Commonality in Liquidity in Transatlantic Multilateral Trading Facilities*

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This Draft: November 2018

* For helpful comments, we acknowledge, Wei Xiong, Christine Parlour, Ryan Riordan, Douglas Cumming, Geert Bekaert, Michael Pagano, Christine Jiang, Laurence Lescourret, Ping-Wen Sun, Allan Zebedee, and Alasdair Turnbull. We also thank, Financial Management Association European meeting, for choosing the paper as a finalist for the best paper award. as well as, participants of the finance seminars and conferences at the IFABS conference at Oxford University, University of Memphis, Clarkson University, Financial Management Association European meeting in Venice, Financial Management Association meeting in Nashville, Midwest Finance Association meeting in Orlando, Eastern Finance Association meeting in Pittsburgh, and Southwestern Finance Association meeting in Dallas.

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Abstract

We use the introduction of transatlantic multilateral trading systems (MTFs), namely, Turquoise and NYSE-Arca-Europe, to examine the impact of changes in market structure on commonality in liquidity. We find that the introduction of transatlantic MTFs increases the co-movement of stocks' liquidity with transatlantic liquidity, while the co-movement with the home market liquidity does not increase. We also find that the higher the MTF trading volume or the number of MTFs trading a stock, the stronger the effect. Further, we find that the commonality in liquidity remains unchanged for a matched control sample of stocks that do not trade on MTFs.

Keywords: Commonality in Liquidity; Multilateral Trading Facilities; Multimarket Trading; Turquoise; NYSE Arca Europe.

JEL Classification: G11, G12, G14

1. Introduction

A growing body of research has shown that a firm's liquidity is governed by a significant common component in liquidity across assets in the same market (Brockman, Chung, & Pérignon, 2009; Chordia, Roll, & Subrahmanyam, 2000; Hasbrouck & Seppi, 2001; Kamara, Lou, & Sadka, 2008; Karolyi, Lee, & van Dijk, 2012; Moshirian, Qian, Wee, & Zhang, 2017).[1] In today's integrated market, especially after the unprecedented wave of mergers among stock exchanges, trading shares of the same stock in multiple trading venues has become the norm rather than an exception (Halling, Moulton, & Panayides, 2013; Moulton & Wei, 2009).[2] Moreover, the introduction of new players in the stock market industry such as the Alternative Trading Systems (ATS) in U.S. and Multi-lateral Trading Facilities (MTF) in Europe has intensified this trend of multimarket trading beyond national boundaries.[3] When a stock is traded in multiple trading systems, the common factors driving its liquidity are fundamentally altered by what happens in those systems. We use the introduction of two transatlantic MTFs to examine the impact of changes in market structure on commonality in liquidity of traded stocks and whether such infrastructure changes may create a new source of systematic cross-border liquidity co-movement and illiquidity risk.

In this paper, we examine the impact of structural changes in the European market on commonality in liquidity of internationally traded stocks. The adaptation of Markets in Financial Instruments Directive (MiFID) regulation reshaped the market structure in the EU by introducing Multilateral trading facilities (MTF) to increase transparency, boost innovation and promote competition among equity trading venues. Multi-lateral trading facilities surpass primary home exchanges in multiple aspects including faster execution speeds, access to lit and dark trading simultaneously, and provide make/take fee structure that remunerates liquidity providing orders

[1] Brockman, Chung, & Pérignon, (2009) finds a distinct global component in commonality in liquidity. They further show that both developed and emerging markets are susceptible to global commonality, although developed markets are more sensitive to liquidity spillover effects than are emerging markets. However, they do not investigate the multi-market trading environment or explain the source behind the global commonality component.

[2] Examples of stock exchange mergers are NYSE-Euronext, NYSE-Euronext with Intercontinental Exchange (ICE), NASDAQ-OMX and London stock exchange with Borsa Italiana.

[3] Current literature on multi-market trading focuses on either the market quality of traded stocks or the distribution of trading volume among competing markets (Baruch, Andrew Karolyi, & Lemmon, 2007; Chowdhry & Nanda, 1991; Halling, Moulton, & Panayides, 2013; Menkveld, 2008; Moulton & Wei, 2009). However, there is a lack of empirical evidence on how commonality in liquidity is affected by changes in stock market structure.

and charges aggressive orders.[4] Such structure and speed of trading have contributed to the rise of algorithmic trading in MTFs (Gresse, 2017; He et al., 2015). For example, in a recent report, European Securities and Markets Authority (ESMA) find high-frequency traders' (HFT) activities in Turquoise MTF represent 63% of value traded, 65% of number trades and 84% of orders submitted (ESMA, 2014).[5] These HFTs activities outside of home market have the potential to increase transatlantic commonality through liquidity supply and arbitrage in MTFs.

Transatlantic MTFs helps us create a quasi-natural experimental design in which we can scrutinize the change in stock's liquidity co-movement after it begins trading in a transatlantic MTF. First, transatlantic MTFs provide investors with the opportunity to trade stocks from different countries that do not share the same institutional environment, macroeconomic factors, information disclosure requirements or financial regulatory authorities.[6] Second, the stock's entry dates to transatlantic trading systems varies significantly among traded stocks and serve as exogenous shocks for many but not all American and European stocks. Hence, such design enables us to create matching samples of control stocks that share the same home market but are not traded in MTF trading systems.[7] Also, studying the MTF events differentiate our contribution from prior literature that focus on home market macroeconomic and region-specific sources of commonality in liquidity (Brockman et al., 2009; Karolyi et al., 2012).

The importance of MTF systems is increasing rapidly as they gain significant trading volume both in absolute terms and market share in the global market (Gresse, 2017). Although market infrastructure's role is well understood for liquidity (Glosten, 1994), and equity premium (Jain, 2005), its role in changing liquidity commonality has not been analyzed yet. We study this with our unique sample of stocks that are traded at Turquoise and NAE MTFs. Turquoise started its operations in August 2008 and expanded its scope to the U.S stocks in 2010. It is now owned by the London Stock Exchange Group (LSEG), in partnership with 12 investment banks.

[4] Both Turquoise and NAE operates separate limit order book for lit and dark trading sharing the same basket of securities.

[5] Turquoise statistics are based on a study of 100 European firms in May, 2013, across 12 trading venues. Another evidence of HFT activity in MTFs is Menkveld (2013) who shows that HFT participation rate in Chi-X MTF is 64.4%.

[6] Brockman et al. (2009) show that unemployment and GDP announcements have significant effect on commonality in liquidity. Our study is different from the vast literature on cross-listed ADRs because we are able to isolate microstructure-trading effects from listing and disclosure effects.

[7] Figure A.1 in the Appendix shows our research design and expected impact of commonality in liquidity for MTF traded stocks versus control stocks in a difference in difference setting.

Turquoise successfully grabbed about 10% of European market share in 2014 and continued to grow its market share actively.[8] Turquoise trades firms from 19 different American and European stock exchanges. In addition, we also analyze NYSE Arca Europe (NAE), a transatlantic MTF that trades stocks from 15 different exchanges. NAE started on March 2009, as a Pan-European trading venue and it extended its trading scope to the U.S. stocks in April 2010. NAE discontinued its operations in April 2014. Our sample covers the period between January 2004 and April 2015 (one year after the NAE closure event) to test the counterfactual.

We investigate commonality in liquidity with two different empirical tests. The first test is based on Chordia et al. (2000) market model framework. We run firm-by-firm time-series regressions of daily proportional changes in an individual stock's liquidity on proportional changes in the aggregate liquidity of all stocks traded on the transatlantic MTF.[9] We control for the home market aggregate liquidity in the same regression to rule out the possibility that our results are driven by unrelated changes in home market co-movements.[10] The second test of commonality extends the work Morck et al. (2000) and Karolyi et al. (2012) to add transatlantic MTFs as a novel source of cross-border commonality. Our analysis requires a comparison between the R^2s of two models in which the individual stock's liquidity is the dependent variable in both models. In the benchmark model, we use the Home market aggregate liquidity as the key explanatory variable. In the second model, both the Home and Transatlantic MTF aggregate liquidity variables are included as key explanatory variables. The difference in R^2s captures the incremental impact of transatlantic MTF systems on commonality in liquidity of MTF traded stocks in the post-MTF period.

Both tests of commonality in liquidity yield the same findings. MTF stocks experience an increase in liquidity commonality with respect to the MTF aggregate liquidity index in the post-MTF period after joining the transatlantic market; their commonality with respect to home market liquidity does not increase. This increase in transatlantic co-movement is exclusive for transatlantic

[8] Figure 1 shows the European trading share of Turquoise between periods of 2009-2014.

[9] We use the proportional change in Amihud and relative spread, however, following Karolyi et al., (2012) we did not calculate the innovation in turnover.

[10] Similar to Dang, Moshirian, Wee, & Zhang (2015), we refer to co-movement of MTF stock's liquidity in the home market with the home market's liquidity as home market liquidity commonality. We refer to the co-movement of MTF stock's liquidity in the home market with the aggregate liquidity of all MTF traded stocks from their respective home market as the transatlantic liquidity commonality. Details on the estimation of commonality measures are in section 3. Brockman et al. (2009) use similar methodology to analyze the extent to which firm's commonality in liquidity is determined by global versus local sources.

MTF stocks; we find no change in commonality for the control samples of matched non-MTF stocks. Similarly, we find that the transatlantic common liquidity component increases R^2 for MTF traded stocks' liquidity in the post-transatlantic period, after controlling for the home market liquidity co-movement. The increase in R^2 in the transatlantic MTF model is statistically significant and has an economically meaningful magnitude compared to the home only benchmark model's R^2. Thus, our results suggest that transatlantic MTFs bring about a new source of cross-border commonality in liquidity, in addition to the well-documented home market liquidity co-movement (Corwin & Lipson, 2011; Hasbrouck & Seppi, 2001; Huberman & Halka, 2001; Karolyi et al., 2012c; Koch, Ruenzi, & Starks, 2016).[11] We further, use the NAE closure event, on April 2014, to add an even more interesting variation in number of active MTFs for a given stock, providing a fertile ground for a scientifically controlled experiment to test the counterfactual. Our results confirm that the transatlantic co-movement of traded stocks increases significantly with the number of MTFs trading it.[12]

One mechanism through which the introduction of MTFs increases commonality is the increased participation rate of HFT in a basket of international stocks that are traded by MTF systems.[13] Such participation may increase liquidity both demand and supply across MTF stocks. In addition, the fees structure employed by MTFs encourages HFT to serve as multi-market liquidity suppliers (Menkveld, 2013).[14] To investigate this hypothesis, we use the trading volume of MTFs as an instrument of HFT activity in MTF. We find that the transatlantic commonality in liquidity of traded stocks intensifies with the trading volume of Turquoise and NAE MTFs. We also find that the transatlantic commonality in liquidity of stocks increases with the number of transatlantic MTFs in which the stock trades. Our results suggest that HFTs' correlated decisions

[11] NYSE Arca Europe is a traditional Multi Trading Facility (MTF) that aims to extend the exchange's European reach beyond Euronext-listed securities to compete with Pan-European MTFs. In 2010, NAE added 100 US firms to be the first truly transatlantic market. The market provides its traders, for the first time, the opportunity to trade stocks from the U.S. along with other European countries in the same market and during European trading hours. Before March 09, 2009, stocks traded in NAE were traded on its home exchange, however, after March 2009, these stocks are traded also on NAE. Section 2 provides the institutional details of NYSE Arca Europe market.

[12] ICE decided to discontinue NYSE Arca Europe operations on April 21, 2014. 826 NAE stocks were also traded in Turquoise MTF. In this specification, the explanatory variable is the number of MTF systems trading a stock, unlike the indicator variable for MTF in other regressions.

[13] Gorton & Pennacchi (1993) suggest that commonality in liquidity increases because lesser informed traders choose to trade composite securities rather than an individual security to place restrictions on positions informed traders' can take when they trade against them in the market. In a different context Hanouna Moussawi and Stahel (2017) show that ETF ownership significantly increases commonality in liquidity across underlying stocks.

[14] HFT report produced by ESMA show that, for a set of 100 European firms, HFT traders have a median of 10 trading account IDs suggesting that HFT is involved in multimarket trading of the same financial securities.

may bring about a new source of stock's commonality in liquidity, regardless of stock's country of origin. These results are consistent Malceniece, Malcenieks and Putnins (2018) findings that suggest that the increase in liquidity co-movement is mainly driven by the ability of HFT liquidity providers to monitor the conditions and correlated demand for liquidity in other stocks and adjust liquidity provision accordingly.[15] In addition, the results are also consistent with Gorton & Pennacchi (1993) theoretical model that predicts that trading a basket of assets increases the commonality in liquidity for the constituent assets in this basket. Our paper helps identify innovation in trading infrastructure which facilitates HFT trading, as a new mechanism of liquidity co-movement in the international market.

The intuition behind the liquidity provision explanation is that financial intermediaries may reduce its liquidity provision across multiple securities during periods of high market uncertainty or market decline. For example, Coughenour & Saad, (2004) find that NYSE firms that are handled by the same specialist firm are exposed to a higher degree of commonality in liquidity due to specialist funding constraints. In such conditions, intermediaries endure losses, face increasing capital constraints and are forced to reduce the provision of liquidity to the market, creating an illiquidity spiral and increasing liquidity co-movement across many securities (Bernardo & Welch, 2004; Brunnermeier & Pedersen, 2009; Coughenour & Saad, 2004). In the context of HFT, Anand and Venkataraman (2016) show that HFT liquidity providers tend to scale back their participation in the market when the market conditions are unfavorable.

MTFs also have the potential to increase transatlantic commonality through correlated trading behavior (Corwin & Lipson, 2000; Kamara, Lou, & Sadka, 2008; Karolyi, Lee, & van Dijk, 2012; Koch, Ruenzi, & Starks, 2016). Kamara et al. (2008) show that liquidity co-movement in large US stocks can be attributed to institutional and index-related correlated trading.[16] Koch et

[15] Malceniece, Malcenieks and Putnins (2018) study the return and liquidity commonality in Chi-X between 2007 and 2009. Although their study is closely related to our paper, we have several distinct contributions by analyzing stock's home market as well as MTF to reflect the changes in liquidity co-movement before and after the introduction of the transatlantic MTFs instead of the traditional Pan-European ones. We study the impact of MTFs during the period over the period 2004-2015, which help us to look beyond the financial crisis period of 2007-2009. Further, we also study the unique case where the same stock is traded in multiple MTFs at the same time and show that the liquidity co-movement increase with the number of MTFs.

[16] Harford & Kaul (2005) and Barberis, Shleifer, & Wurgler (2005) study the changes in return comovement around S&P 500 additions. They find that adding a stock to S&P 500 index drives the stock to comove with the index. Harford and Kaul (2005) find that common effects are strong for order flow and returns in sample of S&P 500 stocks but are weak in sample of non-index stocks. Further, Boyer (2011) shows that S&P/Barra procedures to define their value and growth indices labels cause stock returns to covary in excess of fundamentals. He attributes his results to index labels portfolio allocation decisions of active mutual fund managers.

al., (2016) also find that commonality in liquidity is higher for stocks with higher mutual fund ownership. Karolyi, Lee, & van Dijk, (2012) provide international evidence that commonality in liquidity is driven by correlated trading behavior of institutional investors.

The interconnectedness of asset liquidity through MTFs that we document in this study points to the need for including global risk analysis in market structure modeling and regulation. Our results suggest the existence of transatlantic systematic liquidity co-movement even across stocks that do not share the same market-specific factors. Although there might be common macroeconomic factors that affect the whole region or even the world (Brockman et al., 2009), our experimental design rules out this possibility as we show that the increase in commonality is persistent only for the transatlantic MTFs stocks and not for the control samples.[17] Our findings contribute to the commonality literature by identifying the changes and innovations in market infrastructure that facilitate HFT activity in MTFs as a new common liquidity factor that helps explain the variation in stock's commonality in liquidity. Overall, our results imply that stock liquidity co-movement is not a local phenomenon, and that is merely determined by the movement in the home market, but an international one that depends on the stock's trading venues. Our findings are robust to the use of various liquidity proxies: trading turnover, Amihud (2002), and relative spread as well as alternative measures of commonality.

One potential alternative explanation of our findings is that our results are driven by the influence of large stock exchanges, such as NYSE or London Stock Exchange. To rule out this possibility, we exclude all U.S. and London firms from the MTF liquidity index. Our results show that transatlantic commonality is pervasive and persistent even after excluding U.S. and London stocks from the liquidity index. Another potential alternative explanation is that our results are primarily due to cross-listed stocks in our sample (Dang, Moshirian, Wee, & Zhang, 2015).[18] To rule out this explanation, we exclude all stocks that are also cross-listed in NYSE from our sample.

[17] Brockman et al. (2009) document regional co-movement in European stocks; however, they did not explain the source behind it.

[18] Dang et al. (2015) evaluate the impact of cross listing on a stock's liquidity co-movement. They find that cross listed stocks experience an increase in their host market commonality simultaneously with a decrease in the home market commonality. Further, they suggest that the reported decrease of cross listed stocks (increase) with respect to home (host) liquidity co-movement is more pronounced for stocks from countries with high market segmentation, an opaque information environment, and a poor institutional infrastructure. Brealey, Cooper, & Kaplanis, (2010) find similar results with respect to the return co-movement. Using a sample of cross border mergers, they find that when a target firm's location moves, a large part of its systematic risk switches from being related to its home equity market to that of the acquirer.

We find that the co-movement with NAE and Turquoise market-wide liquidity is robust to this exclusion.

Our study concludes that stock's commonality in liquidity depends on the market structure and its trading venues rather than explained merely by the primary home market. Our findings may have direct implications for asset pricing because systematic liquidity risk is a priced source of risk (Domowitz, Hansch, & Wang, 2005; Lee, 2011; Moshirian et al., 2017; Sadka & Scherbina, 2007).[19] In, addition, MTF induced commonality also affects optimal diversification strategy for global portfolios (Harford & Kaul, 2005; Kamara et al., 2008a; Longstaff, 2001) and the ability of arbitrageurs and other traders to exploit and eliminate ''mispricing'' (see, e.g., Kamara, 1988; Sadka & Scherbina, 2007). In particular, the increase in commonality in liquidity across countries is likely to decrease the diversification benefit from investing in MTF stocks that may otherwise be uncorrelated in segmented international stock markets. Thus, our findings about the role of infrastructure changes have important implications and future opportunities for stock exchanges, individual and institutional traders as well as other market participants.

2. **The Rise of MTFs**

Stock exchanges all around the world are now increasingly changing their business model and restructuring themselves in response to changes in the financial industry landscape such as (1) rapid advancement and innovation in technology that has facilitated trading access and speed; (2) growing market competition and integration; (3) regulatory changes that enhance competition and transparency of the stock markets such as Reg NMS, Reg ATS in the U.S., and MiFID I and MiFID II in Europe.

Together, these developments eroded the significance of physical national stock exchanges and their trading floors. Competitive pressures to increase revenues and cut out costs have forced stock exchanges to think more about strategic moves such as expanding their activities in different geographical markets with a range of innovative financial products. Consequently, we have witnessed numerous exchange mergers and consolidation as well as the emergence of MTFs.

2.1. Turquoise MTF.

[19] Previous literature shows that systematic liquidity risk is priced i.e., stocks whose returns are more sensitive to fluctuations in aggregate liquidity earn higher returns than stocks that exhibit lower sensitivity (Acharya & Pedersen, 2005; Brennan & Subrahmanyam, 1996; Domowitz, Hansch, & Wang, 2005; Pástor & Stambaugh, 2003; Sadka, 2006). Hasbrouck & Seppi (2001) show that commonality in order flow explains roughly two-thirds of the commonality in return.

Turquoise started as a European MTF on August 15, 2008. It currently operates successfully with growing market share in the European market. Turquoise was originally founded by a consortium of nine investment banks; it is owned by London Stock Exchange Group (LSEG) in partnership with investment banks. Turquoise equity platform offers the secondary trading of Pan-European and U.S. equities. With a single connection, members can trade stocks from more than 19 different exchanges over the transatlantic region.[20] Membership is open to qualified firms, with members including banks, brokers, specialist trading firms and retail intermediaries. Turquoise operates two order books, Lit and Dark that share the same set of traded securities. The first batch of American stocks was added to Turquoise MTF on April 23, 2010; other American stocks were added at different points in time between April 2010 and October 2014.

Turquoise MTF includes over 2900 stocks some of them from major world stock indices, including FTSE 100, CAC 40, Euro STOXX 50 and S&P 100. Turquoise has attracted a considerable amount of trading volume despite the intense competition in the global stock market. For example, figure 1 shows that by 2014, Turquoise trading volume has grown by over 15% of the global trading volume of FTSE 250 stocks; 7% of CAC 40 stocks and about 10% of the overall European market. In addition, Turquoise trading value grew to over 80 billion Euros in 2015 (See, Figure 2).

Insert Figures 1 & 2 Here

2.2. NYSE-Arca Europe (NAE)

In February 2008 NYSE-Euronext began a program to create the Universal Trading Platform (UTP) to support all of its markets. The goal of the project is to have a global network that supports the needs of both European and U.S. customers. As UTP rolled out across the Atlantic, the European division of NYSE-Euronext focused on extending the use of UTP and introduced a new major venture – NYSE Arca Europe – on March 09, 2009. NAE is a traditional Multi Trading Facility (MTF) that aims at extending the exchange's European reach beyond Euronext-listed securities to compete with Pan-European MTFs such as BATS Europe and Chi-X. The key strategy of adding the new venture, NAE, is to leverage on existing technology and

[20] For more information about Turquoise MTF and its structure see: http://www.lseg.com/areas-expertise/our-markets/turquoise

connectivity.[21] NAE started as a Pan-European trading venue. Initially, NAE traded blue-chip stocks from Austria, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, Norway, Spain, Sweden, Switzerland, and United Kingdom.

On April 21, 2010, NAE added about 100 U.S. stocks in addition to the existing population of European stocks to become the first truly transatlantic market. The market provides its traders, for the first time, the opportunity to trade U.S. stocks during European trading hours, along with other European stocks in the same trading venue. NAE is fully integrated with NYSE Euronext systems, and existing NYSE Euronext members can trade on the same platform simply by extending their membership.

In December 2012, Intercontinental Exchange (ICE) a futures exchange based in Atlanta reached a deal to buy NYSE Euronext. As part of their comprehensive review of NYSE Euronext business, ICE concluded that the operation of NAE MTF was not aligned with their core business strategy. ICE decided to discontinue the operations of NAE on April 21, 2014. Thus, by using the NAE trading period between March 09, 2009 and April 21, 2014, as well as non-trading periods before and after NAE, we are able to use this exogenous MTF entry and exit shock to test the impact of MTF on transatlantic commonality in liquidity. Thus, we can provide both corroborative and counterfactual evidence. The opening and closing of NAE events result in both cross-section and time-series variation the number of MTFs that affect stock's liquidity commonality. Table 1 presents the sequence of transatlantic events for both Turquoise and NYSE Arca Europe. We also provide further institutional details about the consolidation of NYSE-Euronext infrastructure, which led to the introduction and of NAE, in the internet appendix.

Insert Table 1 Here

3. Data and Methodology

We compile data from Thomson Reuters DataStream; we collect daily total return index (RI), trading volume (VO; expressed in thousands of shares), daily-adjusted price (P; in local currency), number of shares outstanding (NOSH), and market value of equity (MV) for individual stocks, from their home stock exchange. We obtain the instruments lists from Turquoise and NAE

[21] The key advantages of NAE is that it provides an efficient trading solution fully integrated into NYSE Euronext systems, Ultra-low latency, powered by robust, proven cutting edge technology, fee predictability with a pricing structure that delivers very competitive fees, easy connectivity for existing members through existing trading access and full market transparency, leveraging on the depth of the central order book. For more information see: https://europeanequities.nyx.com/en/markets/nyse-arca-europe/key-benefits

websites.[22] We begin with 3895 firms in total, 995 from NAE and 2900 from Turquoise MTF. We exclude securities for which the exchange code in instrument list does not match the DataStream exchange code or if DataStream does not have data for all regression variables. To include a firm in the sample, we require that trading data on at least 100 trading days before and 100 trading days after MTF entry date. Our final sample includes 881 securities from NAE MTF and 2665 from Turquoise MTF. Our sample period spans from January 01, 2004 to April 21, 2015.

To build a reliable international dataset, we follow Ince & Porter (2006) screening procedures for DataStream. We discard daily observations with trading volume that are greater than number of shares outstanding (Karolyi et al. 2012). Similar to Lesmond (2005) and Lee (2011), we classify a day as a non-trading day if more than 90% of stocks in a given exchange have zero returns on that day. Following Karolyi et al. (2012), we include only common stocks excluding all special features securities.[23] In addition, we adopt the screening suggested by Ince & Porter (2006) to account for false return reversion; we discard stock–day observations if $\left(1 + \mathrm{R}_{\mathrm{i,t}}\right) \times \left(1 + \mathrm{R}_{\mathrm{i,t-1}}\right) - 1 \leq 0.5$. Where $\mathrm{R}_{\mathrm{i,t}}$ and $\mathrm{R}_{\mathrm{i,t-1}}$ are the stock return of firm *i* in day *t* and *t-1*, respectively, and at least one of the returns is greater than or equal 200%.[24] Moreover, to avoid survivorship bias, we retain all return data for dead stocks, until the last day of trading. When a stock is delisted, DataStream retains the last value of the trading return index. To exclude observations after the delisting date, we discard observations from the end of the sample to the first non-zero return date. Finally, we winsorize the daily observations in the top or bottom 1% for each exchange and each trading day, to remove the effect of extreme values that may be a result of data errors.

3.1 Liquidity measures

Our three liquidity measures are trading turnover, Amihud (2002), and closing bid-ask spread. First, we use daily turnover as a measure of the trading activity in individual stocks. Turnover is defined as the number of shares traded on a given day divided by the total number of shares outstanding. To avoid the problem of taking the logarithm of zero daily turnovers, we follow

[22] NYSE Arca Europe instrument list is available at the following link: https://europeanequities.nyx.com/markets/nyse-arca-europe. The data set includes Security name, Country Issuer, Country Code, Currency, Primary Market and International Securities Identification Number (ISIN).

[23] Karolyi et al. (2012) exclude depository receipts (DRs), real estate investment trusts (REITs), preferred stocks, investment funds and other stocks with special features. Robustness confirms are not affected by removing stock with special features such as REITs.

[24] Ince & Porter (2006) suggest that monthly return should not exceed 300%. The 300% threshold is somewhat arbitrary. In this paper we follow Lee (2011) who use daily data and use 200% as an arbitrary value instead of 300%.

previous studies and add a constant to turnover (Llorente, Michaely, Saar, & Wang, 2002). We use the following equation to calculate turnover.

$$Turnover_{i,d,t} = Log(1 + \frac{VO_{i,d,t}}{NOSH_{i,d,y}}) \quad (1)$$

Where $Turnover_{i,d,t,}$ and $VO_{i,d,t}$ are the daily turnover and trading volume for stock *i* on the domestic market *d* and day *t*. $NOSH_{i,d,y}$ is the number of shares outstanding at the beginning of year y. A similar approach has been used by, Karolyi et al. (2012). Previous literature documents the existence of common systematic factors in the turnover of individual U.S. stocks (Cremers & Mei 2007; Lo & Wang 2000). Cremers & Mei (2007) also find that three to five systematic turnover factors together can capture between 15 to 26% of the variation in individual stock turnover. Karolyi et al. (2012) use turnover to measure commonality in liquidity in 40 developed and emerging markets.

We use Amihud (2002) as our second measure of liquidity. Amihud (2002) suggests the daily ratio of absolute stock return to dollar volume as a proxy for the illiquidity of a stock. Amihud measure adheres to the intuitive description of liquid markets as those that accommodate a lot of trading volume with little impact on price. We follow Karolyi et al. (2012), to calculate Amihud liquidity measure, we add a constant to the Amihud measure and take the log, to reduce the impact of outliers. To facilitate comparisons with Karoyli et al. (2012), we also multiply the resulting illiquidity measure by -1 to arrive at a variable that is increasing in the liquidity of individual stocks.[25] In this paper, we calculate Amihud measure using the following equation.

$$Amihud_{\ i,d,t} = -Log(1 + \frac{|R_{i,d,t}|}{P_{i,d,t}\, VO_{i,d,t}}) \quad (2)$$

where $Amihud_{i,d,t}$ is the Amihud liquidity proxy, $R_{i,d,t}$ is the return in local currency, $P_{i,d,t}$ is the price in local currency, and $VO_{i,d,t}$ is the trading volume, for stock *i* on the domestic market *d* and day *t*. By construction, as explained in equation 2, Amihud measure is negative, such that greater values indicate greater liquidity.

Previous studies show that this measure is strongly positively related to microstructure estimates, including bid-ask spread, and fixed trading costs. For example, Hasbrouck (2009) and Goyenko, Holden, & Trzcinka (2009) report that Amihud is strongly correlated with TAQ high-

[25] These adjustments are not material for the interpretation of our regression analysis, because they equally affect both stock's liquidity and aggregate liquidity indices.

frequency price impact measures, and intraday liquidity measures. For international evidence, Lesmond (2005) show that Amihud measure has a high correlation with bid-ask spreads in 23 emerging markets. With respect to systematic liquidity risk, many empirical studies rely on the Amihud (2002) liquidity measure to capture systematic liquidity risk (Acharya & Pedersen, 2005; Watanabe & Watanabe, 2008; Karolyi et al., 2012).[26]

We use the DataStream closing bid and ask prices to calculate our third measure of liquidity, relative quoted spread. Relative quoted spread is the differences between the closing ask and the closing bid quotes as a proportion of the bid-ask midpoint calculated as follows:

$$Relative\ Quoted\ Spread_{i,d,t} = \frac{Ask_{i,d,t} - Bid_{i,d,t}}{(Ask_{i,d,t} + Bid_{i,d,t})/2} \quad (3)$$

where $Ask_{i,d,t}$ is the closing ask price and $Bid_{i,d,t}$ is the closing bid price for stock *i* on the domestic market *d* for day *t*.

Several studies have used bid-ask spread to document commonality in liquidity. Chordia et al. (2000) find that bid-ask spread co-move with market-wide and industry-wide liquidity after controlling for well-known individual liquidity determinants. Corwin & Lipson (2011) use electronic order flow data to examine the relative importance of program traders, institutional traders, retail traders, and exchange members in driving commonality in order flow, returns, and liquidity. They document strong evidence of common component in spreads driven by correlated trading decisions of professional traders, as executed through program trades. In the international context, Brockman et al. (2009) find that firm-level changes in liquidity are significantly influenced by exchange-level changes in 47 international exchanges. However, none of these papers examine the effect of transatlantic MTFs on commonality in liquidity.

3.2 Commonality in Liquidity

We employ two different methods to investigate the commonality in liquidity. First, we extend Chordia et al. (2000) methodology to account for local and transatlantic markets in the same regression. Daily proportional changes in an individual stock's liquidity are regressed on

[26] Using the Amihud measure, Acharya & Pedersen (2005) propose the liquidity-adjusted capital asset pricing model, which incorporates three different types of liquidity risk. Watanabe & Watanabe (2008) also use the Amihud measure to investigate whether stock returns' sensitivities to aggregate liquidity fluctuations and the pricing of liquidity risk vary over time. More recently, Karolyi et al. (2012) use the Amihud measure to investigate the time series variation in commonality in the liquidity of individuals stocks around the world.

proportional changes in aggregate liquidity for all MTF stocks and aggregate liquidity in all home market stocks. We use the following firm-by-firm time series regression:

$$\Delta \text{ Liquidity }_{i,t} = \alpha + \beta_1 \Delta\, MTF\ Liquidity_t \text{x MTF}_t + \beta_2 \Delta\, Home\ Liquidity_t \text{x MTF}_t + \beta_3 \text{ MTF}_t + \beta_4 \Delta\, Home\ Liquidity_{t-1} + \beta_5 \Delta\, Home\ Liquidity_t + \beta_6 \Delta\, Home\ Liquidity_{t+1} + \beta_7 \Delta\, MTF\ Liquidity_{t-1} + \beta_8 \Delta\, MTF\ Liquidity_t + \beta_9 \Delta\, MTF\ Liquidity_{t+1} + \beta_{10}\, Home\ Return_{t-1} + \beta_{11}\, Home\ Return_t + \beta_{12}\, Home\ Return_{t+1} + \beta_{13} \Delta \text{ Volatility }_{i,t} + \varepsilon_{i,t} \quad (4)$$

where Δ Liquidity $_{i,t}$ is the proportional change in liquidity measured by either Amihud (2002), or relative spread for stock *i* on day *t*. Karolyi et al. (2012) suggest that turnover is primarily a flow variable and hence it is not necessary to calculate innovation. In our analysis, we follow their suggestion and use raw turnover measure instead of the change in turnover. Thus, Δ Liquidity is measured by Turnover, Δ Amihud, and Δ relative quoted spread, respectively, in three separate regressions. Δ Home Liquidity is the change in equal-weighted average of liquidity measure for all firms trading in the home market. Following prior studies (e.g., Brockman et al., 2009; Chordia et al., 2000; Karolyi et al., 2012) we exclude firm *i* from the computation of aggregate MTF market liquidity and aggregate home market liquidity indices. Δ MTF Liquidity is the change in equal weighted average in liquidity of all firms traded on the NAE or Turquoise MTFs excluding firm *i*. In addition, we also conservatively exclude all traded firms from the same home market as firm *i* from the computation of the proportional change in aggregate MTF market liquidity index to avoid double counting of the home market effect. Removing all other home market firms from MTF liquidity index helps to isolate and eliminate the effect of home market liquidity changes from the MTF liquidity index. MTF is an indicator variable that takes the value of zero for the period before stocks' join the MTF and the value of one otherwise.[27] $\Delta\, MTF\ Liquidity_t$ x MTF_t is the interaction term between the MTF dummy variable and the contemporaneous proportional change in liquidity index for all MTF stocks. $\Delta\, Home\ Liquidity_t$ x MTF_t is the interaction term between the MTF and the contemporaneous proportional change in liquidity for all home market stocks. Δ Volatility $_{i,t}$ is the return volatility, measured as the change in squared return, of firm *i* from day *t* to *t-1*.

Chordia et al. (2000) and Brockman et al. (2009) suggest that adding volatility as a control variable is important because it possibly influences stock's liquidity. Home Return is the daily

[27] Table 1 reports different events in our study with a brief description.

equally-weighted average return of all stocks traded in the home market. Home market return is included to control for the dependence induced by the association between returns and liquidity measures, in order to isolate the effect of MTFs on commonality. Following Chordia et al. (2000) and Brockman et al. (2009), we also include lead and lag terms of the equal weighted average change in home market aggregate liquidity and MTF aggregate liquidity, in addition to the contemporaneous terms. We also include lead and lag equal weighted average of home market return. The lead and lags are included to capture any lagged adjustment in commonality.

Our second measure of transatlantic commonality in liquidity is the R^2 of a regression of individual stock liquidity on the MTF and Home aggregate liquidity during the post-transatlantic period. Morck et al. (2000) use the R^2 of a regression of individual stock return on the market's return to measure price synchronicity. They suggest that a high R^2 in such a regression indicates a high degree of stock price synchronicity. Karolyi et al. (2012) adapt R^2 measure to investigate commonality in liquidity in 40 developed and emerging markets. To obtain Home adjusted R^2, we use the following regression.[28]

$$\begin{aligned}\Delta \text{ Liquidity}_{i,t} = \ & \alpha + \beta_1 \, \Delta \, Home\ Liquidity_{t-1} + \ \beta_2 \, \Delta \, Home\ Liquidity_t \\ & + \beta_3 \, \Delta \, Home\ Liquidity_{t+1} + \varepsilon_{i,t}\end{aligned} \tag{5}$$

For each sample firm, we run a parallel regression that includes both the Home and MTF aggregate liquidity indices in the same regression during the post-transatlantic period. We expect that to find that MTF aggregate liquidity will significantly increase the explanatory power of changes in firm's liquidity. We use the following regression to compute the R^2 of the home and MTF markets.

$$\begin{aligned}\Delta \text{ Liquidity}_{i,t} = \ & \alpha + \beta_1 \, \Delta \, Home\ Liquidity_{t-1} + \ \beta_2 \, \Delta \, Home\ Liquidity_t \\ & + \ \beta_3 \, \Delta \, Home\ Liquidity_{t+1} + \beta_4 \, \Delta \, MTF\ Liquidity_{t-1} \\ & + \beta_5 \, \Delta \, MTF\ Liquidity_t + \beta_6 \, \Delta \, MTF\ Liquidity_{t+1} + \varepsilon_{i,t}\end{aligned} \tag{6}$$

The difference in R-squared of equations (6) and equation (5) measures the incremental impact of transatlantic MTF on commonality.

3.3 The Matched Sample

[28] As a robustness, we include other control variables in the model to obtain Home vs transatlantic MTF R^2. Our results remain unchanged regardless of including or excluding other control variables.

To rule out alternative explanations for our findings, we construct two control samples of firms that share the same home market as the firm that trade in NAE and Turquoise MTFs, respectively, but the control firms do not trade in the MTFs. Our matching algorithm is as follows. We start with all home exchange firms. We follow the same screening procedures outlined at the beginning of this section. Next, we match each firm traded in NAE or Turquoise with the closest average turnover, Amihud (2002) or relative spread over the pre-transatlantic period. We do one-to-one match with replacement to improve the quality of the control sample.[29] To attribute an increase in commonality to MTF infrastructure, MTF traded firms should experience a change in liquidity commonality after the introduction of the MTFs but the firms in the control sample should not.

3.4 Predicted Signs for Transatlantic MTF driven commonality

The expected sign of coefficients for the treatment and control stocks are shown in Figure A.1 in the Appendix. For our hypothesis of increased commonality through transatlantic MTF, the predicted sign is positive for MTF traded stocks with respect to MTF aggregate liquidity after the introduction of MTF, and flat or negative with respected to home market liquidity. For the control stocks the expected sign is flat, i.e., no change in commonality with respect to either MTF or home market aggregate liquidity.

4. **Empirical Results**

4.1 Descriptive statistics

Table 2 presents summary statistics for stocks traded on NAE and Turquoise transatlantic MTFs for the full sample period from January 2004 to April 2015. Panel A, presents sample statistics for NAE with a final sample of 881 stocks and Panel B presents Turquoise sample with a final sample of 2,665 stocks. We report, for each home exchange, the exchange name, number of firms in the MTF, daily average levels and changes in turnover, Amihud (2002), and relative quoted spreads. We also report equally-weighted average return and average market value of traded firms from each exchange. The number of NAE stocks varies significantly across different stock exchanges. The largest stock exchange is London with 327 stocks followed by Milano with 97 stocks. We combine exchanges that have less than 20 stocks traded in NAE in the 'Other'

[29] Our results remain unchanged if we match without replacement or with market value of the stocks instead. We also create a matched sample based on MTF traded firm market value and our results remain robust.

category. It includes 18 firms from Copenhagen, 16 firms from NASDAQ, 16 firms from Dublin, and 12 firms from Budapest.

Panel B, in table 2, provides descriptive statistics for the Turquoise sample. The highest number of MTF stocks comes from Paris Bourse followed by Frankfurt and London Stock exchanges with 390, 339 and 326 stocks, respectively. Turquoise instrument list is available on the London stock exchange website https://www.lseg.com/turquoise-files, and it provides the exact date at which each stock joins or leaves Turquoise MTF platform. The variation in event dates reduces the possibility that our results are driven by other confounding sources of commonality in liquidity, at any given time. As explained in equation 2, Amihud measure is negative by construction so that greater values indicate greater liquidity. It is important to note that the direct comparison of the level of Amihud liquidity measure is not meaningful because of the differences in currency units across countries. However, for the regression analysis, we use the proportionate changes in Amihud to measure the co-movement in liquidity (which makes the comparison meaningful). As expected, we find that NYSE firms have the highest turnover, lowest absolute value of Amihud and relative spread on both NAE and Turquoise samples. In addition, NYSE firms also have the largest market value with an average of $68,501 and $86,061 million for NAE and Turquoise, respectively.

Insert Table 2 Here

4.2 Matched samples

Table 3 presents the summary statistics for our treatment and control samples for the pre-transatlantic period. We construct an NAE and Turquoise control samples of firms that share the same home market but are not traded in MTF trading system. We do a one-to-one match of each MTF traded firm with the firm that has nearest average turnover, Amihud (2002) and relative spread over the period before joining the MTF. In order to make sure that the behavior of the control samples is comparable in the pre-MTF period, we computed the t-statics for the difference in means for all three measures of liquidity. As shown in table 3, the significance of the difference in means between the two samples, treatment, and control, is economically small and statistically insignificant.[30] The results suggest that the liquidity of control samples was indifferent from the

[30] We show the statistic for the full market for brevity, the complete country-by-country statistics are available upon request.

treatment samples before the transatlantic events; which provide a solid foundation for our experiment.

Insert Table 3 Here

4.3 Commonality in liquidity

In this section, we present the commonality in liquidity regression analyses for NAE and Turquoise MTFs samples as well as our control samples. We run firm-by-firm time series regressions of daily proportional changes of an individual stock's liquidity on proportional changes in MTF market liquidity index and change in home market liquidity index. Home market return and return volatility are also included as control variables.

The dependent variables are Turnover, Δ Amihud, and Δ relative quoted spreads, respectively, in three separate regressions. Our main explanatory variable of interest is the interaction term between the concurrent change in liquidity of MTF liquidity index and an indicator variable for the post MTF period of each traded firm. A positive coefficient on the interaction term suggests that the firms' liquidity is significantly influenced by transatlantic MTF liquidity factor in the post MTF period. Table 4 presents the cross-sectional averages of the regression coefficients of NAE, and Turquoise samples. Our results confirm the MTF liquidity commonality prediction, for all three measures of liquidity; we find the interaction terms of $\Delta\, MTF\ Liquidity_t * \mathrm{MTF}_t$ are positive and statistically significant for NAE and Turquoise transatlantic MTFs. We also find that $\Delta\, Home\ Liquidity_t * \mathrm{MTF}_t$ liquidity interaction variable is negative and statistically significant for all liquidity variables except Amihud.[31] Thus, our findings suggest that, in general, stock liquidity co-moves more with MTF stocks and less with domestic stocks, after the introduction of MTF.

Insert Table 4 Here

In Table 5, we run analogous models for the control samples with a pseudo-MTF event date matching the MTF firms' entry dates to investigate whether this transatlantic commonality in liquidity is potentially caused by any other confounding factors.[32] Table 5 reports the results of these placebo regression analyses. Our results confirm that the control firms do not have a

[31] Although the interaction term for Amihud is positive and statistically significant for NAE market, the magnitude of the coefficient is lower than the MTF liquidity interaction term.
[32] Note that, the control samples' stocks did not experience any MTF event and therefore we expect the pseudo interaction variable coefficient to be insignificant for the control samples regressions.

transatlantic common liquidity component. We find that $\Delta\, MTF\; Liquidity_t * \text{Pseudo MTF}_t$ interaction term coefficients are not statistically significant for the control samples.

Our results suggest that transatlantic trading brings about a new source of commonality in liquidity to MTF traded firms that is independent from other potential sources of commonality because such factors should have affected both the MTF samples and the placebo samples. In addition, these results confirm that firm's commonality in liquidity is not solely determined by home exchange. It can spill over onto stocks from other countries with the same base of traders and investors on an MTF. The results suggest that our findings are not driven by other unknown commonality factor and the liquidity of only MTF traded firms is significantly influenced by transatlantic aggregate market liquidity whereas that of control stocks is not. Thus, we can attribute the changes in commonality to MTF infrastructure.

Consistent with prior literature (Brockman et al., 2009; Chordia et al., 2000; Hasbrouck & Seppi, 2001; Kamara et al., 2008a; Karolyi et al., 2012), our results also show that stocks have significant common liquidity component with respect to the home market liquidity but we find that it declines especially for MTF stocks after this infrastructure innovation. Among the control variables, the significant coefficient on return volatility suggests that volatility affects the change in liquidity consistent with Chordia et al. (2000) and Brockman et al. (2009).

Insert Table 5 Here

4.4 MTF Volume and Commonality.

In this section, we use MTF trading volumes to further understand this mechanism of increased transatlantic commonality. If MTF is a channel of liquidity commonality, then the higher the MTF volume, the stronger should be the commonality effect. Recent literature suggests that HFTs are active participants in MTFs and use the introduction of MTF trading venues as an instrument to test the impact HFT activities on the financial market (Menkveld, 2013; Greese, 2017; Malceniece et al. 2018). Menkveld (2013) study the HFTs' activity at Chi-X MTF and suggest that HFT participation rate in MTF is about 65%. ESMA confirmed this trend through their HF trading report to suggest that HFT activities in Turquoise MTF represent 63% of value traded, 65% of number trades and 84% of order submitted. We conjecture that higher MTF volume should result in higher transatlantic commonality. The aggregate monthly trading volume of NAE and Turquoise MTFs are collected from the Federation of European Securities Exchanges (FESE).

Results for the impact of MTF volume on transatlantic commonality are shown in Table 6. We find that interaction terms between the MTF trading volume and contemporaneous liquidity are positive and statistically significant for turnover and Amihud for both NAE and Turquoise MTF. The interaction term is also positive and significant for change in relative spread for NAE MTF. These results generally confirm our hypothesis that as the MTF volume increases, indicating greater activities of HF traders, the transatlantic commonality in liquidity also increases.

Insert Table 6 Here

These results are aligned with Menkveld (2013) findings that HFTs are primarily modern, multi-venue market makers. In addition, these results are also consistent with theoretical model of Cespa and Foucault (2014) that liquidity providers often learn information about assets from other assets. This process causes liquidity spillover and increase liquidity co-movement. HFT also have correlated trading behavior across different markets due to arbitrage and basket trading, according to Tomio (2017). The MTF infrastructure further facilitates such activities of global arbitrage and international basket trading.

4.5 Large stock exchanges and transatlantic co-movement.

Large stock exchanges and movements in their popular indices attract much attention from international investors. One potential alternative explanation for our findings is that we are actually capturing the co-movement among stock included in major indices or large stock exchanges. London stock exchange is the biggest stock exchange in Europe and has 327 and 326 stocks in NAE and Turquoise MTFs respectively. In addition, US firms are generally seen as a strong indicator of international market conditions. To rule out that possibility, we excluded all U.S. and London firms from the transatlantic liquidity index. Table 7 reports the results. Panel A, shows the regression results for NAE and Panel B reports the results for Turquoise MTF. The results show that our findings are not driven primarily by popular indices of London or US exchanges. Even after their exclusion, we continue to find statistically significant positive coefficients for interaction terms between the MTF event variable and the contemporaneous MTF liquidity index. The coefficients are positive and significant for all three measures of liquidity. These results are consistent across the two MTF samples: NAE and Turquoise. In addition, in unreported regressions, we also find that excluding Paris stock exchange, the exchange with the highest number of stocks in Turquoise, from the Turquoise liquidity index does not affect our results.

These findings show that our results are not sensitive to the inclusion or exclusion of large stock exchanges from the transatlantic liquidity index.

Insert Table 7 Here

4.6 Cross-listed stocks

Dang et al. (2015) show that cross-listed stocks liquidity co-movement is not merely determined by aggregate home market liquidity. They find that stocks that are cross listed experience an increase in their host market commonality simultaneously with a decrease in stock's home market commonality after cross listing. To avert the possibility that our results are due to cross listed stocks in our sample, we exclude NYSE cross listed stocks from both NAE and Turquoise MTFs samples. Our results, in table 8, show that the transatlantic liquidity co-movement is persistent across the two MTFs and different liquidity measures. We find that cross listed stocks are not solely responsible for the existence of cross-border commonality in liquidity. Instead, MTFs appear to have meaningful incremental explanatory power for commonality in liquidity.

Insert Table 8 Here

4.7 Counterfactual Evidence with NAE closure

The introduction of MTFs aims at increasing transparency and competition between trading venues. In this section, we use NAE closure event as an additional exogenous shock to MTF traded firms. We start by comparing NAE and Turquoise instrument list. We find that most of NAE stocks are also traded at Turquoise MTF. 826 NAE stocks are shared among the two MTF systems. The closure of NAE enriches our experiment by altering the number of active MTFs trading the same stock. Now, we can examine the incremental effect of trading the same firm at multiple MTFs at the same time. If MTFs is a source of liquidity commonality, then the higher the number of MTFs, the stronger should be the commonality effect.

In this analysis, we use Turquoise MTF aggregate transatlantic liquidity as the global liquidity index because it includes most NAE stocks in addition to the rest of Turquoise stocks. We also create #MTF variable that takes the value 0 before joining either MTF, 1 if the stock is traded at one MTF, and 2 if it is traded at both MTFs. For NAE firms that are no longer traded in an MTF after the NAE closure, the MTF variable will take the value of 0, and 1 for stocks that are still actively traded in Turquoise. Table 9 shows the regression analyses. Our results confirm this hypothesis and further strengthen the prior findings of the paper that there is a common transatlantic systematic liquidity factor arising from MTFs. In addition, our results show a negative coefficient for the interaction term between Home liquidity and the #MTF variable. This indicates that MTF trading reduces home market liquidity co-movement.

Insert Table 9 Here

4.8 R^2 as an alternative measure of commonality in liquidity

In this section, we use R^2 as an alternative measure of commonality in liquidity according to the method described in section 3.2 in detail. Table 10 reports the average R^2 of firm-by-firm regressions of individual firms' liquidity on the aggregate liquidity of MTF and home markets in the post-transatlantic period and compares it with the base model of only home market aggregate liquidity. We find that the difference in adjusted R^2, for all liquidity measures, is positive due to the inclusion of MTF aggregate liquidity index in the regression. The magnitude of the R^2 increase is economically and statistically significant for Turnover and Amihud measures. These results are aligned with our previous findings that the introduction of MTF transatlantic trading venue alters the firm's commonality in liquidity. Overall, the reported evidence shows that a transatlantic-trading venue creates a new source of cross-border liquidity commonality, in addition to the home market commonality documented in previous literature (Brockman et al., 2009; Chordia et al., 2000; Corwin & Lipson, 2011; Hasbrouck & Seppi, 2001; Huberman & Halka, 2001; Kamara et al., 2008a).

Insert Table 10 Here

5. **Conclusion**

Our results provide new evidence of the impact of changes in stock market infrastructure on firm's liquidity co-movement. Rapid changes in stock market business model along with advancements in technology have pressured global stock exchanges to become more competitive and expand its activities into different geographical markets through multilateral trading facilities (MTFs). The introduction of transatlantic MTFs has created a common investors' pool that is interested in trading a geographically dispersed population of financial instruments. Our results suggest that the existence of a common investors' pool with correlated trading behavior in supplying or demanding liquidity bring about a novel source of commonality in liquidity. In addition, our results provide empirical evidence for the Gorton & Pennacchi (1993) model which predicts that trading a basket of assets increases the commonality in liquidity for the constituent assets in this basket.

In this paper, we use the introduction of two transatlantic trading venues NYSE Arca Europe (NAE) and Turquoise, as exogenous shocks to many American and European stocks, to examine the impact of changes in market structure on liquidity co-movement. On a stock-by-stock basis, we find that changes in individual firm's liquidity are significantly influenced by a common liquidity factor in the transatlantic MTF market after joining the MTF. Our result holds even after controlling for the home market co-movement documented in the prior literature. We also find that the higher the MTF volume, the stronger the liquidity commonality. To further enrich our analysis, we show that the greater the number of MTFs trading a stock, the stronger the relation between stock's liquidity and the transatlantic liquidity index. Overall, we find that MTF trading increases stock's transatlantic liquidity commonality and reduces domestic liquidity commonality. Our results are robust to different methods for computing commonality, different liquidity proxies, and different trading events.

Our results suggest the existence of transatlantic systematic liquidity co-movement even across stocks that do not share the same home market, macro-economic factors or other market-specific factors. We show that our results cannot be attributed to the influence of large stock exchanges such as NYSE and London stock exchange or to the influence of cross listed stocks. This paper helps identify innovation in trading infrastructure as a new mechanism through which demand-side and/or supply-side forces of liquidity commonality manifest themselves in the international market. It also highlights the need for including global risk analysis in market structure modeling and regulations. The implication of our results posits interesting questions for future research about the impact of the continuously evolving stock exchange models and how exchange infrastructure might affect the market quality, and systematic risk.

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Table 1: Multi-lateral trading facilities (MTFs) sequence of events

This table presents the sequence of transatlantic events of both NYSE Arca Europe and Turquoise MTFs.

Events	Description	Date
NYSE Arca Europe (NAE): Events range from March-2009 to April-2014		
Debut	On March, 09, 2009, NYSE-Euronext introduces NYSE Arca Europe, Pan-European MTF, to extend exchange's European reach beyond Euronext-listed securities	March, 09, 2009
American stocks	On April 21, 2010, NYSE Arca Europe added U.S. stocks in addition to the existing population of European stocks	April, 21, 2010
Closure	In December 2012, Intercontinental Exchange (ICE) reached a deal to buy NYSE Euronext. As part of their comprehensive review of NYSE Euronext business, ICE concluded that NAE operations is not aligned with their core business strategy. ICE decides to discontinue the operations of NAE on April 21, 2014.	April 21, 2014
Turquoise: Events range from August-2008 to October-2014		
Debut	Nine major investment banks launched Turquoise trading platform on 15 August 2008. Currently, Turquoise is part of London Stock Exchange Group.	August, 15, 2008
American stocks	First batch of American stocks is added to Turquoise MTF on April 23, 2010. Later, other American stocks are added to the trading venue.	April, 23, 2010
Entry date	Stocks are gradually added to the Turquoise MTF. Each stock has a unique entry (live) date. The instrument list also has the date at which each stock left the MTF, if any.	Varies
Continuing Operations	Turquoise continues to operate in the European market with an increasing market share at the time of this writing.	Present

Table 2: Summary statistics for MTF stocks

This table reports summary statistics for MTF stocks' liquidity, return, and market value for the period between January 1st, 2004 and April 21st 2015. Panel A and Panel B report the sample averages for NYSE Arca Europe and Turquoise traded stocks, respectively. Turnover is the logarithm of the ratio of daily trading volume over the number of shares outstanding reported in percentage points. Amihud (2002) is the absolute stock return divided by local currency trading volume as explained in equation (2). Amihud variable is multiplied by -1 so that the resulting measure is increasing in the liquidity of the stock, Amihud statistics are multiplied by 1000. Relative Quoted Spread is computed as the difference between bid-ask prices divided by the midpoint of the bid and ask prices expressed in percentage points. Δ is the proportionate change operator from the day (t-1) to day (t). Return is the average percentage daily return of individual stocks in local currency. Market value (in USD millions) is the average market value of traded firms. Others category in NAE includes 18 firms from Copenhagen, 16 firms from NASDAQ, 16 firms from Dublin stock exchange, and 12 firms from Budapest stock exchange. In Turquoise, others category includes seven stocks from Prague, 16 stocks from NASDAQ, 21 stocks from Dublin and 20 stocks from Budapest. Table 1 is sorted by the number of MTF stocks from a given home exchange.

Home Exchange Name	# of Firms	Turnover	Δ Turnover	Amihud	Δ Amihud	Relative Quoted Spread	Δ Relative Quoted Spread	Daily Return	Market Value
Panel A: NYSE Arca Europe (NAE)									
London	327	0.428	0.440	-0.001	1.640	0.617	0.523	0.039	7,661
Milano	97	0.385	0.257	-0.052	1.287	0.863	0.344	0.011	5,959
Frankfurt	94	0.021	0.561	-0.780	2.204	0.652	0.094	0.028	13,048
NYSE	88	1.046	0.057	0.000	1.584	0.190	0.261	0.033	68,502
Madrid	55	0.562	0.224	-0.022	1.373	0.766	0.493	0.018	10,228
Swiss	47	0.644	0.148	-0.002	1.119	0.215	0.374	0.038	19,655
Stockholm	37	0.761	0.145	0.000	0.990	0.246	0.185	0.053	10,145
Helsinki	25	0.625	0.19	-0.003	1.430	0.210	0.559	0.041	8,328
Vienna	25	0.256	0.295	-0.022	1.700	0.588	-0.283	0.032	3,841
Oslo	24	1.174	0.173	-0.002	1.074	0.400	0.370	0.024	8,112
Others	62	0.964	0.555	-0.036	2.822	0.743	0.402	0.035	29,366
All	881	0.537	0.342	-0.095	1.645	0.572	0.376	0.033	16,644
Panel B: Turquoise									
Paris	390	0.249	0.747	-1.107	2.129	1.765	0.667	0.003	4,556
Frankfurt	339	0.056	0.835	-2.548	2.203	2.235	0.162	-0.012	4,155
London	326	0.450	0.764	-0.001	1.789	0.996	0.474	0.033	7,782
Stockholm	248	0.383	0.937	-0.139	1.374	1.680	0.318	0.008	2,000
Milano	238	0.326	0.687	-0.721	1.655	1.597	0.477	-0.033	2,695
Swiss	197	0.512	0.616	-0.206	1.471	1.444	0.485	0.003	5,874
Oslo	145	0.417	1.462	-0.200	1.705	2.870	0.367	-0.010	1,866
Copenhagen	124	0.370	1.073	-0.307	1.461	2.574	0.313	-0.002	1,639
Helsinki	120	0.232	1.624	-2.281	2.171	2.296	0.441	0.000	1,971
Brussels	104	0.246	0.673	-0.890	2.196	1.710	0.593	-0.001	2,616
Madrid	103	0.445	0.573	-0.223	1.416	1.343	0.533	-0.011	6,655
NYSE	91	0.888	0.062	0.000	1.569	0.084	0.273	0.031	86,062
Amsterdam	89	0.389	0.726	-0.782	1.923	1.607	0.628	-0.004	6,863
Lisbon	38	0.293	1.346	-4.079	1.589	2.415	0.400	-0.028	2,129
Vienna	49	0.209	0.759	-0.506	2.146	1.047	-0.104	0.015	2,209
Others	64	1.177	0.996	-0.303	4.719	1.833	0.353	0.014	26,795
All	2665	0.362	0.819	-0.841	1.891	1.729	0.434	0.001	6582

Table 3: Treatment vs. control samples

This table compares average liquidity measures for MTF and control samples during the pre-transatlantic trading period. Panel A presents results for NAE and Panel B for Turquoise. To form the control sample we match each MTF stock to a stock listed in the same home market (not trading on the MTF) and with the nearest neighbor average of respective liquidity measure in the pre-transatlantic event period. The Difference column contains the difference in means between MTF and control samples and the t-statistic of its significance.

Variables	N	Treatment		Control		Difference	
NYSE Arca Europe		Mean	S.D.	Mean	S.D.	Mean	T-Stat
Turnover	881	0.447	0.940	0.400	0.520	0.047	1.29
Amihud	881	-0.150	2.08	-0.200	1.310	0.059	0.70
Rel. Quoted Spread	881	0.705	1.02	0.725	1.140	-0.020	-0.02
Turquoise		Mean	S.D.	Mean	S.D.	Mean	T-Stat
Turnover	2665	0.434	0.995	0.431	1.180	0.004	0.12
Amihud	2665	-1.540	5.150	-1.530	5.070	0.010	-0.12
Rel. Quoted Spread	2665	1.730	2.310	1.740	2.340	-0.010	-0.08

Table 4: Impact of MTFs on commonality in liquidity

This table presents the regression analyses of stock liquidity on MTF aggregate liquidity for NYSE Arca Europe and Turquoise MTF samples. Cross-sectional averages of coefficients of time series firm by firm regression analyses are reported with t-statistics in parentheses. For each firm, daily proportional changes in an individual stock's liquidity measure are regressed in time series on proportional changes in the equal-weighted average liquidity for all stocks in their respective multilateral trading facility (MTF) in addition to an index composed of all stock traded in the home market:

$$\begin{aligned}\Delta \text{ Liquidity }_{i,t} = {} & \alpha + \beta_1 \, \Delta \, MTF\ Liquidity_t \text{x MTF}_t + \beta_2 \, \Delta \, Home\ Liquidity_t \text{x MTF}_t \\ & + \beta_3 \text{ MTF}_t + \beta_4 \, \Delta \, Home\ Liquidity_{t-1} + \beta_5 \, \Delta \, Home\ Liquidity_t \\ & + \beta_6 \, \Delta \, Home\ Liquidity_{t+1} + \beta_7 \, \Delta \, MTF\ Liquidity_{t-1} + \beta_8 \, \Delta \, MTF\ Liquidity_t \\ & + \beta_9 \, \Delta \, MTF\ Liquidity_{t+1} + \beta_{10} \, Home\ Return_{t-1} + \beta_{11} \, Home\ Return_t \\ & + \beta_{12} \, Home\ Return_{t+1} + \beta_{13} \, \Delta \text{ Volatility }_{i,t} + \varepsilon_{i,t}\end{aligned}$$

The change in liquidity of stock i is regressed on Lag, Concurrent, and Lead changes in the MTF market index (where the MTF index excludes stock i and all other stocks from the home market) and the Lag, Concurrent, and Lead changes in the Home market index (where the Home index excludes stock *i*). Home Return is the equal-weighted average of daily return of the all home market stocks excluding the MTF stocks. Volatility is the stock *i* return volatility, measured by the change in squared return from day $_{(t-1)}$ to day $_{(t)}$. MTF is an indicator variable that takes the value of zero for the period before stocks' entry dates and the value of one afterwards. $\Delta \, MTF\ Liquidity_t \text{x MTF}_t$ is the interaction terms between the MTF and the concurrent change in liquidity of MTF aggregate liquidity index. $\Delta \, Home\ Liquidity_t \text{ x MTF}_t$is the interaction terms between the MTF dummy variable and the concurrent proportional change in liquidity of Home market index.

	Turnover		Δ Amihud		Δ Relative Quoted Spread	
	NYSE Arca Europe	Turquoise	NYSE Arca Europe	Turquoise	NYSE Arca Europe	Turquoise
Δ MTF Liquidity_t x MTF	0.234***	0.216***	0.127***	0.075*	0.134***	0.032***
	(6.26)	(6.40)	(9.01)	(1.89)	(6.52)	(3.34)
Δ Home Liquidity_t x MTF	-0.193***	-0.299***	0.081***	-0.043*	-0.352***	-0.089**
	(-4.02)	(-7.31)	(4.66)	(-1.94)	(-6.34)	(-2.57)
MTF	-0.001***	-0.000	-0.384***	-0.602***	-0.007	0.036**
	(-3.07)	(-1.08)	(-10.52)	(-3.22)	(-0.56)	(2.24)
Δ Home Liquidity_{t-1}	0.113***	0.075***	-0.077***	-0.011***	-0.092***	0.020***
	(8.74)	(10.72)	(-11.73)	(-3.19)	(-3.71)	(3.60)
Δ Home Liquidity_t	0.933***	0.775***	0.518***	0.031***	1.513***	0.645***
	(17.71)	(23.24)	(36.35)	(4.70)	(26.54)	(22.61)
Δ Home Liquidity_{t+1}	0.083***	0.057***	-0.047***	0.005	-0.133***	0.020***
	(7.22)	(8.17)	(-7.27)	(1.19)	(-5.50)	(3.41)
Δ MTF Liquidity_{t-1}	-0.008	0.016**	0.010*	-0.013*	0.009	-0.004***
	(-0.78)	(2.27)	(1.78)	(-1.67)	(1.03)	(-3.43)
Δ MTF Liquidity_t	0.312***	0.175***	0.110***	0.023***	0.072***	0.009***
	(14.02)	(11.59)	(10.94)	(2.75)	(5.36)	(4.09)
Δ MTF Liquidity_{t+1}	-0.074***	-0.031***	0.048***	-0.025***	0.042***	-0.000
	(-5.57)	(-3.55)	(9.54)	(-3.59)	(5.01)	(-0.31)
Home Return_{t-1}	-0.074***	-0.023***	-0.788	0.225**	0.767	-0.382***
	(-12.46)	(-8.66)	(-0.29)	(2.11)	(0.89)	(-3.26)
Home Return_t	-0.041***	-0.011***	0.284***	0.354***	-0.286	-1.400***
	(-8.63)	(-5.38)	(8.38)	(2.95)	(-0.31)	(-11.35)
Home Return_{t+1}	-0.015***	-0.004**	-0.623**	-0.400***	-0.498	-0.329***
	(-4.06)	(-2.52)	(-2.27)	(-3.49)	(-0.64)	(-2.85)
Δ Volatility	0.456***	0.284***	1.521***	2.014***	0.228***	0.578***
	(26.46)	(40.71)	(86.06)	(44.43)	(12.00)	(16.76)
Intercept	0.000	-0.000***	0.637***	3.526***	0.104***	0.299***
	(-1.51)	(-3.53)	(15.11)	(32.90)	(10.31)	(26.62)
Mean R^2	0.221	0.155	0.101	0.045	0.033	0.041

Table 5: Placebo tests with control samples

This table presents the placebo regression analyses for control samples. Cross-sectional averages of coefficients of time series firm by firm regression analyses are reported with t-statistics in parentheses. Control samples are constructed using one-to-one MTF to control matching procedure by choosing the firm with nearest neighbor average of respective liquidity measure in the pre-transatlantic event period. Pseudo-MTF is an indicator variable that takes the value of zero for the period before matched treatment stocks' MTF entry dates and takes the value of one afterwards. Detailed variables definitions for other variables are provided in Table 4.

	Turnover		Δ Amihud		Δ Relative Quoted Spread	
	NYSE Arca Europe	Turquoise	NYSE Arca Europe	Turquoise	NYSE Arca Europe	Turquoise
Δ MTF Liquidity_t x Pseudo MTF	-0.062	0.027	0.057	-0.006	0.045	0.030**
	(-0.94)	(0.32)	(1.39)	(-0.18)	(1.64)	(2.18)
Δ Home Liquidity_t x Pseudo MTF	-0.377***	-0.324***	-0.063	0.011	-0.082	-0.039
	(-3.60)	(-3.07)	(-1.20)	(0.58)	(-1.11)	(-1.15)
Pseudo MTF	0.001***	0.001*	0.039	0.254*	-0.006	-0.020
	(3.72)	(1.91)	(0.35)	(1.69)	(-0.36)	(-1.51)
Δ Home Liquidity_{t-1}	0.118***	0.284***	-0.087***	-0.041	-0.097***	0.005
	(4.04)	(5.17)	(-3.46)	(-1.50)	(-3.16)	(0.46)
Δ Home Liquidity_t	1.352***	0.527***	0.598***	0.079***	1.326***	0.485***
	(11.30)	(7.79)	(15.72)	(3.23)	(18.42)	(12.03)
Δ Home Liquidity_{t+1}	0.032	0.123**	-0.017	-0.031*	-0.033	-0.031***
	(1.17)	(2.54)	(-0.81)	(-1.66)	(-1.28)	(-2.62)
Δ MTF Liquidity_{t-1}	0.029	0.069*	0.012	-0.090*	0.026*	0.004
	(1.11)	(1.80)	(0.56)	(-1.65)	(1.88)	(0.52)
Δ MTF Liquidity_t	0.009	0.204***	0.098***	-0.069	0.028*	0.013*
	(0.23)	(3.73)	(3.58)	(-1.30)	(1.95)	(1.70)
Δ MTF Liquidity_{t+1}	0.110***	0.119**	0.061***	0.009	-0.007	0.015**
	(3.68)	(2.50)	(3.22)	(0.21)	(-0.66)	(2.13)
Home Return_{t-1}	0.035***	0.040***	-3.425	0.153	0.259	-4.299*
	(3.41)	(3.59)	(-0.46)	(0.37)	(0.30)	(-1.85)
Home Return_t	0.044***	0.039***	0.243***	-0.019	0.774	-7.630***
	(5.17)	(3.33)	(3.12)	(-0.05)	(0.67)	(-3.27)
Home Return_{t+1}	0.032***	-0.018	1.114	-0.596	-0.448	-6.013**
	(3.56)	(-1.60)	(1.07)	(-1.15)	(-0.47)	(-2.53)
Δ Volatility	0.622***	0.465***	2.235***	3.595***	0.448***	0.852***
	(21.68)	(15.02)	(22.80)	(19.54)	(6.55)	(10.59)
Intercept	-0.001***	-0.000	1.181***	5.059***	0.055***	0.227***
	(-4.79)	(-1.13)	(5.74)	(10.97)	(3.99)	(15.28)
Mean R^2	0.114	0.117	0.091	0.142	0.059	0.049

Table 6: MTF volume and transatlantic commonality

This table presents the firm-by-firm regression analyses of the effect of MTF trading volume on liquidity commonality. Cross-sectional averages of coefficients of time series firm by firm regression analyses are reported with t-statistics in parentheses. MTF volume is the monthly aggregate trading volume of NYSE Arca Europe and Turquoise collected from the Federation of European Securities Exchanges (FESE). Detailed definitions of other variables are provided in Table 4.

	NYSE Arca Europe			Turquoise		
	Turnover	Δ Amihud	Δ Relative Quoted Spread	Turnover	Δ Amihud	Δ Relative Quoted Spread
Δ MTF $Liquidity_t$ x MTF Volume	0.029***	0.020***	0.021***	0.008*	0.023***	0.000
	(6.21)	(9.30)	(5.87)	(1.94)	(3.98)	(0.04)
Δ Home $Liquidity_t$ x MTF Volume	-0.069***	0.016***	-0.080***	-0.024***	0.006	-0.007
	(-8.33)	(6.02)	(-7.88)	(-4.25)	(1.48)	(-1.14)
MTF Volume	0.000***	-0.068***	0.006***	0.000	-0.177***	0.003
	(3.29)	(-11.62)	(2.72)	(0.70)	(-5.33)	(1.19)
Δ Home $Liquidity_{t-1}$	0.126***	-0.077***	-0.053**	0.066***	-0.014***	0.022***
	(9.70)	(-11.59)	(-2.13)	(9.52)	(-3.65)	(4.03)
Δ Home $Liquidity_t$	0.989***	0.514***	1.658***	0.903***	-0.063*	0.674***
	(18.68)	(37.63)	(27.21)	(15.93)	(-1.69)	(10.37)
Δ Home $Liquidity_{t+1}$	0.089***	-0.046***	-0.109***	0.051***	0.000	0.023***
	(7.30)	(-7.13)	(-4.50)	(7.15)	(0.07)	(3.91)
Δ MTF $Liquidity_{t-1}$	0.019*	0.009	0.015	0.007	-0.013	-0.004***
	(1.79)	(1.58)	(1.55)	(1.00)	(-1.62)	(-3.08)
Δ MTF $Liquidity_t$	0.329***	0.117***	0.069***	0.232***	-0.082*	0.032***
	(14.97)	(11.68)	(4.66)	(7.30)	(-1.87)	(2.76)
Δ MTF $Liquidity_{t+1}$	-0.048***	0.047***	0.046***	-0.028***	-0.016**	-0.001
	(-3.66)	(9.50)	(5.20)	(-3.60)	(-2.24)	(-0.76)
Home $Return_{t-1}$	-0.071***	-0.016	1.523*	-0.021***	0.317***	-0.314***
	(-12.35)	(-0.58)	(1.66)	(-8.50)	(2.96)	(-2.82)
Home $Return_t$	-0.044***	0.280***	1.432	-0.009***	0.306**	-1.359***
	(-8.86)	(8.30)	(1.49)	(-4.20)	(2.41)	(-11.37)
Home $Return_{t+1}$	-0.020***	-0.657**	0.296	-0.004**	-0.399***	-0.288**
	(-5.05)	(-2.40)	(0.35)	(-2.48)	(-3.49)	(-2.54)
Δ Volatility	0.456***	1.521***	0.224***	0.284***	2.065***	0.570***
	(26.50)	(85.85)	(11.27)	(40.72)	(39.73)	(16.74)
Intercept	-0.001***	0.628***	0.042***	-0.001***	5.315***	0.281***
	(-5.81)	(15.26)	(3.36)	(-4.67)	(15.00)	(10.74)
Mean R^2	0.220	0.101	0.036	0.147	0.045	0.041

Table 7: Commonality in liquidity excluding large stock exchanges

This table presents the firm-by-firm regression analyses of MTF stocks excluding large exchanges from the MTF liquidity. Cross-sectional averages of coefficients of time series firm by firm regression analyses are reported with t-statistics in parentheses. Panel A and Panel B present results for firms from NAE and Turquoise multilateral trading facilities respectively. The first model excludes all London Stock exchange firms from the calculation of the MTF aggregate market liquidity, while the second model excludes all U.S. firms. Detailed variables definitions are provided in Table 4.

Panel A: NYSE Arca Europe

	Excluding London			Excluding U.S.A.		
	Turnover	Δ Amihud	Δ Relative Quoted Spread	Turnover	Δ Amihud	Δ Relative Quoted Spread
Δ MTF Liquidity$_t$ x MTF	0.125***	0.124***	0.100***	0.445***	0.122***	0.172***
	(3.55)	(9.42)	(5.12)	(9.85)	(8.84)	(8.10)
Δ Home Liquidity$_t$ x MTF	-0.151***	0.083***	-0.362***	-0.425***	0.078***	-0.390***
	(-3.23)	(4.78)	(-6.54)	(-8.73)	(4.52)	(-6.93)
MTF	-0.001***	-0.383***	0.020*	-0.000**	-0.375***	-0.015
	(-3.40)	(-10.64)	(1.75)	(-2.19)	(-10.29)	(-1.23)
Δ Home Liquidity$_{t-1}$	0.122***	-0.078***	-0.088***	0.099***	-0.077***	-0.090***
	(9.96)	(-11.81)	(-3.52)	(7.64)	(-11.60)	(-3.63)
Δ Home Liquidity$_t$	0.932***	0.527***	1.519***	0.949***	0.519***	1.525***
	(18.90)	(37.79)	(26.72)	(17.94)	(36.35)	(26.45)
Δ Home Liquidity$_{t+1}$	0.097***	-0.048***	-0.130***	0.073***	-0.046***	-0.132***
	(8.05)	(-7.47)	(-5.37)	(5.84)	(-7.14)	(-5.40)
Δ MTF Liquidity$_{t-1}$	-0.015	0.006	-0.023**	-0.009	0.009	-0.001
	(-1.46)	(1.17)	(-2.56)	(-0.78)	(1.57)	(-0.12)
Δ MTF Liquidity$_t$	0.287***	0.082***	0.057***	0.318***	0.108***	0.057***
	(13.20)	(9.58)	(4.14)	(14.84)	(10.78)	(4.20)
Δ MTF Liquidity$_{t+1}$	-0.072***	0.038***	0.024***	-0.075***	0.045***	0.041***
	(-5.48)	(8.50)	(2.78)	(-5.50)	(8.94)	(4.95)
Home Return$_{t-1}$	-0.074***	-1.071	0.494	-0.072***	-1.134	0.518
	(-12.50)	(-0.39)	(0.57)	(-12.67)	(-0.41)	(0.60)
Home Return$_t$	-0.041***	0.275***	-0.446	-0.040***	0.291***	-0.303
	(-8.76)	(8.09)	(-0.49)	(-8.93)	(8.58)	(-0.33)
Home Return$_{t+1}$	-0.014***	-6.591**	-0.736	-0.017***	-6.802**	-0.652
	(-3.83)	(-2.42)	(-0.95)	(-4.61)	(-2.49)	(-0.84)
Δ Volatility	0.456***	1.524***	0.229***	0.459***	1.522***	0.228***
	(26.46)	(86.26)	(12.13)	(26.12)	(85.98)	(12.04)
Intercept	-0.000	0.709***	0.124***	-0.000	0.643***	0.107***
	(-0.01)	(16.90)	(12.50)	(-0.88)	(15.21)	(10.43)
Mean R^2	0.219	0.101	0.033	0.225	0.101	0.033

Panel B: Turquoise						
	Excluding London			Excluding U.S.A.		
	Turnover	Δ Amihud	Δ Relative Quoted Spread	Turnover	Δ Amihud	Δ Relative Quoted Spread
Δ MTF Liquidity_t x MTF	0.186*** (5.43)	0.134*** (3.97)	0.033*** (3.56)	0.324*** (8.54)	0.096*** (2.59)	0.189*** (6.79)
Δ Home Liquidity_t x MTF	-0.276*** (-6.93)	-0.049** (-2.15)	-0.093*** (-2.69)	-0.379*** (-9.34)	-0.057** (-2.50)	-0.101*** (-2.94)
MTF	-0.000 (-1.19)	-0.848*** (-4.74)	0.038** (2.38)	-0.000 (-1.27)	-0.685*** (-3.72)	-0.047** (-2.16)
Δ Home Liquidity_{t-1}	0.077*** (10.81)	-0.011*** (-3.15)	0.021*** (3.66)	0.082*** (11.37)	-0.012*** (-3.36)	0.019*** (3.40)
Δ Home Liquidity_t	0.778*** (23.30)	0.032*** (4.91)	0.645*** (22.65)	0.787*** (23.46)	0.032*** (4.86)	0.643*** (22.62)
Δ Home Liquidity_{t+1}	0.058*** (8.48)	0.004 (1.02)	0.020*** (3.41)	0.062*** (9.03)	0.005 (1.20)	0.018*** (3.10)
Δ MTF Liquidity_{t-1}	0.014** (1.99)	-0.013* (-1.92)	-0.004*** (-4.34)	-0.013 (-1.53)	-0.010 (-1.31)	0.009** (2.26)
Δ MTF Liquidity_t	0.181*** (11.67)	0.015* (1.91)	0.008*** (3.92)	0.200*** (12.18)	0.018** (2.14)	0.012*** (2.84)
Δ MTF Liquidity_{t+1}	-0.033*** (-3.80)	-0.016** (-2.51)	-0.001 (-0.81)	-0.050*** (-5.46)	-0.022*** (-3.21)	0.005 (1.60)
Home Return_{t-1}	-0.024*** (-9.02)	0.231** (2.19)	-3.985*** (-3.43)	-0.023*** (-8.95)	0.226** (2.14)	-3.291*** (-2.76)
Home Return_t	-0.012*** (-5.71)	0.331*** (2.74)	-13.907*** (-11.35)	-0.011*** (-5.29)	0.347*** (2.88)	-1.323*** (-10.59)
Home Return_{t+1}	-0.005*** (-2.94)	-0.402*** (-3.52)	-3.566*** (-3.05)	-0.005*** (-3.05)	-0.407*** (-3.57)	-3.454*** (-2.98)
Δ Volatility	0.284*** (40.66)	2.018*** (44.80)	0.577*** (16.67)	0.283*** (40.76)	2.017*** (44.61)	0.583*** (16.82)
Intercept	-0.000*** (-3.05)	3.504*** (33.35)	0.301*** (26.84)	-0.000** (-2.42)	3.521*** (33.66)	0.288*** (25.54)
Mean R^2	0.153	0.044	0.041	0.157	0.045	0.042

Table 8: Non-Cross listed MTF firms

This table presents firm-by-firm regression analyses of the MTF samples excluding NYSE cross-listed firms. Cross-sectional averages of coefficients of time series firm by firm regression analyses are reported with t-statistics in parentheses. Detailed variables definitions are provided in Table 4.

	NYSE Arca Europe			Turquoise		
	Turnover	Δ Amihud	Δ Relative Quoted Spread	Turnover	Δ Amihud	Δ Relative Quoted Spread
Δ MTF Liquidity_t x MTF	0.235***	0.125***	0.133***	0.210***	0.089**	0.036***
	(6.20)	(8.77)	(6.42)	(6.17)	(2.30)	(3.61)
Δ Home Liquidity_t x MTF	-0.198***	0.079***	-0.340***	-0.299***	-0.045**	-0.089**
	(-4.06)	(4.50)	(-6.11)	(-7.30)	(-2.02)	(-2.57)
MTF	-0.001***	-0.375***	-0.007	-0.000	-0.643***	0.036**
	(-3.00)	(-10.18)	(-0.59)	(-0.90)	(-3.49)	(2.19)
Δ Home Liquidity_{t-1}	0.113***	-0.077***	-0.091***	0.075***	-0.011***	0.021***
	(8.63)	(-11.64)	(-3.64)	(10.72)	(-3.16)	(3.65)
Δ Home Liquidity_t	0.940***	0.520***	1.509***	0.776***	0.031***	0.640***
	(17.54)	(36.17)	(26.19)	(23.20)	(4.70)	(22.52)
Δ Home Liquidity_{t+1}	0.084***	-0.047***	-0.134***	0.057***	0.005	0.019***
	(7.24)	(-7.29)	(-5.46)	(8.25)	(1.22)	(3.33)
Δ MTF Liquidity_{t-1}	-0.008	0.010*	0.008	0.015**	-0.016**	-0.004***
	(-0.76)	(1.75)	(0.86)	(2.14)	(-2.01)	(-3.37)
Δ MTF Liquidity_t	0.313***	0.111***	0.073***	0.173***	0.023***	0.009***
	(13.81)	(10.92)	(5.40)	(11.51)	(2.73)	(4.09)
Δ MTF Liquidity_{t+1}	-0.072***	0.048***	0.043***	-0.031***	-0.025***	-0.000
	(-5.40)	(9.49)	(5.15)	(-3.56)	(-3.61)	(-0.33)
Home Return_{t-1}	-0.074***	0.038	0.696	-0.022***	0.222**	-3.902***
	(-12.26)	(0.01)	(0.81)	(-8.47)	(2.08)	(-3.34)
Home Return_t	-0.040***	0.273***	-0.313	-0.011***	0.346***	-1.390***
	(-8.37)	(8.06)	(-0.34)	(-5.20)	(2.86)	(-11.31)
Home Return_{t+1}	-0.014***	-0.644**	-0.435	-0.004**	-0.403***	-3.560***
	(-3.88)	(-2.38)	(-0.56)	(-2.37)	(-3.53)	(-3.04)
Δ Volatility	0.459***	1.519***	0.227***	0.284***	2.022***	0.581***
	(26.30)	(85.43)	(11.90)	(40.71)	(44.27)	(16.75)
Intercept	-0.000	0.633***	0.102***	-0.000***	3.536***	0.301***
	(-1.54)	(14.89)	(10.09)	(-3.61)	(32.78)	(26.77)
Mean R^2	0.222	0.101	0.034	0.155	0.045	0.041

Table 9: Counterfactual Evidence: Reduced number of MTFs with NAE closure

This table presents firm-by-firm regression analyses of combined sample of NYSE Arca Europe (NAE) and Turquoise Multilateral trading facilities. Each column shows the cross-sectional averages of time series slope coefficients with t-statistics in parentheses MTF Liquidity# is defined as the aggregate liquidity index of Turquoise MTF. #MTF is categorical variable that takes value of zero if the stock is not traded in either NAE or Turquoise MTFs, 1 if traded in one MTF and 2 if traded on both MTFs. After the NAE closure date on April, 21, 2014, MTF takes the value 1 if the firms are still traded on Turquoise and 0 otherwise.

	Turnover	Δ Amihud	Δ Relative Quoted Spread
Δ MTF Liquidity$_t$ x #MTF	0.203***	0.063*	0.025***
	(6.74)	(1.69)	(3.18)
Δ Home Liquidity$_t$ x #MTF	-0.241***	-0.032	-0.093***
	(-6.76)	(-1.54)	(-3.52)
#MTF	-0.000**	-0.564***	0.031**
	(-2.14)	(-3.26)	(2.48)
Δ Home Liquidity$_{t-1}$	0.061***	-0.013***	0.025***
	(9.14)	(-3.55)	(4.02)
Δ Home Liquidity$_t$	0.770***	0.050***	0.671***
	(24.18)	(7.15)	(24.05)
Δ Home Liquidity$_{t+1}$	0.042***	0.006	0.019***
	(6.01)	(1.37)	(2.94)
Δ MTF Liquidity$_{t-1}$	0.016**	-0.015**	-0.003*
	(2.34)	(-2.06)	(-1.73)
Δ MTF Liquidity$_t$	0.177***	0.023***	0.007**
	(12.82)	(2.89)	(2.39)
Δ MTF Liquidity$_{t+1}$	-0.021***	-0.023***	0.002*
	(-2.61)	(-3.44)	(1.81)
Home Return$_{t-1}$	-0.019***	0.209**	-3.389***
	(-7.74)	(2.04)	(-2.98)
Home Return$_t$	-0.007***	0.346***	-1.395***
	(-3.42)	(3.05)	(-11.85)
Home Return$_{t+1}$	-0.002	-0.381***	-3.365***
	(-1.39)	(-3.46)	(-3.03)
Δ Volatility	0.283***	2.003***	0.574***
	(41.24)	(46.25)	(17.48)
Intercept	-0.000**	3.450***	0.292***
	(-2.33)	(32.60)	(26.40)
Mean R^2	0.144	0.047	0.040

Table 10: Commonality in liquidity: Alternative measure R^2

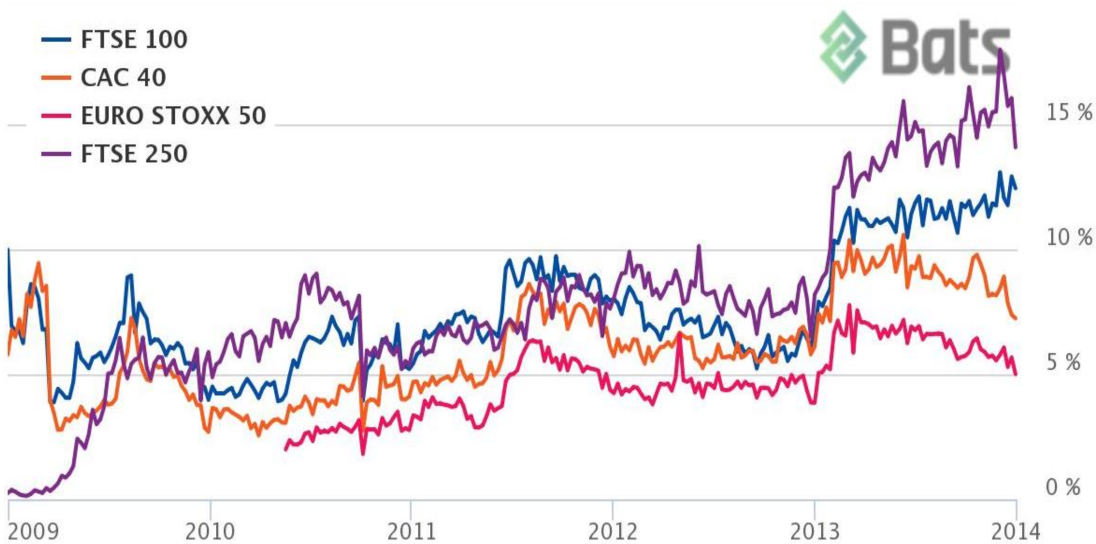
Commonality in liquidity is measured as the equally-weighted average Adjusted R^2 of the individual stocks traded in multilateral trading facility (MTF) in the post transatlantic trading period. Adj-R^2 Home is average adj-R^2 of firm-by-firm regressions of individual stocks' liquidity on the aggregate level of liquidity in the Home market index only in the partial model. Adj-R^2 MTF & Home is average adj-R^2 of firm-by-firm regressions of individual stocks' liquidity on the aggregate level of liquidity in the Home market index as well as the MTF index in the full model:

$$\Delta \text{ Liquidity}_{i,t} = \alpha + \beta_1 \Delta\, Home\ Liquidity_{t-1} + \beta_2 \Delta\, Home\ Liquidity_t + \beta_3 \Delta\, Home\ Liquidity_{t+1} + \beta_4 \Delta\, MTF\ Liquidity_{t-1} + \beta_5 \Delta\, MTF\ Liquidity_t + \beta_6 \Delta\, MTF\ Liquidity_{t+1} + \varepsilon_{i,t}$$

Difference column presents the difference in means in adj-$R^2$of the two models. T-statistic represent the significance of the difference in R^2.

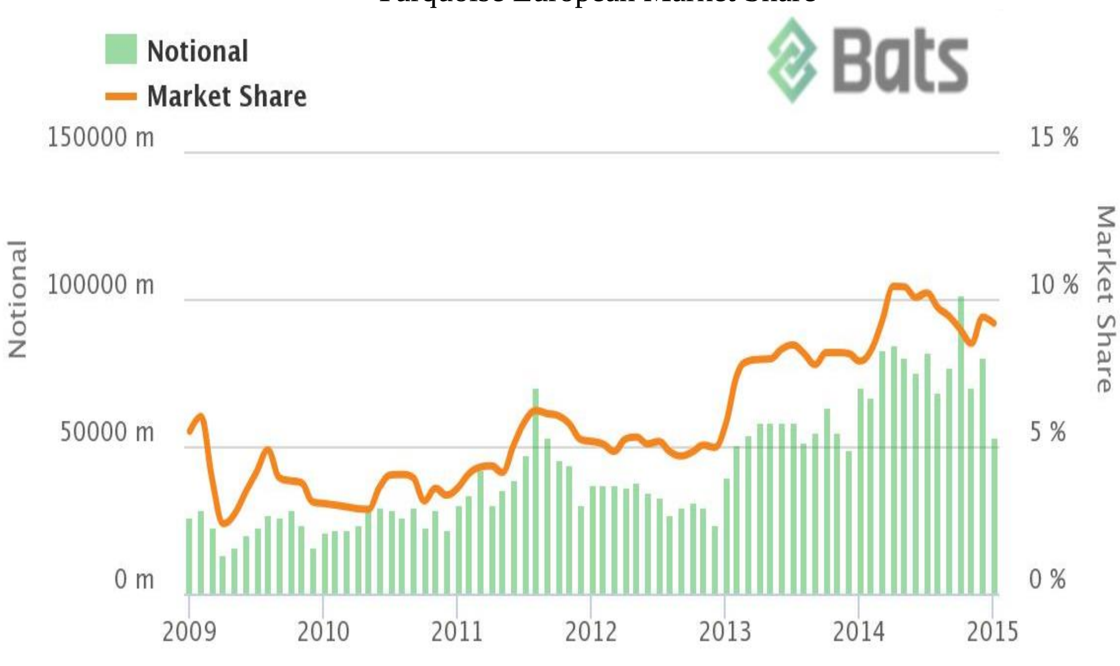
Variable	Adj-R^2 Home	Adj-R^2 MTF & Home	difference	t-stat	% Δ R^2
		NYSE Arca Europe			
Turnover	9.13%	14.36%	5.23%***	9.78	57%
Δ Amihud	2.55%	3.26%	0.71%***	6.12	28%
Δ Relative Quoted Spread	1.07%	1.19%	0.13%	1.57	12%
		Turquoise			
Turnover	5.57%	10.44%	4.86%***	16.29	87%
Δ Amihud	0.73%	1.66%	0.93%***	7.90	128%
Δ Relative Quoted Spread	2.77%	3.08%	0.31%	1.20	11%

Figure1: Turquoise Blue-chips Indices & Market Share



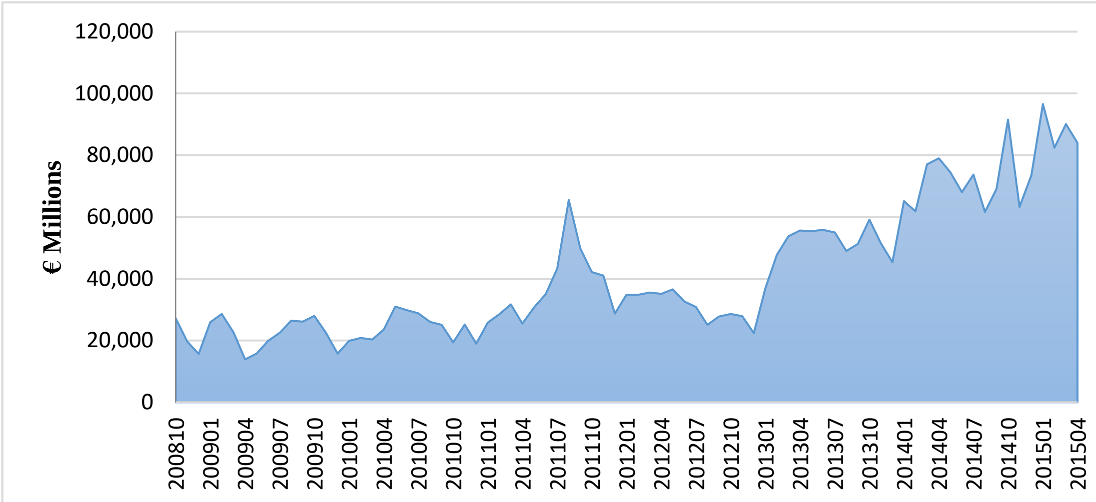
Source: www.BATS.com

Turquoise European Market Share



Source: www.BATS.com

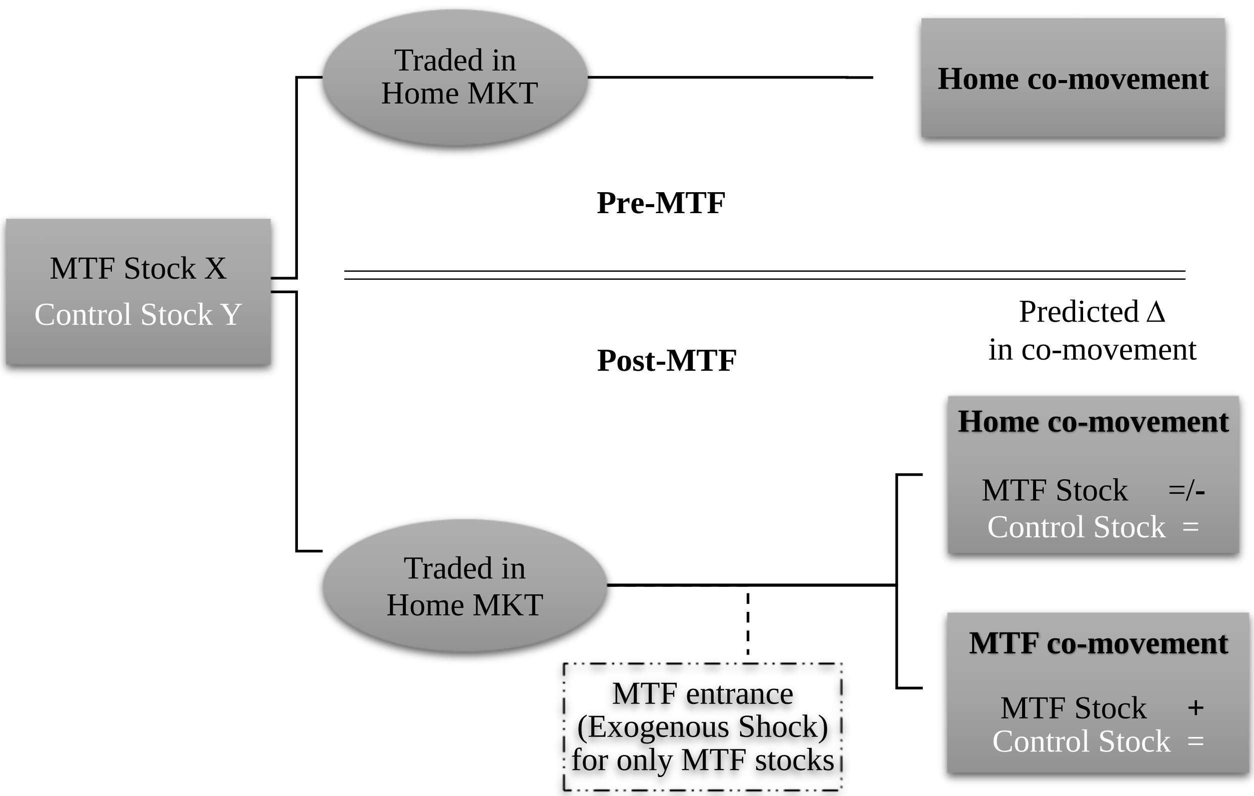
Figure 2:Turquoise Trading Value



Data source: Federation of European Securities Exchange

Appendix

Figure A.1: Research design



Background Information and NAE Market Structure:

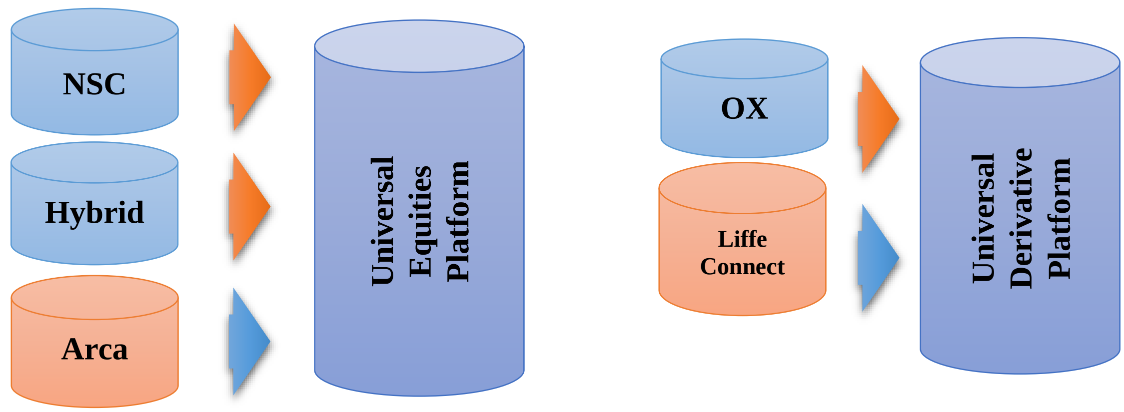
The New York Stock Exchange's (NYSE's) $11billion acquisition of Euronext gave the group control of several major markets in Europe and US, supported by four underlying trading platforms: Arca (for Arca stocks and Arca derivatives), the traditional NYSE order book in the US, the Nouveau Systeme de Cotation (NSC) supporting the Euronext markets, and Liffe Connect for the derivative market. In February 2008 NYSE Euronext began a two-year program to decommission these four platforms and create the Universal Trading Platform (UTP) to support all of its markets. The ultimate goal of such project is that NYSE-Euronext, at the end, will have a global network for both European and US customers. This means that from one single connection, customers will be able to access all NYSE Euronext trading and market data services. Figure A.2 shows the consolidation process of NYSE-Euronext group.

Developing one platform that is sufficiently flexible to suit a different exchange's global needs is an ambitious plan. As for the construction of the UTP, Euronext may have been NYSE's biggest single corporate transaction, but it was only part of a strategy to build scale and technology capabilities through acquisitions. A few weeks after the closure of the Euronext deal in April 2007, NYSE acquired TransactTools, a provider of enterprise messaging, in mid-2008, it acquired Wombat Financial Software, a market data distribution technology provider, all of this in addition to acquiring Archipelago, in 2006, for handling high-volume trading. According to Exchange officials, the UTP brings together the fruits of all of those acquisitions to present customers with a more competitive global offering. The result of that best-of-breed approach is a platform that can deliver latency of 150-400 microseconds, with sub-millisecond round-trip times available to customers in co-location with the search engine. The UTP Capacity is able to handle 100,000 orders per second. Figure A.3 shows the key components of the universal trading platform.

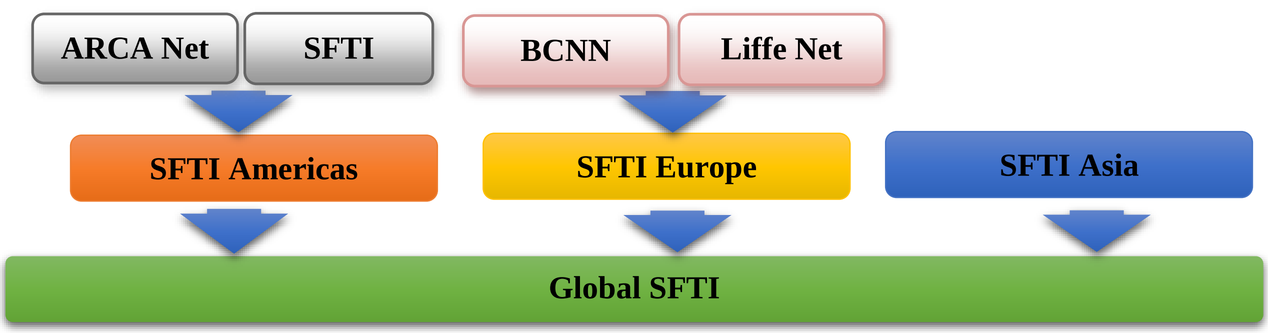
Figure A.2: Consolidation Process in NYSE-Euronext

Figure A.2 shows the consolidation process in NYSE-Euronext group. Panel A shows the replacement of Arca, traditional Hybrid in the US in addition to Nouveau Systeme de Cotation (NSC) in Europe by a single Universal equity platform. In Panel B shows the consolidation of networks in two steps, the first consolidation of European networks Secure Financial Transaction Infrastructure (SFTI) Europe, US networks into SFTI Americas and extend the network to give Asian investors access to NYSE–Euronext group markets. In the second step, the three SFTI networks are connected to each other through one big global SFTI network. Finally, in Panel C, we show the consolidation of data centers, or Liquidity centers, from 10 data centers into 4. The Basildon liquidity center, in UK, is responsible providing a colocation trading facility for all NYSE-Euronext's European markets. However, Mahwah liquidity center located in New Jersey, USA is charged for handling US markets. (Source NAE website.)

Panel A: Consolidation of Platform



Panel B: Consolidation of Networks



Panel C: Consolidation of 10 data (Liquidity) centers (before merger)

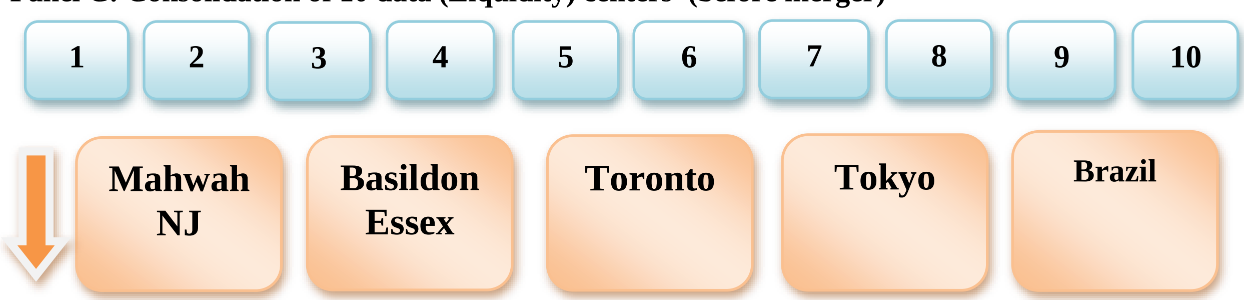
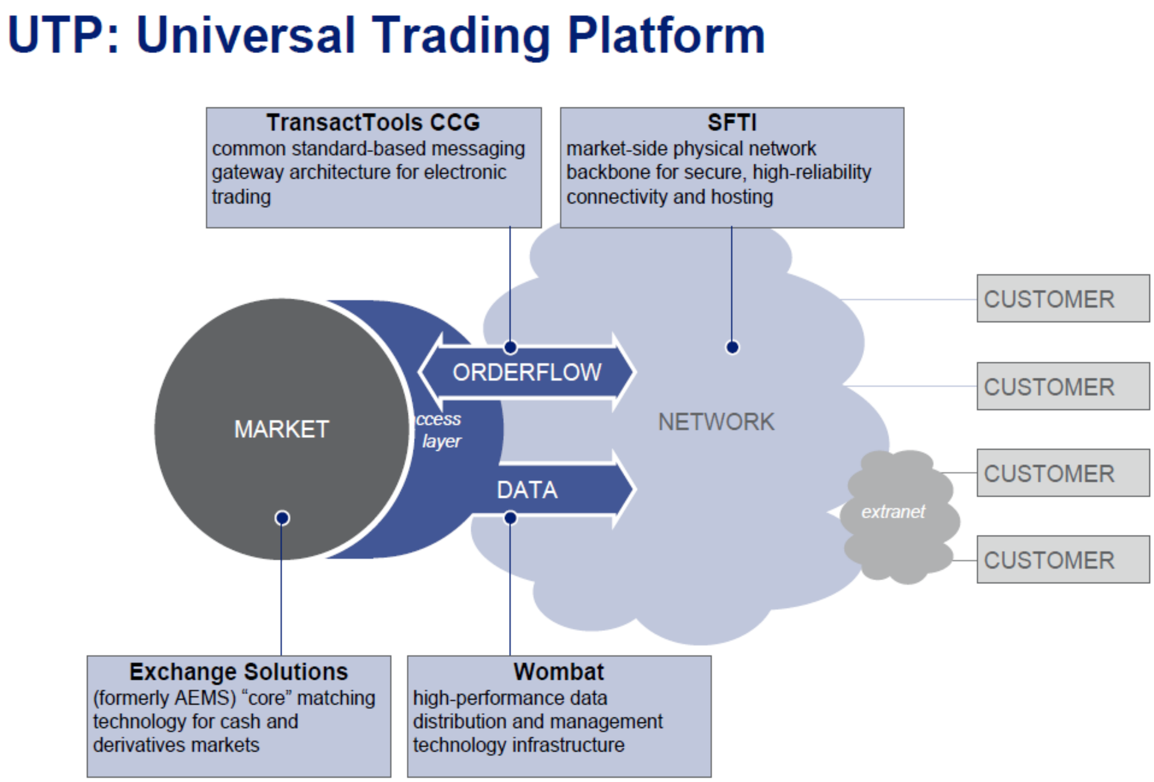


Figure A.3: The Universal Trading Platform

Figure 3 shows the construction of Universal Trading Platform. Customers can access UTP through the SFTI network or through and extranet that is connected to the SFTI network. The SFTI network connects customers to the matching engine for both cash and derivative markets. In the middle layer between customers and Market matching engine, the TransactTools provides the customer with a Common Customer Gateway (CCG) for electronic trading of all NYSE-Euronext group markets including NYSE Arca Europe. In addition, Wombat works as high-performance data distributors to all market participants.



Source: NYSE-Euronext website