event for LSE sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	0.0068***	0.0090***	0.0078***	0.0179**	-0.0052	-0.0154	-0.0217	-0.0739	-0.0497**
(t-statistic)	(6.86)	(4.95)	(7.97)	(2.33)	(-0.11)	(-0.83)	(-1.57)	(-1.45)	(-2.18)
CXE									
Event	-0.0063	-0.0069***	-0.0069**	-0.0322	0.0144	-0.0063	0.0211***	0.0510***	0.0362***
(t-statistic)	(-0.97)	(-3.50)	(-2.00)	(-1.83)	(1.49)	(-1.22)	(4.99)	(2.80)	(5.02)
TQ									
Event	0.0133	-0.0194***	-0.0023	0.1558***	-0.0570**	0.0215***	-0.0316***	0.0231	0.0076
(t-statistic)	(1.04)	(-2.61)	(-0.22)	(16.30)	(-2.59)	(2.85)	(-8.84)	(1.03)	(0.70)

Panel B: 2014 Event for Pan-European sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	0.0030***	0.0074***	0.0047***	0.0279***	-0.0276	-0.0074	0.0022	-0.0555	-0.0384***
(t-statistic)	(3.08)	(6.01)	(4.58)	(2.61)	(-1.22)	(-1.00)	(0.12)	(-1.68)	(-2.78)
CXE									
Event	0.0037	-0.0018	-0.0016	-0.0061	0.0279**	0.0043	0.0041	0.0448***	0.0204***
(t-statistic)	(1.01)	(-0.59)	(-0.42)	(-0.56)	(2.50)	(1.55)	(0.59)	(4.39)	(3.84)
TQ									
Event	0.0347***	-0.0021	0.0072	0.1500***	0.0080	0.0466***	-0.0464***	-0.0095	-0.0182***
(t-statistic)	(4.90)	(-0.21)	(0.80)	(8.55)	(0.36)	(8.63)	(-5.63)	(-1.12)	(-4.49)

Panel C: 2015 Event for LSE sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	0.0292***	0.0013	0.0119***	0.1584***	-0.0763***	0.0278	-0.2672***	-0.0709***	-0.1198***
(t-statistic)	(15.89)	(0.66)	(10.28)	(9.29)	(-2.60)	(1.62)	(-5.20)	(-3.11)	(-4.96)
CXE									
Event	0.0020	-0.0014	-0.0009	-0.0707***	-0.1608***	-0.1043***	0.0838***	-0.0562***	0.0020
(t-statistic)	(0.64)	(-0.83)	(-0.39)	(-6.68)	(-5.88)	(-7.59)	(7.55)	(-3.94)	(0.23)
TQ									
Event	0.0130	0.0011	0.0024	0.0475	0.8243***	0.4720***	0.0698***	0.1671***	0.1157***
(t-statistic)	(1.31)	(0.24)	(0.53)	(0.52)	(4.37)	(3.83)	(3.60)	(3.49)	(5.07)

Panel D: 2015 Event for Pan-European sample -- Time Series (Post Minus Pre) Differences

	Volume/Total Volume			Depth/Average(Depth)			Spread/Average(Spread)		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE									
Event	0.0239***	0.0011	0.0133***	0.1513***	-0.0518***	0.0595***	-0.1993***	-0.0149	-0.1014***
(t-statistic)	(14.99)	(0.53)	(10.56)	(22.60)	(-2.91)	(6.51)	(-15.42)	(-0.81)	(-8.47)
CXE									
Event	-0.0024	0.0033	0.0022	-0.0761***	-0.0577***	-0.0569***	0.0770***	-0.0082	0.0313***
(t-statistic)	(-0.43)	(1.09)	(0.73)	(-7.05)	(-4.61)	(-5.25)	(13.08)	(-0.97)	(7.40)
TQ									
Event	0.0270**	-0.0079	0.0113	0.0835**	0.1562**	0.0852***	0.0164	0.0565**	0.0395**
(t-statistic)	(2.30)	(-1.09)	(1.43)	(2.51)	(2.36)	(2.72)	(0.71)	(2.05)	(2.04)