The impact of fragmentation, exchange fees and liquidity provision on market quality

Michael Aitken[ǂ], Haoming Chen[ǂ] and Sean Foley[1]

[ǂ] *Australian School of Business, University of NSW, Australia*

[1]*Finance Discipline, Faculty of Business,*

University of Sydney, Sydney, 2006, Australia

This Version: 22nd July 2015

Abstract

We analyse the impact of two major financial frictions on market quality in a high-frequency environment: fragmentation and exchange fees. We find that fragmentation significantly improves liquidity, with greater benefits observed with higher entrant market share. The entrant market significantly reduces quoted spreads for stocks that are least constrained by the minimum tick size, whilst constrained stocks experience significant increases in depth. These changes are driven by the entry of fee-sensitive electronic liquidity providers (ELPs). Consistent with theoretical predictions, we find that reductions in exchange trading fees are passed through to the market. However, the main benefit to liquidity is driven by the entry of new ELPs who are able to benefit from cross-venue market making strategies.

[1] Contact Author, Finance Discipline, School of Business, University of Sydney, 2006, Australia: Tel (+612) 8088 4256; Email: sean.foley@sydney.edu.au. The authors would like to thank the CMCRC for funding assistance and thanks SIRCA and Chi-X for access to data. Seminar participants at the 4th annual Behavioural Finance and Capital Markets conference, University of New South Wales and University of Technology, Sydney. This paper has benefitted from the thoughtful comments of Angelo Aspris, Petko Kalev, Amy Kwan, Vinay Patel, Talis Putnins, Andriy Shkilko, Susan Thorpe, Terry Walter, and Jun Uno.

1. Introduction

Explicit and implicit costs represent one of the major financial frictions facing traders today. The proliferation of alternate trading venues has led to a global fragmentation of order flow, bringing competition to bear on both of these financial frictions. Whilst equity market competition can drive explicit trading fees down, the positive network externalities of trading liquidity suggest a consolidated venue may be the optimal structure for liquidity. We examine the impact of the reduction in these frictions due to the introduction of competition for equity trading in the Australian market.

We are able to examine the separate impact of the two mechanisms which Foucault and Menkveld (2008) argue may result in lower spreads in the presence of additional trading venues; competition between market makers duplicating their limit order schedules across market places; and reduced explicit costs as a result of competition between exchanges. We show that while reductions in explicit transaction costs are sufficient to reduce spreads, the primary benefits of fragmentation are attributable to increased competition between market makers across venues reducing implicit costs.

To discern between these two competing effects, we analyse two events: the 2010 reduction in the explicit transaction fees charged by the Australian Securities Exchange (ASX) and the 2011 introduction of Chi-X into the Australian equities market. The staggered introduction of these effects allows us to examine the independent impact of each. We consider the impact of the introduction of competition on a variety of market quality measures, including quoted and effective spreads, price impact, market depth, tick size constraint and Amihud's (2002) illiquidity.

Complementing studies in Europe (Foucault and Menkveld, 2008) and the United States (O'Hara and Ye, 2011) which find that competition reduces both explicit and implicit transaction costs, our study presents four main findings. First, we document that liquidity suppliers pass on reductions in exchange fees in 2010 reducing financial frictions, consistent with Foucault and Menkveld's (2008) theoretical findings. Second, we observe a further improvement in all measures of market quality after the introduction of a competing venue, with the benefits increasing in entrant market share. Thirdly, the vast majority of quoted spread reductions occur in the stocks that were least tick-constrained, while depth improvements occur in tick-constrained stocks, consistent with the queue jumping hypothesis of Foucault and Menkveld (2008). Finally, the availability of broker identifiers across both markets allows us to identify the contemporaneous entry of two new electronic liquidity

providers (ELPs)[2], with their entry into the Australian market accounting for the vast majority of the reduction in spreads and the increases in depth.

Our contribution has two unique and novel features. The first is the high-frequency nature of the modern market structure we examine. The primary studies examining fragmentation of equity market order flow do so at a time when high-frequency trading was in its infancy. As O'Hara and Ye (2011) argue, the widespread use of smart order routers (SOR's) leads fragmented markets to become "virtually consolidated" as participants are able to access prices across all venues almost simultaneously.

The second unique characteristic of the Australian market is the lack of an explicit trade-through prohibition. Many fragmented markets (such as the US and Canada) have regulations making the trading through of a better price illegal. This serves to increase the integration of the fragmented markets, and could be a necessary condition to observe beneficial effects of fragmentation. The Australian market structure enforces a less strict "best execution" policy, which allows brokers to consider factors such as the amount of liquidity available, price and execution costs in their routing decisions. These rules are more analogous to those in Europe, and may result in differing impacts of competition.

The paper is organized as follows. Section 2 documents the introduction of competition to Australia. Section 3 reviews the related literature. Section 4 discusses the data and research design. Section 5 presents the results of our empirical analysis and examines the robustness of our main findings, while section 6 concludes.

2. Institutional Details

2.1 ASX and Chi-X Market Structures

The ASX conducted the listing, trading and settlement of all Australian equities and other financial securities without competition until the 2011 introduction of Chi-X.

Chi-X conducted a segmented rollout, with a "soft launch" of six highly liquid stocks and two ETFs[3] on the 31st of October 2011. The remaining ASX200 constituents and ASX listed ETFs began trading on Chi-X on the 9th of November 2011. A further 57 stocks (primarily additions to the ASX200) were introduced incrementally from December 2011 to March 2013. On the 3rd of May 2013 Chi-X enabled trading on the entire universe of ASX listed securities.

The ASX had three minimum tick sizes for listed stocks, which form the lower bound for quoted spreads. These tick sizes depend on the security's price, being 0.1c for shares priced below 10c, 0.5c for shares priced from 10c to $2 and 1c for shares priced above $2.

[2] These electronic liquidity providers act as quasi-market makers, though they have no official role or responsibilities.

[3] Trading symbols were: BHP, CSL, LEI, ORG, QBE and WOW, ETF's were STW and ISO.

Figure 1 presents the evolution of Chi-X's market share in Australia since introduction. Similar to the evolution of Chi-X as a secondary exchange globally[4], market share in those Australian equities traded on both ASX and Chi-X began at a very low level, remaining below 2% of total daily on-exchange turnover in its first 6 month of operation. Within one year of introduction total market share exceeded 5% and by late 2013 had exceeded 10%

< Insert Figure 1 here >

2.2 Explicit Trading Fee Comparison

On the 1st of July 2010, after the announcement of Chi-X's intention to establish a competing exchange in Australia, the ASX reduced fees for those trading services that would be subject to competition.[5] Table 1 documents the changes to the ASX fee structure as well as the fees of Chi-X on introduction. Services such as the opening and closing auctions that did not face competition experienced no reduction in fees.

< Insert Table 1 Here >

3. Literature Review

Two main strands of literature document the impact of competition on market quality. The first assesses the impact of competition between brokers and separate listing venues. The second examines the impact of order flow fragmentation in the US and European equities markets on market quality.

3.1 Comparison of Bid Ask Spreads in Consolidated and Fragmented Markets

Equity market structure has two potentially competing impacts on transaction costs, with economies of scale reducing costs in consolidated markets while competition between fragmented markets drives costs down (Hamilton, 1979). Securities exchanges may be natural monopolies, with significant economies of scale in clearing, settlement and infrastructure provision due to the high fixed and low marginal costs of matching trades. Pagano (1989) shows that these network externalities result in order flow gravitating towards one single, dominant exchange. In contrast, Economides (1996) argues that competitive forces are

[4] He, Jarnecic and Liu (2015) document market shares for Chi-X by country in the first six months of operation.
[5] ASX Market announcement on 3 June 2010, available at http://www.asxgroup.com.au/media/PDFs/20100603_asx_fees_and_rebates.pdf

necessary to promote operating efficiencies and to ensure that exchanges do not earn excessive monopolistic profits.

The study of a number of new market entrants has provided support for the idea that competition reduces explicit transactions costs. These include Cohen and Conroy (1990) with off-board markets and Battalio (1997) with the entry of a third broker dealer, both in the NYSE; Domowitz et al. (1998) with international cross listing in Mexican stocks and DeFontnouvelle et al. (2003) with direct competition for options order flow in the US.

A number of studies, however, identify significant costs of competition. Bessembinder and Kaufman (1997) provide evidence that fragmentation allows cream skimming of uninformed traders, increasing spreads. Bennett and Wei (2006) demonstrate that stocks transferring from the NASDAQ dealer market to the more consolidated NYSE experience significantly decreased spreads, with liquidity improving most for stocks with the greatest increases in the level of consolidation. Gajewski and Gresse (2007) find that spreads in European stocks are lower in centralised, consolidated electronic order-driven markets than in hybrid markets where orders are fragmented between an order book and competing dealers. The varying market structures and the different types of competition examined in each of these studies likely contribute to the mixed findings.

3.2 Impact of Inter-Exchange Competition for Order Flow on Bid Ask Spreads

The implementation of the Regulation National Market System (Reg NMS) in the United States in 2005 and the Markets in Financial Instruments Directive (MiFID) in Europe in 2007 facilitated the rapid fragmentation of global securities markets. O'Hara and Ye (2011) examine the fragmentation facilitated by Reg NMS, finding reduced effective spreads and enhanced price discovery. O'Hara and Ye (2011) argue that the fragmented trading in US venues benefits from virtual consolidation due to smart order routing and the enforcement of trade-through prohibition.

Foucault and Menkveld (2008) propose two mechanisms by which competition may reduce trading costs; competition from the entrant exchange reducing explicit fees and hence order processing costs; and the lack of time priority between venues allowing "queue jumping" on the entrant exchange in the absence of inter-market time priority, intensifying competition between market makers, increasing total depth and potentially reducing spreads. Foucault and Menkveld (2008) jointly test these hypotheses empirically in the Dutch market, finding increased depth and narrower or unchanged quoted spreads. Foucault and Menkveld (2008) argue that fragmentation may be beneficial only if trade-throughs are prohibited – a feature not currently present in Australia and several other European jurisdictions.

Further evidence on the beneficial impacts of fragmentation is provided by Chlistalla and Lutat (2011) in France and Gresse (2012) for LSE and Euronext listed securities, with

actively traded stocks found to have lower quoted spreads, increased depth and reduced round trip execution costs.[6] In a global study, He, Jarnecic and Liu (2015) provide preliminary evidence that the introduction of an alternative trading venue both improves depth and reduces spreads in the majority of jurisdictions analysed.

3.3 Endogenous Liquidity Providers in Fragmented Markets

Anand and Venkataraman (2012) document the existence of endogenous liquidity providers (ELPs) who have no obligations to supply liquidity. They find that reduced market maker inventory holding costs lead to higher ELP participation. Similarly, Menkveld (2013) finds that the market making activity of a large high frequency trader (HFT) results in bid-ask spread profits exceeding adverse selection costs. The HFT was found to utilise a cross-market strategy with similar turnover in both the incumbent and entrant market. With 78% of its trades originating from limit orders, trading fees significantly impacted the HFT's profitability. We extend Menkveld's (2013) analysis of HFT liquidity provision to its impact on aggregate market liquidity.

4. Data and Research Design

Data on trades and quotes are obtained from *Thomson Reuters Tick History*, time-stamped to the millisecond. The records include trade price, volume and flags for off-market trades, hidden liquidity or trades executed in the opening and closing auctions. Trades and quotes prior to 10:10am and after 4:00pm are removed from our market variables constructed for the continuous trading phase of each day in order to exclude the opening and closing auction process.

We include all stocks that remain ASX200 constituents between the 9th of November, 2011 [7] and the 8th of November 2012. We exclude 11 securities that were removed from the ASX200, 4 securities that were listed after the 9th of November 2010, 3 securities that trade below 10c (due to the large reduction in minimum tick size at this price threshold) and 12 securities that delist due to bankruptcy or takeover, leaving 170 firms.

We analyse the impact of fragmentation in two ways. The first method compares liquidity metrics in the year immediately prior to Chi-X's introduction with the following year. The second method uses Chi-X's percentage market share of total on-market trading turnover as a proxy for the level of fragmentation across each stock-day, allowing us to identify changes in liquidity as order flow fragmentation increases over the first year of Chi-X's operation.

[6] These refer to the cost of trading €100,000 worth of stock.
[7] The date Chi-X admitted all index constituents to its venue.

Additional data for ASX trades with broker identifiers is sourced from SIRCA's Australian Equities database. Each trade record contains fields for trade qualifier descriptions, buyer broker identifier, seller broker identifier and trade initiator. Similar proprietary data is provided by Chi-X Australia.

4.1.1 Cross Sectional Analysis of Transaction Cost 12 Months after Competition

This specification examines the impact of fragmentation on market quality using two periods, the first being one year prior to the introduction of competition (the 9th of November 2010 to the 8th of November 2011), and the second following the introduction of competition (the 9th of November 2011 to the 8th of November 2012). Equation 1 specifies the regression model estimated:

$$y_{id} = \propto_0 + \propto_1 I_{Competition_d} + \propto_2 Price_{id} + \propto_3 Turnover_{id} + \propto_4 Volatility_{id} + \propto_5 Tick\ Size_{id} + \propto_6 FE_i + \varepsilon_{id} \quad (1)$$

where y_{id} is the liquidity metric of interest. $I_{Competition_d}$ is an indicator variable equal to one for stock-day observations in the post-competition period, and zero otherwise, with the pre-competition period constituting our base case. For regressions where the dependent variable is presented in basis points, $Price_{id}$ is the inverse of the time weighted midpoint price, similar to Hendershott et al. (2011). In all other regressions, $Price_{id}$ is the natural logarithm of the daily time-weighted midpoint price of the security. $Turnover_{id}$ is the natural logarithm of the security's daily trading turnover in dollars.[8] $Volatility_{id}$ is calculated as $\frac{high\ price_{id} - low\ price_{id}}{midpoint\ price_{id}}$. $Tick\ Size_{id}$ takes a value of 1 if the price of stock *i* is less than $2 on day *d*, (with a tick size of ½c), and 0 otherwise (with a tick size of 1c). FE_i represents stock-specific fixed effects that control for the relative levels of liquidity, which vary per security.[9]

4.1.2 Continuous analysis of Transaction Costs

Our second specification uses the market share of Chi-X to analyse the impact of fragmentation on liquidity. We calculate market share as the percentage of on-market turnover per security on each venue daily, capturing differences in fragmentation through

[8] As in Benston and Hagerman (1974), we use the natural logarithm of price and volume to avoid skewing results due to the variance of large observations.
[9] Additional dummy variables controlling for day-of-the week variation were introduced similar to Brown, Taylor and Walter (1999) without significantly impacting the results.

time.[10] We avoid potential issues of endogeneity between fragmentation and liquidity variables by using the 5-day moving average of Chi-X trading, 1-day lagged, described in Equation 2, where $ChiX_{id}$ is the percentage of stock *i* dollar volume traded on Chi-X in day *d*.

We analyse data for all trading days from the 9th of November 2011 to the 8th of November 2012, being one year from Chi-X's introduction. Equation 2 documents the regression specification, with the control variables identical to those in Equation 1.

$$y_{id} = \propto_0 + \propto_1 ChiX\ Moving\ Average_{id} + \propto_2 Price_{id} + \propto_3 \ln turnover_{id} + \propto_4 volatility_{id} + \propto_5 Tick\ Size_{id} + \propto_6 FE_i + \varepsilon_{id} \quad (2)$$

For all model specifications, we apply a five day moving average, lagged by one day, to the metrics for Chi-X market share, turnover and volatility to avoid issues of potential endogeneity and reverse causality between Chi-X participation and control variables with liquidity metrics. This procedure is not applied to the control variables for tick size and share price in inverse or logarithmic transformation since these variables are directly related to the prevailing transaction cost measures. Equation 3 presents the moving average calculation, where $Metric_{id}$ is the observed variable for stock *i* on day *d.*

$$Lagged\ Moving\ Average\ Metric_{id} = \frac{1}{5}\sum_{d=-5}^{d=-1} Metric_{id} \quad (3)$$

4.1.3 Impact of ASX fee reduction

Our final specification seeks to identify the isolated impact of a reduction in exchange fees. While there are two potential channels by which competition may reduce spreads, the typically contemporaneous nature of exchange fee reductions and the introduction of competition limit the potential to determine which channel's effects dominate. Prior to the introduction of Chi-X, the ASX reduced explicit fees by almost 50% – from 0.28 to 0.15 basis points. The reduction of exchange fees in 2010 allows us to independently test the impact of exchange fee reductions on market quality. We use an event study to test the impact of the fee reduction, where $I_{Fee\ Reduction}$ is equal to zero prior to the fee reduction and one after. Our regression specification is provided in Equation 4 below, with all other variables defined as in Equation 1:

[10] A significant portion of reported volume does not occur on either the ASX or Chi-X venues. Rather, crosses are generated by brokers and need to be reported to a marketplace. These off-market trades are excluded from our analysis.

$$y_{id} = \propto_0 + \propto_1 I_{Fee\ Reduction} + \propto_2 Price_{id} + \propto_3 \ln turnover_{id} + \propto_4 volatility_{id} + \propto_5 Tick\ Size_{id} + \propto_6 FE_i + \varepsilon_{id} \quad (4)$$

4.2 Transaction Cost Measures

In Equations 1, 2 and 4, y_{id} represents the liquidity measure of interest. We examine quoted spreads, depth, constraint, effective spreads, price impact and Amihud's illiquidity.

We weight quoted spreads by the proportion of the day for which the prevailing quotes are active, allowing us to capture the large proportion of liquidity supplied by high frequency traders operating in the millisecond range[11].

The majority of recent empirical literature has focused on relative spreads in basis points, rather than absolute spreads in cents. Noting the importance of tick size changes identified by Bessembinder (2000) as well as the severely constrained quoted spread observed in our sample (the median spread is 1.095 ticks in the pre-entry period and 1.064 post-entry) we focus on spreads in tick increments. For stocks constrained by the minimum tick size, changes in the relative spread will primarily be caused by share price fluctuations, rather than changes in observed liquidity. Quoted spreads are calculated as:

$$Quoted\ Spread_{i,t} = (Best\ Ask_{i,t} - Best\ Bid_{i,t}) \quad (5)$$

where $Best\ Ask_{i,t}$ is the lowest ask price prevailing on either venue for stock *i* at time *t* and $Best\ Bid_{i,t}$ is the highest bid price. Time weighted quoted spread per stock-day is constructed by weighting all quoted spreads across the consolidated markets per stock-day by the percentage of the trading day the spreads were active. Quoted spreads are presented in basis points and tick increments by dividing the absolute quoted spread by the prevailing midpoint between the best bid and best ask prices, and the relevant tick size, respectively.

One mechanism by which the introduction of competition for order flow between venues could decrease spreads is an increased proportion of the trading day during which quoted spreads are constrained by the minimum tick size. We thus measure the percentage of the trading day for which spreads are constrained by the minimum tick size to complement the standard spread measures since it is impacted less by extreme observations.

$$Constrained\ Percentage_{i,d} = \frac{\sum_{m=1}^{m=21,000,000} Constrained_m}{21,000,000} \quad (6)$$

[11] Hasbrouck and Saar (2013) detect low-latency responses as fast as 2-3ms in their 2009 data.

where $Constrained_m$ is equal to one if the best bid quote is less than the best ask quote by at most one tick at millisecond *m* and zero otherwise, with 21,000,000 being the number of milliseconds between 10:10am and 4:00pm.

Quoted dollar depth is the value that can be immediately traded at the NBBO across both venues, and is constructed by multiplying the price by the volume available at the NBBO at time t, and is described in Equation 7 below:

$$Quoted\ Depth_{i,t} = \left(Best\ Ask_{i,t} * Volume_{a,i,t} + Best\ Bid_{i,t} * Volume_{b,i,t}\right) \quad (7)$$

where $Best\ Ask_{i,t}$ is the lowest ask price on either venue for stock *i* at time *t*, $Volume_{a,i,t}$ is the consolidated volume available at that price, $Best\ Bid_{i,t}$ is the highest bid price on either venue for stock *i* at time *t* and $Volume_{b,i,t}$ is the volume available at that price. We then weight each quoted depth observation for the stock-day by the percentage of the trading day for which that depth level was active.

We also examine effective spreads, which capture the conditions that traders decided to act upon, rather than the posted conditions prevailing in the market. We use both effective spreads and price impact. Effective spreads calculate the cost of a transaction for the liquidity demander and are the difference between the transaction price and the midpoint at the time of the transaction. Effective spread is defined as:

$$Effective\ Spread_{i,d} = \frac{1}{T}\sum_{t=1}^{T} 2q_t(p_t - m_t) \quad (8)$$

where p_t is the transaction price, m_t is the midpoint of the best bid and ask quote prevailing at the time of the trade, and q_t is the trade indicator variable, where a buyer initiated trade takes a value of 1 and a seller initiated trade takes a value of –1. Buyer and seller initiated trades are identified by comparing the prevailing NBBO to the transaction price using the Lee and Ready (1991) algorithm.

Price impact reflects the implicit transaction cost paid by liquidity demanders, less the portion attributed to liquidity supplier revenues. It is a measure of midpoint price movements in the direction of a trade. We use the five minute price impact, assuming that liquidity providers are able to reverse any position they have accrued at the midpoint five minutes subsequent to the trade. Price impact is defined as:

$$Price\ Impact_{i,d} = \frac{1}{T}\sum_{t=1}^{T} 2q_t\ (m_{t+5} - m_t) \quad (9)$$

where m_t is the midpoint at the time of transaction *t*, m_{t+5} is the midpoint prevailing five minutes after the trade, and q_t is the trade direction indicator variable.

Finally, we calculate Amihud's (2002) measure of illiquidity to determine if there has been a change in the market impact of trades. A lower illiquidity ratio indicates that the market was more able to absorb volume shocks without causing large price movements. This metric is logarithmically normalized and constructed as:

$$ILLIQ_{i,d} = \ln\left(1 + 10{,}000 * \frac{1}{H_{i,d}} \sum_{h=1}^{H} \frac{|r_{i,h,d}|}{\$Vol_{i,h,d}}\right) \quad (10)$$

where $r_{i,h,d}$ is the absolute return on stock *i* for day *d* during hour *h* and $\$Vol_{i,h,d}$ is the dollar value transacted in that same period. Hours with no volume are set to the 99th percentile of that stock's distribution to reflect their lack of liquidity in that period.

5. Summary Statistics and Results

5.1 Summary Statistics

Table 2 provides summary statistics for all variables. These are divided into two periods – the one year prior to the introduction of competition and the one year following. Panel A provides details on the liquidity metrics used. Mean quoted spreads declined from 1.227 ticks to 1.164 ticks, whilst median spreads saw a smaller reduction from 1.069 ticks to 1.064 ticks. Declines are also observed in mean effective spreads, reducing by 0.149 ticks to 0.909 ticks. An effective spread below one tick indicates that a portion of trading activity was executed with price improvement against hidden liquidity. Price impact declined 0.168 ticks to 0.608 ticks, indicating lower adverse price movements following trades. We observe no change in our quoted depth measure. Spreads become constrained by the minimum tick size more frequently, with constraint increasing from 85% to 87% of the day.

Panel B presents descriptive statistics for the control variables. Average share price decreased from $8.64 to $7.96, contributing to the increase in relative quoted spreads. Commensurate with this slight reduction in price, the number of stock–days trading with a ½c tick size saw a slight increase. Volatility and trading activity declined over the sample period.

< Insert Table 2 here >

Figure 2 displays equal-weighted quoted spread, effective spread and price impact measures during the period beginning one year prior to the introduction of competition and ending one year after introduction. Over the period, price impact, quoted and effective

spreads all decline following Chi-X's introduction. Quoted spreads are bounded below by one tick, whilst effective spreads may be lower than one tick if trades receive price improvement.

< Insert Figure 2 here >

Figure 3 shows quoted spreads by tick constraint tercile over the one year prior to and following Chi-X's introduction. Large reductions in quoted spreads are observed among the least constrained tercile, where quoted spreads were at minimum tick less than 84% of the time. This indicates that the entry of Chi-X has reduced implicit trading costs.

< Insert Figure 3 here >

Average quoted depths for securities in each tick constraint tercile are presented in Figure 4. An upward trend in quoted depth is observed in the first six months following Chi-X's introduction, with the order book deeper on average in the post-competition period than during the pre-competition period for stocks in the moderately constrained and most constrained terciles.

< Insert Figure 4 here >

5.2 Empirical Results

Our first set of results document the impact of competition by examining the one year pre- and post-introduction. Table 3 documents the impact of Chi-X's introduction on measures of liquidity. Panel A considers the consolidated orders and trades from both the ASX and Chi-X, whilst Panel B considers orders and trades from the ASX only. Separately presenting metrics constructed from only the incumbent market allows us to overcome any potential issues arising from asynchronous time stamps.

Significant declines of 0.05-0.06 ticks are observed for quoted spreads using the ASX and NBBO quotes respectively. Effective spreads decline by 0.14 ticks on the consolidated market and 0.07 ticks on the ASX. The significantly larger decrease on the consolidated market is driven by many Chi-X trades occurring with price improvement at the midpoint between the bid and ask prices, as well as quoted spreads derived from the NBBO being narrower than those on the ASX alone, as identified by He, Jarnecic and Liu (2015). Similar reductions are observed for price impact. Quoted depths at the best bid and ask prices do not show significant changes due to the introduction of competition. Consistent with the improvements in spreads, Amihud Illiquidity also improves with competition. Finally, quotes are constrained by the minimum tick size 2% more frequently in the presence of competition.

< Insert Table 3 here >

Table 4 examines the impact of competition using Chi-X's market share as a continuous variable. This is constructed over the calendar year starting from the introduction of Chi-X on the 9th of November 2011. Consequently, the level of fragmentation experienced in each stock-day varies significantly. O'Hara and Ye (2011) use a similar metric of fragmentation, which allows for a more concise exposition of the relationship between changes in liquidity and increases in competition. Consistent with our first specification, we find that increasing competition for trading activity reduces quoted spreads; with an increase in fragmentation of 10% leading to a reduction in the NBBO quoted spread amongst the ASX 200 securities of 5% of one tick increment, and quoted spreads being constrained by the minimum tick size 2.8% more frequently.

We find reductions in the effective spread and price impact of larger magnitudes than quoted spreads, representing reductions in the cost of liquidity provision. However, no statistically significant change in price impact or quoted depth on ASX is observed as competition increases. This is consistent with order flow migration to Chi-X increasing global liquidity but not local ASX liquidity. An increase in Chi-X market share of 10% is also associated with a 16% increase in quoted depth on the consolidated market, consistent with the duplication of limit orders by market makers documented by Foucault and Menkveld (2008). If volume is duplicated in stocks that are constrained on the ASX in order to "jump" time priority, this will result in greater increases in consolidated depth than in ASX-only depth. This increase in depth appears to increase the markets' ability to absorb large trades, lowering the Amihud illiquidity metric on the consolidated market.

< Insert Table 4 here >

The descriptive statistics from Table 2 show that the median quoted spread of stocks in our sample was 1.069 tick increments, being constrained by the minimum tick size 93% of the time prior to the introduction of competition. Since liquidity improvement in many of the stocks is constrained by the minimum tick size, in Table 5 we separate our analysis by the degree to which quoting activity was tick constrained in the one year prior to the introduction of competition. We construct terciles of stocks by tick constraint, with the first tercile constrained by the minimum tick size less than 84.0% of the time, the third tercile constrained more than 95.8% of the time and the 2nd tercile falling between the two. For a Chi-X market share of 10%, the least constrained stocks saw a 0.17 tick reduction in NBBO quoted spreads, whilst no significant change is observed among the two more constrained terciles.

An increase of competitor market share by 10% increased consolidated quoted depths by between 22 and 23% for the two most constrained stock terciles. No significant change was observed in market depth on the ASX for these terciles, with the majority of the increase in quoted depth for the most tick constrained stocks occurring on Chi-X, supporting the queue-jumping hypothesis of Foucault and Menkveld (2008).

< Insert Table 5 here >

Liquidity changes in basis points, rather than ticks, are presented in Table 6. Panel A presents changes pre- and post- Chi-X entry, whilst Panel B examines a continuous one year interval utilising Chi-X's percentage market share. Whilst the results are qualitatively similar to the analysis in tick increments, much larger variation across the dimensions of liquidity are observed, driven by variation in share price over time. Comparing the pre- and post-entry periods, effective spreads declined 2.94 basis points and price impacts declined 2.56 basis points.

< Insert Table 6 here >

In our final empirical analysis, we utilise the reduction in fees by the ASX in *anticipation* of the introduction of Chi-X in July 2010 as an opportunity to examine the extent to which reductions in explicit fees reduce order processing costs for liquidity providers, lowering their costs of supplying liquidity. Table 6 documents reductions in quoted spreads of 0.02 ticks and 1.16 basis points after the reduction in explicit fees in 2010. This compares to a reduction in explicit fees of 0.26 basis points (0.13 per side) by the ASX over the same period. The significantly higher reductions observed in quoted and effective spreads, combined with increases in depth, percentage of the time for which stocks are constrained by the minimum tick size, and reductions in Amihud illiquidity, imply that the reduction in fees may have also generated increased competition between liquidity providers. Realised spreads, defined as the effective spread earned less the price impact costs experienced due to adverse price movements, are a measure of the returns to liquidity suppliers. Combining the 2.15 basis point decrease in effective spreads with the 1.46 basis point decrease in price impact, realised spreads declined 0.69 basis points from the first half to the second half of 2010, broadly aligning with the magnitude of ASX's fee reduction. This indicates that liquidity providers passed on reductions in order processing costs, with potential additional benefits accruing from increased competition between liquidity providers.

< Insert Table 7 here >

The introduction of an exchange with lower trading fees may also encourage the entry of fee-sensitive liquidity providers into a market. Consistent with the reduced fees on the entrant exchange, two endogenous liquidity providers entered the Australian equities market in 2011 immediately prior to the introduction of competition. Panel A of Figure 5 shows that these endogenous liquidity suppliers contributed 81% of average daily passive liquidity executed on the cheaper entrant venue but only 1% on the more expensive incumbent. Similarly, Panel B shows that these new liquidity providers account for 43% of average daily total turnover on the entrant venue and only 2% of incumbent turnover. The dominance of electronic liquidity provision observed in the entrant venue mirrors the findings of Menkveld (2013) for a large HFT liquidity supplier in Dutch equities.

< Insert Figure 5 here >

5.3 Robustness Tests

We examine the robustness of our findings to six separate specifications. Table 8 presents the findings of these robustness tests. For brevity, we have reported only the coefficient estimate and t-statistic on the competition variable for each regression. Each specification is run with a liquidity metric as the dependent variable, the competition variable as the main independent variable, as well as the same control variables for stock price, trading turnover, volatility, tick size and stock fixed effects as the main specifications.

Specification (1) examines one month pre- and post- introduction as opposed to one year, to ensure that our findings are not a result of broader market fluctuations in the third quarter of 2011. Specification (2) omits the first six months of competition to allow time for broker connectivity and order routing systems to be established, examining the six months from the 9th of May 2012. Specification (3) utilizes the actual level of fragmentation per stock-day, rather than the lagged moving average used to avoid the potential issue of endogeneity. Specification (4) and (5) utilize a threshold dummy-variable for fragmentation, turning from 0 to 1 when stock-day fragmentation exceeds 2% and 5% respectively. This recognizes that the benefits of competition might not increase linearly. Specification (6) broadens the unit of analysis from stock-days to stock-months, motivated by the methodology of O'Hara and Ye (2011). This longer time interval ensures that changes in liquidity are persistent and not driven by time series spurious correlation. For all specifications, we find significant reductions in quoted and effective spreads, as well as improvements in depth and illiquidity on the consolidated market, consistent with our primary specifications.

< Insert Table 8 Here >

As a further robustness check against the potential for time series spurious correlation we consider a bootstrapping approach. Two partitions of stock-day observations each spanning four months are created, with a pre-competition period of July 2011 to October 2011 and a post-competition period of July 2012 to October 2012. Matched calendar months are selected to minimise potential seasonality in liquidity. A subgroup is created by randomly drawing one thousand stock-day observations per partition. The regression specified in Equation 1 is then run with the observations from the subgroup. A competition indicator of 1 is assigned in the post- period and 0 in the pre- period, with this subgroup selection and regression procedure repeated 10,000 times, with the coefficients saved for each round.

The frequency distribution of the coefficient estimates on the competition indicator is shown in Panel A of Figure 6. In the period after Chi-X's introduction, quoted spread reductions range between 0 and 1.1 basis points, with the most frequent reduction being 0.5 basis points, broadly in line with the reductions observed in Table 6.

< Insert Figure 6 Here >

Panel B displays the frequency distribution of t-statistics for statistical significance in quoted spread reduction. In the majority of observations, quoted spread reductions are significant at the 99% level, with t-statistics ranging between 0 and -8.

6. Conclusion

The introduction of competition for equities trading in Australia has led to an increasing level of order flow fragmentation, which ultimately reduces the financial frictions to trading, namely both explicit and implicit fees. We find that quoted and effective spreads for stocks exposed to competition declined as an increasing proportion of order flow migrates from the incumbent to the entrant exchange. In the year since the introduction of competition, quoted spreads among the ASX200 index constituents declined from 1.22 tick increments to 1.16 ticks on average. The reduction in incumbent trading fees *prior* to the introduction of competition enables us to show that while liquidity providers pass through these reductions in explicit fees (which reduce their order processing costs) the majority of the benefits to liquidity are attributable to the introduction of two new fee-sensitive electronic liquidity suppliers who arrive only with the new entrant market.

Consistent with the intermarket queue-jumping strategies predicted by Foucault and Menkveld (2008) for stocks that were previously most constrained by the minimum tick size, we observe the entrant market contributing to a total depth increase of 2.2% at the NBBO for

each percentage of market share it captures, with no significant change in quoted spreads. For stocks previously least constrained by the minimum tick size, quoted spreads declined 0.02 tick increments for each percentage of the entrant venue's market share. Our results are robust to a number of varying specifications, time periods and measures of competition.

Our findings have implications for the recent debates around tick size, fragmentation and maker-taker rebates. Specifically, regulators and market participants should carefully consider the impact any market design changes have on the incentives of liquidity suppliers, not just the level of competition within the market.

References

Aitken, Michael, and Alex Frino. "The Determinants of Market Bid Ask Spreads on the Australian Stock Exchange: Cross-Sectional Analysis." *Accounting & Finance* 36, no. 1 (1996): 51–63.

Aitken, Michael J., Alex Frino, Amelia M. Hill, and Elvis Jarnecic. "The Impact of Electronic Trading on Bid-ask Spreads: Evidence from Futures Markets in Hong Kong, London, and Sydney." *Journal of Futures Markets* 24, no. 7 (2004): 675–696.

Amihud, Yakov. "Illiquidity and Stock Returns: Cross-section and Time-series Effects." *Journal of Financial Markets* 5, no. 1 (January 2002): 31–56.

Anand, Amber, and Kumar Venkataraman. *Should Exchanges Impose Market Maker Obligations?* SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, November 21, 2012. http://papers.ssrn.com/abstract=2179259.

Battalio, R., J. Greene, and R. Jennings. "Do Competing Specialists and Preferencing Dealers Affect Market Quality?" *Review of Financial Studies* 10, no. 4 (October 1, 1997): 969–993.

Bennett, Paul, and Li Wei. "Market Structure, Fragmentation, and Market Quality." *Journal of Financial Markets* 9, no. 1 (2006): 49–78.

Benston, George J., and Robert L. Hagerman. "Determinants of Bid-asked Spreads in the Over-the-counter Market." *Journal of Financial Economics* 1, no. 4 (1974): 353–364.

Berkman, Henk, and Carole Comerton-Forde. "Market Microstructure: A Review from down Under." *Accounting & Finance* 51, no. 1 (2011): 50–78.

Bessembinder, Hendrik. "Tick Size, Spreads, and Liquidity: An Analysis of Nasdaq Securities Trading near Ten Dollars." *Journal of Financial Intermediation* 9, no. 3 (2000): 213–39.

Bessembinder, Hendrik, Jia Hao, and Kuncheng (K C.) Zheng. *Market Making Obligations and Firm Value*. SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, October 19, 2012. http://papers.ssrn.com/abstract=2130875.

Bessembinder, Hendrik, and Herbert M. Kaufman. "A Cross-exchange Comparison of Execution Costs and Information Flow for NYSE-listed Stocks." *Journal of Financial Economics* 46, no. 3 (December 1997): 293–319.

Brown, Philip, Stephen L. Taylor, and Terry S. Walter. "The Impact of Statutory Sanctions on the Level and Information Content of Voluntary Corporate Disclosure." *Abacus* 35, no. 2 (1999): 138–162.

Chlistalla, Michael, and Marco Lutat. "Competition in Securities Markets: The Impact on Liquidity." *Financial Markets and Portfolio Management* 25, no. 2 (2011): 149–172.

Chordia, Tarun, Richard Roll, and Avanidhar Subrahmanyam. "Market Liquidity and Trading Activity." *The Journal of Finance* 56, no. 2 (2001): 501–530.

Cohen, Kalman J., and Robert M. Conroy. "Empirical Study of the Effect of Rule 19c-3, An." *Journal of Law & Economics* 33 (1990): 277.

Degryse, Hans, Frank De Jong, and Vincent Van Kervel. "The Impact of Dark Trading and Visible Fragmentation on Market Quality." *Review of Finance*, June 13, 2014.

Demsetz, Harold. "The Cost of Transacting." *The Quarterly Journal of Economics* 82, no. 1 (February 1968): 33.

Di Noia, Carmine. "Competition and Integration among Stock Exchanges in Europe: Network Effects, Implicit Mergers and Remote Access." *European Financial Management* 7, no. 1 (March 1, 2001): 39–72.

Domowitz, Ian, Jack Glen, and Ananth Madhavan. "International Cross-Listing and Order Flow Migration: Evidence from an Emerging Market." *The Journal of Finance* 53, no. 6 (1998): 2001–2027.

Economides, Nicholas. "The Economics of Networks." *International Journal of Industrial Organization* 14, no. 6 (October 1996): 673–699.

De Fontnouvelle, Patrick, Raymond P. H. Fishe, and Jeffrey H. Harris. "The Behavior of Bid–Ask Spreads and Volume in Options Markets During the Competition for Listings in 1999." *The Journal of Finance* 58, no. 6 (2003): 2437–2464.

Foucault, Thierry, and Albert J. Menkveld. “Competition for Order Flow and Smart Order Routing Systems.” *The Journal of Finance* 63, no. 1 (2008): 119–158.

Frino, Alex, Steven Lecce, and Reuben Segara. “The Impact of Trading Halts on Liquidity and Price Volatility: Evidence from the Australian Stock Exchange.” *Pacific-Basin Finance Journal* 19, no. 3 (June 2011): 298–307.

Gajewski, Jean-François, and Carole Gresse. “Centralised Order Books Versus Hybrid Order Books: A Paired Comparison of Trading Costs on NSC (Euronext Paris) and SETS (London Stock Exchange).” *Journal of Banking & Finance* 31, no. 9 (September 2007): 2906–2924.

Gresse, Carole. *Effects of Lit and Dark Trading Venue Competition on Liquidity: The MiFID Experience*. SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, August 30, 2012. http://papers.ssrn.com/abstract=1918473.

Hamilton, James L. “Marketplace Fragmentation, Competition, and the Efficiency of the Stock Exchange.” *The Journal of Finance* 34, no. 1 (March 1, 1979): 171–187.

Hasbrouck, Joel, and Gideon Saar. “Low-Latency Trading.” *Journal of Financial Markets* 16, no. 4 (November 2013): 646–79.

He, Yan, and Chunchi Wu. “What Explains the Bid-Ask Spread Decline After Nasdaq Reforms?” *Financial Markets, Institutions & Instruments* 12, no. 5 (2003): 347–376.

He, Peng William, Elvis Jarnecic, and Yubo Liu. “The Determinants of Alternative Trading Venue Market Share: Global Evidence from the Introduction of Chi-X.” *Journal of Financial Markets* 22 (January 2015): 27–49.

Hendershott, Terrence, Charles M. Jones, and Albert J. Menkveld. “Does Algorithmic Trading Improve Liquidity?” *The Journal of Finance* 66, no. 1 (2011): 1–33.

Kervel, Vincent van. “Competition for Order Flow with Fast and Slow Traders.” *Review of Financial Studies*, March 13, 2015.

Malinova, Katya, Andreas Park, and Ryan Riordan. *Do Retail Traders Suffer from High Frequency Traders?* SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, December 6, 2012. http://papers.ssrn.com/abstract=2183806.

Mendelson, Haim. “Consolidation, Fragmentation, and Market Performance.” *Journal of Financial and Quantitative Analysis* 22, no. 02 (1987): 189–207.

Menkveld, Albert J. “High Frequency Trading and the New Market Makers.” Journal of Financial Markets, High-Frequency Trading, 16, no. 4 (November 2013): 712–40.

O’Hara, Maureen, and Mao Ye. “Is Market Fragmentation Harming Market Quality?” *Journal of Financial Economics* 100, no. 3 (June 2011): 459–474.

Pagano, Marco. “Trading Volume and Asset Liquidity.” *The Quarterly Journal of Economics* 104, no. 2 (May 1, 1989): 255–274.

Table 1
ASX and Chi-X Trading Fees

The following table presents the trading fee schedules of ASX and Chi-X for order execution, in basis points. Chi-X's fee structure applied from market launch, with the on-market crossing rate corresponding to a "Block Special" and the off-market crossing rate corresponding to a "Large Principal Transaction".

Description	ASX Fee pre 1 July 2010	ASX Fee post 1 July 2010	Chi-X passive execution	Chi-X aggressive execution
Trade Execution Fee	0.280	0.150	0.06	0.12
Trade Execution - Auctions	0.280	0.280	-	-
On-market crossings	0.150	0.100	0.04	0.04
Off-market crossings	0.075	0.050	0.04	0.04

Table 2
Descriptive Statistics on Liquidity Metrics

This table reports summary statistics for liquidity metrics across ASX 200 constituent securities. Our observation periods consist of a one year pre- period prior to Chi-X's introduction and a one year post- period after Chi-X's introduction. Quoted spreads are time-weighted across both ASX and Chi-X. Effective spreads and price impacts are computed based on the prevailing NBBO for transactions across both markets. Price impact is constructed by comparing the midpoint at the time of each trade with that after five minutes. All spreads are calculated in tick increments and in basis points. Depth is constructed as the time-weighted dollar value of orders available at the NBBO aggregated across both markets. The percentage of the trading day during which quoted bid ask spreads are constrained at the minimum tick size is also reported. Amihud illiquidity is the absolute return per hour divided by the dollar turnover transacted in that hour. This is then averaged for each hour to arrive at an illiquidity measure per stock-day. Price is the daily time-weighted NBBO midpoint. Ln turnover is the natural logarithm of the daily trading turnover. Low tick size is equal to one if the daily time weighted midpoint is below two dollars (ie minimum tick size is half of one cent) and zero otherwise. Volatility is calculated daily as the high price, less the low price, as a percentage of the time weighted midpoint price.

	9 November 2010 – 8 November 2011			9 November 2011 – 8 November 2012		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Panel A: Liquidity Metrics						
Quoted Spread (ticks)	1.227	1.069	0.482	1.164	1.064	0.322
Effective Spread (ticks)	1.058	0.978	0.366	0.909	0.871	0.259
Price Impact (ticks)	0.776	0.650	0.730	0.608	0.527	0.587
Quoted Spread (bps)	29.31	26.78	22.24	31.98	27.74	27.26
Effective Spread (bps)	26.05	23.10	20.83	25.42	21.05	22.90
Price Impact (bps)	16.29	12.54	16.53	14.73	10.55	17.40
Depth ($ '0,000s)	43.52	13.77	156.6	41.11	14.21	149.7
Ln Depth	11.94	11.83	1.291	11.95	11.86	1.231
Constrained %	84.63	93.28	19.67	87.31	93.62	16.34
Amihud Illiquidity	1.388	1.213	0.970	1.396	1.231	0.962
Panel B: Control Variables						
Price	8.639	3.938	12.16	7.962	3.663	10.94
Turnover ($ millions)	19.33	5.837	43.82	15.79	5.096	34.24
Ln turnover	15.66	15.58	1.448	15.48	15.44	1.439
Low Tick Size	0.268	0.000	0.443	0.286	0.000	0.452
Volatility	2.328	1.928	1.748	2.229	1.855	1.524

Table 3
Liquidity Metrics for ASX 200 Stocks Relative to Pre-Competition Interval

This table reports changes in time weighted quoted spreads, effective spreads and price impacts in tick increments, quoted depths, percentage of time quoted spreads are constrained at minimum tick and normalized Amuhud illiquidity for ASX 200 constituent stocks, after Chi-X's introduction relative to the pre-entry levels. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, indicator variable for the post-entry period, control variables for price, volume, volatility and tick size, and an error term. Panel A presents the consolidated market, including both ASX and Chi-X data, whilst Panel B reports ASX data only. The pre-entry period runs from 9th of November 2010 – 8th of November 2011 and the post-entry period from 9th of November 2011 – 8th of November 2012. We calculate the difference between the pre-entry and post-entry liquidity metrics and changes in control variables, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date.

Panel A: Consolidated Market

	Quoted Spread	Effective Spread	Price Impact	Ln Depth	Constrained %	Amihud Illiquidity
Post-Entry	-0.06	-0.14	-0.15	0.02	2.24	-0.05
	(-4.49)***	(-16.02)***	(-13.92)***	(1.13)	(4.95)***	(-3.51)***
Ln Price	0.14	0.10	0.23	-0.82	-7.73	0.12
	(2.70)***	(2.79)***	(4.59)***	(-10.29)***	(-5.77)***	(2.40)**
Ln Value	-0.05	-0.04	-0.07	0.50	2.02	-0.41
	(-2.49)**	(-2.92)***	(-3.78)***	(16.08)***	(5.53)***	(-25.53)***
Volatility	0.04	0.03	0.06	-0.24	-2.45	0.18
	(6.45)***	(7.34)***	(9.80)***	(-15.95)***	(-9.66)***	(18.90)***
Tick Size	0.11	0.06	0.17	-0.67	-7.03	0.21
	(3.48)***	(2.85)***	(5.79)***	(-9.39)***	(-6.96)***	(4.74)***
Adjusted R^2	0.0517	0.1538	0.0412	0.2646	0.0772	0.1163
# Obs	84568	84568	84568	84568	84568	84568

Panel B: ASX Only

	Quoted Spread	Effective Spread	Price Impact	Ln Depth	Constrained %	Amihud Illiquidity
Post-Entry	-0.05	-0.07	-0.07	-0.04	1.76	-0.04
	(-3.93)***	(-8.81)***	(-7.24)***	(-1.78)*	(4.00)***	(-2.57)**
Ln Price	0.14	0.10	0.23	-0.82	-7.84	0.12
	(2.72)***	(2.67)***	(4.44)***	(-10.11)***	(-5.87)***	(2.39)**
Ln Value	-0.05	-0.04	-0.07	0.50	1.98	-0.41
	(-2.47)**	(-2.92)***	(-3.78)***	(16.01)***	(5.45)***	(-25.53)***
Volatility	0.04	0.03	0.07	-0.24	-2.45	0.18
	(6.51)***	(7.49)***	(9.83)***	(-15.88)***	(-9.66)***	(19.00)***
Tick Size	0.11	0.06	0.17	-0.67	-7.11	0.22
	(3.51)***	(2.87)***	(5.58)***	(-9.32)***	(-7.09)***	(4.83)***
Adjusted R^2	0.0467	0.0572	0.0211	0.2643	0.0708	0.1158
# Obs	84568	84568	84568	84568	84568	84568

Table 4
Liquidity Metrics for ASX 200 Stocks as Chi-X Market Share Increases

This table reports changes in time weighted quoted spreads, effective spreads and price impacts in tick increments, quoted depths, percentage of time quoted spreads are constrained at minimum tick and normalized Amuhud illiquidity for ASX 200 constituent stocks in the calendar year after Chi-X's introduction. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, 5 day moving average Chi-X market share, control variables for price, volume, volatility and tick size, and an error term. Panel A presents the consolidated market, including both ASX and Chi-X data, whilst Panel B reports ASX data only. The observation period runs from the 9th of November 2011 to the 8th of November 2012. We calculate the difference between liquidity metrics for each percentage of market share captured by Chi-X and changes in control variables, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date.

Panel A: Consolidated Market

	Quoted Spread	Effective Spread	Price Impact	Ln Depth	Constrained %	Amihud Illiquidity
Chi-X Market Share	-0.48	-1.68	-0.96	1.59	28.39	-0.82
	(-3.25)***	(-14.39)***	(-4.68)***	(3.16)***	(3.45)***	(-2.14)**
Ln Price	0.18	0.13	0.27	-0.70	-8.58	0.12
	(1.85)*	(2.14)**	(2.44)**	(-7.87)***	(-3.44)***	(1.59)
Ln Value	-0.03	-0.04	-0.06	0.48	1.59	-0.41
	(-2.95)***	(-5.65)***	(-4.28)***	(14.76)***	(4.33)***	(-20.73)***
Volatility	0.03	0.02	0.05	-0.22	-1.59	0.18
	(4.14)***	(5.16)***	(5.91)***	(-12.22)***	(-7.52)***	(15.58)***
Tick Size	0.12	0.06	0.16	-0.59	-7.58	0.18
	(2.70)***	(2.28)**	(3.17)***	(-7.04)***	(-6.27)***	(3.39)***
Adjusted R^2	0.0454	0.0644	0.0146	0.2080	0.0494	0.0869
# Obs	42506	42506	42506	42506	42506	42506

Panel B: ASX Only

	Quoted Spread	Effective Spread	Price Impact	Ln Depth	Constrained %	Amihud Illiquidity
Chi-X Market Share	-0.34	-0.53	0.32	0.09	20.27	-0.34
	(-2.42)**	(-4.91)***	(1.60)	(0.17)	(2.50)**	(-0.87)
Ln Price	0.20	0.15	0.28	-0.70	-8.91	0.13
	(1.92)*	(2.14)**	(2.39)**	(-7.73)***	(-3.60)***	(1.64)
Ln Value	-0.03	-0.04	-0.05	0.48	1.57	-0.41
	(-2.87)***	(-4.87)***	(-3.83)***	(14.45)***	(4.27)***	(-20.60)***
Volatility	0.03	0.03	0.06	-0.22	-1.61	0.18
	(4.17)***	(5.63)***	(5.98)***	(-12.03)***	(-7.58)***	(15.46)***
Tick Size	0.13	0.08	0.17	-0.59	-7.85	0.19
	(2.77)***	(2.43)**	(3.11)***	(-6.95)***	(-6.49)***	(3.45)***
Adjusted R^2	0.0467	0.0341	0.0130	0.1992	0.0480	0.0855
# Obs	42506	42506	42506	42506	42506	42506

Table 5
Liquidity Metrics for ASX 200 Stocks by Level of Tick Constraint

This table reports changes in time weighted quoted spreads and quoted depths for ASX 200 constituent stocks, in the calendar year after Chi-X's introduction, grouped by terciles from the proportion of time each stock's quoted spread was constrained by the minimum tick size in the year prior to Chi-X's entry. Tercile thresholds for the proportion of time at minimum tick are 84.0% and 95.8%. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, 5 day moving average Chi-X market share, control variables for price, volume, volatility and tick size, and an error term. Panel A presents the consolidated market, including both ASX and Chi-X data, whilst Panel B reports ASX data only. The observation period runs from the 9th of November 2011 to the 8th of November 2012. We calculate the difference between liquidity metrics for each percentage of market share captured by Chi-X and changes in control variables, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date.

Panel A: Consolidated Market

	Least Constrained		Moderately Constrained		Most Constrained	
	Quoted Spread	Ln Depth	Quoted Spread	Ln Depth	Quoted Spread	Ln Depth
Chi-X Market Share	-1.73	-0.49	-0.10	2.25	-0.01	2.18
	(-3.01)***	(-0.69)	(-1.17)	(2.64)***	(-0.21)	(3.99)***
Ln Price	0.48	-0.45	0.05	-0.64	0.03	-0.92
	(2.62)***	(-5.25)***	(5.58)***	(-4.93)***	(5.17)***	(-8.09)***
Ln Value	-0.09	0.42	-0.01	0.52	0.00	0.48
	(-3.89)***	(16.61)***	(-2.99)***	(7.49)***	(-2.74)***	(17.54)***
Volatility	0.08	-0.17	0.01	-0.23	0.01	-0.24
	(5.27)***	(-11.83)***	(6.62)***	(-6.38)***	(7.02)***	(-12.85)***
Tick Size	0.42	-0.74	0.07	-0.67	0.05	-0.62
	(4.86)***	(-17.15)***	(12.14)***	(-5.07)***	(5.44)***	(-7.53)***
Adjusted R^2	0.1103	0.1476	0.0440	0.2221	0.0597	0.2652
# Obs	14278	14278	14006	14006	14222	14222

Panel B: ASX Only

	Least Constrained		Moderately Constrained		Most Constrained	
	Quoted Spread	Ln Depth	Quoted Spread	Ln Depth	Quoted Spread	Ln Depth
Chi-X Market Share	-1.21	-1.95	-0.02	0.65	-0.01	0.74
	(-2.27)**	(-2.75)***	(-0.27)	(0.77)	(-0.15)	(1.38)
Ln Price	0.52	-0.44	0.06	-0.64	0.03	-0.94
	(2.80)***	(-5.03)***	(6.16)***	(-5.05)***	(5.27)***	(-8.06)***
Ln Value	-0.09	0.42	-0.01	0.51	0.00	0.47
	(-3.85)***	(16.70)***	(-2.94)***	(7.36)***	(-2.74)***	(17.13)***
Volatility	0.08	-0.17	0.01	-0.23	0.01	-0.24
	(5.26)***	(-11.95)***	(7.07)***	(-6.26)***	(7.02)***	(-12.62)***
Tick Size	0.43	-0.72	0.07	-0.67	0.05	-0.63
	(5.02)***	(-16.39)***	(12.09)***	(-5.03)***	(5.54)***	(-7.55)***
Adjusted R^2	0.1114	0.1496	0.0463	0.2107	0.0626	0.2525
# Obs	14278	14278	14006	14006	14222	14222

Table 6
Spread Metrics for ASX 200 Stocks in Basis Points

This table reports changes in time-weighted quoted spreads, effective spreads and price impacts in basis points for ASX 200 constituent stocks during the one year prior to and following Chi-X Australia's introduction, as well as on varying levels of Chi-X market share in the calendar year after Chi-X's introduction. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, post- entry indicator in Panel A and 5 day moving average Chi-X market share in Panel B, control variables for price, volume, volatility and tick size, and an error term. The observation period begins on the 9th of November 2010 for Panel A and the 9th of November 2011 for Panel B, and ends on the 8th of November 2012 for both Panels. We calculate the difference between liquidity metrics for changes in each explanatory variable, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date.

Panel A: Pre- and Post- Chi-X Entry

	Consolidated Market			ASX Only		
	Quoted Spread	Effective Spread	Price Impact	Quoted Spread	Effective Spread	Price Impact
Post-Entry	-0.13	-2.94	-2.56	-0.04	-1.14	-0.65
	(-0.72)	(-10.67)***	(-12.63)***	(-0.20)	(-5.20)***	(-3.61)***
Price Inverse	49.98	41.22	17.91	49.97	44.41	21.45
	(104.61)***	(32.58)***	(11.18)***	(104.55)***	(40.10)***	(12.52)***
Ln Value	-1.19	-1.10	-1.29	-1.19	-1.20	-1.38
	(-5.73)***	(-3.79)***	(-5.35)***	(-5.71)***	(-4.67)***	(-6.03)***
Volatility	1.00	0.96	1.98	1.00	1.04	2.07
	(9.89)***	(8.45)***	(12.57)***	(9.87)***	(9.93)***	(13.76)***
Tick Size	-18.28	-16.27	-6.32	-18.26	-17.24	-7.38
	(-26.45)***	(-21.15)***	(-9.55)***	(-26.27)***	(-23.68)***	(-10.37)***
Adjusted R^2	0.9381	0.7387	0.1213	0.9379	0.7873	0.1466
# Obs	84568	84568	84568	84568	84568	84568

Panel B: Continuous One Year Interval

	Consolidated Market			ASX Only		
	Quoted Spread	Effective Spread	Price Impact	Quoted Spread	Effective Spread	Price Impact
Chi-X Market Share	-1.83	-49.49	-12.17	-0.47	-18.30	23.10
	(-0.69)	(-8.84)***	(-2.45)**	(-0.18)	(-4.01)***	(3.93)***
Price Inverse	50.53	40.59	18.31	50.49	43.93	22.05
	(99.39)***	(41.04)***	(9.63)***	(99.70)***	(35.15)***	(9.91)***
Ln Value	-0.94	-1.61	-1.54	-0.94	-1.50	-1.40
	(-8.17)***	(-10.40)***	(-5.17)***	(-8.16)***	(-8.71)***	(-4.31)***
Volatility	0.75	0.75	1.79	0.76	0.95	2.00
	(8.14)***	(6.89)***	(7.54)***	(8.15)***	(8.39)***	(7.87)***
Tick Size	-19.50	-17.10	-7.23	-19.46	-18.39	-8.56
	(-35.23)***	(-30.13)***	(-8.15)***	(-34.62)***	(-28.60)***	(-8.45)***
Adjusted R^2	0.9497	0.6936	0.0981	0.9490	0.7497	0.1222
# Obs	42506	42506	42506	42506	42506	42506

Table 7
Liquidity Change after ASX's 2010 Fee Reduction

This table reports changes in liquidity measures for ASX200 constituent stocks from the period six months prior to until six months after ASX's 2010 trading fee reduction. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, binary fee reduction variable equal to zero prior to ASX's trading fee reduction on 30 June 2010 and one after, controls for price, volume, volatility and tick size, and an error term. The observation period runs from the 1st of January 2010 to the 31st of December 2010. We calculate the difference between the pre- and post- fee change liquidity metrics for changes in each explanatory variable, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date.

Panel A: Spread Measure of Liquidity

	Quoted Spread		Effective Spread		Price Impact	
	Ticks	Basis Points	Ticks	Basis Points	Ticks	Basis Points
Fee Reduction	-0.02	-1.16	-0.05	-2.15	-0.11	-1.46
	(-2.99)***	(-2.06)**	(-7.10)***	(-3.43)***	(-6.16)***	(-3.45)***
Ln Price	0.13		0.10		0.28	
	(5.30)***		(4.29)***		(9.85)***	
Price Inverse		28.42		26.63		9.62
		(3.05)***		(2.88)***		(3.19)***
Ln Value	-0.04	-2.93	-0.05	-3.28	-0.11	-3.30
	(-5.19)***	(-2.88)***	(-6.94)***	(-2.97)***	(-9.48)***	(-6.81)***
Volatility	0.03	1.12	0.02	0.76	0.10	3.35
	(7.75)***	(2.93)***	(6.81)***	(2.46)**	(11.86)***	(17.41)***
Tick Size	0.14	-4.33	0.13	-3.62	0.30	0.62
	(6.22)***	(-0.61)	(5.95)***	(-0.52)	(9.65)***	(0.26)
Adjusted R^2	0.0242	0.5147	0.0353	0.4099	0.0354	0.0507
# Obs	48963	48963	48963	48963	48963	48963

Panel B: Other Measures of Liquidity

	Ln Depth	Constrained %	Amihud Illiquidity
Fee Reduction	0.14	1.27	-0.10
	(5.21)***	(3.41)***	(-5.57)***
Ln Price	-0.96	-6.59	0.28
	(-8.36)***	(-9.03)***	(4.95)***
Ln Value	0.58	2.42	-0.42
	(14.22)***	(7.08)***	(-20.10)***
Volatility	-0.23	-1.73	0.19
	(-9.47)***	(-9.54)***	(15.58)***
Tick Size	-0.48	-8.50	0.17
	(-6.06)***	(-7.61)***	(2.55)**
Adjusted R^2	0.2862	0.0664	0.1132
# Obs	48963	48963	48963

Table 8
Robustness Tests

This table reports coefficient estimates and t-statistics from robustness tests for liquidity metrics in ASX200 constituent stocks on varying model specifications. The econometric specification expresses the liquidity metric for stock *i* on day *d* as the sum of a stock specific mean, alternative measures of Chi-X market presence, control variables for price, volume, volatility and tick size, and an error term. We calculate means and event-effects based on the model estimates under different model specifications to quantify the level of competition. Panel A presents the consolidated market, including both ASX and Chi-X data, whilst Panel B reports ASX data only. The pre- and post- periods in (1) are October 2011 and October 2012 respectively. The continuous observation window in (2) runs from 6 months to 1 year after Chi-X's introduction. The model specification in (3) utilizes actual Chi-X market share, rather than a lagged moving average. The event-variables in (4) and (5) are indicators equal to one for stock-days with Chi-X market share exceeding 2% and 5% of total trading turnover, respectively, and zero otherwise. Regression analysis in (6) is done by aggregating stock-day observations by month, similar to the methodology in O'Hara and Ye (2011). We calculate the difference between liquidity metrics for changes in each explanatory variable, and add a "*/**/***" to the t-statistic if these are significantly different at the 90%/95%/99% level. In the test, we double cluster standard errors by stock and date for (1) to (5) and by stock for (6).

Panel A: Consolidated Market

	(1)	(2)	(3)	(4)	(5)	(6)
Quoted Spread	-0.24	-0.81	-0.41	-0.02	-0.01	-0.63
	(-7.28)***	(-3.32)***	(-9.47)***	(-3.55)***	(-2.36)**	(-3.17)***
Effective Spread	-0.26	-1.37	-1.19	-0.06	-0.05	-2.14
	(-12.84)***	(-7.68)***	(-22.51)***	(-12.49)***	(-11.55)***	(-14.89)***
Price Impact	-0.26	-1.00	-0.79	-0.04	-0.02	-1.13
	(-9.68)***	(-3.25)***	(-9.80)***	(-4.48)***	(-3.98)***	(-4.93)***
Ln Depth	0.35	3.43	2.25	0.04	0.10	1.30
	(8.10)***	(6.36)***	(13.71)***	(2.12)**	(4.47)***	(3.47)***
Constraint %	12.67	41.13	26.11	1.14	0.87	36.69
	(10.50)***	(4.96)***	(9.08)***	(3.47)***	(3.34)***	(4.33)***
Amihud Illiquidity	-0.24	-1.25	-0.93	-0.02	-0.05	-0.65
	(-5.51)***	(-2.56)**	(-6.50)***	(-1.51)	(-3.07)***	(-2.06)**

Panel B: ASX Only

	(1)	(2)	(3)	(4)	(5)	(6)
Quoted Spread	-0.22	-0.65	-0.30	-0.02	-0.01	-0.47
	(-7.14)***	(-2.94)***	(-3.86)***	(-2.87)***	(-1.92)*	(-2.62)***
Effective Spread	-0.16	-0.85	-0.34	-0.02	-0.02	-0.78
	(-8.52)***	(-4.90)***	(-5.58)***	(-3.95)***	(-6.03)***	(-5.82)***
Price Impact	-0.15	-0.40	0.32	0.01	0.01	0.44
	(-5.94)***	(-1.27)	(2.77)***	(1.10)	(1.10)	(1.88)*
Ln Depth	0.26	2.64	1.19	-0.02	0.04	-0.42
	(6.02)***	(4.94)***	(3.85)***	(-0.90)	(2.04)**	(-1.13)
Constraint %	11.81	31.36	19.66	0.85	0.66	27.19
	(10.23)***	(4.11)***	(4.40)***	(2.58)***	(2.66)***	(3.39)***
Amihud Illiquidity	-0.21	-0.81	-0.43	-0.01	-0.03	-0.09
	(-4.96)***	(-1.66)*	(-1.85)*	(-0.50)	(-1.86)*	(-0.27)

Figure 1
Chi-X Australia Market Share of Daily Trading Turnover

This figure presents the percentage of total daily on-market trading turnover in ASX 200 index constituent securities executed on Chi-X Australia from its introduction on the 9th of November 2011 over its first year of operation. Total volume includes on- and off-market (reported) trades for securities traded on both ASX and Chi-X. These off-market trades (for both ASX and Chi-X) are excluded in the reported on market volume.

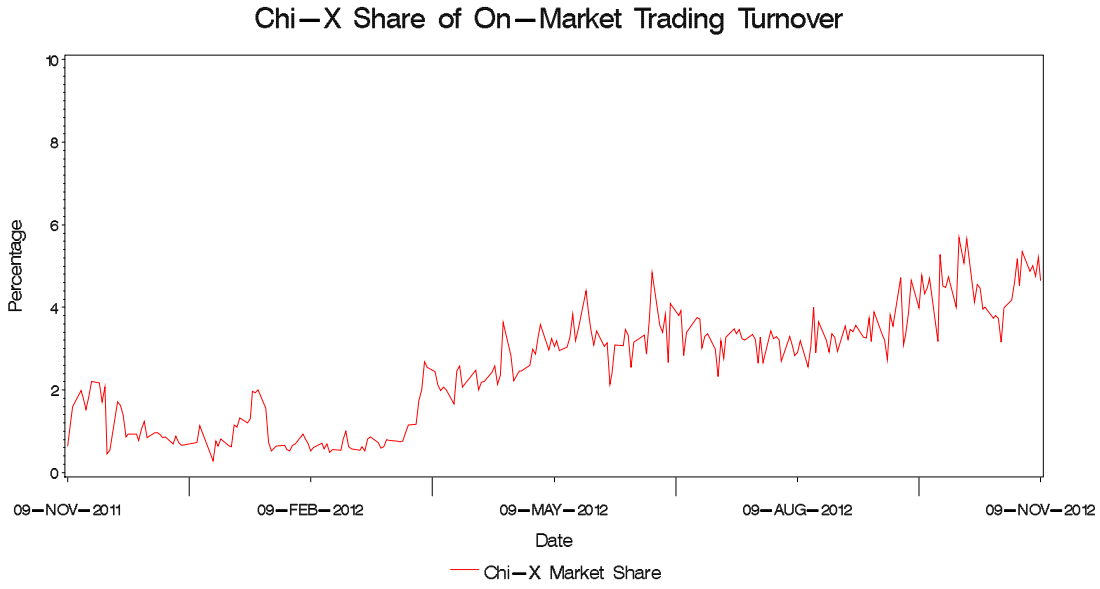


Figure 2
Quoted Spreads, Effective Spreads and Price Impact for ASX 200 Securities

This figure presents average quoted spreads, effective spreads, and price impacts for ASX 200 index constituent securities. The observation period begins on the 9th of November 2010, one year prior to Chi-X Australia's entry, and spans two years. Metrics are presented in tick increments since there is a substantial level of tick constraint across most securities. Quoted spreads experience a lower bound of one tick. Effective spreads may be lower than one tick if some trades benefit from price improvement.

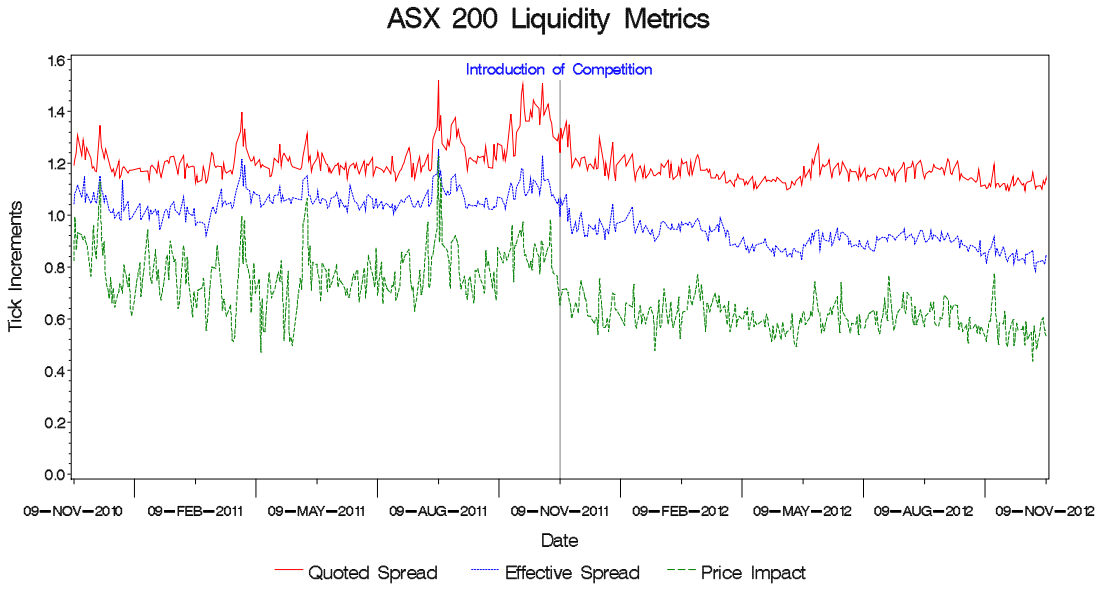


Figure 3
Quoted Spread Constraint for ASX 200 Securities by Tick Constraint

This figure presents the average quoted spreads for ASX 200 index constituent securities by tick constraint tercile. The observation period begins on the 9th of November 2010, one year prior to Chi-X Australia's entry, and spans two years. The equally-sized most constrained, moderately constrained and least constrained groups had a quoted spread of one tick increment more than 95.8% of the time, 84.0% to 95.8% of the time and less than 84.0% of the time respectively during the pre-competition period.

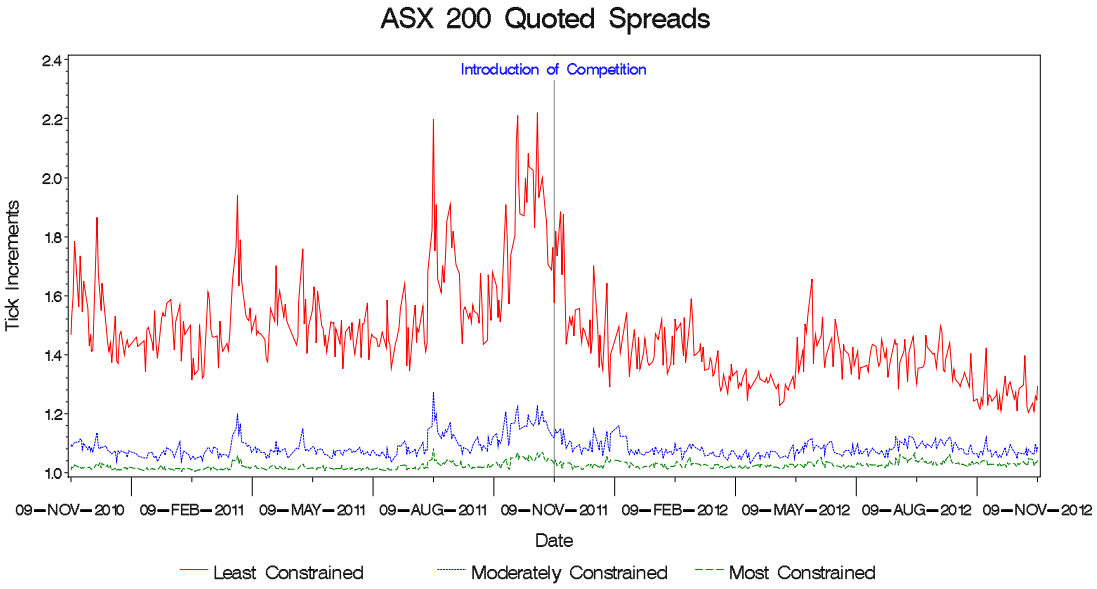


Figure 4
Quoted Depth for ASX 200 Securities by Tick Constraint

This figure presents the average quoted depths for ASX 200 index constituent securities by tick constraint tercile. The observation period begins on the 9th of November 2010, one year prior to Chi-X Australia's entry, and spans two years. The equally-sized most constrained, moderately constrained and least constrained groups had a quoted spread of one tick increment more than 95.8% of the time, 84.0% to 95.8% of the time and less than 84.0% of the time respectively during the pre-competition period.

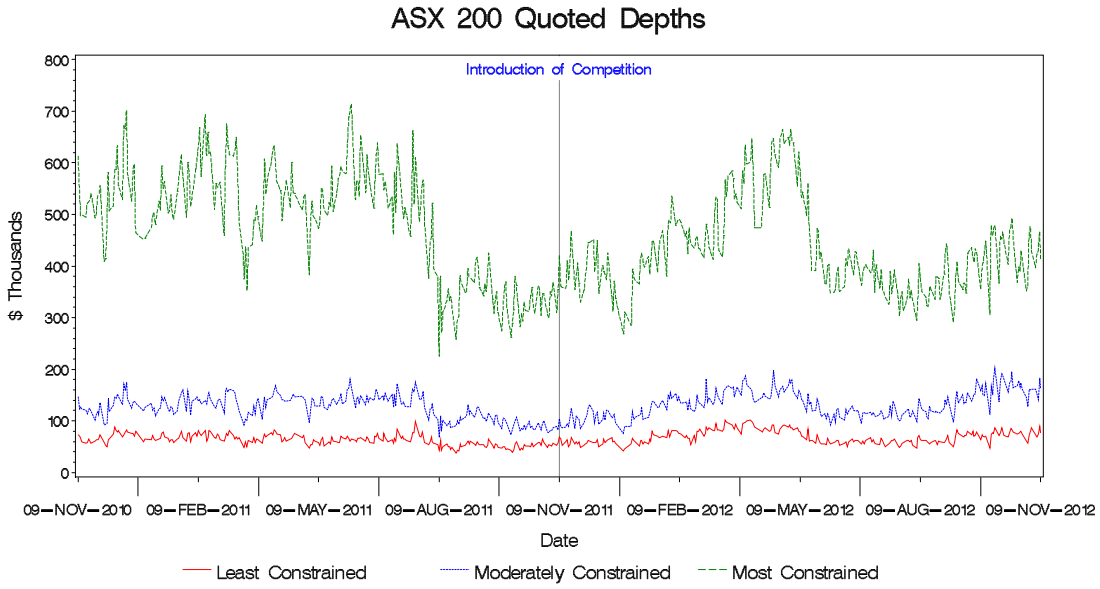
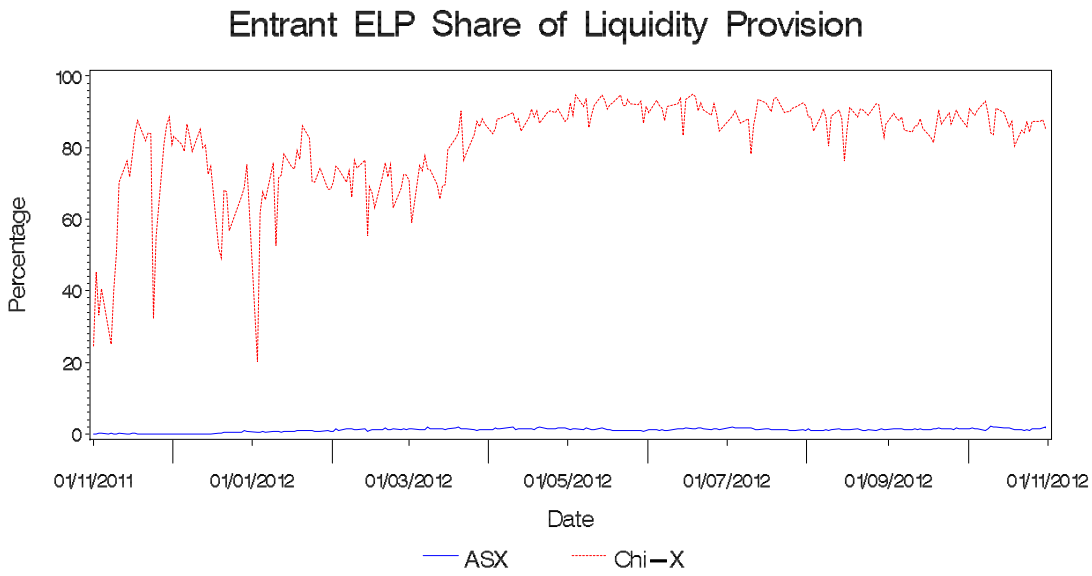


Figure 5
Trading Characteristics of Entrant ELPs

This figure presents the proportion of liquidity supplied on ASX and Chi-X from November 2011 to October 2012 by two fee-sensitive electronic liquidity providers that entered the Australian equities market in 2011. Panel A presents the ELPs' market share of passive liquidity supply among all brokers. Panel B presents the ELPs' market share of trading turnover among all brokers. Off market trades, as well as trades with the same buyer and seller broker identifier, are excluded.

Panel B: Liquidity Provision by Entrant ELPs



Panel B: Trading Turnover of Entrant ELPs

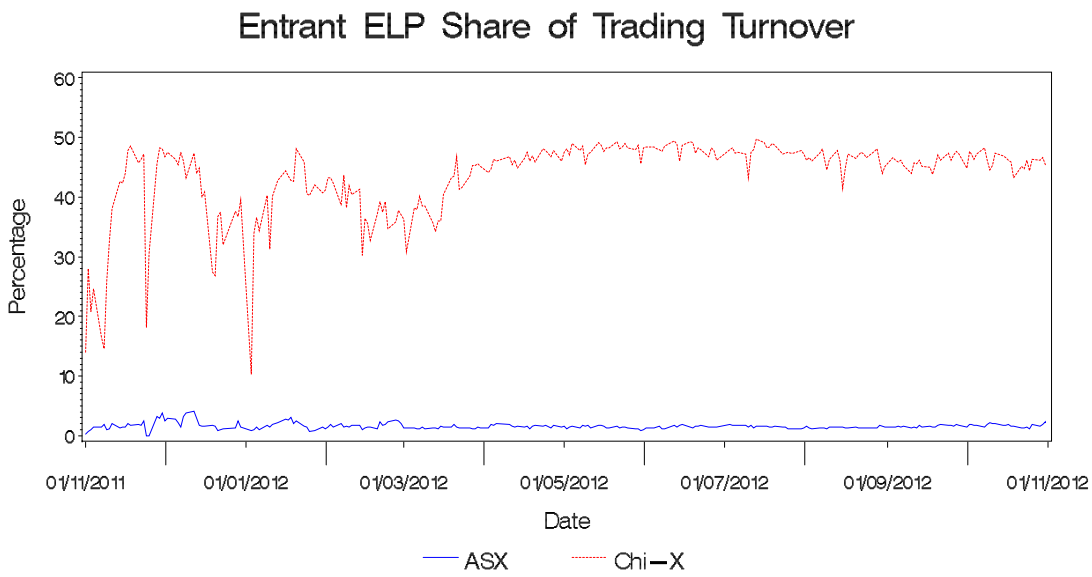
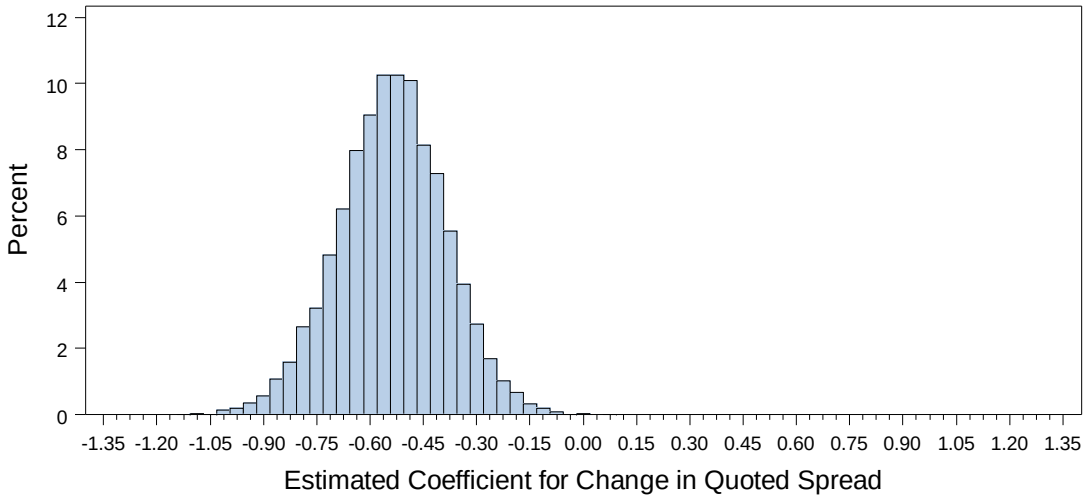


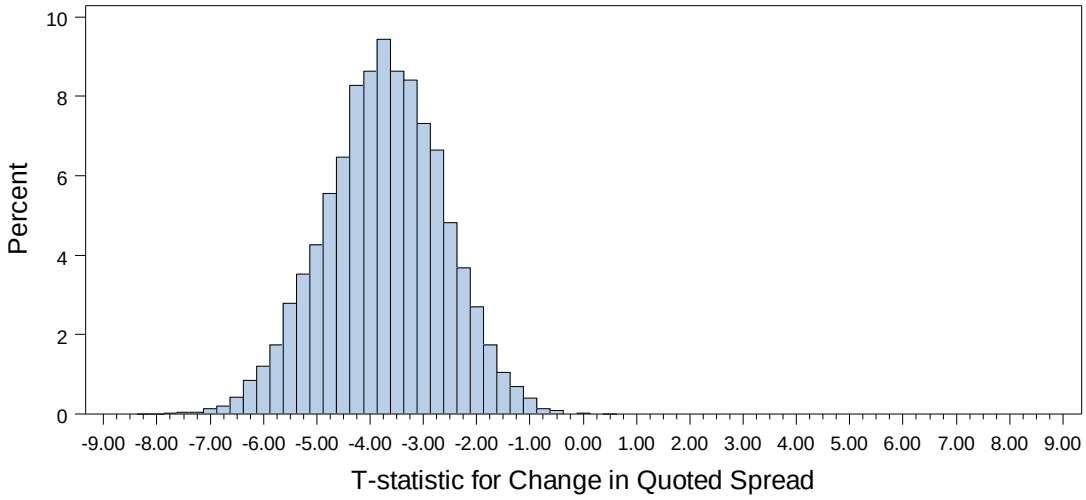
Figure 6
Bootstrap Analysis for Change in Quoted Spread

This figure displays a histogram of estimated coefficients and t-statistics from the bootstrap analysis. The dataset contains all trading days from July to October 2011 in the pre-competition period and July to October 2012 in the post-competition period. We randomly draw 1,000 observations from each period to run a regression model with quoted spread in basis points as the dependent variable, against an indicator for post-competition period observations and controls for price, volume, volatility and tick size. We repeat this procedure 10,000 times and the frequency distribution of estimated coefficients for the post-competition indicator variable from all iterations is plotted below.

Panel A: Estimates of the impact of competition on quoted spread



Panel B: Estimates of the significance of competitions effect on quoted spread



Appendix I

This table displays a list of Chi-X Australia participants and the date they became eligible to commence trading from market launch through to the end of calendar year 2012. Data is taken from Chi-X Australia market operations notices.[12]

Date Admitted	Chi-X Australia Participant
31/10/2011	Bell Potter Securities Limited
	BBY Ltd
	Citigroup Global Markets Australia Pty Limited
	Commonwealth Securities Limited
	Credit Suisse Australia (Equities) Limited
	Deutsche Securities Australia Limited
	GETCO Australia Pty Limited
	Goldman Sachs & Partners Australia Pty Ltd
	Instinet Australia Pty Ltd
	ITG Australia Limited
	J.P. Morgan Securities Australia Limited
	Macquarie Securities (Australia) Limited
	Merrill Lynch Equities (Australia) Limited
	Moelis Australia Securities Pty Ltd
	Morgan Stanley Australia Securities Limited
	Nomura Australia Limited
	Patersons Securities Limited
	Penson Financial Services Australia Pty Ltd
	RBC Securities Australia Pty Ltd
	RBS Equities (Australia) Limited
	UBS Securities Australia Ltd
	Virtu Financial Asia Pty Ltd
16/11/2011	Interactive Brokers LLC
22/05/2012	E.L. & C. Baillieu Stockbroking Ltd
13/08/2012	Australian Investment Exchange Ltd
29/10/2012	ABN AMRO Clearing Sydney Pty Ltd
19/11/2012	State One Stockbroking

[12] Notices available at http://cmsau.chi-x.com/NOTICES/MARKETOPERATIONS.aspx