Do exchange-contracted market makers improve market quality for liquid stocks?

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Abstract

This paper studies the market impacts of contracted liquidity providers by investigating the event in which NASDAQ OMX Stockholm (NOMX) introduced a liquidity provider scheme for OMXS30 constituent stocks, which are the most actively traded stocks on NOMX, in 2012. The liquidity provider scheme reduces transaction fees for registered market members if they fulfill the liquidity supplying requirement specified by the scheme. The results suggest that, on NOMX, OMXS30 stocks became more liquid after the scheme's introduction. The liquidity improvement on NOMX was not accompanied by a lower liquidity level on Chi-X, the major alternative trading venue for OMXS30 stocks. The results do not support the view that liquidity migrated to NOMX from the alternative market after the introduction of the liquidity provider scheme. The order processing cost decreased after the scheme's introduction, implying that qualified market makers have benefited from a cost reduction from the scheme and charge less compensation for supplying liquidity than before. Liquidity consumers' costs have reduced accordingly. This result implies a welfare transfer from the exchange to investors. The adverse selection cost on NOMX also fell after the introduction of the liquidity provider scheme.

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1. Introduction

Modern equity markets are mostly designed as limit order markets and rely on voluntary liquidity suppliers. For actively traded large stocks, Hagströmer and Nordén (2013) show that algorithmic traders often take on the role of market makers and supply liquidity for stocks. Financial Instruments Directive II (MIFID II) is currently discussing proposals on regulating contracted market-making activities of algorithmic trading firms[2]. Such firms will have to enter into a contract with trading venues in order to supply liquidity. The contract should specify the proportion of the trading time for which market makers should supply liquidity to the market and the volume they should supply.

Small and less traded firms can hire designated market makers (DMMs) to supply liquidity to their stocks. Typically, trading venues set requirements on how DMMs should supply liquidity by maintaining the bid-ask spread below a certain nominal level during a specific portion of the continuous trading hours, referred to as the maximum spread rule. In addition, trading venues can require a minimum depth DMMs should submit[3]. Within the spread and depth requirements of the trading venues, listed firms can negotiate with DMMs for additional constraints on the liquidity supply, e.g., a narrower spread, greater depth, etc. DMMs are paid by the listed firms in return for supplying liquidity. In addition to less traded small-cap firms, less liquid exchange-traded funds (ETFs) can also pay the exchange that contracts the DMMs to supply liquidity. In this case, the ETFs hire market makers indirectly to supply liquidity.

On April 1, 2012, NASDAQ OMX Stockholm (henceforth NOMX) introduced a liquidity provider scheme (LPS). This voluntary scheme requires the participants to supply liquidity to the underlying stocks of the OMXS30 index, 30 actively traded large-cap stocks on NOMX. As a compensation for supplying liquidity, the LPS participants are entitled to lower transaction fees on both liquidity-supplying and liquidity-demanding trades. More specifically, LPS participants are required to quote at the European best bid and offer (EBBO). EBBOs are

[2] The Markets in Financial Instruments Directive (MiFID) is a European Union (EU) law that provides harmonized regulation for investment services across the 31 member states of the European Economic Area (the 28 EU member states plus Iceland, Norway and Liechtenstein). Its aim is to improve the competitiveness of EU financial markets by creating a single market for investment services and activities, and ensuring a high degree of harmonized protection for investors in financial instruments, such as shares, bonds, derivatives and various structured products. See http://ec.europa.eu/finance/securities/isd/mifid/index_en.htm, accessed on April 2, 2015.

[3] As an example, the maximum spread rule for DMMs proposed by NASDAQ OMX Stockholm is 4%. DMMs must post two-sided quotes according to the rule at least 85% of the continuous trading time. The exchange requires that DMMs quote depths of at least four trading lots for both the buy and sell sides.

the best quotes among the NOMX, BATS, Chi-X and Turquoise exchanges[4]. To be counted as supplying liquidity on the buy/sell side, LPS participants must submit orders with a value exceeding SEK 50,000 to the European best bid/European best offer. When supplying liquidity, LPS participants may choose freely among the 30 large-cap stocks and the buy or sell sides. LPS participants can enjoy the benefits of the LPS, as long as the turnover-weighted average liquidity-supplying time exceeds 50% of the time for the average of the buy and sell sides.

This paper empirically analyzes the market impacts of the LPS on the OMXS30 stocks in terms of liquidity, components of the spread, and liquidity risk. The market liquidity impact of the LPS is not certain. On the one hand, the liquidity effect could be positive. The LPS provides incentives for participants to supply liquidity to NOMX. To benefit from the reduced transaction fee, the contracted participants must fulfill the obligation by supplying liquidity, and consequently liquidity could improve. On the other hand, there is a possibility that the LPS has not improved liquidity for NOMX as market participants may find the cost reduction insufficient compensation for supplying liquidity.

In addition to studying NOMX, we investigate the liquidity impact of the LPS on Chi-X. Outside NOMX, OMXS30 stocks are traded on multilateral trading facilities (MTFs) including Chi-X, BATS, Turquoise and Burgundy. We focus on the biggest competitor to NOMX in terms of market share, Chi-X. This analysis investigates whether, if there is improved liquidity on NOMX after the introduction of the LPS, it is accompanied by a liquidity decrease on Chi-X. If so, it will indicate that liquidity migrates away from NOMX's competitor market to NOMX.

After looking at the liquidity impact, we measure liquidity risk and examine whether it changes after the introduction of the LPS. Menkveld and Wang (2013) document that liquidity risk decreases after firms hire DMMs, because the co-variation between the stocks' liquidity and the market liquidity is reduced by market-making activities. DMMs are often hired by small and illiquid firms, whereas the LPS was introduced for the 30 most actively traded large-cap stocks on NOMX. Liquidity risk is documented to be larger for illiquid stocks, which tend to have higher volatility and to be smaller in size than liquid stocks (Acharya and Pedersen 2005, Pastor and Stambaugh 2003). However, this does not mean

[4] The European best bid quote is the highest buy price among those trading venues, while the European best offer quote is the lowest sell price among them

there is no liquidity risk for large and more frequently traded stocks. The market may still reward the liquidity risk of taking on large-cap stocks. For example, Acharya and Pedersen (2005) demonstrate that the liquidity risk, measured in liquidity betas, is not zero even for the largest portfolio. Lee (2011) finds a statistically significant premium for liquidity betas after controlling for the market capitalization.

This study contributes to the literature on market impacts from contracted market makers. The LPS specifies liquidity providers with relative liquidity supply obligations. The market impacts from relative obligations have not been the focus of previous studies. The LPS is different from the case of DMMs which has been empirically examined. Venkataraman and Waisburd (2007) and Menkveld and Wang (2013) document that on the Paris Bourse and Euronext (both order-driven markets), DMMs improve market quality in terms of higher liquidity, lower liquidity risk, and smaller order imbalance. Similarly, Anand et al. (2009) and Skjeltorp and Odegaard (2015) document improved stock liquidity and increased value after the introduction of DMMs in Sweden and Norway. DMM contracts typically contain a maximum spread rule, which specifies a nominal value at which the DMM must supply liquidity. The spread requirement from the LPS is specified in relation to the EBBO, which includes the primary market and several MTFs. If the EBBO is wide, i.e., the spread is wide collectively across several markets, LPS participants are not obliged to improve it to a certain nominal level in order to produce a cost reduction. LPS participants can choose the distribution of their activities across the OMXS30 constituents. This partial obligation is different from a DMM contract, which is typically designed to benefit a specific stock.

We contribute to the literature on competition among trading venues. The LPS increases the competitiveness of NOMX by specifying the liquidity supply requirement at the EBBO. OMXS30 stocks are traded simultaneously on NOMX and several MTFs, of which Chi-X is the largest competitor to NOMX. This market structure enables us to investigate directly the impact of the LPS on NOMX's competitor. Foucault and Parlour (2004) argue that the co-existing market structure does not maximize welfare compared to a monopoly market design. Foucault and Menkveld (2008) document that the London Stock Exchange's (LSE's) accommodating of Dutch stocks trading benefited market quality by increasing the aggregated market depth for the LSE and Euronext exchanges. Malinova and Park (2015) study the transaction fee changes on the Toronto Stock Exchange under increased competition with other fragmented markets. The Toronto Stock Exchange has implemented a maker-taker fee structure, which provides economic rewards to liquidity providers, and charges liquidity consumers. The LPS is different from the maker-taker fee structure, even though both are considered to improve the liquidity competitiveness of their exchanges. Moreover, the LPS rewards qualified participants by reducing the transaction fees for both liquidity-supplying and liquidity-demanding trades, whereas the maker-taker pricing charges the liquidity demanders.

The descriptive statistics from the data suggest that NOMX is the most active market in terms of the trading of OMXS30 constituents. NOMX accounts for the majority share of the trading volume (~ 65%) in the OMXS30 stocks, among the other alternative markets, both before and after the introduction of the LPS[5]. The bid and ask quotes on NOMX with a value of not less than 50,000 SEK are at EBBO most of the time (~ 86%) both before and after the LPS's introduction. In contrast, the equivalent time proportion for the Chi-X decreased by approximately 7% after the LPS was introduced.

Using a difference-in-difference approach, our analysis suggests that the OMXS30 constituent stocks' liquidity is reduced after the introduction of the LPS, i.e., the bid-ask spread decreases by 1.08 basis points. This result is in line with the liquidity improvement gained from employing DMMs (Anand et al. 2009, Menkveld and Wang 2013). The documented spread decrease in this paper is economically meaningful. The average daily trading volume for the OMXS30 stocks is approximately 10.7 billion SEK during the month before the LPS introduction. The decrease in the bid-ask spread is equivalent to a daily trading cost saving of nearly 1.2 million SEK[6]. We do not observe a migration of liquidity from Chi-X to NOMX after the LPS is introduced. The liquidity level on Chi-X increases after the LPS's introduction as well. Regarding liquidity risk, our findings suggest that the liquidity risk remains unchanged for the OMXS30 stocks on NOMX.

This study decomposes the bid-ask spread to investigate the channel through which the spread is reduced and how market participants benefit from the reduced spread. The results suggest that the order-processing cost decreases for the market makers after the LPS's introduction. This is likely due to the fact that qualified market makers receive the benefit of lower transaction fees from NOMX. Market makers claim less compensation for supplying liquidity,

[5] The alternative markets we considered were BATS, Chi-X, Turquoise and Burgundy. Among the alternative markets, Chi-X facilitates the greatest trading volume (~22%) in OMXS30 constituent stocks. More than 80% of the trading volume in OMXS30 stocks among the fragmented markets takes place in NOMX and Chi-X.

[6] The data are available at https://newsclient.omxgroup.com/cdsPublic/viewDisclosure.action?disclosureId=499617&lang=en

which is shown in reduced spreads. This reduction benefits liquidity consumers by decreasing their trading costs in crossing the bid-ask spread. Another component of the spread, the adverse selection cost, becomes smaller for the OMXS30 stocks on NOMX after the LPS is introduced. This is in line with previous findings about DMMs' role in reducing information asymmetry (e.g., Perotti and Rindi 2010). Liquidity suppliers experience adverse selection costs when they trade with informed traders. The reduced adverse selection cost in the results is consistent with the literature. First, uninformed traders use more aggressive orders when the spread tightens, which decreases liquidity suppliers' adverse selection costs (Malinova and Park 2015). Second, market makers, as uninformed traders, trade more actively (and consume liquidity) to manage their inventory position after the LPS is introduced (Amihud and Mendelson 1980).

The rest of this paper is organized as follows. Section 2 describes the institutional setting of NOMX and the details of the LPS, the difference-in-difference methodology and the data. Section 3 outlines the measures of market quality and presents the results. Section 4 concludes the study.

2. Institutional setting, methodology and data

Institutional setting

This paper studies the event of the introduction of the LPS in NOMX. NOMX organizes an electronic limit order book for equity trading. The market is open from 9 am to 5.30 pm on a normal trading day. Marketable limit orders are matched and executed in the order book by price-member-visibility-time priority. Member priority refers to the execution priority for market orders from members who have submitted limit orders at the best price on the opposite side. Visibility priority implies execution priority for displayed limit orders ahead of hidden orders. The opening price is decided by an opening call auction. The continuous trading session halts at 5:25 pm. A closing call auction takes place after that. See Hagströmer and Nordén (2013) for a more detailed description of the general market setting.

[Insert Figure 1 about here]

Figure 1 presents the trading volumes in the OMXS30 constituent stocks across different trading venues, i.e., BATS, Burgundy, Chi-X, NOMX and Turquoise. The market share in terms of trading volume is measured in both currency terms, i.e., million Swedish Krona (MSEK) and relative terms, i.e., as a fraction of the total trading volume. The time period covers the one month before and the one month after the LPS's introduction. We document that the trading volume for NOMXS30 occurs mostly on NOMX (~ 65%). Chi-X is the largest competitor of NOMX in terms of market share (~ 22%). From one month before the introduction of the LPS to one month afterwards, the market share for NOMX (Chi-X) changed from 66.51% to 63.75% (21.10% to 23.71%). The decrease in trading volume share for NOMX reflects the fact that NOMX is less active during the summer holidays in Sweden. We control for the trading volume in our main analysis.

[Insert Figure 2 about here]

[Insert Table 1 about here]

Figure 2 presents the trading volume distribution across the OMXS30 stocks for each trading venue. The total trading volume varies across stocks, from less than 100 MSEK to 1,250 MSEK. However, the lion's share of the trading volume is conducted on NOMX for all stocks, during the time periods both before and after the LPS's introduction. After NOMX, Chi-X is the venue where most of the rest of the trading volume in OMXS30 constituent stocks takes place.

Table 1 presents the fraction of time when the best quotes from NOMX and Chi-X are equal to EBBO. EBBO is constructed from the intraday quote updates as the highest bid and the lowest ask quotes among the BATS, Chi-X, NOMX and Turquoise venues. The minimum time between two quote updates is 1 millisecond. We evaluate the time fraction during which NOMX's best quotes with value exceeding 50,000 SEK are equal to EBBO for each stock, each day, and each buy/sell side. The results are aggregated across stocks. For most of the continuous trading hours, the best quotes from NOMX are equal to EBBO. This is true on both the buy and the sell side during the sample period (~86%). The difference between the time periods before and after the introduction of the LPS is not significant. In contrast, the best quotes from Chi-X are equal to EBBO on average approximately 65% of the time before the LPS's introduction, decreasing to approximately 57% of the time afterwards. The differences are statistically significant.

Difference-in-difference methodology

The sample stocks used in this study can be classified into three groups: (1) the constituent OMXS30 stocks traded on NOMX (LPS group stocks), (2) the constituent OMXS30 stocks traded on Chi-X, and (3) 30 large-cap stocks traded on NOMX, but not included in the OMXS30 index (referred to as benchmark stocks).

We study the liquidity changes for the constituent OMXS30 stocks on NOMX after the LPS's introduction. The 30 large-cap stocks that are not included in the OMXS30 index are used as the benchmark. The benchmark stocks are not covered by the LPS. We do not expect the LPS to have had an impact on them. The benchmark stocks are traded on the same trading system and exchange venue as the OMXS30 constituents and are exposed to the same market microstructure changes. By comparing the market impact for the OMXS30 stocks against the benchmark, we remove the general market changes, e.g., liquidity and trading activities after the introduction of the LPS, in terms of an effect on our results.

We investigate whether liquidity migrates from alternative markets to NOMX by examining the Chi-X venue. As shown in Figure 1, most of the trading volume for OMXS30 constituents occurs on NOMX. Chi-X is the largest competitor of NOMX in terms of share of trading volume. Similarly to when studying the market impact on NOMX, we compare the liquidity impact on OMXS30 constituents on Chi-X to the benchmark stocks.

The data period covers two months, one month before the LPS was introduced (pre-event period), and one month afterwards (post-event period). The pre-event period contains 22 trading days and runs from March 1, 2012 to March 31, 2012. The post-event period contains 19 trading days and runs from June 1, 2012 to June 30, 2012. Following Menkveld and Wang (2013), we set two months (from April 1, 2012 to May 31, 2012) as the event period, and exclude them from our analysis. In the liquidity risk analysis, we stretch the data periods to three months before and three months after the LPS's introduction. The pre-event period for the liquidity risk analysis runs from January 1, 2012 to March 31, 2012, and the post-event period runs from June 1, 2012 to August 31, 2012.

[Insert Table 2 about here]

Table 2 presents the summary statistics for the market capitalization, trading volume and liquidity levels for the OMXS30 stocks on NOMX (column *LPS*) and the benchmark stocks (column *Benchmark*). The measures for the liquidity level include the relative bid-ask spread and depth. The market capitalization is reported as at the end of March 2012, and expressed in

MSEK. Trading volume, spread and depth are averaged across the trading days in March 2012. Trading volume is the average of the daily trading volume in MSEK. The intraday spread is calculated as the bid-ask spread divided by the midpoint when there is an update on the bid and/or ask quotes. The daily spread is obtained from the time-weighted average. Table 2 reports the monthly average of the daily spread for each stock. The intraday depth is the MSEK volume required to change the best bid and ask quotes on average. Like the spread, depth in Table 2 reports the average of the daily depth, which is the time-weighted average of the intraday depth.

As presented in Table 2, the spread varies between 3.73 and 12.51 basis points (bps) for the OMXS30 stocks, and 9.05 and 70.83 bps for the benchmark stocks. The average volume needed to change the best bid or ask price is between 0.16 and 1.66 MSEK for the LPS stocks, and 0.04 and 0.6 MSEK for the benchmark. In general, the trading volume is higher for stocks with larger market capitalization.

Data

The source of the data is Thomson Reuters' Tick History, maintained by the Securities Research Centre of Asia-Pacific (SIRCA). The data set consists of intraday trade and quote information from the continuous trading session on the BATS, Burgundy, Chi-X, NOMX and Turquoise trading venues. We exclude the five minutes immediately after the market opens, and the five minutes before the market closes, to avoid a potential call auctions effect. The intraday continuous trading session lasts from 9:05 am to 5:20 pm. The quotes data include quote updates on the best bid and ask prices, and the number of shares available at the best bid and ask prices, i.e., the bid and ask size. The minimum data update time duration is one millisecond. The trade data include the execution price and trading volume. This study filters the data so that the bid prices are no larger than the ask prices, and the bid and ask sizes are not zero. We exclude trades that occur outside the exchange venues by using the trading flag maintained by SIRCA. We also exclude trades outside the spreads, i.e., trades with transaction prices lower (higher) than the best bid (ask) quotes immediately before the trades occur. However, we keep trades from large market orders that "walk the book", i.e., large market orders executed at several price levels. In order to keep such trades, we allow trades that occur in the same millisecond, if the first of these trades is not outside the spreads.

3. Market quality and liquidity providers

This study investigates how the market quality changes after the introduction of the LPS. The parameters used to measure market quality include the liquidity-level variables, presented in Section 3.1, the components of the spread, presented in Section 3.2, and the liquidity risk, presented in Section 3.3. We calculate these measurements and investigate how they change after the LPS's introduction. The differences are compared to a benchmark group in the difference-in-difference analysis.

3.1. Liquidity level and liquidity providers

The LPS motivates liquidity-supplying activities for the OMXS30 constituent stocks on NOMX. Our analysis begins with an investigation of whether the LPS is associated with an improvement in the liquidity level on NOMX. The liquidity-level variables include the quoted spread (*Qspread*), the spread measured in tick size (*Tspread*), the effective spread (*Espread*), and the depth (*Depth*). *Qspread*, *Tspread* and *Depth* are time-weighted averages for each stock and day. *Espread* is a volume-weighted average for each stock and day. They are defined as

$$Qspread_{s,d} = \sum_{q=1}^{Q_{s,d}} \frac{K_{s,q}}{\sum_{q=1}^{Q_{s,d}} K_{s,q}} \left(ask_{s,q} - bid_{s,q}\right)/mid_{s,q}\,, \quad (1)$$

$$Tspread_{s,d} = \sum_{q=1}^{Q_{s,d}} \frac{K_{s,q}}{\sum_{q=1}^{Q_{s,d}} K_{s,q}} (ask_{s,q} - bid_{s,q})/tick_{s,q}\,, \quad (2)$$

$$Espread_{s,d} = \sum_{n=1}^{N_{s,d}} \frac{V_{s,n}}{\sum_{n=1}^{N_{s,d}} V_{s,n}} 2q_{s,n}(p_{s,n} - mid_{s,n})/mid_{s,n}\,, \quad (3)$$

$$Depth_{s,d} = \sum_{q=1}^{Q_{s,d}} \frac{K_{s,q}}{\sum_{q=1}^{Q_{s,d}} K_{s,q}} (ask_{s,q} * asksize_{s,q} + bid_{s,q} * bidsize_{s,q})/2\,, \quad (4)$$

where s and d index stock s and day d. $Q_{s,d}$ and $N_{s,d}$ are the number of quote updates and trades respectively. $K_{s,q}$ is the time duration for quote q, and $V_{s,n}$ is the trading volume measured in number of shares for trade n. $bid_{s,q}$ and $ask_{s,q}$ are the best buy and sell prices. $tick_{s,q}$ is the tick size, the minimum price change for stock s, at a quote level equal to q. $mid_{s,q}$ ($mid_{s,n}$) is the midpoint of the bid and ask quotes prevailing at the time of quote q (trade n). $q_{s,n}$ is the trade side indication, and is set to +1 for a buyer-initiated trade, and -1 for a seller-initiated trade. We roughly follow Lee and Ready (1991) to determine $q_{s,n}$. A trade is classified as buyer-initiated if its execution price is above the prevailing bid-ask midpoint, and seller-initiated if the execution price is below the midpoint. Our classification differs from that of Lee and Ready (1991) for trades whose execution prices are equal to the prevailing bid-ask midpoints. In Lee and Ready (1991), these trades are classified as buyer (seller)-initiated if the execution price is higher (lower) than previous execution prices. In our study, they are excluded from the sample. Hidden orders are allowed on the NOMX and Chi-X markets. Trades that occur at the prices of the prevailing bid-ask midpoints can be either buyer-initiated or seller-initiated market orders that are executed against hidden liquidity. In our study, it is not sufficient to classify the trade side by comparing the price to previous execution prices. Similarly to Menkveld and Wang (2013), we winsorize all variables by setting values larger (smaller) than 97.5% (2.5%) equal to the 97.5% (2.5%) quantile.

[Insert Table 3 about here]

Table 3 presents the liquidity-level variables for the sample stock groups during the pre-event and post-event periods. The pre-event period is one month before the introduction of the LPS, i.e., from March 1, 2012 to March 31, 2012, containing 22 trading days. The post-event period is one month after the LPS's introduction, i.e., from June, 1, 2012 to June 31, 2012, containing 19 trading days. The *LPS* (*Chi-X*) column is the average of the OMXS30 constituent stocks traded on NOMX (Chi-X). The *Benchmark* column is the average of the 30 large-cap stocks on NOMX, but not included in the OMXS30 index. The results suggest that the market is less liquid during the post-event period than pre-event. All spread variables widen for the OMXS30 stocks (traded on both NOMX and Chi-X) and the benchmark stocks. Depth decreases for all groups. The differences are all statistically significant. Comparing the liquidity measurements among groups, LPS is the most liquid group (lowest spreads and largest depth), followed by Chi-X and Benchmark, for both the pre-event and post-event periods.

To investigate whether the stock liquidity level on NOMX improves after the LPS's introduction, we apply a difference-in-difference approach. The 60*41 stock-day data are fit into the following panel-data regression (30 stocks for each stock group, i.e., the LPS and benchmark stock group, and 22/19 days before/after the LPS's introduction):

$$y_{s,d} = \alpha + \beta_1 Post * LPS + \beta_2 Post + \boldsymbol{\beta'_3 Control_{s,d}} + \varepsilon_{s,d}. \quad (5)$$

where *s* indexes stock, and *d* indexes day. $y_{i,d}$ is the liquidity-level variables, including the quoted spread, tick size spread, effective spread, and depth. As shown in Table 3, there are differences in the liquidity levels between the LPS and benchmark stocks. For example, the quoted spread during the pre-event period for the benchmark stocks is about twice the size of the LPS stocks (18.21 for the benchmark, and 8.80 for the LPS stocks). To keep the liquidity levels comparable among the sample groups, we scale the variables for the benchmark stocks so that they are equal to the LPS group during the pre-event period on average. For all the benchmark stocks, we multiply $Qspread_{s,d}$ by 8.80/18.21, $Tspread_{s,d}$ by 1.53/3.45, $Espread_{s,d}$ by 7.39/14.61 and $Depth_{s,d}$ by 0.92/0.16.

Post is an event dummy variable set to 1 after the LPS's introduction. *LPS* is a group dummy variable for the stocks that belong to the LPS group, i.e., the OMXS30 constituent stocks traded on NOMX. $\boldsymbol{Control_{s,d}}$ are daily control variables for each stock *s*, including trading volume and volatility as suggested by Brogaard et al. (2015). Trading volume is the logged daily trading volume expressed in SEK for each stock. Volatility is the time-weighted average of the intraday volatility for each stock and day. Intraday volatility is calculated as the squared changes in the logged bid-ask midpoints, expressed in basis points.

[Insert Table 4 around here]

Table 4 shows the results of the panel regression. $Q\widehat{spread}$, $T\widehat{pread}$, $E\widehat{spread}$ and $\widehat{Depth}$ are the scaled liquidity-level variables. The parameter of interest is β_1, the coefficient for *Post*LPS.* It is negative for the regressions with spread measurements as the dependent variable (the first three columns). This indicates that, on NOMX, the spread decreases for the OMXS30 stocks after the LPS's introduction, compared to the benchmark group. Market depth (the last column) increases compared to the benchmark, but the increase is not statistically significant. These results indicate a liquidity improvement after the contracting of liquidity providers on NOMX.

The above results indicate that liquidity improves after the introduction of the LPS for NOMX. We further investigate whether the liquidity improvement on NOMX is accompanied by liquidity migration from other markets. To answer this question, we analyze the changes in liquidity on Chi-X after the LPS's introduction. Chi-X is NOMX's largest competitor in facilitating trading activities for OMXS30 stocks during the sample period. We apply a difference-in-difference approach similar to that described above. The 60*41 stock-day data points are fit into a panel-data regression (30 stocks for each stock group, i.e., the Chi-X and benchmark stock groups, and the 22/19 days before/after the LPS's introduction):

$$y_{s,d} = \alpha + \beta_1 Post * ChiX + \beta_2 Post + \boldsymbol{\beta'_3 Control_{s,d}} + \varepsilon_{s,d} . \quad (6)$$

where $ChiX$ is a group dummy variable for the stocks that belong to the Chi-X group, i.e., the OMXS30 stocks traded on Chi-X. $y_{s,d}$ are the liquidity-level variables, including the quoted spread, tick size spread, effective spread, and depth. Similarly to in the regression for NOMX in equation (5), the $y_{s,d}$ for the benchmark stocks are scaled so that they are equal to the Chi-X group during the pre-event period on average. For all the benchmark stocks, we multiply $Qspread_{s,d}$ by 9.17/18.21, $Tspread_{s,d}$ by 1.60/3.45, $Espread_{s,d}$ by 7.24/14.61 and $Depth_{s,d}$ by 0.39/0.16.

[Insert Table 5 around here]

Table 5 shows the results of the panel regression. $\widehat{Qspread}$, $\widehat{Tpread}$, $\widehat{Espread}$ and $\widehat{Depth}$ are the scaled liquidity-level variables. The parameter of interest from the panel-data regression is β_1, the coefficient of *Post*ChiX*. In Table 5, the values of β_1 are all negative for the spread regressions (the first three columns), and positive for the depth regression (the last column). The results for Chi-X are similar to those for NOMX, in that the liquidity level improves for OMXS30 stocks traded on Chi-X after the introduction of the LPS, in comparison to the benchmark group. In our results, we do not observe a liquidity migration from Chi-X to NOMX after the introduction of the LPS in NOMX. The liquidity improvement is observed across both markets, NOMX and Chi-X, for the OMXS30 stocks.

3.2. Spread decomposition

Our results above indicate that the spread decreases significantly after the introduction of the LPS. In this section, we decompose the spread and investigate the channels for spread reduction. We conjecture that two channels may have contributed to the lower spread. First, there could be less information asymmetry after the introduction of the LPS. Perotti and Rindi (2010) and Malinova and Park (2015) indicate that information asymmetry may be reduced due to the activity of liquidity suppliers and consequently spreads reduce. Second, reduced order-processing costs could be another source of the lower spreads on NOMX. Qualified LPS participants enjoy reduced transaction fees from NOMX in return for supplying liquidity. Reduced transaction fees decrease the costs for market makers of handling transactions. As a result, market makers claim less compensation for supplying liquidity and we accordingly observe a lower spread. In order to study these two possible channels, we decompose the effective spread. We adopt three different methods as the previous literature (e.g., Van Ness et al. 2001) suggests that different methods capture different aspects and can lead to different conclusions.

HS decomposition

We decompose the effective spread in three ways. First, as discussed by Huang and Stoll (1996), the effective spread can be decomposed into the realized spread, and price impact components. The realized spread (*Rspread*) captures the post-trade revenues for liquidity providers. It is also called price reversal, since liquidity providers make a profit when the price fluctuates and reverses. The excess of the effective spread over the realized spread, referred to as the price impact (*Pimpact*) in our study, measures liquidity providers' loss to informed traders. The price impact indicates the degree of information asymmetry. The components are calculated as below:

$$Rspread_{s,d} = \sum_{n=1}^{N_{s,d}} \frac{V_{s,n}}{\sum_{n=1}^{N_{s,d}} V_{s,n}} 2q_{s,n}(p_{s,n} - mid_{s,n+5min})/mid_{s,n}\,, \quad (7)$$

$$Pimpact_{s,d} = \sum_{n=1}^{N_{s,d}} \frac{V_{s,n}}{\sum_{n=1}^{N_{s,d}} V_{s,n}} 2q_{s,n}(mid_{s,n+5min} - mid_{s,n})/mid_{s,n}\,. \quad (8)$$

where $mid_{s,n+5min}$ is the bid-ask midpoint five minutes after trade *n* occurs. The other parameters are identical to those presented in equations (1)-(4).

Sadka decomposition

For our second method of decomposing the effective spread, we follow Sadka (2006), who presents a regression model based on Glosten and Harris (1988). There are two components of the spread in the model, i.e., an adverse selection cost component, and a component that is a combination of the order processing and inventory costs. For each stock and period (pre-event and post-event periods), we specify the following regression:

$$\Delta p_t = c_0 \Delta q_t + c_1 \Delta x_t + z_0 \widetilde{q_t} + z_1 \widetilde{x_t} + \mu_t. \quad (9)$$

where t indexes the aggregated transactions. We follow Kim and Murphy (2013), aggregating sequences of consecutive buyer-initiated or seller-initiated orders. For each series of consecutive trades, the aggregated trading volume is the total trading volume measured as the number of shares, and the aggregated execution price is the volume-weighted-average price.

Δp_t is the price change of the aggregated transactions. q_t is the indicator for the aggregated transaction side, i.e., 1 (-1) for buyer (seller)-initiated trades. x_t is the trading flow, measured as the signed trading volume, i.e., q_t multiplied by the number of shares traded. $\widetilde{q_t}$ is the unanticipated trade side, and $\widetilde{x_t}$ is the unanticipated trading flow. As in Sadka (2006), those values can be obtained from

$$x_t = \gamma_0 + \sum_{n=1}^{5} x_{t-n} + \widetilde{x_t}\ , \tag{10}$$

$$\widetilde{q_t} = q_t - 1 + 2\Phi(-\widehat{x_t}/\sigma_{\widetilde{x_t}}). \tag{11}$$

where Φ is the cumulative density function of the standard normal distribution. $\widehat{x_t}$ is the fitted value of the trading flow from an AR(5) regression as indicated by equation (10). $\sigma_{\widetilde{x_t}}$ is the standard deviation of the unanticipated trade side.

Similarly to in Kim and Murphy (2013), the daily effective spread (*ESP*) for each stock can be calculated from the parameter estimates from equation (9)[7]. After that, we decompose the effective spread into adverse selection (*AS*) and inventory/order-processing (*IO*) components similarly to Brogaard et al. (2015):

$$ESP_d = \frac{1}{M_d}\sum_{t=1}^{M_d} 2 * |\widehat{c_0}q_t + \widehat{c_1}x_t + \widehat{z_0}\widetilde{q_t} + \widehat{z_1}\widetilde{x_t}|/mid_t, \tag{12}$$

$$IO_d = \frac{Espread_d}{ESP_d} * \frac{1}{M_d}\sum_{t=1}^{M_d} 2 * |\widehat{c_0}q_t + \widehat{c_1}x_t|/mid_t, \tag{13}$$

$$AS_d = \frac{Espread_d}{ESP_d} * \frac{1}{M_d}\sum_{t=1}^{M_d} 2 * |\widehat{z_0}\widetilde{q_t} + \widehat{z_1}\widetilde{x_t}|/mid_t, \tag{14}$$

where $\widehat{c_0}, \widehat{c_1}, \widehat{z_0}$ and $\widehat{z_1}$ are estimates from equation (9), mid_t is the prevailing bid-ask midpoint at the time when the aggregated transaction takes place. M_d is the number of aggregated transactions on day d. $Espread_d$ is the daily effective spread calculated in Section 3.1. In this model, $\widehat{z_1}$ and $\widehat{z_0}$ together capture the adverse selection share of the spread. $\widehat{z_1}$ captures the price changes of the market orders due to their size. As suggested by Easley and O'Hara (1987) and Perotti and Rindi (2010), sizable orders often reflect private information. $\widehat{z_0}$ captures the adverse selection component that is independent from size. $\widehat{c_0}\ and\ \widehat{c_1}$ capture the combined order-processing and inventory cost.

[7] In Kim and Murphy (2013), the daily effective spread for each stock is calculated as $\frac{1}{M_d}\sum_{t=1}^{M_d} 2 * |p_t - mid_t - \mu_t| = \frac{1}{M_d}\sum_{t=1}^{M_d} 2 * |c_0 q_t + c_1 x_t + z_0\widetilde{q_t} + z_1\widetilde{x_t}|$, where mid_t is the prevailing bid-ask midpoint, and μ_t is the innovation from equation (9).

LSB decomposition

As our third way of calculating the adverse selection component of the spread, we follow Lin, Sanger and Booth (1995, henceforth LSB). LSB propose a method for estimating the information component of the effective spread. For each individual stock and day, we run the following regression:

$$\Delta m_{t+1} = \lambda z_t + e_{t+1}, \quad (15)$$

where m_{t+1} is the midpoint of the bid and ask quotes immediately after trade t. z_t it is the signed half-effective spread, and is defined as $z_t = q_t * |p_t - m_t|$. z_t is negative for seller-initiated trades and positive for buyer-initiated trades. λ measures the proportion of the effective spread due to adverse selection, which is reflected by immediate midpoint changes after trading activities at transaction time t.

To study how the components of the spread change after the introduction of the LPS, we run a panel-data regression. We apply a difference-in-difference analysis using the benchmark group. The data set contains 60*41 stock-day observations, i.e., 30 LPS stocks, 30 benchmark stocks and 22/19 days before/after the LPS's introduction. The data set is used in the following regression:

$$y_{s,d} = \alpha + \beta_1 Post * LPS + \beta_2 Post + \boldsymbol{\beta'_3 Control_{s,d}} + \varepsilon_{s,d}\,. \quad (16)$$

where $y_{s,d}$ are the spread component variables, including *Rspread*, *Pimpact*, *AS*, *IO* and λ. Similarly to in the panel regression specified by equation (5) in Section 3.1, we scale the component variables for the benchmark stocks to make them comparable to the LPS group[8]. *Post* is a time dummy indicating the post-event period. *LPS* is a group dummy indicating stocks that belong to the LPS group, i.e., OMXS30 stocks traded on NOMX. The control variables are trading volume and volatility, similar to those in regression (5).

[Insert Table 6 about here]

[8] We scale the effective spread component variables for the benchmark stocks by multiplying them by the ratio of the pre-event mean for the LPS stocks over the pre-event mean for the benchmark stocks. For example, we multiply the benchmark stocks' *Rspread* by 0.62, which is the pre-event average of *Rspread* for the LPS stocks divided by pre-event average of *Rspread* for the benchmark stocks. Similarly, we multiply the benchmark *Pimpact* by 0.52, *AS* by 0.48, *IO* by 0.54, and λ by 1.04.

Table 6 presents the results of the panel-data regression for the effective spread components. $\widehat{Rspread}$, $\widehat{Pimpact}$, $\widehat{AS}$, $\widehat{IO}$, and $\hat{\lambda}$ denote the scaled component variables. The parameter of interest is β_1, the coefficient for $Post * LPS$. β_1 is negative for all spread component variables (except for $\widehat{Pimpact}$), indicating a deceasing trend for the LPS group compared to the benchmark group. The decreased realized spread implies that the short-term profitability for liquidity providers fell after the introduction of the LPS. The inventory/order-processing cost ($\widehat{IO}$) decreased significantly. This reflects the fact that the LPS has lowered the transaction fees for qualified market makers, who consequently now claim less compensation from liquidity consumers. The adverse selection components, measured by $\widehat{AS}$ from Sadka (2006) and $\hat{\lambda}$ from LSB, decreased significantly. This result is in line with Malinova and Park (2015), who suggest that adverse selection costs decrease when the quoted bid-ask spread decreases, because more uninformed traders use aggressive orders when the quoted spread tightens. Our result is also in line with the findings documented by Perotti and Rindi (2010) and Menkveld and Wang (2013), in which the adverse selection cost is reduced after the contracting of designated market makers.

3.3. Liquidity risk and liquidity providers

Menkveld and Wang (2013) document that, after hiring DMMs to supply liquidity, firms' liquidity risk decreases as the co-variation between the stocks' liquidity and the market liquidity is reduced under the maximum spread rule. The LPS motivates participants to supply liquidity, which may better meet investors' liquidity demands when the market liquidity level is low in general. In practice, LPS participants are required to supply liquidity to some degree, which can lead to the LPS stocks' liquidity and/or return co-moving less with the market liquidity and/or return. In this case, stock liquidity risks may change after the LPS's introduction.

This section studies how the liquidity risk changes after the introduction of the LPS. As we work with daily-level data for each stock in the liquidity risk analysis, we prolong the data period from one month to three months around the LPS event. The pre-event period in this section runs from January 1, 2012 to March 31, 2012, and the post-event period runs from June 1, 2012 to August 31, 2012. We follow Acharya and Pedersen (2005) in measuring the liquidity risk:

$$E(R_{s,p} - C_{i,p}) = E(R_{f,p}) + \lambda \frac{cov(R_{s,p} - C_{s,p}, R_{m,p} - C_{m,p})}{var(R_{m,p} - C_{m,p})},$$

$$= E(R_{f,p}) + \lambda \left[\frac{cov(R_{s,p}, R_{m,p})}{var(R_{m,p} - C_{m,p})} - \frac{cov(R_{s,p}, C_{m,p})}{var(R_{m,p} - C_{m,p})} - \frac{cov(C_{s,p}, R_{m,p})}{var(R_{m,p} - C_{m,p})} + \frac{cov(C_{s,p}, C_{m,p})}{var(R_{m,p} - C_{m,p})} \right],$$

$$= E(R_{f,p}) + \lambda[\beta_s^{rr} + \beta_s^{rc} + \beta_s^{cr} + \beta_s^{cc}], \quad (17)$$

where $R_{s,p}$ ($R_{m,p}$) is the daily return for stock s (the market) during time period p. The daily return is the average of the one-minute returns for each day. There are two time periods, i.e., before and after the introduction of the LPS. $R_{f,p}$ is the risk-free rate. $C_{s,p}$ ($C_{m,p}$) is the daily trading cost during time period p for stock s (the market). λ is the risk premium. $\beta_s^{rc}, \beta_s^{cr}$ and β_s^{cc} are the liquidity betas we investigate. We use the combination of the OMXS30 stocks on NOMX and the benchmark stocks as the market. The OMXS30 and thirty benchmark stocks together comprise the 60 large-cap stocks on NOMX out of 80 large-cap stocks in total. The market return and transaction cost are the equally weighted averages over the OMXS30 and benchmark stocks.

We use the filtered effective spread as the trading cost. The effective spread is empirically documented as persistent, as discussed by Lee (2011) and Hagströmer et al (2013). In our data set, the average first-order autocorrelation for the daily effective spread is 0.62, and 67% of the stocks' autocorrelations are significant. Similarly to Acharya and Pedersen (2005), we use an AR (2) process to filter the effective spread and we use the innovation as the transaction cost. None of the filtered effective spreads has a significant first-order autocorrelation.

β_s^{rr} is equivalent to the market beta in a CAPM. β_s^{rc} captures the liquidity risk arising from the co-variation between the asset return and market liquidity. $cov(R_{s,p}, C_{m,p})$ is negatively correlated with the expected returns because investors prefer stocks whose returns are high when the market is illiquid. $cov(C_{s,p}, R_{m,p})$ is also negatively correlated with the expected return. This suggests that stocks that are more liquid when the market is down are appreciated by investors. β_s^{cc} captures the co-movement between the individual asset liquidity and market liquidity. It is positively correlated with the expected return, which implies that investors demand higher returns for stocks that are hard to liquidate when the market is illiquid in general.

To test how the liquidity risk changes after the LPS's introduction in the NOMX trading venue, we run a panel-data regression for the liquidity betas. We use a 60*2 stock-period (30

OMXS30 stocks, 30 benchmark stocks, and the pre-event and post-event periods) data set in the following regression:

$$y_{s,p} = \alpha + \beta_1 Post * LPS + \beta_2 Post + \boldsymbol{\beta_3' Control_{s,p}} + \varepsilon_{s,p}\,. \tag{17}$$

where $y_{s,p}$ are the liquidity risk betas for each stock and period. *Post* is an event dummy indicating the post-event period. *LPS* is a group dummy indicating stocks that belong to the LPS group, i.e., OMXS30 stocks traded on NOMX. Similarly to before, we use the trading volume and volatility as the control variables. The control variables are averaged from the daily level into pre-event and post-event periods.

[Insert Table 7 about here]

Table 7 shows that, consistent with Acharya and Pedersen (2005) and Menkveld and Wang (2013), most liquidity risk betas are positive for both the LPS and benchmark groups. The panel-regression results suggest that, compared to the benchmark stocks, the LPS stocks' liquidity betas do not change after the introduction of the LPS. This result indicates that, through the contracting of liquidity suppliers through the LPS, the magnitudes with which the stocks' liquidity and returns co-move with the market do not change significantly.

4. Conclusion

This study empirically investigates the market impact of the liquidity provider scheme (LPS) introduced by NOMX on April 1, 2012. By reducing transaction fees, this program benefits market participants that supply liquidity to the OMXS30 stocks. Our results suggest that the bid-ask spread decreases after the introduction of the LPS in NOMX. This liquidity improvement in NOMX is not accompanied by liquidity migration from Chi-X, which is the biggest market share competitor of NOMX. Liquidity improves for both NOMX and Chi-X after the introduction of the LPS. This simultaneous liquidity improvement lends support to the theoretical prediction made by Lescourret and Moinas (2014) that, with the market fragmentation and technological advancement that have occurred, liquidity suppliers can supply liquidity to multiple trading venues, which results in interrelated spreads among different trading venues. Our results imply that introducing a competition-enhancing rule such as the LPS can increase the market liquidity collectively for competing markets.

We decompose the spread to investigate how investors benefit from the liquidity improvement. We document that the order-processing component of the spread decreases after the introduction of the LPS. Market makers enjoy reduced transaction fees if they fulfill the liquidity-supplying requirements of the LPS. Our results imply that reduced transaction fees lower market makers' transaction-handling costs, which allows them to charge less for supplying liquidity. As a result, liquidity consumers' trading costs decrease ceteris paribus. This result provides evidence of a welfare transfer from the exchange to investors. More specifically, the market makers benefit from the LPS by paying lower transaction fees to the exchange. This lowers the order-processing costs for market makers, which is eventually observed in the spread.

The adverse selection component of the spread also decreases on NOMX after the introduction of the LPS. Liquidity suppliers suffer lower losses due to trading with informed traders. We conjecture that there could be several explanations for the reduction in the adverse selection component. First, Malinova and Park (2015) suggest that less informed traders use aggressive orders when the quoted spread tightens. In our case, the LPS could decrease the spread by lowering the order-processing costs for market makers. Less informed traders would then use aggressive orders and consume liquidity from market makers. In other words, market makers would encounter lower losses due to trading with informed traders, or the adverse selection cost would decrease. Second, the LPS requires the participants to supply liquidity for more than 50% of the time on average. If the LPS participants act as uninformed market makers and take inventory on the stock market, they may need to buy or sell stocks to manage their inventory (Amihud and Mendelson 1980). Therefore, the trading activities of the LPS participants as uninformed traders will decrease the adverse selection component. Third, Brogaard et al. (2015) suggest that market makers can upgrade their trading speed by obtaining faster connections to the exchange server. The advantage in speed reduces the adverse selection costs for market makers. In our case, if the LPS attracts more market makers with a speed advantage to supply liquidity for the underlying stocks, then the adverse selection cost may reduce as a result.

Table 1. Time proportion for which NOMX and Chi-X are present at European best bid and offer (EBBO)

	NOMX		Chi-X	
	Buy	Sell	Buy	Sell
Pre	86.66%	86.23%	64.49%	65.17%
Post	86.25%	86.48%	57.60%	57.61%
Post-Pre	-0.41%	0.25%	-6.90%***	-7.56%***
	(0.46)	(0.65)	(0.00)	(0.00)

This table presents the time proportion during which NOMX and Chi-X are present at the European best bid (EBB) and European best offer (EBO) with orders larger than 50,000 SEK. The time proportion is measured for each OMXS30 constituent stock and each day during the sample period, and then averaged across stocks. The pre-event period (*Pre*) covers the one month before the LPS was introduced (March, 2012). The post-event period (*Post*) covers the one month after the LPS was introduced (June, 2012). The difference between the pre-event and post-event periods is reported in row *Post-Pre*. The numbers reported in parentheses are p-values from t-tests. *, ** and *** indicate significance at the 1%, 5% and 10% levels.

Table 2. Stock characteristics for LPS and benchmark stocks

This table presents the properties of the LPS and benchmark stocks. Market capitalization (Market Cap) is taken from the monthly equity statistics available on the NASDAQ website: https://newsclient.omxgroup.com/cdsPublic/viewDisclosure.action?disclosureId=499617&lang=en. *Market Cap* reports the values as of the end of March 2012, expressed in million Swedish Krona (MSEK). Other statistics are the average between March 1 and March 31, 2012. *Volume* is the average daily trading volume in MSEK. *Spread* is the difference between the bid and ask quotes divided by their midpoint, expressed as the daily time-weighted average in basis points (bps). *Depth* is the MSEK volume required to change the best bid or ask price on average. *Depth* reports the daily time-weighted average across the trading days in March 2012.

LPS	Market Cap (MSEK)	Volume (MSEK)	Spread (bps)	Depth (MSEK)	Bench-mark	Market Cap (MSEK)	Volume (MSEK)	Spread (bps)	Depth (MSEK)
NOKI	2 657	122.90	6.90	0.27	SMF	163	6.50	57.37	0.04
SSAB a	15 060	184.96	11.22	0.47	TIEN	516	6.29	29.35	0.24
MTG b	22 193	89.21	10.80	0.16	STE R	6 010	43.73	16.38	0.60
SECU b	22 197	71.00	12.51	0.32	LUMI sdb	6 107	91.86	13.94	0.12
BOL	28 418	302.10	11.33	0.99	PEAB b	8 846	8.59	19.89	0.06
GETI b	41 897	85.48	8.30	0.43	HAKN	9 044	4.99	26.84	0.08
ELUX b	42 069	257.43	9.93	0.70	FABG	9 436	18.55	17.41	0.11
LUPE	45 080	212.66	9.71	0.56	WALL b	9 943	5.71	22.01	0.07
SKA b	45 872	130.21	11.12	1.11	NCC b	10 853	50.14	13.32	0.21
SCV b	55 040	215.25	11.10	0.66	HOLM b	11 290	41.05	11.65	0.15
ATCO b	55 645	123.48	10.60	0.73	INDU c	11 574	25.01	15.94	0.13
SWMA	56 104	144.07	6.27	0.35	AXFO	12 477	13.49	12.06	0.12
ALFA	57 088	192.46	9.45	1.02	AOIL	12 522	53.15	12.22	0.15
AZN	57 129	312.56	4.95	1.25	SAAB b	13 245	14.70	17.45	0.09
TEL2 b	57 206	245.96	8.79	1.21	ORI sdb	14 149	64.58	14.37	0.14
SKF b	66 635	363.04	8.54	0.85	HUFV a	14 200	10.76	16.05	0.10
INVE b	66 820	172.27	9.34	1.18	CAST	14 337	33.23	14.06	0.13
ABB	67 988	191.59	9.54	1.56	TREL b	16 762	66.93	12.52	0.18
SCA b	69 799	190.15	10.28	1.03	LUND b	17 290	12.94	16.27	0.08
ASSA b	72 538	198.50	8.26	0.62	HUSQ b	17 855	72.60	9.28	0.08
SWED a	99 386	407.64	10.60	1.66	MEDA a	19 072	72.18	11.57	0.26
SEB a	101 991	296.06	6.84	0.54	MELK	19 830	2.95	70.83	0.07
SAND	119 794	432.16	8.01	0.91	LATO b	20 617	5.30	45.06	0.07
SHB a	129 694	391.64	6.50	1.20	RATO b	21 998	42.10	13.46	0.14
ATCO a	134 387	456.09	8.01	1.37	ALIV	24 390	115.25	10.90	0.19
VOLV b	141 219	721.54	7.07	1.28	INDU a	28 088	12.00	21.24	0.14
TLSN	199 790	441.75	3.73	0.34	EKTA b	30 698	137.44	9.05	0.20
ERIC b	206 445	574.99	8.41	1.66	KINV b	35 169	66.92	10.62	0.34
NDA	243 443	475.85	9.26	1.63	HEXA b	43 435	107.06	13.02	0.24
HM b	349 685	731.36	5.32	1.40	MIC sdb	72 864	65.12	13.11	0.27

Table 3. Liquidity levels for the LPS, Chi-X and benchmark stocks

This table presents the liquidity levels for the LPS, Chi-X and benchmark sample stocks. The LPS (Chi-X) sample includes the OMXS30 constituent stocks that are traded on NOMX (Chi-X). The benchmark sample consists of 30 large-cap stocks traded on NOMX, but not included in the OMXS30 index. The liquidity-level variables include quoted spread (*Qspread*), tick size spread (*Tspread*), effective spread (*Espread*) and depth (*Depth*). They are calculated according to equations (1) to (4). Quoted spread and effective spread are reported in basis points (bps), and depth is reported in million Swedish Krona (MSEK). This table reports the average of the liquidity level for the pre-event period (*Pre*) and the post-event period (*Post*). The pre-event period is the one month before the LPS's introduction i.e., March 2012, and the post-event period is the one month afterwards, i.e., June 2012. *Post-pre* computes the differences between the two periods, and the numbers reported in parentheses are p-values from t-tests. *, ** and *** indicate significance at the 1%, 5% and 10% levels.

Statistics	Period	LPS	Chi-X	Benchmark
Qspread (bps)	Pre	8.80	9.17	18.21
	Post	10.15	10.60	23.37
	Post-Pre	1.36***	1.42***	5.17***
		(0.0000)	(0.0000)	(0.0000)
Tspread	Pre	1.53	1.60	3.45
	Post	1.64	1.70	4.12
	Post-Pre	0.11***	0.10***	0.66***
		(0.0003)	(0.0030)	(0.0000)
Espread (bps)	Pre	7.39	7.24	14.61
	Post	8.37	7.96	18.05
	Post-Pre	0.99***	0.73***	3.44***
		(0.0000)	(0.0000)	(0.0000)
Depth (MSEK)	Pre	0.92	0.39	0.16
	Post	0.70	0.33	0.11
	Post-Pre	-0.22***	-0.06***	-0.05***
		(0.0000)	(0.0000)	(0.0000)
Trading Volume (MSEK)	Pre	291.15	107.52	42.37
	Post	244.86	110.31	38.47
	Post-Pre	-46.29***	2.79	-3.91
		(0.0001)	(0.5696)	(0.1419)
Volatility	Pre	0.00	0.07	0.01
	Post	0.01	0.62	0.08
	Post-Pre	0.01***	0.55***	0.07
		(0.0000)	(0.0013)	(0.1390)

Table 4. LPS and liquidity level

	$\widehat{Qspread}$	$\widehat{Tspread}$	$\widehat{Espread}$	$\widehat{Depth}$
Post*LPS	-1.08***	-0.18***	-0.74***	0.05
	(0.0000)	(0.0000)	(0.0000)	(0.1390)
Post	2.10***	0.23***	1.60***	-0.27***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volume	-1.04***	-0.14***	-0.53***	0.16***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volatility	0.08***	0.00**	-0.25***	0.00
	(0.0080)	(0.0390)	(0.0060)	(0.3780)
Time Effect	YES	YES	YES	YES
Stock fixed effect	YES	YES	YES	YES
Observation	2460	2460	2460	2460

This table presents the panel-data regression for the liquidity-level variables. The data set contains 60*41 stock-day observations. There are 30 stocks for each stock group, i.e., the LPS and the benchmark stocks. The LPS stocks are the underlying stocks for the index OMXS30 traded on NOMX. The benchmark stocks are the 30 large-cap stocks traded on NOMX, but not included in the OMXS30 index. The pre-event period covers the one month before the LPS's introduction (22 trading days), and the post-event period covers the one month afterwards (19 trading days). The dependent variables are scaled liquidity-level variables, including the quoted spread ($\widehat{Qspread}$), the tick size spread ($\widehat{Tspread}$), the effective spread ($\widehat{Espread}$) and the depth ($\widehat{Depth}$). The explanatory variables include the event dummy variable (*Post*), group dummy variables for the LPS (*LPS*) and Chi-X (*Chi-X*) samples, and the interaction of the group and event dummies. Control variables include trading volume (*Volume*) and *Volatility*. Trading volume is the logged SEK daily trading volume. For each day, volatility is calculated as the average of the intraday volatility, which is the squared difference in logged one-minute quote midpoints. The liquidity variables and volatilities are measured in basis points (bps). The regressions include both time and stock fixed effects. Using Driscoll and Kraay (1998, the standard errors are corrected and robust to disturbances that are heteroskedastic, autocorrelated and cross-sectionally dependent. The numbers reported in parentheses are p-values. *, ** and *** indicate significance at the 1%, 5% and 10% levels.

Table 5.LPS and liquidity level on Chi-X

	$\widehat{Qspread}$	$\widehat{Tspread}$	$\widehat{Espread}$	$\widehat{Depth}$
Post*ChiX	-0.90***	-0.17***	-0.86***	0.08**
	(0.0000)	(0.0000)	(0.0000)	(0.0180)
Post	2.49***	0.29***	1.95***	-0.38***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volume	-1.14***	-0.16***	-0.42***	0.19***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volatility	0.02	0.01	0.00	-0.01***
	(0.2710)	(0.2590)	(0.9100)	(0.0000)
Time Effect	YES	YES	YES	YES
Stock fixed effect	YES	YES	YES	YES
Observation	2460	2460	2460	2460

This table presents the panel-data regression for the liquidity-level variables. The data set contains 60*41 stock-day observations. There are 30 stocks for each stock group, i.e., the Chi-X and the benchmark stocks. The pre-event period covers the one month before the LPS's introduction (22 trading days), and the post-event covers the one month afterwards (19 trading days). The dependent variables are scaled liquidity-level variables, including the quoted spread ($\widehat{Qspread}$), the tick size spread ($\widehat{Tspread}$), the effective spread ($\widehat{Espread}$) and the depth ($\widehat{Depth}$). The explanatory variables include the event dummy variable (*Post*), group dummy variables for the LPS (*LPS*) and Chi-X (*Chi-X*) samples, and the interaction of the group and event dummies. Control variables include trading volume (*Volume*) and *Volatility*. Trading volume is the logged SEK daily trading volume. For each day, volatility is calculated as the average of the intraday volatility, which is the squared difference in logged one-minute quote midpoints. The liquidity variables and volatilities are measured in basis points (bps). The regressions include both time and stock fixed effects. Using Driscoll and Kraay (1998) the standard errors are corrected and robust to disturbances that are heteroskedastic, autocorrelated and cross-sectionally dependent. The numbers reported in parentheses are p-values. *, ** and *** indicate significance at the 1%, 5% and 10% levels.

Table 6. LPS and effective spread components

	HS		Sadka		LSB
	$\widehat{Rspread}$	$\widehat{Pimpact}$	$\widehat{AS}$	$\widehat{IO}$	$\hat{\lambda}$
Post*LPS	-0.87**	0.05	-0.36***	-0.30***	-0.04**
	(0.0210)	(0.8470)	(0.0000)	(0.0000)	(0.0490)
Post	-0.56**	2.22***	0.60***	0.93***	-0.07***
	(0.0170)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volume	-0.42	-0.05	0.06	-0.50***	0.04***
	(0.1320)	(0.8640)	(0.3110)	(0.0000)	(0.0030)
Volatility	0.35***	-0.70***	-0.06**	-0.13***	0.08***
	(0.0000)	(0.0000)	(0.0250)	(0.0000)	(0.0000)
Time Effect	YES	YES	YES	YES	YES
Stock fixed Effect	YES	YES	YES	YES	YES
Observation	2460	2460	2460	2460	2460

This table presents the results of the panel regression for the effective spread components. We fit the 60*41 stock-day observations into the regression $y_{s,d} = \alpha + \beta_1 Post * LPS + \beta_2 Post + \boldsymbol{\beta}'_{\mathbf{3}} \boldsymbol{Control_{s,d}} + \varepsilon_{s,d}$. The dependent variables are the daily spread components. *Post* is an event dummy variable, indicating the period after the LPS's introduction. *LPS* is a group dummy variable, indicating a stock belonging to the LPS group. Trading volume and volatility are used as the control variables. *Volume* is the daily logged SEK trading volume. *Volatility* is the daily time-weighted average of the intraday volatility, calculated as the squared difference in logged quote midpoints. Column *HS* refers to the decomposing of the effective spread into the realized spread (Rspread) and price impact (Pimpact). Column *Sadka* refers to the adverse selection (*AS*) and inventory/order-processing (*IO*) components. *LSB* refers to the model proposed by Lin et al. (1995) with adverse selection parameter λ. We scale the components for the benchmark stocks, i.e., $\widehat{Rspread}$, $\widehat{Pimpact}$, $\widehat{AS}$, $\widehat{IO}$ and $\hat{\lambda}$, to make them comparable to the LPS sample. The numbers reported in parentheses are p-values from t-tests. *, ** and *** indicate significance at the 1%, 5% and 10% levels.

Table 7. Liquidity risk

This table presents the liquidity risk analysis around the event of the introduction of the LPS. The LPS group (column *LPS* in Panel A) consists of the constituent stocks of the OMXS30 index. The benchmark group (column *Benchmark*) contains 30 large-cap stocks traded on NOMX, but not listed on OMXS30. The liquidity betas β^{rc}, β^{cr} and β^{cc} are calculated according to equation (17). Panel A reports the averages of the liquidity betas for each group in basis points (bps). The pre-event period (row *Pre* in panel A) covers the three months before the LPS's introduction, i.e., 64 trading days from January 1, 2012 to March 31, 2012. The post-event period (row *Post*) covers the three months afterwards, i.e., 64 trading days from June 1, 2012 to August 31, 2012. *Post-pre* is the difference between the post-event and pre-event periods. The numbers in parentheses are p-values from t-tests of whether the levels differ significantly from 0. *, ** and *** indicate significance at the 1%, 5% and 10% levels. In Panel B, we run a panel-data regression to test whether the liquidity betas change after the LPS's introduction. *Post* is an event dummy indicating the post-event period. *LPS* is the group dummy indicating stocks that belong to the LPS group.

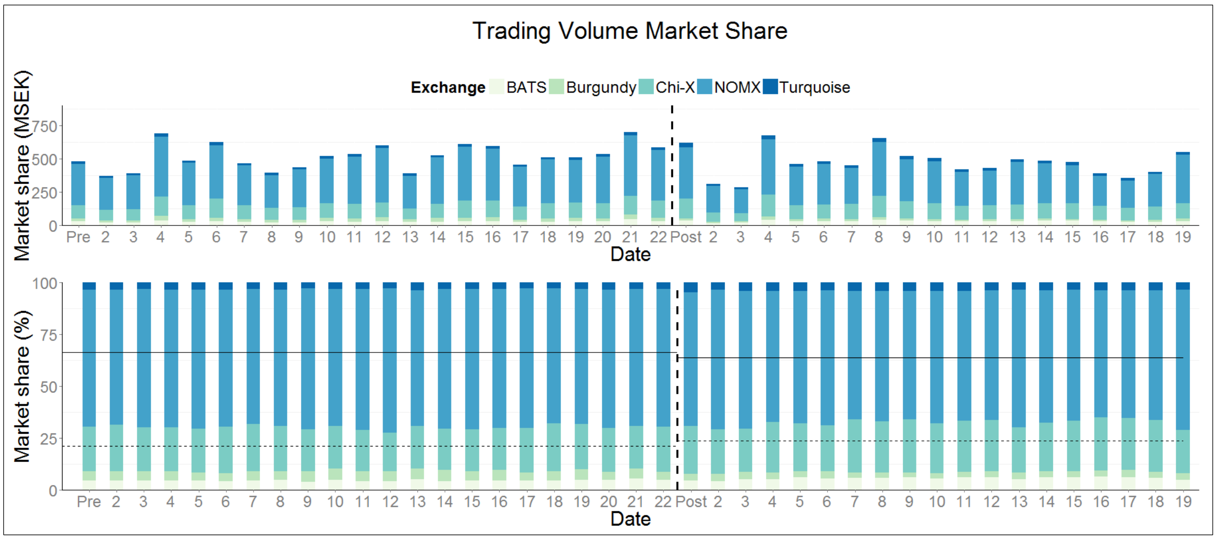
Panel A: Liquidity beta

	LPS			Benchmark		
	β^{rc} (bps)	β^{cr} (bps)	β^{cc}	β^{rc} (bps)	β^{cr} (bps)	β^{cc}
Pre	0.04***	-0.02***	0.16**	0.02***	0.04***	1.55***
	(0.0000)	(0.0038)	(0.0343)	(0.0000)	(0.0066)	(0.0002)
Post	0.11***	0.05***	0.33***	0.12***	0.15***	1.24***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0002)	(0.0000)
Post-Pre	0.07***	0.07	0.17*	0.11**	0.10	-0.31
	(0.0000)	(0.3405)	(0.0752)	(0.0160)	(0.6404)	(0.5320)

Panel B: Testing liquidity risk

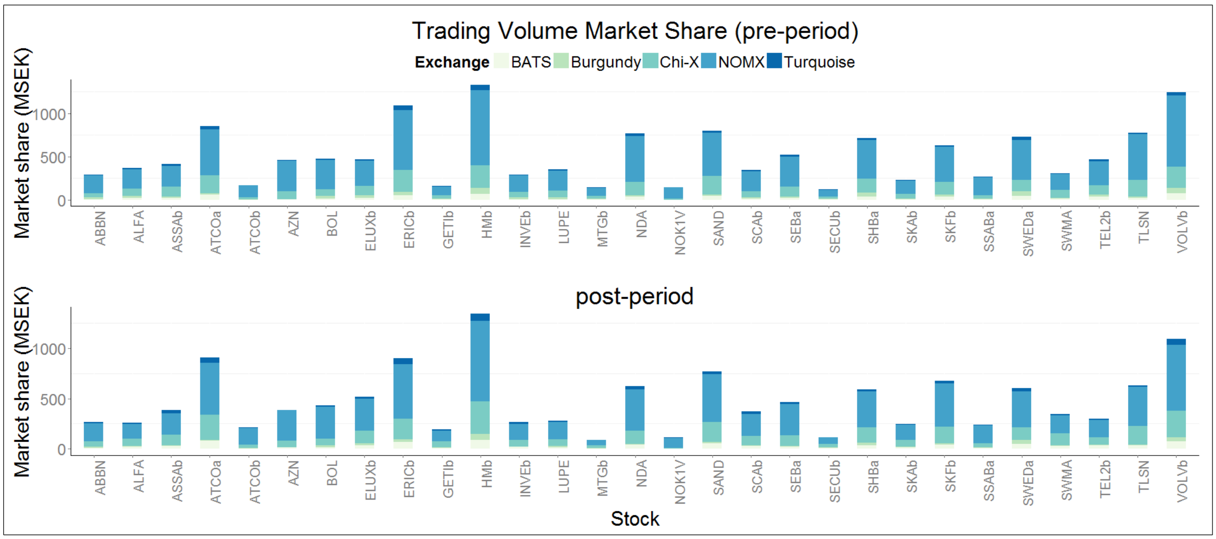
	β^{rc} (bps)	β^{cr} (bps)	β^{cc}
Post*LPS	-0.03	-0.03	0.19
	(0.1420)	(0.5960)	(0.4990)
Post	0.09***	0.06	-0.18
	(0.0030)	(0.4540)	(0.5460)
Volume	-0.05	-0.12	-0.27
	(0.2650)	(0.2160)	(0.4440)
Volatility	0.00	0.00	0.00
	(0.7140)	(0.3910)	(0.8990)
Constant	1.78	3.97	9.52
	(0.2560)	(0.2090)	(0.3910)
Stock fixed effect	YES	YES	YES
Observation	120	120	120

Figure 1. Daily market share among trading venues for OMXS30 stocks



This figure illustrates the daily market shares of the trading venues at which the OMXS30 constituents are traded. The upper panel presents the trading volume measured in millions of Swedish Krona (MSEK). The lower panel presents the venue's trading volume share out of the aggregated volume across venues. The trading venues include BATS, Burgundy, Chi-X, NOMX and Turquoise. The vertical dashed line separates the sample period into before and after the LPS's introduction (pre-event and post-event periods respectively). The pre-event period covers the one month before the LPS's introduction, March 2012. The post-event period covers the one month after the LPS's introduction, June 2012. The horizontal solid lines in the lower panel illustrate the average market share for NOMX during the pre-event period (66.51%) and the post-event period (63.75%). The dashed horizontal lines illustrate the market share for Chi-X during the pre-event period (21.10%) and post-event period (23.71%). The differences between the post-event period and pre-event period are statistically significant for both NOMX and Chi-X.

Figure 2. Period trading volume for OMXS30 stocks across venues



This figure presents the trading volumes for OMXS30 constituent stocks on different trading venues, including BATS, Burgundy, Chi-X, NOMX and Turquoise. The upper panel shows the daily average trading volume before the LPS's introduction (pre-event period), i.e. March 2012. The lower panel shows the average trading volume after the LPS's introduction (post-event period), i.e. June 2012. The trading volume is measured in million Swedish Krona (MSEK). The average trading volume share of NOMX across OMXS30 stocks is 66.51% during the pre-event period and 63.75% during the post-event period. The difference is not statistically significant.

References

Acharya, V. V., and Pedersen, L. H. (2005). Asset pricing with liquidity risk. Journal of Financial Economics 77, 375-410.

Amihud, Y., and Mendelson, H. (1980). Dealership market: Market-making with inventory. Journal of Financial Economics 8, 31-53.

Anand, A., Tanggaard, C., and Weaver, D. G. (2009). Paying for market quality. Journal of Financial and Quantitative Analysis 44, 1427-1457.

Brogaard, J., Hagströmer, B., Nordén, L., and Riordan R. (2015). Trading Fast and Slow: Colocation and Market Quality. Review of Financial Studies. Forthcoming.

Easley, D., and O'Hara, M. (1987). Price, trade size, and information in securities markets. Journal of Financial Economics 19, 69-90.

Foucault, T., and Parlour, C. (2004). Competition for listings. Rand Journal of Economics 35, 329-355.

Foucault, T., and Menkveld A. J. (2008). Competition for Order Flow and Smart Order Routing Systems. Journal of Finance 63, 119-158.

Glosten, L., and Harris, L. E. (1988). Estimating the components of the bid–ask spread. Journal of Financial Economics 21, 123-142.

Hagströmer, B., Hansson, B., and Nilsson, B. (2013). The components of the illiquidity premium: An empirical analysis of US stocks 1927–2010. Journal of Banking & Finance 37, 4476-4487.

Hagströmer, B., and Nordén, L. (2013). The diversity of high frequency traders. Journal of Financial Markets 16, 741-770.

Huang, R. D., and Stoll, H. R. (1996). Dealer versus auction markets: A paired comparison of execution costs on NASDAQ and the NYSE. Journal of Financial Economics 41, 313-357.

Kim, S., and Murphy, D. (2013). The Impact of High-Frequency Trading on Stock Market Liquidity Measures. Working Paper.

Lee, C., and Ready, M. A. (1991). Inferring trade direction from intraday data. Journal of Finance 46, 733-746.

Lee, K. H. (2011). The world price of liquidity risk. Journal of Financial Economics 99, 136-161.

Lin, J. C., Sanger, G. C., and Booth, G. G. (1995). Trade Size and Components of the Bid-Ask Spread. Review of Financial Studies 8, 1153-1183.

Malinova, K., and Park, A. (2015). Subsidizing Liquidity: The Impact of Make/Take Fees on Market Quality. Journal of Finance 70, 509-536.

Menkveld, A. J., and Wang, T. (2013). How do designated market makers create value for small-caps? Journal of Financial Markets 16, 571-603.

Pastor, L., and Stambaugh, R. F. (2003). Liquidity Risk and Expected Stock Returns. Journal of Political Economy 111, 642-685.

Perotti, P., and Rindi, B. (2010). Market makers as information providers: the natural experiment of STAR. Journal of Empirical Finance 17, 895-917.

Sadka, R. (2006). Momentum and post-earnings-announcement drift anomalies: The role of liquidity risk. Journal of Financial Economics 80, 309-349.

Skjeltorp, J. A., and Odegaard, B. A. (2015). When do listed firms pay for market making in their own stock? Financial Management 44, 241-266.

Van Ness, B. F., Van Ness R. A., and Warr R. S. (2001). How Well Do Adverse Selection Components Measure Adverse Selection? Financial Management 30, 77-98.

Venkataraman, K., and Waisburd, A. (2007). The value of the designated market maker. Journal Financial and Quantitative Analysis 42, 735-758.