Trading Fees and Intermarket Competition

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Abstract

We study the 2013 changes in maker-taker pricing fees implemented by BATS on its two European venues, CXE and BXE. The CXE rebate reduction deteriorates market quality and market share, whereas the BXE rebate removal and take-fee reduction improve them. We derive a model of two competing limit order books, in which large (small) stocks are characterized by investors with higher (lower) propensity to supply liquidity and by greater (lower) trading activity. Consistent with our model, we show that traders in large stocks are more reactive to rebate reductions while traders in small stocks are more reactive to take-fee reductions.

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1. Introduction

In today's fragmented equity trading environment, trading venues use trading fees to compete for order flow. Most venues operate limit order books, and rely on endogenous provision of liquidity, therefore many of them subsidize liquidity supply by offering a rebate (a negative make fee) to traders submitting limit orders. However, trading 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 regulators. Maker-taker pricing is an important competitive tool for trading venues in today's fragmented markets, and may benefit investors to the extent that it allows intra-tick trading, thus reducing the trading frictions caused by the fact that prices are discrete. 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]

Resolving this debate requires a fundamental understanding of the effects that maker-taker pricing has on market quality and on the distribution of order flow across venues. To identify these effects absent a randomized control trial or natural experiment, we rely on venue-specific changes in maker-taker pricing as the treatment, and compare changes in market quality on, and market share of, treated and competing venues in the same market, to changes in the same measures for a control sample from a different market. Specifically, we investigate the impact of fee changes on the trading behavior of investors in a multi-venue framework. We study the January 2013 change to maker-taker pricing implemented by BATS Europe (BATS) in its European venues, BXE and CXE.[3] BATS eliminated the rebate on liquidity supply and reduced the positive charge on liquidity demand on BXE, and reduced the rebate on liquidity supply on CXE.[4] Meanwhile, the maker-taker pricing fees charged by its main competitor, Turquoise (TQ), remained unchanged. We examine the effects of these fee changes on displayed liquidity (market quality) and market share using a difference-in-difference approach, drawing a sample from the Australian stock exchange to control for global changes in liquidity.

To derive empirical predictions, we develop a model of two identical limit order books with

[1]According to the OICV-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 necessarily 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 paying a fee and the taker of liquidity 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]BATS Europe is a subsidiary of BATS Global Markets, which in turn was acquired by CBOE Holdings in March, 2017.

[4]Note that consistent with Chao, Yao, and Ye (2019), traders' heterogeneity leads to multiple fee structures set by BATS for its trading platforms.

discrete prices - i.e., governed by a tick size - that compete for the provision of liquidity. Our model extends the existing literature by providing analytical solution to a model with two competing standard limit order books, discrete prices and trading fees. As predicted by the model, we document significant changes in market shares and displayed liquidity following the fee changes, both for BATS' venues and for Turquoise. Moreover, we discover significant cross-sectional differences in the response to fee changes.

Maker-taker pricing has enabled new entrants to compete effectively with incumbent exchanges, potentially leading to narrower quoted spreads, but the practice has been also criticized. Angel, Harris, and Spatt (2015) argue that maker-taker pricing obfuscates true spreads, that it distorts order routing decisions, and that it hurts both internalizing dealers and venues that do not use maker-taker pricing.[5] 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. (2015) recommend that the SEC either requires 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 (2018) 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 (2012) 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, exchanges and the SEC have also weighed in on the maker-taker pricing debate. Some argue that the maker-taker pricing contributes to market complexity, and that the SEC should either eliminate maker-taker pricing or at least lower the cap on access fees. Others claim markets are functioning well and that no changes to fee caps are needed.

In March 2018, the SEC proposed a Transaction Fee Pilot for NMS stocks (Rule 610T) with the goal to "facilitate an informed, data-driven discussion about transaction fees and rebates and their impact on order routing behavior, execution quality and market quality in

[5] This concern has been validated using options market data, Battalio, Corwin, and Jennings (2016) 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 (2013) also show that high frequency traders (HFT) market makers pass through some of the rebates to active traders.

general" according to SEC Chairman Jay Clayton.[7] Rule 610T would create two test groups of stocks: one with a new lower cap of $0.0010 on positive make and take fees (but no cap on rebates); and another that prohibits rebates but keeps the current fee cap of $0.0030. The remaining stocks would be control stocks and the current fee cap of $0.0030 would apply and there would be no restrictions on rebates. Importantly, only exchanges would be subject to the rule, but not Alternative Trading Systems (ATS). Assuming no cross-subsidization across stocks, a maker-taker venue would need to lower both the rebate (so that it is lower than the take fee) and the take fee to meet the lower cap for stocks in the first test group under the Rule. For stocks in the second test group, rebates would have to be lowered to zero, while the take fee in principle could remain unchanged for a maker-taker venue under the Rule. However, competitive pressures would in the latter case likely result in a lowering also of the positive take fee. The proposed Transaction Fee Pilot was adopted by the SEC in December 2018. However, ISE, Nasdaq, and Cboe together filed a petition challenging the Pilot, arguing it was arbitrary and capricious, would give other market players not subject to the Rule an advantage, and that the Pilot was beyond the SEC's authority.[8] A federal appeals court in June 2020 sided with the petitioners, concluded that the regulator exceeded its authority, vacating the Rule and remanding the case.[9] Hence, we need to look to markets outside of the U.S. to gather evidence on how maker-taker pricing affects displayed liquidity and the distribution of order flow across venues. That is exactly what we do in this paper. Like the envisioned Transactions Fee Pilot, we study a fragmented market where different fee structures apply in different venues for the same stock. However, unlike the Pilot, the fee reductions we study are voluntary and are undertaken by MTFs - the European equivalent of ATSs - instead of by an exchange. The CXE rebate reduction maps into Rule 610T test group one, whereas the BXE elimination of the rebate and reduction of the take fee maps into what we would expect to happen under Rule 610T for test group two.

To help us frame the empirical analysis, we develop a model of a dynamic limit order book with a discrete pricing grid that faces competition from another identical limit order book. Our model departs from Buti, Rindi, and Werner (2017) in that it has endogenous liquidity supply, trading fees and a competing limit order book.[10] We use the model to derive predictions on the effects of a change in fees on market quality and market share in a fragmented market. The new feature of our model is that it includes both the tick size and a competing venue. Our model complements both the Colliard and Foucault (2012) model in that it has a tick size, and the Foucault, Kadan, and Kandel (2013) model in that it includes a competing market.

[7] https://www.sec.gov/news/press-release/2018-43.

[8] Only one national exchange, IEX, filed an amicus brief siding with the SEC.

[9] https://www.sec.gov/news/press-release/2018-298, http://business.cch.com/srd/19-1042-1847356.pdf

[10] The first version of this paper included a model of a limit order book competing with a crossing network. We thank Charles Jones, Björn Hagströmer, and Satchit Sagade for suggesting to investigate the model with two competing limit order books.

This is relevant as Colliard and Foucault (2012) show that in a market with competing venues the absence of a tick size allows investors to react to a change in trading fees by changing their order submission strategies in such a way that they neutralize the change in the total fees breakdown. Foucault et al. (2013) subsequently show that when the limit order book is governed by a tick size, investors may no longer neutralize the change in fee breakdown. However, Foucault et al. (2013) obtain this result within a single market framework. We instead show how a change in both a symmetric and an asymmetric fee breakdown affects investors' order submission strategies when a limit order book with discrete prices faces competition from another identical limit order book. Finally, the focus of our analysis is on the effects of a change in fees on the quality of the limit order book instead of the optimal fee structure as in Chao et al. (2019) and Riccó, Rindi, and Seppi (2022).

With the support of our model we show how fee changes affect different metrics of market quality in a market that has a tick size and at the same time faces competition from another trading venue. We also show how in a fragmented market, a change in fees on one venue is likely to affect traders' order routing decisions, and hence results in a migration of orders between venues.

More specifically, we model two identical competing limit order books - Market I and Market II - to study the effects of Market I fee changes on its own displayed liquidity and market share as well as any effects on Market II where fees remain unchanged at zero. Our model predicts that a Market I reduction of the rebate on liquidity provision (negative make fee) with no change in the take fee - essentially the CXE fee change - generates a migration of orders to Market II, and as a result market quality and market share in Market I deteriorate while market quality and market share in Market II improve. Our model shows that these effects are stronger for stocks where competition for the provision of liquidity and trading activity are more intense, thus stimulating a stronger negative effect on liquidity supply (limit orders), and inducing a stronger negative effects on liquidity demand (market orders). We therefore expect the reduction of the rebate on liquidity provision to have a stronger negative effect on large stocks - characterized by higher competition for liquidity provision coupled with the higher level of trading activity - than on small stocks.

Our model also predicts the effects of a simultaneous reduction of the rebate on liquidity provision and of the take fee in Market I when trading fees remain unchanged at zero in Market II - essentially the BXE fee change. Our results show that the reduction in the take fee makes Market I cheaper and attracts orders at the inside quotes resulting in an improvement of market quality and market share in Market I. In contrast, the reduction in rebate on liquidity provision has an offsetting negative effect on Market I relative to Market II. Interestingly, our results show that for small stocks, i.e., stocks characterized by investors with a lower propensity for liquidity provision, the positive effect of the reduction in take fees on market quality is stronger, whereas the negative effect of the reduction in the rebate on liquidity provision is weaker, the opposite holding for large stocks. We can therefore conclude that the effects of a simultaneous reduction of the take fee and of the rebate on liquidity provision are overall more positive for small stocks relative to large stocks.

To provide an intuition for this result, consider Market I that offers a rebate for liquidity suppliers and charges a fee to liquidity demanders, while Market II has no fees. In other words, Market I is a maker-taker venue while Market II uses symmetric pricing with zero fees. All liquidity suppliers would like to earn a rebate in Market I, but, as Market II is cheaper than Market I, most trading activity focuses on the inside quotes in Market II. However, some activity persists in Market I due to some patient liquidity suppliers seeking rebates and placing their orders at wide quotes in Market I hoping their limit orders will execute at better prices when the available liquidity in Market II is exhausted. More liquidity will build beyond the inside quotes in Market I for large stocks where investors are more strongly attracted by rebates (more willing to supply liquidity) and for which there are more opportunities for orders to get filled (more trading activity). Hence, maker-taker markets for large stocks will have more depth at price levels beyond the inside quotes when competing with cheaper markets.

When both the take fee and the rebate are reduced on Market I, we observe two main channels of transmission with opposite effects. First, the reduction in the take fee induces investors to move from the inside quotes of Market II to the now cheaper inside quotes of Market I with a positive effect on Market I. This effect is stronger for small stocks where the propensity of investors to demand liquidity is larger relative to the propensity to supply liquidity. Second, the reduction in the rebate reduces the incentive for liquidity suppliers to build liquidity at prices beyond the inside quotes in Market I with a negative effect on Market I. This negative effect will be weaker for small stocks characterized by fewer traders harvesting rebates and lower trading activity where the liquidity posted beyond the first level of the book by traders seeking rebates is presumably smaller. We therefore obtain that overall the positive effect of a simultaneous reduction in both the take fee and the rebate is stronger for small than for large stocks.

In real markets, it is the relative fees that matter for traders' order selection and order routing decisions. Hence, when testing our model predictions we consider the net change in trading fees. Therefore, not only do we consider the direct reduction in CXE rebate with respect to TQ that did not change its pricing, as well as the direct reduction in BXE rebate and take fee with respect to TQ, but we also consider the net reduction in BXE trading fees with respect to CXE that reduced its rebate.

For our empirical analysis, we use a stratified sample of 120 LSE-listed firms and run a panel difference-in-difference regression specification, having 120 matched-firms from the Australian stock exchange as control, to uncover the effects of BATS fee changes on market quality and market share. Our results are consistent with the empirical predictions of our model. In particular, we find that the CXE's rebate reduction results in a deterioration of market quality and market share for CXE, and an improvement of market quality and market share - for large stocks - for the competing venue TQ. Recall that this is what the would expect to happen for stocks in test group one of the SEC Transactions Fee Pilot. We also find that the change in the BXE's maker-taker pricing results in improved BXE market quality and market share - stronger for small stocks - and in a deterioration of market share for the competing venue TQ in small stocks. This is what we would expect to happen for stocks in test group two of the Pilot. Hence, consistent with our model's predictions, we find that while the competing venue TQ did not change its maker-taker pricing, it was affected by both of the BATS fee changes. In particular, the overall effect on TQ market quality and market share is consistent with both order flow migration to TQ for large firms - due to CXE's fee change- and with order flow migration away from TQ for small firms - due to BXE's fee changes. Concerns about these types of spillovers from exchanges subject to the fee caps to ATSs that would not be subject to the caps, were a major reason for the petitioners' successful challenge to the SEC Transactions Fee Pilot.

To evaluate the robustness of our findings, we proceed as follows. First, we re-estimate our difference-in-difference specification using LSE as a control. Though we do not believe LSE is a direct competitor to BATS, we follow the methodology of Boehmer, Jones, and Zhang (2020) and identify the overall treatment effect (calculating both the direct effect and indirect effect via LSE) on BXE, CXE and the competing TQ market. The new results support our previous findings. Second, we look at the effect of the fee change on cum-fee spreads (quoted spread plus twice the take fee) to test whether our results on market quality are driven by traders' neutralizing the change in fees through quote adjustments of the bid-ask spreads (Colliard and Foucault (2012)). We find strong effects not only on quoted spreads but also on the cum-fee spreads. Lastly, we investigate but do not find support that our cross-sectional findings - the different effects of fee changes for large and for small firms - are driven by relative tick-size. Focusing on firms that have similar levels of relative tick-size, we still find results that are qualitatively and quantitatively different for large and small firms.

Our paper contributes to the literature by taking intermarket competition into account when studying the effects of maker-taker pricing fee changes empirically. We show that both the reduction in the rebate, and the simultaneous reduction in the rebate and in the take fee have a different effect for large capitalization stocks compared to small capitalization stocks. In particular, the reduction in fees leads to worse market quality for large capitalization stocks. This finding has policy implications since - in contrast with critics of maker-taker pricing (including market operators such as BATS) who have asked for reductions or even bans of maker-taker pricing - it suggests that the elimination of rebates is going to be particularly detrimental for liquid stocks. Lastly, 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.

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 data sets and the methodology in Section 4. In Section 5 we discuss our empirical results. Section 6 consists of conclusions and the policy implications of our findings.

2. Literature review

Theoretical models of maker-taker fees have initially focused on whether the breakdown of the total fee charged by a venue into rebate and take fee matters for order flow composition, market quality, and welfare. Colliard and Foucault (2012) develop a model of limit order trading with no tick size and show that the breakdown does not affect the order flow composition, the trading rate, or welfare. Foucault et al. (2013) model of a limit order book with a positive tick size, populated by two distinct groups of algorithmic traders with monitoring costs – market makers and market takers,– and show that the total fee breakdown matters. 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. More recently, two papers study the optimal market access pricing. Chao et al. (2019) model a 2-period limit order book with a tick size to show that in equilibrium the optimal fee structure is either the maker-taker or -symmetrically- the taker-maker. They show that an exchange setting make and take fees simultaneously chooses the price of the execution service (make fee) and the quality of the execution service (take fee). This simultaneous choice creates an incentive for the owner - say - of two trading platforms like BATS Europe to engage in second-degree price discrimination and set different fee structures across the two trading platforms. Riccó et al. (2022) extend Chao et al. (2019) by considering different regulatory restrictions, a third period and HFTs to show that optimal access pricing depends on the population which characterizes the market, i.e., the amount of ex-ante heterogeneity in investors' private values, and that with large gains from trade it can result in strictly positive fees. They also show that the widespread use of rebate-based access pricing can be explained by the growing importance of HFT post Reg-NMS.

Among the existing empirical works on maker-taker fees, 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 maker-taker 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 ostensibly supporting Colliard and Foucault (2012). As Malinova and Park (2015), we consider markets with discrete prices but we test the predictions of our model that unlike Colliard and Foucault (2012) has discrete prices. We find that a decrease in make and take fees is related to changes in both quoted and cum-fee spreads.[11]

Tham, Sojli, and Skjeltorp (2018) using data from the Nasdaq OMX BX and exogenous changes in maker-taker fees show that cross-side liquidity externalities exist and conclude that the reason is that an increase in market makers' monitoring benefits market takers ("liquidity supply begets liquidity demand") as predicted by Foucault et al. (2013). Black (2022) uses the Nasdaq February 2015 experiment which lowered its fee structure temporarily on 14 stocks for a four month period and documents that a simultaneous reduction in make and take fees results in lower market efficiency. Cardella, Hao, and Kalcheva (2017) investigate 108 instances of fee changes for U.S. exchanges in 2008-2010 and find that an increase in take fees has a larger impact on trading activity than an increase in make fees. 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 negatively related to total trading fees and latency, while positively related to liquidity relative to the listing exchanges. Clapham, Gomber, Lausen, and Panz (2017) study the Xetra Liquidity Provider Program at Deutsche Boerse which introduced liquidity rebates and find that the program results in higher liquidity, larger contribution to market-wide liquidity and a higher market share for the venue implementing the rebates, but that market-wide turnover and liquidity do not change. Anand, Hua, and McCormick (2016) study the 2012 introduction of maker-taker pricing in the NYSE Arca options market, and document that execution costs (including fees) for liquidity demanders decline and that the maker-taker pricing encourages market makers to improve quoted prices. Comerton-Forde, Grégoire, and Zhong (2019) and Lin, Swan, et al. (2019) study the effects of the U.S. tick size pilot on venues with different maker-taker (and inverted) pricing models and document that an increase in the tick size results in redistribution of volume towards inverted fee venues.

We make two important contributions to this literature. First, our cross-sectional results -supported by our model- suggest that any maker-taker fee changes have asymmetric effects on market quality and market share for small versus large firms. In fact, as we show with the BXE simultaneous reductions in both take fees and rebates, the effects for large companies are detrimental whereas small companies benefit from the fee changes. Secondly, by focusing our investigation on a multi-market design, we are able to quantify the effects of reductions in maker-taker pricing both for venues that implement the fee changes and for direct competitors.

[11] Using Rule 605 data O'Donoghue (2015) finds that changes in the split of trading fees between liquidity suppliers and demanders affect order choice and thereby execution quality.

3. Theoretical Background and Empirical Predictions

3.1. Model

In this section we briefly describe our model.[12] Traders arrive sequentially over the trading game that lasts N periods, $t_z = t_1, .., t_N$ and in the spirit of Riccó et al. (2022) we consider two different specifications with different investor trading activity, one with three periods, $N = 3$, $t_z = \{t_1, t_2, t_3\}$, and one with four periods, $N = 4$, $t_z = \{t_1, t_2, t_3, t_4\}$. At each period t_z a risk-neutral investor comes to the market with a private valuation equal to γ_{t_z} which is an i.i.d. drawn from a uniform distribution, $\gamma \sim U[\underline{\gamma}, \overline{\gamma}]$, $\underline{\gamma}$ being the lowest valuation and $\overline{\gamma}$ the highest valuation traders may have.[13] The support width $S = \overline{\gamma} - \underline{\gamma}$ - symmetrically distributed around the asset value AV - indicates the dispersion of traders' gains from trade.

Traders coming to the market with extreme values of γ_{t_z} are more eager to trade by taking liquidity, whereas traders arriving with γ_{t_z} values close to AV are more willing to supply liquidity. The larger the support, the more heterogeneous investors' gains from trade are. The smaller the support, the less dispersed investors' gains from trade are around the asset value, and the more inclined investors are in supplying rather than taking liquidity. We consider two scenarios, one with a large support, $S = [0.0, 2.0]$, and one with a smaller support, $S = [0.05, 1.95]$. Trade size is unitary.

We model two identical limit order books that we label Market I (mrkI) and Market II (mrkII) respectively. Each limit order book, Market I or Market II, has a grid of four prices, $P_i^j = \left\{S_2^j, S_1^j, B_1^j, B_2^j\right\}$, for $j = mrkI, mrkII$, two on the ask and two on the bid side of the book around the same asset value AV. Both trading platforms have a tick size equal to τ, so the ask prices are equal to $S_1^j = AV + \frac{1}{2}\tau$ and to $S_2^j = AV + \frac{3}{2}\tau$ respectively for the inside and outside quotes, and symmetrically the bid prices are equal to $B_1^j = AV - \frac{1}{2}\tau$ and to $B_2^j = AV - \frac{3}{2}\tau$. The state of the limit order book of market j at time t_z is the vector $lob_{t_z}^j = \left\{l_{t_z}^{P_i^j}\right\}$, where $l_{t_z}^{P_i^j}$ is the depth (number of orders/shares) of the limit order book j at price P_i^j at time t_z.

In each period t_z, a trader arrives, observes the state of the two limit order books and chooses among different possible trading strategies, $y_{t_z}^j$, where $Y_{t_z}$is the set of possible trading strategies at time t_z. Table 1 reports the payoffs from the different orders that a trader can choose at t_z when arriving either at Market I or at Market II. An investor can choose to submit a limit order $(LO_{t_z}^j(P_i^j))$ or a market order $(MO_{t_z}^j(P_i^{j,b}))$ either to Market I or to Market II, or

[12] See Appendix 1 for more detailed discussion on the model solution.

[13] As in Colliard and Foucault (2012) and in many other models of limit order books (e.g., Hollifield, Miller, and Sandås (2004); Goettler, Parlour, and Rajan (2005); or Goettler, Parlour, and Rajan (2009)) heterogeneity in investors' private valuations generates gains from trade. See Duffie, Gârleanu, and Pedersen (2005) for economic foundation.

can alternatively decide not to trade (NT_{t_z}).[14] Hence, $Y_{t_z} = \{LO^j_{t_z}(P^j_i), MO^j_{t_z}(P^{j,b}_i), NT_{t_z}\}$.

At t_1 both Market I and Market II open empty and therefore traders will only be able to offer liquidity by posting limit orders. At t_2 (t_2 and t_3) traders can either take or make liquidity via market or limit orders, and at t_3 (t_4), which is the last period of the trading game if $N = 3$ ($N = 4$), traders will only submit market orders or decide not to trade as the execution probability of a limit order is zero. Conditional on their private valuation and the state of the two limit order books, traders opt not to trade (NT_{t_z}) in any period t_z when the payoffs of the possible $LO_{t_z}(P^j_i)$ and $MO_{t_z}(P^{j,b}_i)$ are non-positive. Traders face trading fees that can be positive or negative (rebates). In particular a trader will face a take fee TF (tf) if he takes liquidity by posting a market order on Market I (Market II); a trader will face a make fee MF (mf) if he posts a limit order on Market I (Market II). For example, if Market I opts for a maker-taker pricing structure that consists in a positive take fee ($TF > 0$) and a negative make fee ($MF < 0$) a market participant sending a market order to Market I will have to pay a take fee to the trading platform when the market order is executed. Traders opting instead to post a limit order to Market I will receive a rebate when the limit order is executed. In this case, the rebate is a reward that traders receive when they supply liquidity to the limit order book, whereas the take fee is a charge traders have to pay when they take liquidity.

Both Market I and Market II are governed by standard price and time priority rules. If at time t_1 a trader posts, for example, a limit sell order to Market I at the second level of the book, the next period a trader can undercut the resting limit order by posting a more aggressive limit sell order on the first level on either Market I or Market II limit order book. Furthermore, he can hit the limit order initially posted to Market I with a market buy order, or he can post a limit buy order to Market II at the second level of the book. He can finally decide not to trade.

A trader arriving at time t_z will choose the order, $y^j_{t_z}$, that maximizes the expected payoff, $\pi^j_{t_z}$, given his private valuation of the asset, γ_{t_z}, the state of the two limit order books, $lob^j_{t_{z-1}} = \left\{l^{Pj}_{t_{z-1},i}\right\}$, and the trading fees, Ω^j, where $\Omega^{mrkI} = \{MF, TF\}$ and $\Omega^{mrkII} = \{mf, tf\}$:

$$\begin{aligned} & \max_{y^j_{t_z} \in Y_{t_z}} \pi^j_{t_z}\left(y^j_{t_z} \mid \gamma_{t_z}, lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\right) \\ = & \max_{y^j_{t_z} \in Y_{t_z}} \pi^j_{t_z}\left(y^j_{t_z} \mid \Lambda_{t_z}\right) \end{aligned} \tag{1}$$

where $\Lambda_{t_z} = \{\gamma_{t_z}, lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\}$. When choosing their order submission strategies, traders face a trade-off between non-execution costs and price opportunity costs. If they opt for $MO^j_{t_z}(P^{j,b}_i)$, they get immediate execution at the best ask price, $S^{j,b}_{t_z} = min\left\{S^j_{t_z,i} | l^{S^{mrkI}}_{t_z,i}, l^{S^{mrkII}}_{t_z,i}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\right\}$ if it is a buy order or at the best bid

[14] We label the best ask and the best bid prices with the superscript "b".

price, $B^{j,b}_{t_z} = max\left\{B^j_{t_z,i}|l^{B^{mrkI}}_{t_z,i}, l^{B^{mrkII}}_{t_z,i}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\right\}$, if it is a sell order, where $l^{Sj}_{t_z,i}$ ($l^{Bj}_{t_z,i}$) indicates the number of shares available at the i-th price level of the ask side (bid side) of the j-th market. If instead they choose a $LO^j_{t_z}(P^j_i)$, they face execution uncertainty but they will get a better price if the order executes. When the expected payoffs for an order routed either to Market I or to Market II are the same, we assume that the trader randomizes and routes the order with equal probability to both trading platforms.

Following Colliard and Foucault (2012), the model is solved by backward induction, and as in Chao et al. (2019), conditional on the pricing grid characterized by the tick size, τ, and the support of traders' valuation, S, it has a closed-form solution for each set of trading fees, Ω. We start from the end of the trading game, t_3 (for $N = 3$), when traders rationally submit only $MO^j_{t_3}(P^{j,b}_i)$, and solve the model for the equilibrium market buy and market sell orders, $y^j_{t_3}$. As the equilibrium probabilities of market buy and market sell orders at t_3 are the execution probabilities of $LO^j_{t_2}(P^j_i)$ (to sell and to buy respectively) at t_2, the model can then be solved at t_2, and recursively at t_1 (see Appendix 1). Similar arguments hold for $N = 4$. The obtained equilibrium order submission probabilities allow us to draw predictions on order flows and also to build market quality metrics.

Limit orders in each period t_z and in each market j, $LO^j_{t_z}(P^j_i)$, are computed as the weighted average of the probability of observing a limit order conditional on the different equilibrium states of the book, $lob^j_{t_z}$, where the weights are the probabilities of the different states of the book in period t_z : $E\left[LO^j_{t_z}|\Lambda_{t_z}\right]$. Market orders, $MO^j_{t_z}(P^{j,b}_i)$, are computed in a similar way: $E\left[MO^j_{t_z}|\Lambda_{t_z}\right]$. We build measures of quoted spread ($Quoted\,Spread^j$), depth at the best bid-offer ($BBODepth^j$), and market share (MS^j) based on the equilibrium limit orders (LO^j) and market orders (MO^j) submission probabilities. In each period t_z and in each market j the quoted spread, $Quoted\,Spread^j_{t_z}$, is computed as the weighted average of the probability of observing the inside spread conditional on the different equilibrium states of the book, $lob^j_{t_z}$, the set of fees involved, Ω^j, and the length of the trading game, N, where - as before - the weights are the probabilities of the different states of the book in period t_z : $E\left[\left(S^{j,b}_{t_z,i} - B^{j,b}_{t_z,i}\right)|\Lambda_{t_z}\right]$.[15] Depth at the best bid-offer, $BBODepth^j_{t_z}$ is computed as the weighted average of the sum of the shares available at the best bid and ask prices, $E\left[\left(l^{S^{j,b}}_{t_z} + l^{B^{j,b}}_{t_z}\right)|\Lambda_{t_z}\right]$. We then average $Quoted\,Spread^j$ and $BBODepth^j_{t_z}$ over all the periods of the trading game: when $N = 3$ we compute the averages over the three periods, t_1, t_2 and t_3; when $N = 4$ we compute the averages over t_1 through t_4. Market share for Market I, MS^{mrkI}, is measured as the average of market orders in Market I over the same trading periods, divided by the sum

[15] In our model liquidity supply is endogenous. When computing the quoted spread, we assume that when the book is empty, at either the ask or the bid side, the maximum possible spread is five ticks. We have also derived effective spread which does not rely on this assumption, but to economize space and consistently with our empirical analysis, we only report $Quoted\,Spread^j$ and $BBODepth^j$.

of the average of market orders in Market I and Market II over the same periods, e.g., $MS^{mrkI} = \frac{\sum_{t_z} MO_{t_z}^{mrkI}}{\sum_{t_z} MO_{t_z}^{mrkI} + \sum_{t_z} MO_{t_z}^{mrkII}}$. We measure market share for Market II in a similar way.[16]

We use our models to discuss the effects of a change in fees in Market I on the equilibrium order submission probabilities and the derived order flows and market quality metrics of both Market I and Market II. While our framework may be considered a stylized model of intraday trading, all results are averaged across the different periods of the trading game. Therefore our results allow us to draw predictions on how a change in trading fees affects the overall activity of the trading day captured by the daily data we use for our empirical analysis.

Our model allows us to draw predictions for two markets that compete for the provision of liquidity having the same support and trading activity. The assumption here is that if a stock is traded by investors having large heterogeneous gains from trade on Market I, it is also traded by the same type of investors in Market II; equally, if a stock is traded by speculative short term investors in one market, it is also traded by the same type of investors in the other market.

3.2. Model Results and Empirical Predictions

In this section we discuss the mechanisms that according to our models drive the change in market quality following a change in trading fees. We aim to draw predictions for our empirical experiment in which BATS decreased the rebate on liquidity provision for CXE, and both the rebate and the take fee for BXE. We therefore study first the effects of a change in the rebate and then a change in both the rebate and the TF.[17]

Results on the effects of a change in rebate on liquidity provision on Market I are presented in Table 2.[18] Results on the effects of a change in both the take fee and the rebate on liquidity provision are presented in Table 3.[19]

Tables 2 and 3 report results for the two protocols with a large support, $S = [0, 2]$, (columns 1 through 5) and a small support, $S = [0.05, 1.95]$ (columns 6 through 10), and compare them for both our 3-period (Panel A) and 4-period (Panel B) model. This way we can investigate first how - given the level of trading activity $N = 3$ or $N = 4$ - our results change when - for

[16]Appendix 1 shows how the metrics of market quality are obtained starting from the equilibrium order submission probabilities.

[17]To economize space, we only report results for the values of the trading fees that allow us to discuss the main effects at work. Our results are robust to all parameter values within the ranges of fees considered.

[18]In real markets trading fees are generally set such that total fee, which is the sum of MF and TF, is positive. This guarantees that the exchange has a profit upon execution of each order. To capture the controlled effect of a change in rebate, we consider the change in rebate on liquidity provision in Market I holding the TF constant at zero. Results are qualitatively the same if we consider a reduction of the rebate on liquidity provision in a market with a maker-taker fee structure, i.e., with $TF > |MF| > 0$ such that the total fee is positive throughout our comparative static analysis.

[19]We report the results for Market II respectively in Tables A6 and A7 in Appendix 1.

example - the distribution of investors' private valuations becomes smaller; second, we can investigate how - given the support of investors' private valuations - our results change when the number of trading periods increases and the market becomes characterized, for example, by a higher level of trading activity.

To understand the effects on market quality - all else equal - of a reduction in the support or/and an increase in trading activity, consider the results for the equilibrium order submission probabilities of both limit and market orders, as well as the derived metrics of market quality reported in columns (1) and (6) of Table 2 (or of Table 3). These results are obtained by solving the model for the regime with all the trading fees set equal to zero, $\{MF, TF, mf, tf\} = \{.00, .00, .00, .00\}$.[20]

All else equal, when the support decreases from $S = [0, 2]$ to $S = [0.05, 1.95]$ both in the 3-period and in the 4-period model, traders willingness to supply liquidity increases thus increasing $BBODepth$. All else equal, when trading activity increases from $N = 3$ to $N = 4$, orders have an additional period to execute and therefore both liquidity demand and overall liquidity supply increase.[21] This explains why both volume (MO) and $BBODepth$ increase and $Quoted\,Spread$ improves. Tables A6 and A7 in the appendix show that the same results hold for Market II as the model is symmetric.

Taken together, these results show that we can solve our dual market framework under two scenarios. The combination of higher trading activity (four trading periods) and higher willingness to supply liquidity (small support - $S = [0.05, 1.95]$) leads to smaller spread and greater depth, and we consider this scenario a proxy for *Large Stocks*. Conversely, the combination of lower trading activity (three trading periods) and lower willingness to supply liquidity (large support - $S = [0.00, 2.00]$) leads to larger spread and lower depth, and we consider this scenario a proxy for *Small Stocks*. The results corresponding to these two scenarios are marked in gray in Tables 2 and 3 for Market I (and A6 and A7 for Market II in the Appendix)

3.2.1. Change in Make Fee - MF

We start by changing the rebate on liquidity provision only on Market I holding all the other fees constant at zero, $\{TF, mf, tf\} = \{.00, .00, .00\}$. We isolate the change in the rebate to

[20] Appendix 1 shows how the metrics of market quality are obtained starting from the equilibrium order submission probabilities.

[21] Note that even if the average order submission probability of limit orders across the trading game somewhat decreases in the 4-period model compared to the 3-period one, traders' incentive to liquidity provision overall increases in the 4-period protocol. The reason is that as the book fills up with limit orders, over time there is less room for traders to post additional limit orders; therefore, even though in the first two periods of the trading game the average order submission probability of limit orders in the 4-period model increases compared to the 3-period model, as the book fills up with limit orders, in the additional third period, t_3, the average probability of limit order submission decreases, with the consequence that the overall average of limit order submission probability in the 4-period model decreases.

understand the causal effects that such a change in trading fees determines on the quality of both Market I and Market II when they compete for the provision of liquidity.[22] We solve our models for 3 sets of trading fees in Market I: $\{MF, TF\} = \{.00, .00\}$, $\{MF, TF\} = \{-.001, .00\}$, and $\{MF, TF\} = \{-.005, .00\}$, while holding the trading fees in Market II constant at zero: $\{mf, tf\} = \{.00, .00\}$.

Throughout our simulations we consider changes in the fee breakdown which may of may not be associated with a change in total fees. When prices are discrete due to the existence of a tick size a change in the fee breakdown matters irrespective of the change in total fees. For this reason, we focus on the relative changes in the make and take fees as opposed to the change in the total fee.[23]

Table 2 reports results for Market I whereas Table A6 reports results for Market II. We first discuss the effects of a change in rebate in the regime with a large support and three trading periods (Panel A, columns 1 though 5), and then show how results change when the support is smaller and there are four rather than three trading periods. This way we can compare our results for the *Large Stocks* vs the *Small Stocks* scenario.

Panel A columns 1 through 3 show the effects of a change from a regime without fees, $\{MF, TF\} = \{.00, .00\}$, to a regime with a rebate on liquidity provision, $\{MF, TF\} = \{-.001, .00\}$. Results reported in column 4 show the equilibrium order submission probabilities associated with a further increase in rebate, $\{MF, TF\} = \{-.005, .00\}$, and results in column 5 show the percentage change ($\Delta\%$) of the equilibrium order submission probabilities following the change in regime from $\{MF, TF\} = \{-.001, .00\}$, to $\{MF, TF\} = \{-.005, .00\}$.

The increase in rebate in Market I (Table 2) enhances traders' willingness to supply liquidity resulting in an increase in LO. The increased propensity to offer liquidity increases competition for the provision of liquidity so that as the book becomes deeper, market quality improves with $Quoted\,Spread$ decreasing and $BBODepth$ increasing. The increase in limit orders stimulates an increase in MO, so that volume also increases. MS increases substantially in Market I but

[22] Although it may happen for short periods of time that trading platforms strategically set their pricing such that the total fee (make fee plus take fee) is negative, in general trading platforms set their fees such that the total fee is positive. We change the make fee to investigate the trade-offs that govern our model. We will discuss the more realistic case of an increase in total fee in Section 3.2.2.

[23] Colliard and Foucault (2012) and Foucault (2012) - Section 4.2 - show that in a market with no tick size, following a symmetric change in fee breakdown (such that the fraction of fees charged to takers, and rebate to makers, decreases equally), investors react to the decreased limit orders execution probability by posting limit orders more aggressively in such a way to induce takers to increase their demand of liquidity and exactly compensate its initial reduction. This way the change in fees breakdown is neutralized and although it results in a narrower quoted spread, it does not affect the cum-fee spread. It follows that with continuous prices, the cum-fee spread only changes following an asymmetric change in the fee breakdown, hence following a change in total fees. Consistently with Foucault et al. (2013) instead, we show that when prices are discrete, a symmetric change in fee breakdown cannot be neutralized by investors order submission strategies thus leading to a change in the cum fee spread. With discrete prices the fee breakdown matters irrespective of the change in the total fee and therefore what is relevant is the relative change in the make and take fees rather than the change the total fee. In fact, it can be shown that a number of distinct fee breakdowns leading to the same change in total fee differently affect the quoted spread.

some activity still survives on Market II (Table A6). When the queues on Market I become too long, investors switch to the top of Market II where they do not get the rebate but obtain higher execution probability. As TF is zero both in Market I and in Market II, liquidity takers are indifferent between taking liquidity from Market I or from Market II.[24] The same line of reasoning would not apply if one of the two markets was cheaper in terms of take fee, as in that case liquidity takers would only take liquidity from the cheapest market.

When the rebate is further increased to $MF = -0.005$, both liquidity supply and liquidity demand further increase with the higher rebate on liquidity provision, enhancing competition for the provision of liquidity at the inside quotes of Market I and market quality improves. Note that when the rebate is increased further, competition gets intense at the inside quotes of Market I so that the probability that the book will open with an order already posted at the top of Market I increases thus increasing the probability that investors will switch to the inside quotes of Market II ($LO(P_1)$ in Table A6) thus reducing MS on Market I.

Columns 2 through 5 in Table A6 show the effects of the increase in the rebate on liquidity provision ($MF = -0.001$) and of its further enhancement ($MF = -0.005$) on the equilibrium limit and market order submission probabilities and market quality metrics of Market II. Limit and market orders migrate to Market I so LO - and in particular MO - decrease substantially. However, due to the increased competition for the provision of liquidity at the top of the two limit order books, a good proportion of limit orders ($LO(P_1)$) survives in Market II at the first level of the book sustaining $BBODepth$ and containing the negative effect on $Quoted\ Spread$, which slightly improves when the rebate is further enhanced on Market I. These results are consistent throughout all of our four protocols.

[24] For example, in the 3-period model with $S = [0, 2]$ and $\{MF, TF, mf, tf\} = \{.00, .00, .00, .00\}$, consider the branches of the trading game that start at t_1 with the ask side of Market I - the bid side of being symmetric. At t_1 investors post both $LO^{mrkI}(S_2)$ with probability 0.0082 and $LO^{mrkI}(S_1)$ with probability 0.2418; at t_2 if the book open with a $LO^{mrkI}(S_2)$, investors post $LO^{mrkI}(S_1)$ and $LO^{mrkII}(S_1)$ with probability 0.2488, $LO^{mrkI}(B_2)$ and $LO^{mrkII}(B_2)$ with probability 0.0123, and $MO^{mrkI}(S_2)$ with probability 0.4779; if instead at t_2 the book opens with $LO^{mrkI}(S_1)$ investors post $LO^{mrkII}(S_1)$ with probability 0.4959, $LO^{mrkI}(B_2)$ and $LO^{mrkII}(B_2)$ with probability 0.0082, and $MO^{mrkI}(S_1)$ with probability 0.4878.

When all else equal the rebate on MF is increased in Market I, with $MF = -0.001$ and $\{TF, mf, tf\} = \{.00, .00, .00\}$, at t_1 investors post limit order only on Market I that now grants a rebate on MF. More precisely they post $LO^{mrkI}(S_2)$ with probability 0.0159 and $LO^{mrkI}(S_1)$ with probability 0.4841. At t_2 if the book opens with a $LO^{mrkI}(S_2)$, investors do not post - as in the case without fees - limit orders on Market II. They post both $LO^{mrkI}(S_1)$ and $LO^{mrkI}(B_2)$ on Market I with a much greater probability, 0.4975 and 0.025 respectively, and post $MO^{mrkI}(S_2)$ with probability 0.4775. If instead at t_2 the book opens with $LO^{mrkI}(S_1)$ investors have to resort to Market II to post aggressive limit orders at the first level of the book and therefore post $LO^{mrkII}(S_1)$ with a high probability 0.4955; they also post $LO^{mrkI}(S_2)$ with probability 0.01712, and $MO^{mrkI}(S_1)$ with probability 0.4873. This explains the increase in limit orders of Market I, but also the reason why a good deal of activity survives at the top of Market II.

Support and Trading Activity

Not surprisingly, results reported in Table 2 for Market I and in Table A6 for Market II show that the effects of an increase in the rebate (more negative MF) on both liquidity provision (LO), market quality ($Quoted\,Spread$ and $BBODepth$), and market share (MS) become stronger when the support of investors' valuation is smaller (columns 6 through 10) and hence investors are more willing to supply rather than take liquidity, and as a consequence they are more willing to take advantage of the increased rebate on liquidity provision.

Tables 2 and A6 show that the effects of an increase in rebate in Market I are also stronger when the number of trading periods increases. In the 4-period framework the driving effect on liquidity supply of Market I (LO) is stronger resulting in stronger effects on market quality proxied by $Quoted\,Spread$ and $BBODepth$. Even though Market I offers a rebate on liquidity provision, in the 4-period model investors post - overall - orders to Market II with a higher probability compared - all else equal - to the 3-period framework. The reason is that there is now an additional period in which Market I book can open with a limit order posted at the inside quotes - in which case investors may find it profitable to post their orders at the inside quotes of Market II. The increased limit orders posted to Market II explain why MS of Market I improves less when a rebate on liquidity provision is introduced in a market with higher activity both in the protocol with a larger support and in the protocol with a smaller support.

Taken together, these findings lead to our Proposition 1.

Proposition 1. *All else equal, consider the introduction of a rebate on liquidity provision in one limit order book - Market I - that competes with an identical limit order book - Market II. Both limit order books can be characterized by either a large -* $S = [0, 2]$ *- or a small -* $S = [0.05, 1.95]$ *- support of investors' private valuations, or by either high or low trading activity (*$N = 4$ *or* $N = 3$ *trading periods):*

- *Liquidity supply and hence liquidity demand cluster on Market I resulting in an improvement in quoted spread and depth at the best bid-offer.*
- *Liquidity supply and liquidity demand decrease in Market II and migrate to Market I but some activity survives in Market II due to competition for the provision of liquidity at the inside quotes.*
- *When the support of the investors' private valuation is smaller,* $S = [0.05, 1.95]$*, traders' propensity to supply liquidity increases and results are overall stronger.*
- *When trading activity increases, competition for the provision of liquidity increases:*

– *Market quality improves.*

– *Migration of order flows from Market I to Market II increases resulting in smaller increase of MS in Market I and smaller reduction of MS in Market II.*

- *When the rebate is further increased on Market I, market quality further improves but the increased competition for the provision of liquidity on Market I induces traders to post limit orders on Market II, resulting in a migration of order flows from Market I to Market II and a negative effect on MS of Market I.*

Appendix 1 show how to derive analitically the equilibrium order submission strategies that lead to the results obtained in Proposition 1. Considering that the effects of a change in the rebate on liquidity provision are stronger both when investors' valuations are less dispersed (the support is smaller) and when trading activity increases, we can draw our empirical predictions by making reference to the *Large Stocks* and the *Small Stocks* scenarios. Consistently with our empirical experiment, we consider a reduction - rather than an increase - of a rebate on liquidity provision:

Empirical Prediction 1. *If Market I decreases its rebate on liquidity provision relative to Market II, order flows migrate out of Market I into Market II, causing market quality to deteriorate and market share to decrease in Market I; and causing market quality to improve and market share to increase in Market II.*
The positive effects on market quality (Quoted Spread and BBOdepth) for Market II are stronger for large stocks characterized by higher competition in the provision of liquidity and greater trading activity. Whereas the positive effect on market share is weaker. Due to the increased competition for the provision of liquidity on Market II there are more opportunities for investors to migrate from Market II to Market I resulting in a smaller improvement in the market share (MS) of Market II.

3.2.2. Change in Make Fee and Take Fee - $MF\&TF$

We now change both the MF (rebate) and the TF on Market I, holding the fees in Market II constant at zero, $\{mf, tf\} = \{.00, .00\}$. Tables 3 and A7 report results for Market I and Market II respectively. As for the case of a change in MF, we solve our models for 3 sets of trading fees in Market I: $\{MF, TF\} = \{.00, .00\}$, $\{MF, TF\} = \{-.001, .001\}$, and $\{MF, TF\} = \{-.001, .002\}$. As before, we start by considering the effects of an increase in both rebate on liquidity provision and TF in Market I in our 3-period model with the large support, $S = [0.00, 2.00]$. Table 3, Panel A, columns 1 through 3 show the effects of a change from a regime without fees, $\{MF, TF\} = \{.00, .00\}$, to a regime with a negative MF and a positive TF, $\{MF, TF\} = \{-.001, .001\}$. This allows us to infer - all else equal - the effects of a change in TF. Results reported in column 4 show the equilibrium order submission probabilities associated with a more realistic maker-taker regime where the TF is greater in absolute value that the rebate entailing an increase in total fee, $\{MF, TF\} = \{-.001, .002\}$, compare to the maker-taker regime reportede in columne 2; and results in column 5 show the percentage change ($\Delta\%$) in the equilibrium order submission probabilities following a change in regime from $\{MF, TF\} = \{.00, .00\}$, to $\{MF, TF\} = \{-.001, .002\}$. The same columns in Panel B show the results on the effects of the same change in trading fees resulting from our 4-period model, and columns 6 through 10 in both Panel A and B report results for the smaller support, $S = [0.05, 1.95]$.

When a rebate on liquidity provision is introduced in Market I together with a positive TF of the same size, both liquidity supply, LO, and liquidity demand, MO, decrease in Market I with the strongest effect taking place for limit and market orders at the inside quotes, so that $LO(P_1)$ and $MO(P_1)$ decrease substantially. The result is a migration of order flows from Market I to Market II with a deterioration of all our metrics of market quality for Market I and an improvement of the same metrics for Market II. As discussed in Section 3.2.1, the introduction of - only - a rebate on liquidity provision in Market I generates an overall migration of order flows to Market I with an improvement in market quality; therefore, comparing that overall positive outcome with the one generated by the increase in both the rebate on liquidity provision and the TF, we can infer that the net effect of the increase of the TF reverses the overall positive effect of the introduction of a rebate on liquidity provision and depresses order flows especially on the first level of the book of Market I. Liquidity suppliers know that even if they could potentially get a rebate by posting a limit order on Market I, the execution probability of their limit orders would drop to zero if any limit order were available at the same time and at the same price level on the cheaper Market II, and therefore aggressive liquidity suppliers prioritize Market II. Some less aggressive liquidity suppliers instead post their limit orders at the second price level of Market I as they know that when liquidity will be exhausted at the top of Market II, liquidity takers arriving sequentially will have to resort to hitting their limit orders, in which case - that would happen with a small probability - they would be granted a rebate. The fee change from $\{MF, TF\} = \{.00, .00\}$ to $\{MF, TF\} = \{-.001, .002\}$ reported in Panel A, column 4 and 5 of Table 3 shows the effects of a more realistic change in fees resulting in qualitatively similar results. In the 3-period model the differences are immaterial.

Table 3 and Table A7 show respectively how our results change when the support is smaller, $S = [0.05, 1.95]$, in columns 6 through 10, and when the number of trading periods increases to $N = 4$ in Panel B. A smaller support translates into traders being more willing to supply liquidity and less willing to take liquidity, and hence more attracted by a rebate on liquidity provision and less reactive to a change in the TF. This has two effects. First, as investors are more attracted by the rebate, this means that after the increase in trading fees to $\{MF, TF\} = \{-.001, .002\}$ those patient investors who do not post their limit orders at the inside quote of Market II, will post their limit orders at the outside quotes of Market I with a higher - although still small - probability. This increase in liquidity supply on Market I counterbalances the negative effect on market quality of the migration of order flows to the inside quotes of Market II due to the positive TF on Market I, thus improving market quality on Market I. Second, as investors are less willing to take liquidity, the increase in the TF has a weaker negative effect on market quality.

The effects of an increase in the number of trading periods is similar. With four trading periods, patient traders have an extra opportunity to exploit the rebate on liquidity provision and post limit orders at the outside quotes of Market I. This means that the enhanced trading activity translates into a positive effect on market quality, thus further counterbalancing the negative effects of the positive TF on Market I. Thus both less heterogeneous gains from trade and a higher number of trading periods make traders more willing to take advantage of the rebate offered by Market I despite the positive charge on TF. These findings lead to our second set of main results:

Proposition 2. *All else equal, consider the simultaneous increase of the rebate on liquidity provision and of the TF in one limit order book - Market I - that competes with an identical limit order book - Market II. Both limit order books can be characterized by either a large -* $S = [0, 2]$ *- or a small -* $S = [0.05, 1.95]$ *- support of investors' private valuations, or by either high or low trading activity (*$N = 4$ *or* $N = 3$ *trading periods):*

- *Liquidity supply and liquidity demand migrate from Market I to Market II and market quality, proxied by quoted spread and depth at the best bid-offer, deteriorates in Market I.*
- *Liquidity supply and hence liquidity demand cluster on Market II resulting in a general improvement in quoted spread and depth at the best bid-offer in Market II.*
- *The migration of orders flows to Market II and the resulting effects on market quality and market share of both Market I and Market II are weaker when the markets are characterized by a smaller support,* $S = [0.05, 1.95]$*, or by higher trading activity,* $N = 4$*.*

Appendix 1 show how to derive analitically the equilibrium order submission strategies that lead to the results obtained in Proposition 2. Taken together our results show that when a rebate on liquidity provision coupled with a positive TF is increased in Market I that competes with an identical Market II, order flows migrate to Market II and market quality and market share deteriorate on Market I and improve on Market II.

The negative effect on market quality is somewhat weaker when the two markets in question - Market I and Market II - are characterized by investors with less heterogeneous private valuations, whose trading strategies are more responsive to a change in the rebate on liquidity provision and less responsive to a change in the TF. The effects are also weaker when the two markets are characterized by higher trading activity. Hence, overall, our *Large Stocks* scenario should be characterized by a weaker negative effect on market quality following the change in the fee structure than our *Small Stocks* scenario which instead should be characterized by a stronger negative effect on both market quality and market share.

We can therefore draw our Empirical Prediction 2 by summarizing our results for a reduction rather than an increase in the rebate on liquidity provision and TF still taking into account our two combined scenarios of *Large Stocks* and *Small Stocks*:

Empirical Prediction 2. *If Market I decreases both its rebate on liquidity provision and its take fee relative to Market II, the activity at the inside quotes of Market I increases with the result that market quality and market share improve in Market I and deteriorate in Market II. The improvement of market quality and market share is stronger (weaker) for small (large) stocks characterized by investors with more (less) heterogeneous gains from trade and lower (higher) trading activity .*

Following the reduction in rebate on liquidity provision and in TF, less active markets characterized by traders less attracted by rebates and more willing to take liquidity will benefit the most from the new fee structure as investors in these markets will react less aggressively to the rebate reduction and more aggressively to the TF reduction thus minimizing the negative effect of the reduced rebate and magnifying the positive effect of the reduction of TF.

4. Data Description and Methodology

4.1. Market Structure and Intermarket Competition

We study the January 1, 2013, changes in BATS maker-taker fees. 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 4 illustrates the trading fee schedules in basis points (bps) that apply for LSE listed firms in each BATS venue 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).

BXE and CXE primarily faced competition from the transparent MTF Turquoise (TQ) which also operated a continuous order book executing orders based on price, display, and time priority.[25] TQ charged takers 0.30 bps and used a value-based rebate ranging from 0.14 bps to 0.28 bps for monthly value traded above €2.5bn.[26] They also faced competition from the LSE which operates a transparent, continuous order book, 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.[27] Value-tiers are typically determined based on monthly value traded, and rebates are distributed and fees collected ex post on a monthly basis.

European stocks were also actively traded on several dark venues during our sample period, including: two venues operated by BATS - BXE-Dark and CXE-Dark - both were 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 - a continuous midpoint order book with price followed by time priority.[28] Their fees are summarized in Table 4.

To illustrate the degree of intermarket competition in our 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 our covered venues. Figure 1, (Figure 1a) reports the distribution of market share for November and December, 2012.[29] It shows that LSE trades (continuous and auction) represent 62.5% of share volume, while lit MTFs capture 33.0%, and dark MTFs capture 4.5% of share volume. BATS lit venues' market share is 27.6% and BATS overall market share is 30.2%.

4.2. Data and Sample

We rely on a sample consisting of 120 LSE-listed stocks. The sample is constructed using the following stratification methodology. We begin with a sample of all publicly traded companies listed 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 capitalization is greater than £500m in order to have

[25]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 (2017) for a discussion of the fragmentation of European equity trading.

[26]For reference, the average December 2012 exchange rate was £0.813/€.

[27]The LSE used maker-taker pricing up to 2009.

[28]BXE Dark, CXE Dark, and TQ Dark all use the midpoint from the LSE market as their reference price.

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

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.

For each of our sample stock-venue combinations, we calculate our daily market quality measures and market share using Refinitiv DataScope Select 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 Refinitiv end-of-day data to obtain volume, high, low and closing prices.

To capture the effect of BATS fee changes on measure of market quality, we employ a difference-in-difference specification (described in detail in Section 4.4) where we use a similar sample of Australian firms as a control group. We follow the same stratification methodology used for the LSE sample, to choose the 120 firms of this control sample from the population of Australian firms listed in the Austalian stock exchange (ASX).

4.3. Descriptive Statistics

Our model speaks to the effect of a change in maker-taker fees on market quality at the venue level. Therefore, we calculate market quality measures both for the venues that are changing fees, BXE and CXE, and for their main competitor TQ as well as for the LSE. We calculate five different measures of market quality for each venue as follows: volume is the daily number of shares (in 000s) traded using the end-of-day files from Refinitiv Datascope Select; depth is the time-weighted daily average of the intraday quoted BBO depth in shares at the ask-side and the bid-side of each quote; 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 (£); %spread is the time-weighted daily average of the intraday ask price minus the bid price of each quote divided by the midquote (average of the ask and bid prices); and volatility is the difference between the high and low trading price each trading day (using the end-of-day files from Refinitiv Elektron) divided by the high price. Market share is the daily number of shares traded divided by the total number of shares traded across all venues (CXE, BXE, TQ and LSE).

Table 5 reports summary statistics across stocks based on average daily values for each market quality measure at the listing exchange during December 2012. We also report summary statistics for the distribution of market capitalization in millions as well as price levels in British pounds (£). Firms are classified into size terciles based on market capitalization of the firms one year before the first month of the event (i.e., January 2012).[30] We report summary

[30]Similarly, in unreported results we examine sub-samples based on the median price level (low and high priced stocks).

statistics for the overall sample (overall) and for the subsamples of the highest (large) and lowest (small) market capitalization terciles. Table 5 shows that the our sampling methodology ensures that we have a significant dispersion in firm characteristics as well as market quality measures. As expected, size and price are higher and market quality better for large than for small firms.

We compare market quality measures at each MTF venue (BXE, CXE, and TQ) to the LSE in Figure 2 for the period December 2012 (which is the pre-period for our event study analysis which is described in the methodology section below). The figure also depicts whether the venue mean is significantly different from the listing exchange mean based on a simple differences in group means test. All differences are statistically significant with the exception of BXE %spread and CXE volatility, in both cases for the large sub-sample. Furthermore Figure 2 demonstrates that the listing exchange is the dominant venue in terms of share of volume and this is true both overall, and for large and small stocks. CXE captures the second largest fraction of share of volume, 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.

MTFs on average have lower market quality than the listing exchange (lower depth and wider spreads). Comparing MTFs, depths relative to the listing exchange are highest for CXE, while they are almost identical for BXE and TQ. MTFs spreads relative to the listing exchange are lowest for CXE and TQ, while BXE has the widest spreads. Finally, volatility is significantly lower on the MTFs compared to the listing exchange overall, and is also more muted on the MTFs for small than for large stocks.

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.[31] 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 allows us to reduce the potential effects of confounding factors.[32]

We start by studying time-series of average daily market quality measures. Specifically, we compute equal-weighted daily means across stocks for each venue both for the overall sample (120 firms) and for sub-samples based on size terciles. The result is four time-series (overall, large, medium, and small) of roughly forty daily observations (trading days) for each venue (BXE, CXE, TQ and LSE).[33] We evaluate the change in volume (log), quoted depth (log),

[31] We exclude the week of Christmas in December, and instead add the last week of November.

[32] 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.

[33] We winsorize extreme values of the dependent variable at the 1% level for the overall sample to reduce the

quoted spread, and market share for each venue and sample following the fee changes based on a time-series regression:

$$y_t^V = \mu + \delta \cdot Post_t + \varepsilon_t \quad (2)$$

where y_t^V is the measure of market quality for venue V and $Post_t$ 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, volume, 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 TQ and the listing exchange 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 suggests that we need to investigate both a direct and an indirect effect of the fee changes (Boehmer et al. (2020)).

Therefore, to establish the causal effect of fee changes on measures of market quality, and to address exogenous market trends, we employ a difference-in-difference methodology using Australian firms' market quality measures as a control (control venue ASX). The Australian market is similar to the European market, both in terms of the degree of fragmentation and HFT activity.[34] Moreover, there are no trading fee changes in either one of our event windows for the venues trading Australian stocks, making this a good control group. We rely on a sample of Australian stocks that is stratified based on market capitalization and price.[35] Specifically, we estimate the following panel regression specification:

$$y_{i,t}^{V,ASX} = \mu + \beta_1 \cdot Treatment_i^V + \beta_2 \cdot Post_t + \beta_3 \cdot Treatment_i^V * Post_t + \eta_{i,t} \quad (3)$$

influence of extreme observations. We also exclude option expiration dates, i.e., for the January 2013 fee change we exclude the 21st of December 2012 and the 18th of January 2013.

[34]HFT activity for European markets for 2013 and 2014 are roughly 25% according to TABB Group, and the level of HFT trading is reasonably steady at 27% of total turnover according to the Australian Securities and Investments Commission report (2015).

[35]Descriptive statistics of the ASX sample are shown in Appendix 2. They are based on average daily values of each marker quality measure at the ASX during December 2012, similarly to Table 5 for the LSE sample. We also report summary statistics of market capitalization in millions as well as price levels, both measured in Australian Dollars (AUD) for the same period as for the LSE sample. For reference, the exchange rate was AUD 1.5/£1

where $y_{i,t}^{V,ASX}$ is the measure of market quality (either market share, volume (log), spread, or quoted depth (log)) for stocks in venue V and the control venue ASX, subscript i indicates an individual stock, subscript t denotes time in days, $Treatment_i^V$ is a dummy variable that takes on a value of one for stocks in the venue V and zero for stocks in the control venue ASX, and $Post_t$ is a dummy variable that takes on a value of one for days in the post-event period and zero otherwise. Standard errors are clustered by firm and date. The estimated coefficient $\hat{\beta}_3$ measures the change in market quality in venue V associated with the change in trading fees over and above time series changes in market quality that are unrelated to fee changes (captured by the estimated coefficient $\hat{\beta}_2$ of the control venue ASX) and the cross-sectional differences between the market quality measures across venues V and ASX (in the period before the fee changes) captured by the estimated coefficient $\hat{\beta}_1$ of the venue V.

We also estimate a similar difference-in-difference panel version of the relationship between market quality in venue V and the fee changes controlling for market quality on the listing exchange LSE, to evaluate the robustness of our results. Specifically, we estimate the following regression specification:

$$y_{i,t}^{V,LSE} = \mu + \beta_1 \cdot Treatment_i^V + \beta_2 \cdot Post_t + \beta_3 \cdot Treatment_i^V * Post_t + \eta_{i,t} \qquad (4)$$

where $y_{i,t}^{V,LSE}$ is the measure of market quality for stocks in venue V and the control venue is now the listing exchange LSE. For this analysis, we also use standard errors that are clustered by firm and date. We acknowledge that LSE cannot be used as proper control since it can also be affected by the fee changes –following our theory we expect such indirect effects since we are in an environment with significant intermarket competition. Nevertheless, and following Boehmer et al. (2020) we believe that we can learn from capturing these indirect effects. In particular, whereas in Equation (4), the estimated coefficient $\hat{\beta}_3$ measures the direct change in market quality in venue V associated with the change in trading fees, we note that the estimated coefficient $\hat{\beta}_2$ absorbs any indirect effect caused by spillover from the listing exchange's response to the fee changes in venue V. Hence, we focus on the joint direct and indirect effect of fee changes ($\hat{\beta}_3$ +$\hat{\beta}_2$).

5. Empirical Results

In this section, we start by discussing the mapping between theory and the BATS fee changes. We then report results based on the time-series event-study methodology for each MTF: BXE, CXE, and TQ, and for the listing exchange LSE. Next, we report the results based on our main specificiation: using difference-in-difference panel regressions with a control group of Australian firms, to properly control for exogenous market trends. To confirm that our panel regression results are robust, we report similar results based on a number of tests including (1) difference-in-difference panel regressions using trading on the LSE as a control, (2) investigating the fee-changes effects on (a) cum-fee spreads, and (b) a sub-sample of our firms that have matched relative tick sizes.

5.1. Fee Changes and Mapping with the Theory

In late 2012, BATS announced a plan to change its pricing effective January 1, 2013, of its two transparent trading venues. Specifically, as reported in the second sets of columns in Table 4, BATS eliminated the liquidity rebate from its BXE venue completely (from 0.18 bps to zero), and reduced the take fee from 0.28 bps to 0.15 bps. Furthermore, BATS reduced the CXE liquidity rebate from 0.20 bps to 0.15 bps while leaving the take fee at 0.30 bps. As TQ did not change its pricing, the relative changes in fees/competitiveness across the three European trading venues are the following:[36]

↓ **rebate MF** : CXE reduced the rebate (negative MF) ($\Delta MF = 5bps$) compared to TQ;

↓ **rebate MF** & **TF** : BXE reduced the rebate (negative MF) and the take fee (positive TF) ($\Delta MF = 18bsp$ and $\Delta TF = -13bsp$) compared to TQ;

↓ **rebate MF** & **TF** : BXE reduced the rebate (negative MF) and the take fee (positive TF) moderately ($\Delta MF = 13bsp$ and $\Delta TF = -13bsp$) compared to CXE.

Our model predicts that the effects of a change in the rebate, or of the simultaneous reduction of the rebate and of the take fee, depend on whether the stock has investors that are more or less prone to supply liquidity (proxied for by the support of private valuations) and whether the trading activity (proxied by the length of the trading game) is higher or lower. Large stocks attract competitive liquidity providers - for example HFTs with valuations close to the asset value - and as discussed in Section 3.2 we map large (small) stocks to the stocks that in the model are characterized by a small (large) support of investors' private valuations. In addition, large (small) stocks tend to have a higher (lower) trading activity, and we therefore map large (small) stocks to the stocks that in the model are characterized by a higher (lower) trading activity.

Given the proposed mapping, our model predicts that - all else equal - the CXE reduction in the rebate compared to TQ should result in worse market quality - measured by quoted spread and BBODepth - on CXE, and improved market quality on TQ; it should also induce a migration of order flow from CXE to TQ. In addition, the model predicts that the deterioration

[36] LSE has to a large extent a captive order flow and it offers a flat fee (£0.10) for all order types. As shown in Table 4, it is also substantially more expensive in terms of take fee, hence we do not expect its market share and market quality to be much affected by the change in take fee either.

of CXE quoted spread and BBODepth and the improvement of TQ quoted spread and BBODepth should be stronger for large stocks than for small stocks, and the migration of order flow from CXE to TQ should also be stronger for large stocks.

Our model also predicts that - all else equal - the BXE simultaneous reduction of the rebate and the take fee compared to TQ, should generate a migration of order flows from TQ to BXE and an improvement (deterioration) of market quality on the BXE (TQ), stronger for small stocks. Finally, our model predicts that - all else equal - the BXE milder reduction in rebate and the reduction in the take fee compared to CXE, should generate a migration of order flows from CXE to BXE and an improvement (deterioration) of market quality on BXE (CXE), stronger for small stocks. Considering all the relative changes in fees, the net effects of the overall BATS change in pricing on the three MTFs should be:

BXE: an improvement in market quality and market share, stronger for small stocks, as BXE experienced a reduction in the rebate and the take fee both compared to CXE and to TQ;

CXE: a deterioration of market quality and market share, stronger for large stocks, compared to TQ - for the reduction in rebate only; and a further deterioration in market quality and market share compared to BXE - resulting from the BXE reduction in both the rebate and the take fee;

TQ: an improvement in market quality and increase in market share for large stocks and a reduction in market quality and a reduction in market share for small stocks. This is the net effect of the improvement in market quality and market share (stronger for large stocks) generated by the reduction in CXE rebate, and of the reduction in market quality and market share (stronger for small stocks) resulting from the BXE reduction in both the rebate and the take fee.

5.2. Collapsed Time-Series Regressions

We first evaluate the effect of BATS' fee changes on volume (log), quoted spreads, quoted depth (log), and market share for each venue for the overall sample and for the two sub-samples based on a collapsed time-series regression following Equation (2). The results in Table 6 show that for stocks overall, volume increase for all venues, but market shares increase only for BXE and TQ, is unchanged for CXE, and declines for the listing exchange. Spreads for stocks overall decline somewhat on BXE and increase on LSE, while we find that depth declines on BXE and increases on TQ.

The results for stocks overall mask significant cross-sectional differences. Consider first small stocks where volume increased only on BXE and LSE. BXE market share of trading small stocks increases at the expense of CXE and TQ. Small stock spreads decline on BXE without a reduction in depth, but spreads and depths are unchanged on the other MTFs and depth increases on LSE. For large stocks, volume increases on both BATS venues - BXE and CXE, and on TQ. While CXE large stock market share does not change, both BXE and TQ gain market share at the expense of LSE. However, TQ is clearly the winner in terms of gaining market share for large stocks despite not having changed its fees at all. Large stock spreads increase for both BATS markets and depth decreases for BXE. For TQ, depth for large stocks increases with no change in spreads. These results suggest significant cross-sectional difference in the effects of BATS fee changes between large and small small firms across venues. In particular, we can detect beneficial market quality effects in TQ market for large firms whereas BXE shows improvements for small firms. In the following subsection, we investigate whether these preliminary conclusions hold up in panel regressions.

5.3. Panel Regressions

We next analyze the effects of the BATS fee changes in a difference-in-difference panel regression specification with Australian stocks as controls, following Equation (3). Note that in this case, the market share regressions compare each venue's market share of trading LSE-listed stock, e.g. BXE/(BXE+CXE+TQ+LSE), to the market share of ASX of trading ASX-listed stocks, ASX/(ASX+Australian Chi-X). Recall that in this specification, we are interested in the interaction coefficient on $Post * Treatment$.[37]

Table 7, Panel A reports the results for BXE. Overall, we find that volume increases, spreads decline, and market share increases significantly following the BXE fee changes. By contrast, there is no effect on depth. The results for stocks overall are consistent with our model Prediction 2 that the rebate and take fee reductions encourage order flow to migrate to BXE and market quality improves. The results for sub-samples of large and small stocks also support our model Prediction 2. Small stocks - proxied in the model by stocks populated by investors with lower propensity for liquidity provision and by lower trading activity - benefit the most from the BXE fee reduction and attract both limit and marketable orders with the result of improving market quality and market share. As our model predicts, we expect order flow to come either from CXE or TQ, or from both markets. (Looking at panels B and C we indeed find evidence of that). Large stocks instead do not benefit from the reduction in the fees and experience a deterioration of spreads. This is also consistent with the model Prediction 2 that in a stylized way predicts a much smaller improvement of large stocks' market quality on BXE since the reduction in the rebate reduces the incentive for liquidity suppliers to build liquidity - at prices beyond the inside quotes.

[37]For completeness, we also report in Table 7 the joint effect of $Post{+}Post * Treatment$ (following Boehmer et al. (2020)), but we focus on that only when we run a difference-in-difference panel regression specification using LSE as a control in the robustness Section 5.4.

Results reported in Panel B for CXE show that, after we control for market developments on our control market, ASX, spreads increase significantly both for the overall sample and for the sub-samples of stocks. In addition market share deteriorates for small stocks. Consistent with our model Prediction 1, these negative effects could be the result of the CXE rebate reduction compared to TQ (i.e., a stronger effect on large stocks). It could also be the result of the BXE simultaneous rebate and take fee reductions (with a stronger effect on small stocks) consistent with our model Prediction 2. To uncover whether both effects are at play we look at the BATS fee change effects on the competitor market TQ, which did not implement any maker-taker pricing changes.

The results for TQ - reported in Table 7 Panel C - show that for the overall sample, depth and market share increase significantly without any significant change in spreads or volume. For large stocks we find a significant decrease in spreads, a significant increase in depth and also in market share. This significant improvement in market quality and market share is the outcome of the CXE reduction in rebate and the resulting migration of order flow from CXE (consistent with Prediction 1). Note, however, that we do not find any improvements for small firms. In particular, we observe a reduction in market share suggesting an outflow of orders from TQ to BXE driven by the BXE reductions in rebate and take fee. This asymmetry in the effects on TQ between large and small firms is predicted by our model since the effects of BXE fee changes are expected to be stronger for small firms. Overall, this suggests that both our model Prediction 1 - applied by CXE reduction in rebate - and Prediction 2 - applied by BXE reductions in both rebate and take fee - are necessary to explain the documented market quality and market share changes in TQ large and small firms.

Taken together our results show that the reduction in BATS fees only benefited small firms in the BXE market. The negative externality of BATS strategic change in pricing resulted in an improvement of TQ market quality and market share for large stocks. A market that did not change its fees.

The final panel in Table 7 - Panel D - reports the effect of BATS' fee changes on LSE. We find a significant increase in market share for small stocks together with a marginally significant increase in spreads but no significant changes on volume or depth. For large stocks, we find a marginally significant decrease in market share. Note that the results for LSE are weaker than the results discussed in the previous subsection. The reason is that many of the patterns we discovered for LSE in Table 6 are no different from what we observe in the control sample from ASX, and the panel difference-in-difference regressions corrects for exactly this.[38]

[38] LSE market share for small stocks increases relative to ASX because of a secular decline in ASX market share in this market segment over our sample period.

5.4. Robustness

We run one more panel difference-in-difference regression specification in order to verify the robustness of our results. Specifically, instead of using a sample of ASX-listed stocks as controls we use trading of the same stocks on the LSE as a control for trading on BXE, CXE, and TQ, following Equation (4). The results are reported in Table 8 for each of the lit venues that compete with the LSE: BXE, CXE, and TQ. In this specification, the coefficient on *Post* captures the effect on LSE trading of BATS' fee changes, while the coefficient on the interaction term $Post * Treatment$ captures the differential effect on the three venues BXE, CXE, and TQ respectively relative to LSE. Virtually no coefficient on *Post* is statistically significant for volume, spreads, and depth. This is consistent with the results in Table 7, Panel D, which showed that there were no significant changes in volume or market quality for LSE. However, as expected since we have already documented large shifts in LSE market share following BATS' fee changes, the coefficient on *Post* is highly significant for the market share results in the last three columns. Recognizing the effect of BATS fee changes on LSE, and following Boehmer et al. (2020), we report the sum of the direct and the indirect treatment effects at the bottom of each panel.

Starting with the market share results, LSE market share as captured by the coefficient on *Post* falls by roughly 2.2 percentage points for large stocks and about 1.4 percentage points overall with no change for small stocks. Adding these indirect effects to the interaction coefficient, the results for BXE in Panel A show that the total effect on market share for large stocks is insignificant while market share for small stocks and stocks overall increase of 1.5 and 0.9 percentage points respectively. A similar calculation shows that the total effect on market shares for CXE is a significant increase for large stocks of 0.5 percentage points and a decline for small stocks of 0.9 percentage points, but does not affect overall sample market share on this venue. Similarly, for TQ we find a significant total effect on market share for large stocks and overall of 1.7 and 0.8 percentage points respectively, and a marginally significant reduction in market share for small stocks of 0.4 percentage points. The magnitude and significance of the shifts in market share are similar to those we observed in Table 6. Using LSE as control results provide similar support to our model as Section 5.3.

We also investigate the effect of the fee change on cum-fee spreads (quoted spread plus twice the take fee), following Malinova and Park (2015). We run univariate (time-series) regressions, as shown in Equation (2), for each of our trading venues (BXE, CXE, TQ and LSE). Since the listing exchange (LSE) follows a take fee schedule, we calculate cum-fee spreads for this market based on both the lower (e.g., 0.20 bps for LSE) and upper (e.g., 0.45 bps for LSE) take fees. In contrast to Malinova and Park (2015)—who base their model on Colliard and Foucault (2012) without a tick size—but in support of our model, we find that cum-fee spreads are affected by fee changes. In particular, our cum-fee results show: (1) an overall increase in CXE cum-fee spreads driven by large firms, and (2) a decrease (increase) in BXE cum-fee spreads in small (large) firms. These results are similar to our quoted spread time-series results in Section 5.2, though the economic significance appears to be smaller.[39]

Lastly, we address the concern that our finding of a differential effect of fee-changes for large and small firms may be due to differences in relative tick size. We note that in our sample of LSE-listed firms, this is not a relevant factor, because market operating rules force trading prices to be positively correlated with tick sizes (the dynamic tick size rule), thereby ensuring that relative tick size does not vary significantly.[40] Nevertheless, to be thorough, we do identify and exclude from our sample 7 large firms that follow a slightly different dynamic tick size rule (the SET0 group) for which there are minor differences in tick size. For the remaining sample the relative tick sizes among large and small size groups are identical. We rerun our analysis and confirm and that our key finding of a differential effect of fee-changes across large and small firms still holds as the results are quantitatively and qualitatively similar to our main findings.

6. 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. We shed light on this debate by studying how reduced rebates and take fees influence both market quality and market share in a context of inter-market competition.

We first develop a theoretical model with two identical venues, operating limit order books governed by price and time priority. Our model shows that order flow between venues is key to understanding 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 maker-taker fees implemented by BATS on its two European venues - BXE and CXE - in 2013 and compare the outcomes to the model's predictions. The model emphasizes that the fee changes will likely also affect competing venues, and we therefore analyze what happens to market shares and market quality not only on BXE and CXE, but also on the competing venue TQ as well as the listing exchange.

BXE eliminated its rebates entirely, and significantly reduced the take-fee. Consistent with our model's predictions, these fee reductions attracted order flow to BXE, thus improving market quality and market share. The reduction in the take fee made BXE cheaper, thereby attracting order flows. The rebate elimination had weaker negative effects for small stocks. Hence the overall positive effect of the change in BXE fee structure was stronger for small capitalization stocks. CXE lowered only its rebate and still, consistent with our model

[39]Due to space considerations, these results are not reported but are available from the authors upon request.
[40]This is why we do not incorporate relative tick size in our theoretical model.

predictions, we find that this reduction had a detrimental effect on market quality, leading to increased spreads. Importantly, to highlight that intermarket competition affects other markets, we also study TQ which did not change any of its fees. We find that market quality and market share improves significantly for large stocks on TQ following BATS' fee changes.

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, may be ill advised.

Documenting cross-sectional differences in the effect of fee changes in BXE and CXE venues leads naturally to the following question: was the BATS fee change successful? This is a challenging question to answer, as we are unable to observe the counterfactual, i.e., what would have happened had BATS not changed its fees. We believe, nevertheless that we can shed light on this question by examining what happened to (a) market share across venues and (b) (estimated) changes in fee revenues due to the now higher fees. Regarding the former, Figure 1 shows that BATS combined market share in LSE-listed firms declined from 30.2% in November and December 2012 (Figure 1a) to 28.3% in February and March 2013 (Figure 1b). The distribution across BATS venues also shows that the loss of market share was primarily caused by traders leaving CXE which is where rebates were reduced. By contrast, the BXE venue, where both fees were reduced actually gained market share, suggesting that there is a place for a venue without liquidity rebates and low take fees. Regarding the effect on BATS revenues, our initial investigation shows that BATS' fee changes did lead trading revenues to rise significantly in both venues. In particular, we conservatively estimate a revenue increase of 1.20% for BXE and 2.54% for CXE. Hence, our results suggest that the BATS fee changes were indeed successful in this regard.

We close by highlighting our contributions to the literature. We take intermarket competition between two limit order books 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.

We also focus our analysis on a multi-platform reduction in rebates and take fee. 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 the proposed changes. We believe that since the SEC Transactions Fee Pilot proposal is currently frozen, our study provides the closest substitute, since the two venues fee-changes closely match the two test groups (only rebate reductions versus simultaneous reductions in make-take fees) proposed by the pilot. Overall, our findings can be used as a guide for how make-take pricing fees affect market quality and market share in multi-market trading environments.

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Table 1: **Order Submission Strategies**

In this table column 1 reports the payoffs of traders' order submission strategies, $\pi^{j}_{t_z}$. Column 2 reports the payoff of orders posted on Market I $\pi^{mrkI}_{t_z}$ and column 3 the payoffs of orders posted on Market II $\pi^{mrkII}_{t_z}$ where $j = mrkI$ for Market I and $j = mrkII$ for Market II. Market orders to sell $(MO^{j}_{t_z}(B^{j,b}_{i}))$ and market orders to buy $(MO^{j}_{t_z}(S^{j,b}_{i}))$ execute against the best bid price, $B^{j,b}_{t_z} = max\left\{B^{j}_{t_z,i}|l^{B^{mrkI}}_{t_z,i}, l^{B^{mrkII}}_{t_z,i}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\right\}$, or the best ask price, $S^{j,b}_{t_z,i} = min\left\{S^{j}_{t_z,i}|l^{B^{mrkI}}_{t_z,i}, l^{B^{mrkII}}_{t_z,i}, \Omega^{mrkI}, \Omega^{mrkII}, N, S\right\}$ respectively, where $l^{B^j}_{t_z,i}$ ($l^{S^j}_{t_z,i}$) is the number of shares available at the $i-th$ price level of the bid side (ask side) of the $j-th$ market at time t_z. Traders have a personal evaluation of the asset which is, $\gamma \sim U[\underline{\gamma}, \overline{\gamma})$. MF (mf) is the make fee and TF (tf) is the take fee for Market I (Market II). Limit orders to sell, $LO^{j}_{t_z}(S^{j}_{i})$, and limit orders to buy, $LO^{j}_{t_z}(B^{j}_{i})$, posted at time t_1, t_2 or t_3 may execute at the limit price, S^{j}_{i} and B^{j}_{i}, respectively. Limit buy and sell orders execution probabilities are respectively $Pr_{t_z}(S^{j}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S)$ and $Pr_{t_z}(B^{j}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S$); The payoff of no-trade, NT_{t_z}, is 0 in both markets.

Strategy	Payoffs: Market I (mrkI) $\pi^{mrkI}_{t_z}$	Payoffs: Market II (mrkII) $\pi^{mrkII}_{t_z}$
Market Order to Sell: $MO^{j}_{t_z}(B^{j,b}_{i})$	$B^{mrkI,b}_{i} - \gamma_{t_z} - TF$	$B^{mrkII,b}_{i} - \gamma_{t_z} - tf$
Limit Order to Sell: $LO^{j}_{t_z}(S^{j}_{i})$	$(S^{mrkI}_{i} - \gamma_{t_z} - MF)\times$ $Pr_{t_z}(S^{mrkI}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S)$	$(S^{mrkII}_{i} - \gamma_{t_z} - mf)\times$ $Pr_{t_z}(S^{mrkII}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S)$
No Trade: NT_{t_z}	0	0
Limit Order to Buy: $LO^{j}_{t_z}(B^{j}_{i})$ Limit Order to Buy: $LO^{j}_{t_z}(B^{j}_{i})$	$(\gamma_{t_z} - B^{mrkI}_{i} - MF)\times$ $Pr_{t_z}(B^{mrkI}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S)$	$(\gamma_{t_z} - B^{mrkII}_{i} - mf)\times$ $Pr_{t_z}(B^{mrkII}_{i}|lob^{mrkI}_{t_z}, lob^{mrkII}_{t_z}, \Omega^{mrkI}, \Omega^{mrkII}, N, S)$
Market Order to Buy: $MO^{j}_{t_z}(S^{j,b}_{i})$	$\gamma_{t_z} - S^{mrkI,b}_{i} - TF$	$\gamma_{t_z} - S^{mrkII,b}_{i} - tf$

Table 2: **Equilibrium Order Submission Strategies and Market Quality in Market I. Change in MF of Market I only (for Market II tf=mf=0.000). 3-period vs. 4-period model and $S = [0, 2]$ vs. $S = [0.05, 1.95]$**

This Table reports for Market I the average equilibrium probabilities of the following order flows and market quality metrics: limit orders, $LO(P_i)$, and market orders, $MO(P_i)$, with the orders breakdown for the outside (P_2) and inside (P_1) price levels - for one side of the market, the other side being symmetric, Quoted Spread ($Quoted\,Spread$), BBOdepth ($BBODepth$), and market share, MS. The table reports results obtained under four protocols (models): with a large support $S = [0, 2]$ (columns 1 through 5) and a small support $S = [0.05, 1.95]$ (columns 6 through 10); and with 3 periods (Panel A) and 4 periods (Panel B). TF and MF for Market I are reported in rows 1 and 2 (for Market II $\{mf, tf\} = \{.00, .00\}$). Results are reported for different values of MF, holding $TF = 0.000$, specifically: for $MF = 0.000$ (columns 1 and 6), for $MF = -0.001$ (columns 2 and 7), and for $MF = -0.005$ (columns 4 and 9). Columns 3 and 8 report the percentage change ($\Delta\%$) in the market quality metrics between $MF = 0.000$ and $MF = -0.001$ and columns 5 and 10 report the percentage change ($\Delta\%$) in the market quality metrics between $MF = -0.001$ and $MF = -0.005$. The metrics are reported as averages across all periods of the trading game for each of the 4 protocols (3 and 4 periods and large and small support, respectively). For all protocols, the asset value $AV = 1$ and tick size $\tau = 0.01$.

	$S = [0, 2]$					$S = [0.05, 1.95]$				
Market I TF	**0.000**	**0.000**	**Δ%**	**0.000**	**Δ%**	**0.000**	**0.000**	**Δ%**	**0.000**	**Δ%**
Market I MF	**0.000**	**-0.001**	**(2) and (1)**	**-0.005**	**(4) and (2)**	**0.000**	**-0.001**	**(7) and (6)**	**-0.005**	**(9) and (7)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Panel A. 3-period model										
LO	0.3781	0.5166	36.63%	0.5172	0.10%	0.3783	0.5175	36.79%	0.5181	0.11%
$LO(P_2)$	0.0062	0.0123	99.01%	0.0121	-1.98%	0.0065	0.0129	98.99%	0.0127	-2.02%
$LO(P_1)$	0.1829	0.2460	34.52%	0.2465	0.21%	0.1826	0.2458	34.58%	0.2464	0.23%
MO (Volume)	0.1251	0.2105	68.25%	0.2106	0.06%	0.1251	0.2106	68.32%	0.2107	0.07%
$MO(P_2)$	0.0020	0.0040	98.96%	0.0039	-2.06%	0.0021	0.0042	98.94%	0.0041	-2.10%
$MO(P_1)$	0.0605	0.1012	67.22%	0.1014	0.15%	0.0604	0.1011	67.25%	0.1012	0.16%
$No\ Trade$	0.2456	0.2454	-0.09%	0.2446	-0.34%	0.2454	0.2452	-0.09%	0.2443	-0.36%
$Quoted\,Spread$	0.0409	0.0374	-8.53%	0.0373	-0.13%	0.0409	0.0374	-8.55%	0.0373	-0.13%
$BBODepth$	0.4624	0.6414	38.70%	0.6437	0.36%	0.4627	0.6423	38.82%	0.6447	0.37%
MS	0.5000	0.8411	68.21%	0.8409	-0.01%	0.5000	0.8414	68.29%	0.8413	-0.02%
Panel B. 4-period model										
LO	0.3368	0.5115	51.87%	0.5119	0.08%	0.3369	0.5120	51.96%	0.5125	0.09%
$LO(P_2)$	0.0455	0.0908	99.64%	0.0903	-0.53%	0.0457	0.0911	99.61%	0.0906	-0.56%
$LO(P_1)$	0.1229	0.1650	34.20%	0.1657	0.42%	0.1228	0.1649	34.24%	0.1656	0.44%
MO (Volume)	0.1556	0.2521	61.95%	0.2523	0.08%	0.1556	0.2522	62.04%	0.2524	0.08%
$MO(P_2)$	0.0176	0.0352	99.85%	0.0352	-0.19%	0.0177	0.0354	99.84%	0.0353	-0.20%
$MO(P_1)$	0.0602	0.0908	50.85%	0.0910	0.18%	0.0601	0.0907	50.90%	0.0908	0.19%
$No\ Trade$	0.1835	0.1835	-0.05%	0.1831	-0.21%	0.1834	0.1833	-0.05%	0.1828	-0.22%
$Quoted\,Spread$	0.0408	0.0372	-9.00%	0.0371	-0.22%	0.0408	0.0372	-9.03%	0.0371	-0.23%
$BBODepth$	0.5106	0.7455	46.00%	0.7493	0.50%	0.5112	0.7469	46.11%	0.7508	0.52%
MS	0.5000	0.6705	34.10%	0.6703	-0.03%	0.5000	0.6707	34.14%	0.6705	-0.04%

Table 3: **Equilibrium Order Submission Strategies and Market Quality in Market I. Change in MF and in TF. 3-period vs. 4-period model: $S = [0, 2]$ vs. $S = [0.05, 1.95]$**

This Table reports for Market I the average equilibrium probabilities of the following order flows and market quality metrics: limit orders, $LO(P_i)$, and market orders, $MO(P_i)$, with the orders breakdown for the outside (P_2) and inside (P_1) price levels - for one side of the market, the other side being symmetric, Quoted Spread ($Quoted\,Spread$), BBOdepth ($BBODepth$), and market share, MS. The table reports results obtained under four protocols (models): with a large support $S = [0, 2]$ (columns 1 through 5) and a small support $S = [0.05, 1.95]$ (columns 6 through 10); and with 3 periods (Panel A) and 4 periods (Panel B). TF and MF for Market I are reported in rows 1 and 2 (for Market II tf=mf=0.000). Results are reported for different values of MF, specifically: for $\{MF, TF\} = \{.00, .00\}$ (columns 1 and 6), for $\{MF, TF\} = \{-.001, .001\}$ (columns 2 and 7), and for $\{MF, TF\} = \{-.001, .002\}$ (columns 4 and 9). Columns 3 and 8 report the percentage change ($\Delta\%$) in the market quality metrics between $\{MF, TF\} = \{.00, .00\}$ and $\{MF, TF\} = \{-.001, .001\}$ and columns 5 and 10 report the percentage change ($\Delta\%$) in the market quality metrics between $\{MF, TF\} = \{.00, .00\}$ and $\{MF, TF\} = \{-.001, .002\}$. The metrics are reported as averages across all periods of the trading game for each of the 4 protocols (3 and 4 periods and large and small support, respectively). For all protocols, the asset value $AV = 1$ and tick size $\tau = 0.01$.

	$S = [0, 2]$					$S = [0.05, 1.95]$				
Market I TF	**0.000**	**0.001**	**Δ%**	**0.002**	**Δ%**	**0.000**	**0.001**	**Δ%**	**0.002**	**Δ%**
Market I MF	**0.000**	**-0.001**	**(2) and (1)**	**-0.001**	**(4) and (1)**	**0.000**	**-0.001**	**(7) and (6)**	**-0.001**	**(9) and (6)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Panel A. 3-period model										
LO	0.3781	0.0185	-95.12%	0.0184	-95.14%	0.3783	0.0194	-94.87%	0.0193	-94.89%
$LO(P_2)$	0.0062	0.0092	48.77%	0.0092	48.29%	0.0065	0.0097	48.86%	0.0097	48.63%
$LO(P_1)$	0.1829	0.0000	-99.99%	0.0000	-100.00%	0.1826	0.0000	-99.99%	0.0000	-100.00%
MO (Volume)	0.1251	0.0060	-95.18%	0.0060	-95.20%	0.1251	0.0063	-94.94%	0.0063	-94.96%
$MO(P_2)$	0.0020	0.0030	48.61%	0.0030	50.12%	0.0021	0.0032	48.69%	0.0032	50.07%
$MO(P_1)$	0.0605	0.0000	-99.99%	0.0000	-100.00%	0.0604	0.0000	-99.99%	0.0000	-100.00%
$No\ Trade$	0.2456	0.4063	65.41%	0.4063	65.42%	0.2454	0.4057	65.34%	0.4057	65.34%
$Quoted\,Spread$	0.0409	0.0498	21.77%	0.0498	21.73%	0.0409	0.0498	21.74%	0.0498	21.70%
$BBODepth$	0.4624	0.0214	-95.38%	0.0213	-95.39%	0.4627	0.0225	-95.15%	0.0224	-95.16%
MS	0.5000	0.0241	-95.19%	0.0239	-95.21%	0.5000	0.0253	-94.95%	0.0251	-94.97%
Panel B. 4-period model										
LO	0.3368	0.3336	-0.95%	0.1731	-48.60%	0.3369	0.3336	-0.99%	0.1734	-48.53%
$LO(P_2)$	0.0455	0.1652	263.31%	0.0865	90.21%	0.0457	0.1651	261.66%	0.0867	89.71%
$LO(P_1)$	0.1229	0.0016	-98.69%	0.0000	-100.00%	0.1228	0.0017	-98.63%	0.0000	-100.00%
MO (Volume)	0.1556	0.0959	-38.40%	0.0521	-66.52%	0.1556	0.0960	-38.33%	0.0523	-66.36%
$MO(P_2)$	0.0176	0.0475	169.52%	0.0260	48.00%	0.0177	0.0475	168.22%	0.0262	47.85%
$MO(P_1)$	0.0602	0.0004	-99.26%	0.0000	-100.00%	0.0601	0.0005	-99.23%	0.0000	-100.00%
$No\ Trade$	0.1835	0.1863	1.47%	0.1863	1.50%	0.1834	0.1862	1.54%	0.1862	1.52%
$Quoted\,Spread$	0.0408	0.0446	9.24%	0.0472	15.81%	0.0408	0.0446	9.24%	0.0472	15.80%
$BBODepth$	0.5106	0.5335	4.48%	0.2750	-46.14%	0.5112	0.5336	4.39%	0.2755	-46.11%
MS	0.5000	0.2632	-47.36%	0.1883	-62.35%	0.5000	0.2639	-47.23%	0.1893	-62.14%

Table 4: **Trading Fee Schedules for UK and Irish listed firms.**
This table reports the trading fee schedules that apply for the LSE-listed firms during our sample period right before December 31st, 2012 to the period right after January 1st, 2013. We look at both transparent (lit) venues and dark pools. In particular, the venue that we examine are: BXE-Lit, CXE-Lit, TQ-Lit, LSE-Lit and 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.

		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: * The 0.00 make fee only applies to passive executions qualifying under Liquidity Provider Scheme for FTSE 350 securities. 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 5: **Descriptive Statistics for 2013 Event, LSE Sample.**
This table reports summary statistics for our main variables. Our 120 LSE listed stocks sample is stratified by price and market capitalization, based on daily averages for the month of January 2012. All variables reported in the tables, daily measures at the stock level, are for the listing exchange 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-side of each quote respectively. *Spread* is defined as the time-weighted daily average of the intraday difference between the ask price and the bid price of each quote. *%Spread* is defined as the time weighted daily average of the intraday ask price minus the bid price divided by the midquote of each quote. *Volatility* is defined as the difference between the high and low trading priced of each trading day divided by the high price of that day (using the end-of-day files from TRTH). The descriptive statistics for the five measures of market quality are based on daily numbers for each stock in the one-month pre-period (December 2012). We also report *market capitalization* (in £millions) and *price* levels (in £) both variables are daily measures for the month of January 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.

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

Table 6: **Measures of Market Quality. Time-Series Changes for the 2013 Event.**
This table reports the changes in market quality measures (Volume (Log), Quoted Spread, Depth (Log), and Market Share) for the 2013 event using a one-month pre- and one-month post-event window. We investigate four market venues: BATS (BXE), Chi-X (CXE), Turquoise (TQ), and the primary market (LSE). Our post minus pre (differences) 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 as shown in Equation (2). We run regressions for the overall sample and two subsamples of the highest (*Large*) and lowest (*Small*) market capitalization terciles. The table reports estimated coefficients and t-statistics (in parentheses) for the LSE 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 10%, 5%, and 1% levels, respectively

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
BXE												
Event	0.0914**	0.4975***	0.2558***	0.0327**	-0.5563**	-0.1829*	-0.1050***	0.0188	-0.0437***	0.0008	0.0134***	0.0075***
(t-statistic)	(2.75)	(4.08)	(3.75)	(2.54)	(-2.46)	(-1.83)	(-4.35)	(0.56)	(-3.84)	(0.70)	(3.13)	(2.94)
CXE												
Event	0.0895***	0.0424	0.0724***	0.0147***	0.1702	0.0423	-0.0309	0.0097	-0.0102	0.0040**	-0.0113***	-0.0017
(t-statistic)	(3.23)	(1.43)	(3.31)	(3.33)	(0.70)	(0.97)	(-0.77)	(0.45)	(-0.62)	(2.34)	(-5.51)	(-0.74)
TQ												
Event	0.2643***	-0.0035	0.1916**	-0.0179	-0.0505	-0.0123	0.2350***	-0.0358	0.0785***	0.0162***	-0.0054**	0.0067***
(t-statistic)	(4.42)	(-0.06)	(2.62)	(-1.17)	(-0.65)	(-0.30)	(4.62)	(-1.11)	(3.82)	(6.19)	(-2.21)	(2.62)
LSE												
Event	0.0380	0.1271***	0.0595**	0.0084	0.0666	0.0544*	0.0074	0.0576***	0.0158*	-0.0210***	0.0033	-0.0129***
(t-statistic)	(1.39)	(3.28)	(2.04)	(0.76)	(1.61)	(1.82)	(0.40)	(2.88)	(1.81)	(5.75)	(0.64)	(-3.54)

Table 7: **Measures of Market Quality - Panel Regressions of the 2013 Event using ASX Sample as Control.**
The table reports the changes in market quality (Volume (log), Spread, Depth (log), and Market Share) using panel difference-in-difference regressions for the 2013 event using a one-month pre- and one-month post-event window. We investigate four market venues (treatment group): BATS (BXE), Chi-X (CXE), Turquoise (TQ), and the primary market (LSE). For our control group we use a stratified sample of 120 Australian firms listed in the Australian Stock Exchange. To measure the change in market quality for each of the market venues, we follow the standard difference-in-difference specification as shown in Equation (3). The interaction variable event*treatment indicates the post-event period effect for our treatment group. We run regressions for the overall sample and two subsamples of the highest (Large) and lowest (Small) market capitalization terciles. Each Panel reports estimated coefficients and t-statistics (in parentheses) for each for the four venues. For all specifications, we employ clustered standard errors by firm and date. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively

Panel A: Panel Difference-in-difference Regressions for BXE (using ASX market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	14.7353***	13.7542***	14.2493***	0.0084**	0.0220*	0.0124***	9.2607***	9.6809***	9.5454***	0.9047***	0.9192***	0.9122***
(t-statistic)	(74.50)	(64.89)	(118.12)	(2.57)	(1.85)	(7.15)	(33.65)	(31.94)	(56.76)	(119.92)	(141.35)	(208.96)
Post	0.0784	0.0416	0.0084	0.0005	-0.0143	-0.0075	-0.0348	0.0353	-0.0437	-0.0067	-0.0160**	-0.0128**
(t-statistic)	(0.50)	(0.24)	(0.09)	(0.14)	(-1.18)	(-1.16)	(-0.50)	(0.22)	(-0.82)	(-1.02)	(-2.17)	(-2.29)
Treatment	-1.8564***	-4.2969***	-3.1792***	0.9582***	3.9609***	2.7605***	-1.7956***	-2.9689***	-2.6045***	-0.8375***	-0.8634***	-0.8496***
(t-statistic)	(-6.73)	(-11.34)	(-14.19)	(7.00)	(4.53)	(4.19)	(-5.75)	(-8.66)	(-13.62)	(-100.73)	(-98.93)	(-152.22)
Post*Treatment	0.0364	0.4568**	0.2714***	0.0325***	-0.5222***	-0.1612***	-0.0745	-0.0251	-0.0038	0.0092	0.0305***	0.0217***
(t-statistic)	(0.25)	(2.52)	(3.33)	(12.80)	(-2.69)	(-16.86)	(-1.29)	(-0.16)	(-0.08)	(1.26)	(3.66)	(3.47)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Nobs	3200	3200	9600	3192	3180	9570	3200	3200	9600	3193	3189	9581
Adj R^2	0.32	0.53	0.40	0.38	0.18	0.06	0.27	0.44	0.40	0.98	0.98	0.98
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.1147*	0.4984***	0.2798***	0.0331	-0.5365***	-0.1688	-0.1093	0.0102	-0.0474	0.0025	0.0145***	0.0088***
(t-statistic)	(1.68)	(5.07)	(5.14)	(1.04)	(-2.63)	(-1.08)	(-1.43)	(0.12)	(-1.02)	(0.86)	(4.29)	(4.87)

Panel B: Panel Difference-in-difference Regressions for CXE (using ASX market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	14.7322***	13.7706***	14.2545***	0.0101***	0.0137***	0.0105***	9.2595***	9.6815***	9.5456***	0.9054***	0.9201***	0.9129***
(t-statistic)	(74.59)	(65.01)	(118.24)	(6.54)	(3.28)	(19.84)	(33.64)	(31.94)	(56.76)	(117.03)	(137.77)	(198.94)
Post	0.0805	0.0331	0.0060	0.0005	0.0030	-0.0040	-0.0332	0.0342	-0.0434	-0.0068	-0.0164**	-0.0131**
(t-statistic)	(0.52)	(0.19)	(0.07)	(0.28)	(0.23)	(-0.84)	(-0.48)	(0.22)	(-0.81)	(-1.01)	(-2.18)	(-2.26)
Treatment	-0.5130*	-3.4882***	-2.0943***	0.7567***	3.6290***	2.3365***	-0.7743**	-2.8654***	-2.0481***	-0.6534***	-0.8056***	-0.7282***
(t-statistic)	(-1.91)	(-8.97)	(-8.78)	(7.41)	(3.45)	(3.83)	(-2.53)	(-8.25)	(-10.26)	(-64.41)	(-64.97)	(-80.99)
Post*Treatment	0.0328	0.0154	0.0751	0.0142**	0.2038***	0.1116***	-0.0032	-0.0334	0.0256	0.0132	0.0062	0.0130*
(t-statistic)	(0.23)	(0.10)	(1.07)	(2.50)	(51.21)	(2.87)	(-0.06)	(-0.22)	(0.56)	(1.46)	(0.75)	(1.92)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Nobs	3200	3200	9600	2192	3180	9570	3200	3200	9600	3193	3189	9581
Adj R^2	0.04	0.43	0.21	0.40	0.10	0.05	0.06	0.42	0.27	0.96	0.96	0.95
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.1133*	0.0486	0.0811	0.0147	0.2067	0.1076	-0.0364	0.0008	-0.0177	0.0063*	-0.0102**	-0.0001
(t-statistic)	(1.71)	(0.48)	(1.39)	(0.61)	(0.75)	(0.70)	(-0.48)	(0.01)	(-0.36)	(1.95)	(-2.56)	(-0.04)

Panel C: Panel Difference-in-difference Regressions for TQ (using ASX market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	14.7357***	13.7683***	14.2553***	0.0086***	0.0016	0.0049	9.2606***	9.6817***	9.5459***	0.9046***	0.9197***	0.9123***
(t-statistic)	(74.45)	(65.04)	(118.09)	(2.80)	(0.20)	(0.86)	(33.65)	(31.94)	(56.77)	(119.98)	(140.46)	(206.88)
Post	0.0782	0.0360	0.0056	0.0012	-0.0053	-0.0024	-0.0342	0.0335	-0.0437	-0.0066	-0.0160**	-0.0127**
(t-statistic)	(0.50)	(0.21)	(0.06)	(0.33)	(-0.34)	(-0.24)	(-0.50)	(0.21)	(-0.83)	(-1.00)	(-2.16)	(-2.26)
Treatment	-2.0256***	-3.9284***	-3.0343***	0.8976***	3.3707***	2.3792***	-1.8392***	-3.0579***	-2.6297***	-0.8470***	-0.8538***	-0.8442***
(t-statistic)	(-7.27)	(-11.09)	(-14.70)	(7.41)	(4.96)	(4.11)	(-5.89)	(-8.95)	(-13.80)	(-98.30)	(-100.99)	(-145.72)
Post*Treatment	0.2235	-0.0266	0.1204	-0.0206***	-0.0172	0.0325	0.2659***	-0.0794	0.1147**	0.0243***	0.0111	0.0200***
(t-statistic)	(1.50)	(-0.15)	(1.30)	(-23.98)	(-0.59)	(0.60)	(4.91)	(-0.52)	(2.40)	(3.26)	(1.38)	(3.09)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Nobs	3200	3200	9600	3192	3180	9568	3200	3200	9600	3193	3189	9581
Adj R^2	0.32	0.52	0.39	0.40	0.20	0.06	0.24	0.46	0.39	0.98	0.98	0.98
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.3017***	0.0094	0.1261**	-0.0194	-0.0225	0.0301	0.2317***	-0.0459	0.0709	0.0177***	-0.0049	0.0073***
(t-statistic)	(4.22)	(0.10)	(2.33)	(-0.70)	(-0.13)	(0.20)	(3.04)	(-0.54)	(1.51)	(6.09)	(-1.47)	(3.98)

Panel D: Panel Difference-in-difference Regressions for LSE (using ASX market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	14.7233***	13.7561***	14.2442***	0.0096***	-0.0115	-0.0038	9.2560***	9.6773***	9.5425***	0.9020***	0.9173***	0.9100***
(t-statistic)	(74.71)	(64.97)	(118.40)	(4.76)	(-0.48)	(-0.27)	(33.62)	(31.90)	(56.70)	(120.49)	(135.65)	(199.31)
Post	0.0833	0.0430	0.0114	0.0018	0.0193	0.0152	-0.0289	0.0366	-0.0410	-0.0059	-0.0144*	-0.0117**
(t-statistic)	(0.54)	(0.25)	(0.13)	(0.89)	(0.81)	(1.10)	(-0.42)	(0.23)	(-0.76)	(-0.86)	(-1.89)	(-2.01)
Treatment	0.4036	-1.0956***	-0.5287***	0.8860***	2.0407***	1.6562***	-0.4282	-1.9507***	-1.4325***	-0.2833***	-0.1547***	-0.2277***
(t-statistic)	(1.46)	(-3.76)	(-2.80)	(7.20)	(5.16)	(5.52)	(-1.39)	(-5.37)	(-7.20)	(-29.60)	(-8.53)	(-22.35)
Post*Treatment	-0.0274	0.0724	0.0535	0.0051	0.0326*	-0.0000	0.0260	0.0054	0.0508	-0.0149*	0.0158**	-0.0021
(t-statistic)	(-0.20)	(0.45)	(0.77)	(1.19)	(1.76)	(-0.00)	(0.46)	(0.04)	(1.07)	(-1.69)	(2.07)	(-0.30)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Nobs	3200	3200	9600	3190	3180	9567	3200	3200	9600	3193	3189	9581
Adj R^2	0.02	0.10	0.03	0.38	0.22	0.09	0.02	0.24	0.15	0.82	0.31	0.55
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.0559	0.1155	0.065	0.0069	0.0519	0.0152	-0.0029	0.042	0.0098	-0.0208***	0.0014	-0.0138***
(t-statistic)	(0.82)	(1.45)	(1.37)	(0.24)	(0.53)	(0.19)	(-0.04)	(0.47)	(0.20)	(-5.90)	(0.25)	(-4.51)

Table 8: **Measures of Market Quality - Panel Regressions of the 2013 Event using LSE Sample as Control.**
The table reports the changes in market quality (Volume (log), Spread, Depth (log), and Market Share) using panel difference-in-difference regressions for the 2013 event using a one-month pre- and one-month post-event window. We investigate four market venues (treatment group): BATS (BXE), Chi-X (CXE) and Turquoise (TQ). For our control group we use the LSE. To measure the change in market quality for each of the market venues, we follow the standard difference-in-difference specification as shown in Equation (4). The interaction variable event*treatment indicates the post-event period effect for our treatment group. Since we expect indirect effects on the LSE market due to intermarket competition, and following Boehmer et al. (2020) we also report the joint direct and indirect effects (event+event*treatment). We run regressions for the overall sample and two subsamples of the highest (Large) and lowest (Small) market capitalization terciles. Each Panel reports estimated coefficients and t-statistics (in parentheses) for each for the three venues (BXE, CXE, and TQ). For all specifications, we employ clustered standard errors by firm times date. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A: 2013 Event for LSE sample – Panel Difference-in-difference Regressions for BXE (using LSE market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	15.1447***	12.6536***	13.7196***	0.8924***	2.0417***	1.6542***	8.8244***	7.7179***	8.1044***	0.6202***	0.7630***	0.6832***
(t-statistic)	(317.50)	(243.73)	(376.07)	(30.23)	(20.42)	(21.43)	(230.59)	(163.17)	(309.20)	(272.41)	(157.56)	(271.04)
Post	0.0327	0.1256*	0.0604	0.0074	0.0333	0.0025	0.0016	0.0559	0.0164	-0.0219***	0.0016	-0.0136***
(t-statistic)	(0.49)	(1.67)	(1.18)	(0.18)	(0.24)	(0.02)	(0.03)	(0.86)	(0.45)	(-7.34)	(0.25)	(-3.83)
Treatment	-2.2600***	-3.2014***	-2.6506***	0.0722***	1.9201***	1.0744***	-1.3674***	-1.0182***	-1.1719***	-0.5541***	-0.7086***	-0.6219***
(t-statistic)	(-159.12)	(-47.25)	(-99.28)	(6.36)	(12.64)	(11.45)	(-57.55)	(-50.07)	(-92.51)	(-194.17)	(-117.98)	(-206.37)
Post*Treatment	0.0639***	0.3743***	0.2105***	0.0264*	-0.5563***	-0.1530	-0.1009	-0.0356	-0.0560***	0.0236***	0.0134	0.0225***
(t-statistic)	(3.46)	(4.29)	(6.18)	(1.78)	(-2.98)	(-1.04)	(-3.37)	(-1.27)	(-2.82)	(6.63)	(1.59)	(5.33)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.0966	0.4990***	0.2709***	0.0338	-0.5230*	-0.1505	-0.0993**	0.0203	-0.0396	0.0017	0.0151***	0.0089***
(t-statistic)	(1.44)	(4.49)	(4.25)	(0.76)	(-1.85)	(-0.69)	(-1.99)	(0.37)	(-1.30)	(1.54)	(6.47)	(8.35)

Panel B: 2013 Event for LSE sample – Panel Difference-in-difference Regressions for CXE (using LSE market as control)

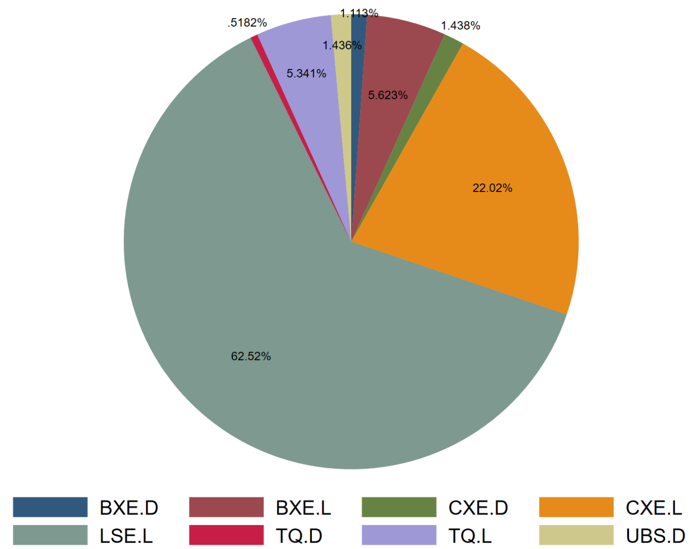
	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	15.1416***	12.6700***	13.7249***	0.8941***	2.0334***	1.6523***	8.8231***	7.7184***	8.1046***	0.6210***	0.7639***	0.6839***
(t-statistic)	(318.01)	(241.83)	(374.38)	(30.50)	(20.20)	(21.61)	(230.88)	(163.03)	(308.13)	(270.40)	(158.15)	(271.67)
Post	0.0349	0.1168	0.0579	0.0073	0.0493	0.0059	0.0031	0.0550	0.0167	-0.0221***	0.0013	-0.0139***
(t-statistic)	(0.52)	(1.54)	(1.13)	(0.18)	(0.35)	(0.11)	(0.06)	(0.85)	(0.46)	(-7.37)	(0.19)	(-3.92)
Treatment	-0.9166***	-2.3926***	-1.5656***	-0.1293***	1.5882***	0.6804***	-0.3461***	-0.9147***	-0.6156***	-0.3700***	-0.6508***	-0.5005***
(t-statistic)	(-88.53)	(-44.23)	(-65.01)	(-14.51)	(7.87)	(7.27)	(-17.08)	(-43.66)	(-49.87)	(-96.24)	(-88.61)	(-119.22)
Post*Treatment	0.0578***	-0.0640	0.0153	0.0086	0.1384	0.1161	-0.0299	-0.0427	-0.0269	0.0272***	-0.0106	0.0136**
(t-statistic)	(4.22)	(-0.85)	(0.45)	(0.71)	(0.46)	(0.75)	(-1.05)	(-1.41)	(-1.57)	(5.37)	(-1.05)	(2.30)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.0927	0.0527	0.0732	0.0159	0.1876	0.1219	-0.0267	0.0123	-0.0102	0.0051**	-0.0093**	-0.0003
(t-statistic)	(1.46)	(0.46)	(1.05)	(0.47)	(0.49)	(0.57)	(-0.57)	(0.22)	(-0.28)	(2.22)	(-2.52)	(-0.10)

Panel C: 2013 Event for LSE sample − Panel Difference-in-difference Regressions for TQ (using LSE market as control)

	Volume (Log)			Spread			Depth (Log)			Market Share		
	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall	Large	Small	Overall
Intercept	15.1451***	12.6677***	13.7257***	0.8926***	2.0215***	1.6468***	8.8243***	7.7187***	8.1049***	0.6202***	0.7634***	0.6834***
(t-statistic)	(317.31)	(243.60)	(376.99)	(30.32)	(20.44)	(21.48)	(230.55)	(163.22)	(309.08)	(272.60)	(157.63)	(270.86)
Post	0.0322	0.1194	0.0571	0.0080	0.0423	0.0077	0.0021	0.0543	0.0164	-0.0218***	0.0016	-0.0135***
(t-statistic)	(0.48)	(1.58)	(1.12)	(0.20)	(0.30)	(0.07)	(0.04)	(0.84)	(0.45)	(-7.31)	(0.25)	(-3.81)
Treatment	-2.4293***	-2.8329***	-2.5056***	0.0116	1.3300***	0.7231***	-1.4109***	-1.1073***	-1.1972***	-0.5636***	-0.6990***	-0.6165***
(t-statistic)	(-154.99)	(-55.62)	(-119.48)	(1.56)	(13.38)	(9.28)	(-60.95)	(-56.61)	(-102.85)	(-197.27)	(-113.87)	(-203.06)
Post*Treatment	0.2379***	-0.1152	0.0439	-0.0254**	-0.0686	0.0410	0.2382***	-0.0869***	0.0633***	0.0389***	-0.0053	0.0211***
(t-statistic)	(6.30)	(-1.55)	(1.24)	(-2.44)	(-0.49)	(0.30)	(7.71)	(-3.04)	(3.91)	(10.28)	(-0.63)	(4.90)
Option Exp. Date Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adding the indirect and direct treatment effects:												
Post+Post*Treatment	0.2701***	0.0042	0.1010	-0.0174	-0.0262	0.0487	0.2403***	-0.0326	0.0797**	0.0170***	-0.0037*	0.0075***
(t-statistic)	(3.60)	(0.04)	(1.60)	(-0.45)	(0.23)	(0.24)	(4.82)	(-0.61)	(2.55)	(13.09)	(-1.68)	(6.55)

Figure 1: **Market Share Pie-Charts of the LSE sample 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 sample in the pre-period of the 2013 event (November and December 2012) and in the period after fee change in January 2013 (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).

(a) 2013 Event Pre-Period (November and December 2012)



(b) 2013 Event Post-Period (February and March 2013)

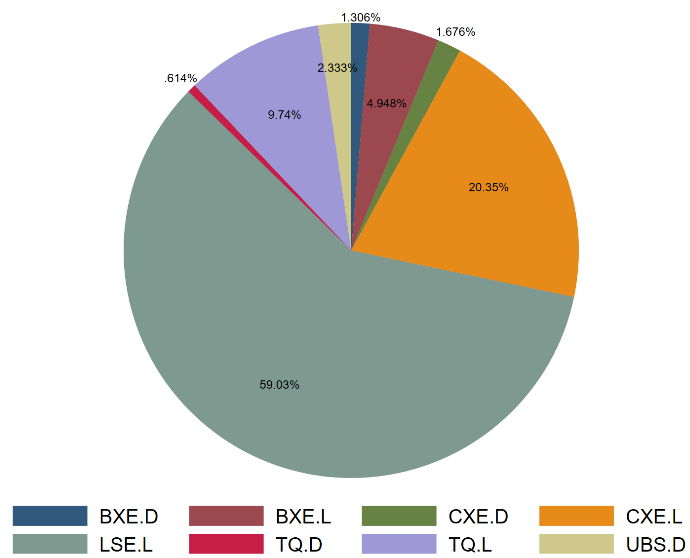
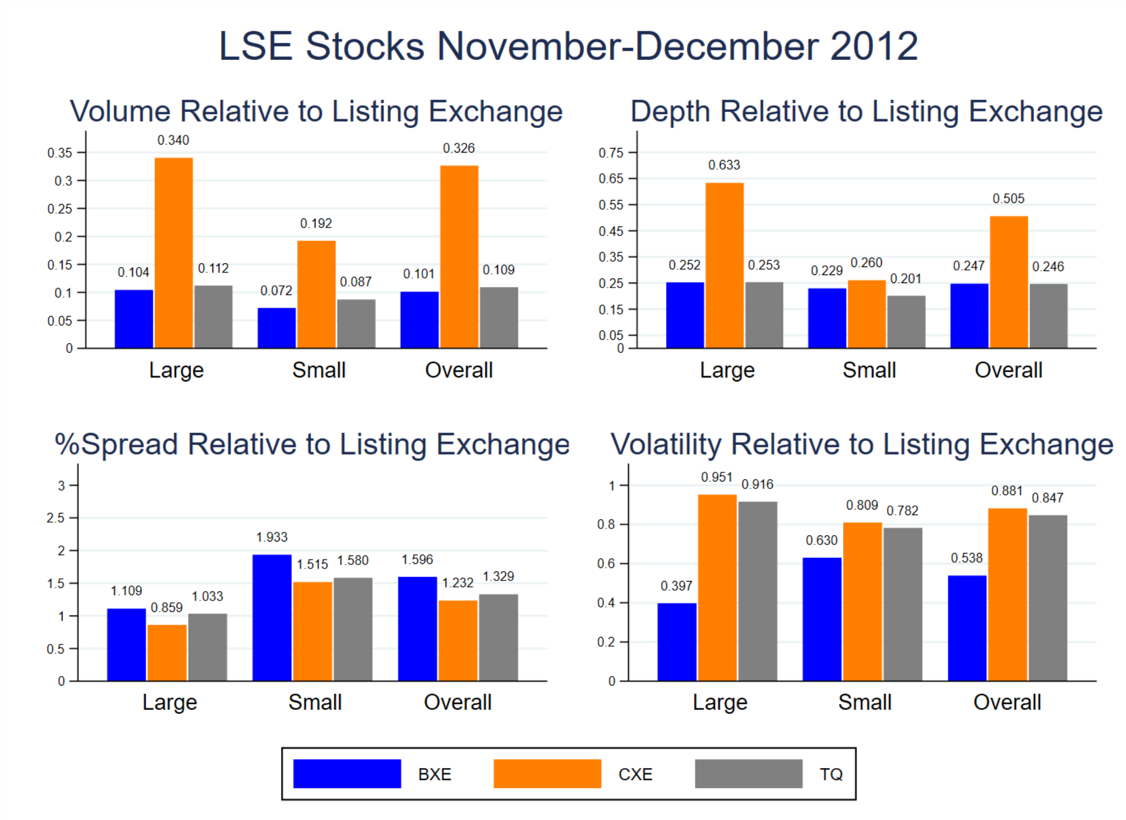


Figure 2: **Market Quality Measures across Markets**
The figure show average daily market quality measures (Volume, Depth, %Spread, and Volatility) of the three market venues (BXE, CXE, TQ) relative to the listing exchange (LSE) in the pre-period (Nov/Dec 2012) of the 2013 Event. It depicts relative market quality measures for the overall sample and two sub-samples of the highest (Large) and lowest (Small) market capitalization terciles. Filled bars indicate that a venue mean is significantly different from the listing exchange mean based on a simple differences-in-group-means test.



Appendix 1

Model Solution and proof of Proposition 1 and 2

In this Appendix we show how to solve the 3-period model; the solution of the 4-period model follows the same line of reasoning. At each period t_z, a trader uses the information from the state of the book of both Market I and Market II 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_{z+1} (and possibly t_{z+2}) 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, $LO_{t_3}(P_i^j)$, are equal to zero and therefore to choose the order submission strategy $(ST^*_{t_3})$ that maximizes the expected payoff $(\pi^e_{t_3})$ conditional on their private valuation of the asset, γ, traders solve problem (5) by choosing between market orders, $MO_{t_3}(P_i^{j,b})$, and no-trade $NT_{t_3}(0))$:

$$max_{ST^*_{t_3}} \pi^e_{t_3} \left\{ MO_{t_3}(P_i^{j,b}),\, NT_{t_3}(0) \mid \gamma,\, lob^j_{t_3} \right\} \tag{5}$$

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

$$\gamma_{t_3}^{ST^*_n, ST^*_{n-1}} = \left\{ \gamma \in \mathbb{R} \,:\, \pi^e_{t_3}\left(ST^*_n \,|\, lob^j_{t_3}\right) - \pi^e_{t_3}\left(ST^*_{n-1} \,|\, lob^j_{t_3}\right) = 0 \right\} \tag{6}$$

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

$$Pr[ST^*_n \,|\, lob^j_{t_3}] = F(\gamma_{t_3}^{ST^*_{n+1}, ST^*_n} \,|\, lob^j_{t_3}) - F(\gamma_{t_3}^{ST^*_n, ST^*_{n-1}} \,|\, lob^j_{t_3}) \tag{7}$$

Clearly, the probability to observe a $MO_{t_3}(P_i^{j,b})$ at t_3 is the execution probability of a $LO_{t_2}(P_i^j)$ 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 the states of the book in the two markets 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 a general example, consider a case at t_3 with the book that opens empty and with one sell order standing on the first level of Market II and one buy order standing on the second level of Market I. This means that the payoffs from the t_3 strategies are:

$$\begin{aligned} \pi^e_{t_3}(MO_{t_3}(S_1^{mrkII})\,|\,lob^j_{t_3}) &= \gamma AV - S_1^{mrkII} - tf \\ \pi^e_{t_3}(NT_{t_3}(0)\,|\,lob^j_{t_3}) &= 0 \\ \pi^e_{t_3}(MO_{t_3}(B_2^P)\,|\,lob^j_{t_3}) &= B_2^{mrkI} - \gamma AV - TF \end{aligned} \tag{8}$$

Hence the t_3 equilibrium strategies are:

$$ST^*_{(\cdot)} = \begin{cases} MO_{t_3}(S_1^{mrkII}) & \text{if } \gamma \in [\underline{\gamma}, \frac{S_1^{mrkII}-tf}{AV}) \\ NT_{t_3}(0) & \text{if } \gamma \in [\frac{S_1^{mrkII}-tf}{AV}, \frac{B_2^{mrkI}+TF}{AV}) \\ MO_{t_3}(B_2^{mrkI}) & \text{if } \gamma \in (\frac{B_2^{mrkI}+TF}{AV}, \overline{\gamma}] \end{cases} \tag{9}$$

and the t_3 equilibrium order submission probabilities are:

$$Pr[ST^*_{(\cdot)}\,|\,lob^j_{t_3}] = \begin{cases} \int_{\gamma\in\left\{\gamma\,:\,ST^*_{(\cdot)}=MO_{t_3}(1,S_1^{mrkII})\right\}} g(\gamma)\,d\gamma \\ \int_{\gamma\in\left\{\gamma\,:\,ST^*_{(\cdot)}=NT_{t_3}(0)\right\}} g(\gamma)\,d\gamma \\ \int_{\gamma\in\left\{\gamma\,:\,ST^*_{(\cdot)}=MO_{t_3}(1,B_2^{mrkI})\right\}} g(\gamma)\,d\gamma \end{cases} \tag{10}$$

where $g(\gamma)$ is the probability density function (PDF) of γ.
Note that $Pr[MO_{t_3}(S_1^{mrkII})\,|\,lob^j_{t_3}]$ and $Pr[MO_{t_3}(B_2^{mrkI})\,|\,lob^j_{t_3}]$ correspond to the execution probabilities of the previous period (t_2) limit orders respectively posted to Market II and Market I, i.e., $[LO_{t_2}(S_1^{mrkII})\,|\,lob^j_{t_2}]$ and $[LO_{t_2}(B_2^{mrkI})\,|\,lob^j_{t_2}]$, which are the dynamic link between periods t_3 and t_2.

As an example, we now solve the model to obtain the results shown in Table A7 for one set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$. Results for the other sets of fees can be obtained in a similar way. Tables A1, A2 and A3 show the equilibrium strategies (column 1) at t_3, t_2 and t_1 respectively for all the possible states of the book starting from an empty book at t_1. Each table also shows the payoff associated to each equilibrium strategy (column 2), the γ thresholds indicating the corresponding support of the TN distribution for each equilibrium strategy (column 3), and the resulting submission probabilities (column 4).[41]

The model is solved by backward induction, so as an example, following the branch of the trading game that starts at t_1 with $LO_{t_1}(S_1^{mrkII})$, the book opens at t_2 as [0000-0100].[42] Given the three equilibrium strategies that result when we condition to this opening book at t_2, $[NT_{t_2}(0)$, $LO_{t_2}(B_2^{mrkI})$ and $MO(S_1^{mrkII})]$, at t_3 the book may open with three different states, [0000-0100], [0001-0100], and [0000-0000], respectively. The last column of each table shows the submission probability of the equilibrium orders which are then used to compute

[41]The γ thresholds indicate the optimal trading strategies that result from comparing the payoffs of all the possible orders a trader can choose conditional on each state of the book in any trading period (Equation (6)).

[42][0000-0100] indicates the state of Market I and Market II respectively, $[l^{S_2^{mrkI}} l^{S_1^{mrkI}} l^{B_1^{mrkI}} l^{B_{2-}^{mrkI}} l^{S_2^{mrkII}} l^{S_1^{mrkII}} l^{B_1^{mrkII}} l^{B_2^{mrkII}}]$.

both the metrics of order flows (average limit orders, LO^j, and average market share MS^j), and the metrics of market quality, (average quoted spread, $Spread^j$ and average depth at the best bid-offer, $BBODepth^j$), shown in Table 3 for the above mentioned set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$. Finally, Tables A4 and A5 show how to obtain both the order flows and the market quality metrics for this set of fees, starting from the equilibrium order submission strategies. Therefore, Tables A4 and A5 link Tables A1, A2 and A3 with Table 3.[43] Results for different sets of fees can be obtained in a similar way.

Effects of change in dispersion of beliefs and number of trading periods

Table 3 (and Table A7) reports results for both the 3-period and the 4-period models and compares them for the two protocols with a large support, $S = [0, 2]$, and a small support, $S = [0.05, 1.95]$, respectively. This way we can investigate first how - given the trading activity $N = 3$ or $N = 4$ - our results change when we change the distribution of the gains from trade in such a way that investors' private valuation are distributed over a smaller support - implying that overall gains from trade are less dispersed around the asset value; second, we can investigate how - given the support of investors' private valuation - our results change when the market is characterized by a different trading activity.

To understand how both the 3-period and the 4-period models change - all else equal - following a reduction in the support or/and an increase in trading activity, consider the results for the equilibrium order submission probability of both limit and market order submissions, as well as the derived metrics of market quality reported in columns 2 and 7 of Tables 3 and A7. These results are obtained by solving the model for the regime with all the trading fees set equal to zero, $\{MF, TF, mf, tf\} = \{.00, .00, .00, .00\}$.[44]

All else equal, when the support decreases from $S = [0, 2]$ to $S = [0.05, 1.95]$ both in the 3-period and in the 4-period model, traders willingness to supply liquidity increases thus increasing LO^j as well as $BBOdepth^{mrkI}$. When the support decreases, extreme gains from trade decrease and there are fewer traders willing to post aggressive limit orders at the inside quotes, thus explaining the small switch of limit orders from the inside, $LO^{mrkI}(P_1)$, to the outside quotes, $LO^{mrkI}(P_2)$. As a result, market orders, driven by the switch of limit orders, also slightly move from the inside $MO^{mrkI}(P_1)$, to outside quotes, $MO^{mrkI}(P_2)$.

All else equal, when the trading activity increases from $N = 3$ to $N = 4$, the execution probability of limit orders increases as orders have an additional period to execute. As a consequence, some limit orders move from the inside to the outside quotes and overall liquidity

[43] Results for average values reported in Tables A4 and A5 have been obtained by rounding at the fourth decimal value and they may slightly differ from the results reported in column 3 of Table 3 which have been obtained without any rounding.

[44] Appendix 1 shows how the metrics of market quality are obtained starting from the equilibrium order submission probabilities.

supply increases.[45] This explains why $BBODepth^{mrkI}$ and $Quoted\,Spread^{mrkI}$ improve.

[45]Note that even if the average order submission probability of limit orders across the trading game decreases in the 4-period model compared to the 3-period one, liquidity provision overall increases in the 4-period protocol. The reason is that as the book fills up with limit orders, over time there is less room for traders to post additional limit orders; therefore, even though in the first two periods of the trading game the average order submission probability of limit orders in the 4-period model increases compared to the 3-period model, as the book fills up with limit orders, in the additional third period, t_3, the average probability of limit order submission decreases, with the consequence that the overall average of limit order submission probability in the 4-period model decreases.

Table A1: **Equilibrium Strategies at $\mathbf{t_3}$** This table shows how to derive the equilibrium order submission strategies at t_3 of the 3-period model - for the following set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$ and for $\gamma \in ([0.0, 2.0]$. At t_1 both Market I and Market II open with an empty book, [0000-0000], where each element in the square bracket, $l_{t_z}^{S_i^j}$, corresponds to the depth of the book at each price level of both Market I and Market II at time t_z, $[l^{S_2^{mrkI}} l^{S_1^{mrkI}} l^{B_1^{mrkI}} l^{B_2^{Prm}} - l^{S_2^{mrkII}} l^{S_1^{mrkII}} l^{B_1^{mrkII}} l^{B_2^{mrkII}}]_{t_z}$. Given the chosen set of fees, four are the equilibrium strategies at t_1, $LO_{t_1}(S_1^{mrkII})$, $LO_{t_1}(S_2^{mrkI})$, $LO_{t_1}(B_1^{mrkII})$ and $LO_{t_1}(B_2^{mrkI})$. We only consider the sell side of the market, the buy side being symmetrical. Given the equilibrium limit sell orders, the possible states of the books at the beginning of t_2 are: [0000-0100] and [1000-0000]. Given the equilibrium strategies at t_2 and therefore the possible states of the books at the beginning of t_3, this table shows the equilibrium Strategies at t_3 (column 1), their payoffs (column 2), the γ thresholds (column 3) and the order submission probabilities (column 4).

Equilibrium Strategy	**Payoff**	**γ Threshold**	**Order Submission Probability**
at t_1 mrkI and mrkII books open empty [0000-0000]: equilibrium strategy $LO_{t_1}(S_1^{mrkII})$			
at t_2 mrkI and mrkII books open [0000-0100]			
	t_2 **equilibrium strategy** NT_{t_2}		
at t_3 mrkI and mrkII books open [0000-0100]			
$NT_{t_3}(0)$	0	$\{0.0000, 1.0050\}$	0.5025
$MO_{t_3}(S_1^{mrkII})$	$\gamma AV - S_1^{mrkII} - tf = \gamma - 1.0050$	$\{1.0050, 2.0000\}$	0.4975
	t_2 **equilibrium strategy** $LO_{t_2}(B_2^{mrkI})$		
at t_3 mrkI and mrkII books open [0001-0100]			
$MO_{t_3}(B_2^{mrkI})$	$B_2^{mrkI} - \gamma AV - TF = 0.9840 - \gamma$	$\{0.0000, 0.9840\}$	0.4920
$NT_{t_3}(0)$	0	$\{0.9840, 1.0050\}$	0.0105
$MO_{t_3}(S_1^{mrkII})$	$\gamma AV - S_1^{mrkII} - tf = \gamma - 1.0050$	$\{1.0050, 2.0000\}$	0.4975
	t_2 **equilibrium strategy** $MO_{t_2}(S_1^{mrkII})$		
at t_3 mrkI and mrkII books open [0000-0000]			
$NT_{t_3}(0)$	0	$\{0.0000, 2.0000\}$	1.0000
at t_1 mrkI and mrkII books open empty [0000-0000]: equilibrium strategy $LO_{t_1}(S_2^{mrkI})$			
at t_2 mrkI and mrkII books open [1000-0000]			
	t_2 **equilibrium strategy** $LO_{t_2}(S_1^{mrkII})$		
at t_3 mrkI and mrkII books open [1000-0100]			
$NT_{t_3}(0)$	0	$\{0.0000, 1.0050\}$	0.5025
$MO_{t_3}(S_1^{mrkII})$	$\gamma AV - S_1^{mrkII} - tf = \gamma - 1.0050$	$\{1.0050, 2.0000\}$	0.4975
	at t_2 **equilibrium strategy** $LO_{t_2}(S_1^{mrkI})$		
at t_3 mrkI and mrkII books open [1100-0000]			
$NT_{t_3}(0)$	0	$\{0.0000, 1.0060\}$	0.5030
$MO_{t_3}(S_1^{mrkI})$	$\gamma AV - S_1^{mrkI} - TF = \gamma - 1.0060$	$\{1.0060, 2.0000\}$	0.4970
	at t_2 **equilibrium strategy** $LO_{t_2}(S_2^{mrkII})$		
at t_3 mrkI and mrkII books open [1000-1000]			
$NT_{t_3}(0)$	0	$\{0.0000, 1.0150\}$	0.5075
$MO_{t_3}(S_2^{mrkII})$	$\gamma AV - S_2^{mrkII} - tf = \gamma - 1.0150$	$\{1.0150, 2.0000\}$	0.4925
	at t_2 **equilibrium strategy** $LO_{t_2}(B_2^{mrkI})$		
at t_3 mrkI and mrkII books open [1001-0000]			
$MO_{t_3}(B_2^{mrkI})$	$B_2^{mrkI} - \gamma AV - TF = 0.9840 - \gamma$	$\{0.0000, 0.9840\}$	0.4920
$NT_{t_3}(0)$	0	$\{0.9840, 1.0160\}$	0.0160
$MO_{t_3}(S_2^{mrkI})$	$\gamma AV - S_2^{mrkI} - TF = \gamma - 1.0160$	$\{1.0160, 2.0000\}$	0.4920
	at t_2 **equilibrium strategy** $MO_{t_2}(S_2^{mrkI})$		
at t_3 mrkI and mrkII books open [0000-0000]			
$NT_{t_3}(0)$	0	$\{0.0000, 2.0000\}$	1.0000

Table A2: **Equilibrium Strategies at** t_2 This table shows how to derive the equilibrium order submission strategies at t_2 of the 3-period model - for the following set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$ and for $\gamma \in [0.0, 2.0]$. At t_1 both Market I and Market II open with an empty book, [0000-0000], where each element in the square bracket, $l_{t_z}^{S_i^j}$, corresponds to the depth of the book at each price level of both Market I and Market II at time t_z, $[l^{S_2^{mrkI}} l^{S_1^{mrkI}} l^{B_1^{mrkI}} l^{B_2^{rim}} - l^{S_2^{mrkII}} l^{S_1^{mrkII}} l^{B_1^{mrkII}} l^{B_2^{mrkII}}]_{t_z}$. Given the chosen set of fees, four are the equilibrium strategies at t_1, $LO_{t_1}(S_1^{mrkII})$, $LO_{t_1}(S_2^{mrkI})$,$LO_{t_1}(B_1^{mrkII})$ and $LO_{t_1}(B_2^{mrkI})$. We only consider the sell side of the market, the buy side being symmetrical. Given the equilibrium limit sell orders, the possible states of the books at the beginning of t_2 are: [0000-0100] and [1000-0000]. Column 1 shows the Equilibrium strategies at t_2, column 2 shows their payoffs, and columns 3 and 4 shows the γ thresholds and the order submission probabilities respectively.

Equilibrium Strategy	Payoff	γ Threshold	Order Submission Probability
	at t_1 mrkI and mrkII books open empty [0000-0000]: equilibrium strategy $LO_{t_1}(S_1^{mrkII})$		
at t_2 mrkI and mrkII books open [0000-0100]			
$NT_{t_2}(0)$	0	$\{0.0000, 0.9840\}$	0.4920
$LO_{t_2}(B_2^{mrkI})$	$(\gamma AV - B_2^{mrkI} - MF) \times Pr(MO_{t_3}(B_2^{mrkI})\|[0001-0100]) = -0.4841 + 0.4920\gamma$	$\{0.9840, 1.0253\}$	0.0207
$MO_{t_2}(S_1^{mrkII})$	$\gamma AV - S_1^{mrkII} - tf = -1.005 + \gamma$	$\{1.0253, 2.0000\}$	0.4873
	at t_1 mrkI and mrkII books open empty [0000-0000]: equilibrium strategy $LO_{t_1}(S_2^{mrkI})$		
at t_2 mrkI and mrkII books open [1000-0000]			
$LO_{t_2}(S_1^{mrkII})$	$(S_1^{mrkII} - \gamma AV - mf) \times Pr(MO_{t_3}(S_1^{mrkII})\|[1000-0100]) = 0.49998 - 0.4975\gamma$	$\{0.0000, 0.0110\}$	0.0055
$LO_{t_2}(S_1^{mrkI})$	$(S_1^{mrkI} - \gamma AV - MF) \times Pr(MO_{t_3}(S_1^{mrkI})\|[1100-0000]) = 0.49998 - 0.4970\gamma$	$\{0.0110, 0.0210\}$	0.0050
$LO_{t_2}(S_2^{mrkII})$	$(S_2^{mrkII} - \gamma AV - mf) \times Pr(MO_{t_3}(S_2^{mrkII})\|[1000-1000]) = 0.49989 - 0.4925\gamma$	$\{0.0210, 0.9995\}$	0.4893
$LO_{t_2}(B_2^{mrkI})$	$(\gamma AV - B_2^{mrkII} - MF) \times Pr(MO_{t_3}(B_2^{mrkI})\|[1001-0000]) = -0.48413 + 0.4920\gamma$	$\{0.9995, 1.0470\}$	0.0237
$MO_{t_2}(S_2^{mrkI})$	$\gamma AV - S_2^{mrkI} - TF = -1.016 + \gamma$	$\{1.0470, 2.0000\}$	0.4765

Table A3: **Equilibrium Strategies at** t_1 This table shows how to derive the equilibrium order submission strategies at t_1 - of the 3-period model - for the following set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$ and for $\gamma \in [0.0, 2.0]$. At t_1 both Market I and Market II open with an empty book, [0000-0000], where each element in the square bracket, $l_t^{S_i^j}$, corresponds to the depth of the book at each price level of both Market I and Market II at time t_z, $[l^{S_2^{mrkI}} l^{S_1^{mrkI}} l^{B_1^{mrkI}} l^{B_2^{mrkI}} - l^{S_2^{mrkII}} l^{S_1^{mrkII}} l^{B_1^{mrkII}} l^{B_2^{mrkII}}]_{t_z}$. Given the chosen set of fees, four are the equilibrium strategies at t_1, $LO_{t_1}(S_1^{mrkII})$, $LO_{t_1}(S_2^{mrkI})$, $LO_{t_1}(B_1^{mrkII})$ and $LO_{t_1}(B_2^{mrkI})$ which are shown in column 1. Column 2 shows their payoffs, and column 3 and 4 shows the γ thresholds and the order submission probabilities respectively.

Equilibrium Strategy	Payoff	γ Threshold	Order Submission Probability
	at t_1 mrkI and mrkII books open empty [0000-0000]		
$LO_{t_1}(S_1^{mrkII})$	$(S_1^{mrkII} - \gamma AV - mf) \times [(Pr(MO_{t_2}(S_1^{mrkII})\|[0000-0100]) + (1 - Pr(MO_{t_2}(S_1^{mrkII})\|[0000-0100])) \times Pr(MO_{t_3}(S_1^{mrkII})\|[0000-0100]))] = 0.7461 - 0.7424\gamma$	$\{0.0000, 0.9839\}$	0.4919
$LO_{t_1}(S_2^{mrkI})$	$(S_2^{mrkI} - \gamma AV - MF) \times [(Pr(MO_{t_2}(S_2^{mrkI})\|[1000-0000]) + (1 - Pr(MO_{t_2}(S_2^{mrkI})\|[1000-0000]) - Pr(LO_{t_2}(S_1^{mrkI})\|[1000-0000]) - Pr(LO_{t_2}(S_1^{mrkII})\|[1000-0000])) \times Pr(MO_{t_3}(S_2^{mrkI})\|[1000-0000]))] = 0.4960 - 0.4882\gamma$	$\{0.9839, 1.0000\}$	0.0081
$LO_{t_1}(B_2^{mrkI})$	$(\gamma AV - B_2^{mrkI} - MF) \times [(Pr(MO_{t_2}(B_2^{mrkI})\|[0001-0000]) + (1 - Pr(MO_{t_2}(B_2^{mrkI})\|[0001-0000]) - Pr(LO_{t_2}(B_1^{mrkI})\|[0001-0000]) - Pr(LO_{t_2}(B_1^{mrkII})\|[0001-0000])) \times Pr(MO_{t_3}(B_2^{mrkI})\|[0001-0000]))] = -0.4804 + 0.4882\gamma$	$\{1.0000, 1.0161\}$	0.0081
$LO_{t_1}(B_1^{mrkII})$	$(\gamma AV - B_1^{mrkII} - mf) \times [(Pr(MO_{t_2}(B_1^{mrkII})\|[0000-0010]) + (1 - Pr(MO_{t_2}(B_1^{mrkII})\|[0000-0010])) \times Pr(MO_{t_3}(B_1^{mrkII})\|[0000-0010]))] = -0.7387 + 0.7424\gamma$	$\{1.0161, 2.0000\}$	0.4919

Table A4: **Equilibrium Order Submission Strategies, Order Flows and Market Quality** This Table shows how to obtain the metrics on order flows and market quality (column 1) presented in Tables 2 and A6 for the following set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$. Column 2 reports the equilibrium order submission probability of limit and market orders Market I and Market II in each period t_z, $LO^j_{t_z}$ and $MO^j_{t_z}$, and the equilibrium average of limit orders, market orders and market share, LO^j, MO^j and MS^j. Column 3 shows how the values reported in column 2 are computed from the equilibrium strategies. Results are reported for both Market I (mrkI) and Market II (mrkII) market. Traders have a personal evaluation of the asset which is a Uniform distribution, $\gamma \sim U[\overline{\gamma}, \underline{\gamma}]$ with $S = [0, 2]$ and $AV = 1$.

Metric	**Value**	**Analytical Computation**
$LO^{mrkI}_{t_1}$	0.0162	$Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) + Pr(LO_{t_1}(B^{mrkI}_2)\vert.)) = 0.0081 + 0.0081$
$LO^{mrkI}_{t_2}$	0.0208	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times Pr(LO_{t_2}(B^{mrkI}_2)\vert 0000-0100) + (2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times (Pr(LO_{t_2}(S^{mrkI}_1)\vert 1000-0000) + Pr(LO_{t_2}(B^{mrkI}_2)\vert 1000-0000)$ $= (2 \times 0.4919) \times 0.0207 + (2 \times 0.0081) \times (0.0050 + 0.0237)$
LO^{mrkI}	0.0185	$(LO^{mrkI}t_1 + LO^{mrkI}t_2)/2 = (0.0162 + 0.0208)/2$
$MO^{mrkI}_{t_2}$	0.0077	$2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.) \times Pr(MO_{t_2}(S^{mrkI}_2)\vert 1000-0000) = 2 \times 0.0081 \times 0.4765$
$MO^{mrkI}_{t_3}$	0.0104	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.) \times (Pr(LO_{t_2}(S^{mrkI}_1)\vert 1000-0000) \times Pr(MO_{t_3}(S^{mrkI}_1)\vert 1100-0000) + Pr(LO_{t_2}(B^{mrkI}_2)\vert 1001-0000)$ $\times(Pr(MO_{t_3}(S^{mrkI}_2)\vert 1001-0000) + Pr(MO_{t_3}(B^{mrkI}_2)\vert 1001-0000))) + (2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.))$ $\times Pr(LO_{t_2}(B^{mrkI}_2)\vert 0000-0100) \times Pr(MO_{t_3}(B^{mrkI}_2)\vert 0001-0100))$ $= 2 \times 0.0081 \times (0.0050 \times 0.4970 + 0.0237 \times (0.492 + 0.492)) + 2 \times 0.4919 \times 0.0207 \times 0.4920$
MO^{mrkI}	0.0091	$(MO^{mrkI}_{t_2} + MO^{mrkI}_{t_3})/2 = (0.0077 + 0.0104)/2$
MS^{mrkI}	0.0242	$MO^{mrkI}/(MO^{mrkI} + MO^{mrkII}) = 0.0091/(0.0091 + 0.3671)$
$LO^{mrkII}_{t_1}$	0.9838	$(Pr(LO_{t_1}(S^{mrkII}_1)\vert.) + Pr(LO_{t_1}(B^{mrkII}_1)\vert.)) = (0.4919 + 0.4919)$
$LO^{mrkII}_{t_2}$	0.0080	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times 0 + (2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times (Pr(LO_{t_2}(S^{mrkII}_1)\vert 0000-0100) + Pr(LO_{t_2}(S^{mrkII}_2)\vert 0000-0100)) =$ $= (2 \times 0.4919) \times 0 + (2 \times 0.0081) \times (0.0055 + 0.4893)$
LO^{mrkII}	0.4959	$(LO^{mrkII}_{t_1} + LO^{mrkII}_{t_2})/2 = (0.9838 + 0.0080)/2$
$MO^{mrkII}_{t_2}$	0.4794	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times Pr(MO_{t_2}(S^{mrkII}_1)\vert 0000-0100) + (2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times 0=$ $= (2 \times 0.4919) \times 0.4873 + (2 \times 0.0081) \times 0$
$MO^{mrkII}_{t_3}$	0.2548	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.))\times[(Pr(NT_{t_2}(0)\vert 0000-0100) + Pr(LO_{t_2}(S^{mrkI}_2)\vert 0000-0100)) \times Pr(MO_{t_3}(S^{mrkII}_1)\vert 0000-0100)] + 2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)$ $\times(Pr(LO_{t_2}(S^{mrkII}_1)\vert 1000-0000) \times Pr(MO_{t_3}(S^{mrkII}_1)\vert 1000-0100) + Pr(LO_{t_2}(S^{mrkII}_2)\vert 1000-0000) \times Pr(MO_{t_3}(S^{mrkII}_2)\vert 1000-1000) =$ $= 2 \times 0.4919 \times [(0.4920 + 0.0207) \times 0.4975] + (2 \times 0.0081) \times (0.0055 \times 0.4975 + 0.4893 \times 0.4925)$
MO^{mrkII}	0.3671	$(MO^{mrkII}_{t_2} + MO^{mrkII}_{t_3})/2 = (0.4794 + 0.2548)/2$
MS^{mrkII}	0.9758	$MO^{mrkII}/(MO^{mrkI} + MO^{mrkII}) = 0.3671/(0.0091 + 0.3671)$

Table A5: **Equilibrium Order Submission Strategies, Order Flows and Market Quality**

This Table shows how to obtain the metrics on order flows and market quality (column 1) presented in in Tables 2 and A6 for the following set of trading fees: $\{MF, TF\} = \{-.001, .001\}$ and $\{mf, tf\} = \{.00, .00\}$. Column 2 reports both the equilibrium market quality metrics for periods t_1 and t_2, $Spread^j_{t_z}$ and $BBODepth^j_{t_z}$, and the equilibrium average market quality metrics, $Spread^j$ and $BBODepth^j$. Column 3 shows how the values reported in column 2 are computed from the equilibrium strategies. Results are reported for both Market I (mrkI) and Market II (mrkII). Traders have a personal evaluation of the asset $\gamma \sim U[\underline{\gamma}, \overline{\gamma}]$, $S = [0, 2]$ and $AV = 1$. We assume that when the book is empty the quoted spread is equal to 5 ticks, i.e., 0.05. To economize space we indicate the empty book, $\overline{0000 - 0000}$, as '|.'

Metric	Value	Analytical Computation
$Spread^{mrkI}_{t_1}$	0.0498	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times 0.04 + (1 - 2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times 0.05 = (2 \times 0.0081) \times 0.04 + (1 - 2 \times 0.0081) \times 0.05$
$Spread^{mrkI}_{t_2}$	0.0497	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times [Pr(LO_{t_2}(S^{mrkI}_1\vert 1000 - 0000) \times 0.03 + Pr(LO_{t_2}(B^{mrkI}_2\vert 1000 - 0000) \times 0.03 + Pr(MO_{t_2}(S^{mrkI}_2\vert 1000 - 0000) \times 0.05 + (1 - (Pr(LO_{t_2}(S^{mrkI}_1\vert 1000 - 0000)+$
		$Pr(LO_{t_2}(B^{mrkI}_2\vert 1000 - 0000) + Pr(MO_{t_2}(S^{mrkI}_2\vert 1000 - 0000))) \times 0.04] + 2 \times Pr(LO_{t_2}(S^{mrkII}_1\vert.) \times [Pr(LO_{t_2}(B^{mrkI}_2\vert 0000 - 0100) \times 0.04 + (1 - Pr(LO_{t_2}(B^{mrkI}_2\vert 0000 - 0100)) \times 0.05]$
		$= (2 \times 0.0081) \times [0.005 \times 0.03 + 0.0237 \times 0.03 + 0.4765 \times 0.05 + (1 - 0.005 - 0.0237 - 0.4765) \times 0.04] + (2 \times 0.4919) \times [0.0207 \times 0.04 + (1 - 0.0207) \times 0.05]$
$Spread^{mrkI}$	0.0497	$(Spread^{mrkI}_{t_1} + Spread^{mrkI}_{t_2})/2 = (0.0498 + 0.0497)/2$
$Spread^{mrkII}_{t_1}$	0.0303	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times 0.03 + (1 - 2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times 0.05 = 2 \times 0.4919 \times 0.03 + (1 - 2 \times 0.4919) \times 0.05$
$Spread^{mrkII}_{t_2}$	0.0398	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times [Pr(MO_{t_2}(S^{mrkII}_1)\vert 0000 - 0100) \times 0.05 + (1 - Pr(MO_{t_2}(S^{mrkII}_1)\vert 0000 - 0100)) \times 0.03] + (2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.) \times [Pr(LO_{t_2}(S^{mrkII}_1)\vert 1000 - 0000) \times 0.03+$
		$Pr(LO_{t_2}(S^{mrkII}_2)\vert 1000 - 0000) \times 0.04 + (1 - Pr(LO_{t_2}(S^{mrkII}_1)\vert 1000 - 0000) - Pr(LO_{t_2}(S^{mrkII}_2)\vert 1000 - 0000)) \times 0.05]$
		$= (2 \times 0.4919) \times [0.4873 \times 0.05 + (1 - 0.4873) \times 0.03] + (2 \times 0.0081) \times [0.0055 \times 0.03 + 0.4893 \times 0.04 + (1 - 0.0055 - 0.4893) \times 0.05]$
$Spread^{mrkII}$	0.0351	$(Spread^{mrkII}_{t_1} + Spread^{mrkII}_{t_2})/2 = (0.0303 + 0.0398)/2$
$BBODepth^{mrkI}_{t_1}$	0.0162	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times 1 + (2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times 0 = (2 \times 0.0081) \times 1 + (2 \times 0.4919) \times 0$
$BBODepth^{mrkI}_{t_2}$	0.0292	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times [Pr(LO_{t_2}(S^{mrkI}_1\vert 1000 - 0000) \times 1 + Pr(LO_{t_2}(B^{mrkI}_2\vert 1000 - 0000) \times 2 + Pr(MO_{t_2}(S^{mrkI}_2\vert 1000 - 0000) \times 0 + (1 - (Pr(LO_{t_2}(S^{mrkI}_1\vert 1000 - 0000)+$
		$Pr(LO_{t_2}(B^{mrkI}_2\vert 1000 - 0000) + Pr(MO_{t_2}(S^{mrkI}_2\vert 1000 - 0000))) \times 1] + 2 \times Pr(LO_{t_2}(S^{mrkII}_1\vert.) \times [Pr(LO_{t_2}(B^{mrkI}_2\vert 0000 - 0100) \times 1 + (1 - Pr(LO_{t_2}(B^{mrkI}_2\vert 0000 - 0100)) \times 0]$
		$= (2 \times 0.0081) \times [0.005 \times 1 + 0.0237 \times 2 + 0.4765 \times 0 + (1 - 0.005 - 0.0237 - 0.4765) \times 1] + (2 \times 0.4919) \times [0.0207 \times 1 + (1 - 0.0207) \times 0]$
$BBODepth^{mrkI}$	0.0227	$(BBODepth^{mrkI}_{t_1} + BBODepth^{mrkI}_{t_2})/2 = (0.0162 + 0.0292)/2$
$BBODepth^{mrkII}_{t_1}$	0.9838	$(2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.)) \times 0 + (2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times 1 = (2 \times 0.0081) \times 0 + (2 \times 0.4919) \times 1$
$BBODepth^{mrkII}_{t_2}$	0.5124	$(2 \times Pr(LO_{t_1}(S^{mrkII}_1)\vert.)) \times [Pr(MO_{t_2}(S^{mrkII}_1)\vert 0000 - 0100) \times 0 + (1 - Pr(MO_{t_2}(S^{mrkII}_1)\vert 0000 - 0100)) \times 1] + (2 \times Pr(LO_{t_1}(S^{mrkI}_2)\vert.) \times [Pr(LO_{t_2}(S^{mrkII}_1)\vert 1000 - 0000) \times 1+$
		$Pr(LO_{t_2}(S^{mrkII}_2)\vert 1000 - 0000) \times 1 + (1 - Pr(LO_{t_2}(S^{mrkII}_1)\vert 1000 - 0000) - Pr(LO_{t_2}(S^{mrkII}_2)\vert 1000 - 0000)) \times 0]$
		$= (2 \times 0.4919) \times [0.4873 \times 0 + (1 - 0.4873) \times 1] + (2 \times 0.0081) \times [0.0055 \times 1 + 0.4893 \times 1 + (1 - 0.0055 - 0.4893) \times 0]$
$BBODepth^{mrkII}$	0.7481	$(BBODepth^{mrkII}_{t_1} + BBODepth^{mrkII}_{t_2})/2 = (0.9838 + 0.5124)/2$

Table A6: **Equilibrium Order Submission Strategies and Market Quality in Market II. Change in MF of Market I only (for Market II tf=mf=0.000). 3-period vs. 4-period model and $S = [0, 2]$ vs $S = [0.05, 1.95]$**

This Table reports for Market II the average equilibrium probabilities of the following order flows and market quality metrics: limit orders, $LO(P_i)$, and market orders, $MO(P_i)$, with the orders breakdown for the outside (P_2) and inside (P_1) price levels - for one side of the market, the other side being symmetric, Quoted Spread ($Quoted\,Spread$), BBOdepth ($BBODepth$), and market share, MS. The table reports results obtained under four protocols (models): with a large support $S = [0, 2]$ (columns 1 through 5) and a small support $S = [0.05, 1.95]$ (columns 6 through 10); and with 3 periods (Panel A) and 4 periods (Panel B). TF and MF for Market I are reported in rows 1 and 2 (for Market II $\{mf, tf\} = \{.00, .00\}$). Results are reported for different values of MF, holding $TF = 0.000$, specifically: for $MF = 0.000$ (columns 1 and 6), for $MF = -0.001$ (columns 2 and 7), and for $MF = -0.005$ (columns 4 and 9). Columns 3 and 8 report the percentage change ($\Delta\%$) in the market quality metrics between $MF = 0.000$ and $MF = -0.001$ and columns 5 and 10 report the percentage change ($\Delta\%$) in the market quality metrics between $MF = -0.001$ and $MF = -0.005$. The metrics are reported as averages across all periods of the trading game for each of the 4 protocols (3 and 4 periods and large and small support, respectively). For all protocols, the asset value $AV = 1$ and tick size $\tau = 0.01$.

			$S = [0, 2]$					$S = [0.05, 1.95]$		
Market I TF	**0.000**	**0.000**	**Δ%**	**0.000**	**Δ%**	**0.000**	**0.000**	**Δ%**	**0.000**	**Δ%**
Market I MF	**0.000**	**-0.001**	**(2) and (1)**	**-0.005**	**(4) and (2)**	**0.000**	**-0.001**	**(7) and (6)**	**-0.005**	**(9) and (7)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Panel A. 3-period model										
LO	0.3781	0.2399	-36.57%	0.2403	0.16%	0.3783	0.2394	-36.73%	0.2398	0.17%
$LO(P_2)$	0.0062	0.0000	-100.00%	0.0000	0.00%	0.0065	0.0000	-100.00%	0.0000	0.00%
$LO(P_1)$	0.1829	0.1199	-34.42%	0.1201	0.16%	0.1826	0.1197	-34.47%	0.1199	0.17%
MO (Volume)	0.1251	0.0398	-68.20%	0.0398	0.16%	0.1251	0.0397	-68.28%	0.0398	0.17%
$MO(P_2)$	0.0020	0.0000	-100.00%	0.0000	0.00%	0.0021	0.0000	-100.00%	0.0000	0.00%
$MO(P_1)$	0.0605	0.0199	-67.14%	0.0199	0.16%	0.0604	0.0198	-67.16%	0.0199	0.17%
$Quoted\,Spread$	0.0409	0.0444	8.60%	0.0444	-0.02%	0.0409	0.0444	8.62%	0.0444	-0.02%
$BBODepth$	0.4624	0.2800	-39.44%	0.2805	0.16%	0.4627	0.2795	-39.60%	0.2800	0.17%
MS	0.5000	0.1589	-68.21%	0.1591	0.08%	0.5000	0.1586	-68.29%	0.1587	0.09%
Panel B. 4-period model										
LO	0.3368	0.1622	-51.84%	0.1621	-0.05%	0.3369	0.1620	-51.93%	0.1619	-0.05%
$LO(P_2)$	0.0455	0.0000	-99.94%	0.0000	-100.00%	0.0457	0.0000	-99.94%	0.0000	-100.00%
$LO(P_1)$	0.1229	0.0811	-34.05%	0.0811	-0.01%	0.1228	0.0810	-34.09%	0.0809	-0.01%
MO (Volume)	0.1556	0.1239	-20.42%	0.1241	0.18%	0.1556	0.1238	-20.44%	0.1240	0.19%
$MO(P_2)$	0.0176	0.0000	-99.97%	0.0000	-100.00%	0.0177	0.0000	-99.97%	0.0000	-100.00%
$MO(P_1)$	0.0602	0.0296	-50.79%	0.0296	-0.10%	0.0601	0.0295	-50.83%	0.0295	-0.11%
$Quoted\,Spread$	0.0408	0.0445	9.01%	0.0445	-0.01%	0.0408	0.0445	9.04%	0.0445	-0.01%
$BBODepth$	0.5106	0.2740	-46.33%	0.2743	0.09%	0.5112	0.2737	-46.46%	0.2740	0.10%
MS	0.5000	0.3295	-34.10%	0.3297	0.07%	0.5000	0.3293	-34.14%	0.3295	0.07%

Table A7: **Equilibrium Order Submission Strategies and Market Quality in Market II. Change in MF and TF of Market I only (for Market II tf=mf=0.000). 3-period vs. 4-period model:** $S = [0, 2]$ **vs.** $S = [0.05, 1.95]$

This Table reports for Market II the average equilibrium probabilities of the following order flows and market quality metrics: limit orders, $LO(P_i)$, and market orders, $MO(P_i)$, with the orders breakdown for the outside (P_2) and inside (P_1) price levels - for one side of the market, the other side being symmetric, Quoted Spread ($Quoted\,Spread$), BBOdepth ($BBODepth$), and market share, MS. The table reports results obtained under four protocols (models): with a large support $S = [0, 2]$ (columns 1 through 5) and a small support $S = [0.05, 1.95]$ (columns 6 through 10); and with 3 periods (Panel A) and 4 periods (Panel B). TF and MF for Market I are reported in rows 1 and 2 (for Market II tf=mf=0.000). Results are reported for different values of MF, specifically: for $\{MF, TF\} = \{.00, .00\}$ (columns 1 and 6), for $\{MF, TF\} = \{-.001, .001\}$ (columns 2 and 7), and for $\{MF, TF\} = \{-.001, .002\}$ (columns 4 and 9). Columns 3 and 8 report the percentage change ($\Delta\%$) in the market quality metrics between $\{MF, TF\} = \{.00, .00\}$ and $\{MF, TF\} = \{-.001, .001\}$ and columns 5 and 10 report the percentage change ($\Delta\%$) in the market quality metrics between $\{MF, TF\} = \{.00, .00\}$ and $\{MF, TF\} = \{-.001, .002\}$. The metrics are reported as averages across all periods of the trading game for each of the 4 protocols (3 and 4 periods and large and small support, respectively). For all protocols, the asset value $AV = 1$ and tick size $\tau = 0.01$.

	$S = [0, 2]$					$S = [0.05, 1.95]$				
Market I TF	**0.000**	**0.001**	**Δ%**	**0.002**	**Δ%**	**0.000**	**0.001**	**Δ%**	**0.002**	**Δ%**
Market I MF	**0.000**	**-0.001**	**(2) and (1)**	**-0.001**	**(4) and (1)**	**0.000**	**-0.001**	**(7) and (6)**	**-0.001**	**(9) and (6)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Panel A. 3-period model										
LO	0.3781	0.4959	31.15%	0.4960	31.18%	0.3783	0.4957	31.04%	0.4958	31.06%
$LO(P_2)$	0.0062	0.0020	-68.14%	0.0020	-68.28%	0.0065	0.0021	-68.20%	0.0021	-68.28%
$LO(P_1)$	0.1829	0.2460	34.51%	0.2460	34.51%	0.1826	0.2458	34.57%	0.2458	34.63%
MO (Volume)	0.1251	0.2448	95.66%	0.2448	95.69%	0.1251	0.2445	95.44%	0.2445	95.48%
$MO(P_2)$	0.0020	0.0006	-68.04%	0.0006	-67.72%	0.0021	0.0007	-68.09%	0.0007	-67.79%
$MO(P_1)$	0.0605	0.1217	101.14%	0.1218	101.25%	0.0604	0.1216	101.20%	0.1216	101.32%
$Quoted\,Spread$	0.0409	0.0383	-6.20%	0.0383	-6.24%	0.0409	0.0383	-6.21%	0.0383	-6.24%
$BBODepth$	0.4624	0.5846	26.41%	0.5846	26.44%	0.4627	0.5847	26.37%	0.5847	26.37%
MS	0.5000	0.9759	95.19%	0.9761	95.21%	0.5000	0.9747	94.95%	0.9749	94.97%
Panel B. 4-period model										
LO	0.3368	0.3368	0.00%	0.4972	47.64%	0.3369	0.3370	0.00%	0.4971	47.56%
$LO(P_2)$	0.0455	0.0017	-96.18%	0.0805	76.99%	0.0457	0.0018	-95.99%	0.0804	75.93%
$LO(P_1)$	0.1229	0.1666	35.57%	0.1681	36.77%	0.1228	0.1666	35.68%	0.1682	36.94%
MO (Volume)	0.1556	0.2684	72.42%	0.2246	44.37%	0.1556	0.2677	72.05%	0.2242	44.06%
$MO(P_2)$	0.0176	0.0005	-97.24%	0.0220	24.81%	0.0177	0.0005	-97.10%	0.0219	23.72%
$MO(P_1)$	0.0602	0.1071	77.85%	0.1075	78.53%	0.0601	0.1070	77.99%	0.1074	78.67%
$Quoted\,Spread$	0.0408	0.0403	-1.30%	0.0388	-4.93%	0.0408	0.0403	-1.32%	0.0388	-4.96%
$BBODepth$	0.5106	0.4884	-4.35%	0.6399	25.33%	0.5112	0.4894	-4.26%	0.6407	25.33%
MS	0.5000	0.7368	47.36%	0.8117	62.35%	0.5000	0.7361	47.23%	0.8107	62.14%

Appendix 2: ASX Sample Descriptive Statistics

Table A14: **Descriptive Statistics for 2013 Event, ASX Sample.**
This table reports summary statistics for the control group ASX variables. Our 120 ASX listed stocks sample is stratified by price and market capitalization, based on daily averages for the month of January 2012. All variables reported in the tables, daily measures at the stock level, are for the listing exchange 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-side of each quote respectively. *Spread* is defined as the time-weighted daily average of the intraday difference between the ask price and the bid price of each quote. %*Spread* is defined as the time weighted daily average of the intraday ask price minus the bid price divided by the midquote of each quote. The descriptive statistics for the four measures of market quality are based on daily numbers for each stock in the one-month pre-period (December 2012). We also report *market capitalization* (in £millions) and *price* levels (in £) both variables are daily measures for the month of January 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.

Market Quality Measures		**Mean**	**Median**	**ST dev**	**Q1**	**Q3**
	Large	4,795	4,054	1,778	3,652	5,202
Volume (000s)	Small	2,714	2,536	1,044	2,118	2,745
	Overall	3,905	3,553	1,506	3,016	4,228
	Large	60,644	60,506	9,633	54,803	63,221
Depth	Small	114,969	123,049	37,122	81,329	141,860
	Overall	87,779	88,367	16,151	75,053	99,292
	Large	0.019	0.018	0.002	0.018	0.020
Spread	Small	0.014	0.014	0.001	0.013	0.014
	Overall	0.016	0.016	0.001	0.016	0.016
	Large	0.167%	0.166%	0.009%	0.161%	0.175%
% Spread	Small	0.560%	0.567%	0.021%	0.545%	0.576%
	Overall	0.357%	0.358%	0.011%	0.347%	0.367%
	Large	18,540	8,600	23,366	5,296	18,670
Market Capitalization (AUD Mill)	Small	1,050	1,063	168	909	1,178
	Overall	7,290	2,014	15,595	1,183	5,158
	Large	15.440	11.450	13.721	4.460	24.000
Price	Small	3.654	2.640	3.663	1.371	4.703
	Overall	9.172	4.525	11.687	2.620	11.341