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Abstract

The equity trading landscape all over the world has changed dramatically in recent years. We have witnessed the advent of new trading venues and significant changes in the market shares of existing ones. We use an extensive panel dataset from the European equity markets to analyze the market shares of five categories of lit and dark trading mechanisms. Market design features, such as minimum tick size, immediacy and anonymity; market conditions, such as liquidity and volatility; and the informational environment have distinct implications for order routing decisions and trading venues' resulting market shares. Furthermore, these implications differ distinctly for small and large trades, probably because traders jointly optimize their trade size and venue choice. Our results both confirm and go beyond current theoretical predictions on trading in fragmented markets.

Keywords: Dark Trading, Fragmentation, Anonymity, Immediacy

JEL Classification: G10, G12

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1. Introduction

A considerable fraction of trading in the US and European equities market is conducted in markets that do not have perfect pre-trade transparency and/or do not provide uniform access to all investors. Some off-book markets encompass a variety of market models such dark pools (predominantly crossing networks), internalization of customer orders by broker-dealers, and bilateral negotiation in the over-the-counter (OTC) market. Public lit markets, on the other hand, include transparent limit order markets operated by established exchanges and new competitors.

Some forms of off-book trading are subject to less stringent trading venue regulation as compared to the lit markets. These regulatory differences likely affect traders' order routing decisions. An understanding of the relative attractiveness of different mechanisms is a precondition to the analysis of their impact on various dimensions of market quality, such as liquidity and price efficiency. Empirical research examining the determinants of traders' order routing choices to different types of venues is limited. In this paper, we attempt to fill this gap.

Traders' order routing decisions likely involve at least two dimensions - order size and choice of the venue. Moreover, decisions along these two dimensions are likely to be co-determined. For example, a passive mutual fund may decide to re-balance its portfolio by splitting up the orders in individual stocks and executing them simultaneously on different venues. Alternatively, the fund manager may decide to negotiate a price for the entire portfolio in the OTC market. In general, this joint choice of order size and trading venue will be a function of investors' trading motives, the size and composition of their portfolios, market conditions, and the trading protocols of the venues which are accessible to them. The market shares of the different trading venues will, in turn, be the outcome of the combined choices of all investors.

We examine the determinants of these market shares in the European equities market. Our data allows us to separate trading mechanisms into five categories: continuous lit trading, trading in auctions, dark pools, internalization platforms, and the OTC market. We focus on the impact of the different protocols employed by these markets on their market shares. Our empirical approach is similar to Boehmer et al. (2007) who examine the impact of SEC-mandated execution quality reports published by market centers on traders' order-routing decisions.

The paper makes four main contributions to the literature. Existing theoretical models examining order routing decisions do so in a simplified setting involving one lit and one off-book market. For example, Zhu (2014), Ye (2011), and Buti et al. (2011) investigate these decisions in the presence of a crossing network and an exchange operating either as a dealer market or as a limit order market. In Seppi (1990), traders choose between a dealer market and an OTC block trading venue. Empirical studies, with the exception of Fong et al. (2001), do not distinguish between different categories of dark markets either. We argue that such a granular categorization is necessary to uncover the different motives underlying traders' order routing decisions and their relationship to the specific trading protocols of the different venues and market conditions. For example, we find that the market share of dark pools is reduced when depth in the main market increases, presumably because higher depth in the main market makes trading in dark pools relatively less attractive. At the same time, however, we find that the market share of large OTC trades increases, possibly because OTC dealers can more easily unwind large positions when depth in the main market is high and are therefore more willing to take large positions on their books. Thus, an increase in the depth on the main market has different implications for the different trading venues.

Second, our analysis considers the joint choice of trading venue and order size. Venues differ from each other in terms of their absorptive capacity as proxied by the trade size.[1] 56% of the total volume is executed in the continuous lit markets, predominantly using small trades. This is likely due to the activity of high frequency traders and of algorithms that slice large orders into small pieces and execute them over a period of time. At the other extreme, the OTC market, which accounts for 31% of total volume, for the most part involves large trades. Considering the joint choice of trading venue and order size also allows us to identify variables that have a different impact on the attractiveness of a trading venue for small and large trades. For example low liquidity is associated with higher costs of trading in the lit market. On the one hand this should make OTC trading relatively more attractive. However, it is also associated with higher inventory and/or adverse selection risk for OTC dealers as it becomes more costly for them to unwind their positions. Consistent with this argument we find that higher spreads in the main market result in a higher OTC market share for small trades but in a lower OTC market share for large trades.

Third, we show that variations between the different venues along two dimensions - immediacy and anonymity - allow traders to optimally choose the best venue given their underlying

[1] Pagano (1989) argues that fragmented markets have a tendency to consolidate due to network externalities. However, if the markets differ in terms of their absorptive capacity, fragmented markets can co-exist.

motives to trade. We define immediacy as the extent to which market participants are able to trade instantaneously and with certainty. A venue allowing traders to trade with high probability and speed provides a high level of immediacy. Anonymity refers to traders' ability to execute an order without disclosing her identity to other market participants. Figure 1 maps the different venues along these two dimensions. Lit continuous order books (such as those operated by exchanges) provide high levels of immediacy and anonymity because traders can anonymously access these venues at high speeds and trade with complete certainty by accepting publicly available prices. Auctions operated by exchanges, while providing the same level of anonymity, offer low immediacy as these are scheduled at fixed points in time. Off-exchange venues (with the exception of public dark pools) are comparatively less anonymous and have a level of immediacy between that of continuous lit markets and auctions. For example, customers having a trading relationship with OTC dealers can trade non-anonymously with certainty, although trading speeds may be slower. Dark pools and internalizers offer more anonymity and higher speeds than the OTC market. However, a lower (higher) execution probability in dark pools (internalizers) means immediacy is limited (high).

We find that there is a jump in OTC activity in very large trade sizes around a stock's ex-dividend date. These trades likely pertain to the set-up and unwinding of delta-neutral tax arbitrage strategies and are largely uninformed. The OTC market is the preferred choice of venue for such trades, as its lack of anonymity allows investors who can credibly signal their uninformed motive to negotiate better prices for which they are willing to sacrifice immediacy (Seppi, 1990). The exact opposite is observed around earnings announcements. Order flow shifts away from the OTC market (as well as from auctions) and towards the continuous lit market as informed traders value the high level of immediacy and anonymity offered by the lit market. Dark pool market share also increases around earnings announcements as their opaque nature allows traders to better hide their trading intentions (Ye, 2011). OTC market share, on the other hand, decreases, most likely because OTC dealers are unwilling to take on inventory risk in times of high informational asymmetry.

Finally, our paper contributes to the debate on cream skimming and tick size violations. Degryse et al. (2015) and Hatheway et al. (2016) observe that off-book venues in the Dutch and US equity markets respectively, cream-skim uninformed order flow away from lit venues (Easley et al., 1996). Hatheway et al. (2016) associates this to sub-penny pricing i.e., exemption from SEC Rule 612 which mandates lit venues to not trade at an increment below $0.01, in the US. In our sample we also observe that between 20% and 40% of off-book trades violate the tick sizes agreed to by exchanges and other lit public markets. However, almost all dark pool tick violations appear to be trades crossed at the exchange midpoint. On the other hand, internalizing dealers and OTC dealers sometimes do seem to provide trivial price improvements over lit market quotes. This could be because OTC and internalizing dealers at least partially utilise their risk capital to provide liquidity to their customers, whereas dark pools identified in our data match buyers and sellers without the operator's involvement.

Our results have two major policy implications specifically related to the introduction of MiFID II in the EU. First, MiFID II requires the implementation of two caps on trading in dark pools. An individual dark pool is not allowed to be responsible for more than 4% of total trading volume, and the market share of all dark pools cannot jointly exceed 8% of total trading activity.[2] Our results, which are mainly applicable to liquid European stocks, suggest that the anonymity offered by regulated dark pools is especially important to informed market participants. If the caps constrain them to operate in dark pools, their orders may have to be routed to the public lit markets which, in turn, might have implications for liquidity and price discovery. Second, MiFID II introduces market-wide regulator-mandated tick sizes. However, this regulation does not extend to OTC and internalizing dealers. Dealers circumventing price priority in the lit market by providing trivial price improvements reduce the incentives of liquidity providers to provide competitive quotes in public lit markets. Therefore, regulators should consider the role played by non-standard tick sizes as part of the cost-benefit trade-off associated with off-book trading.

The remainder of the paper is structured as follows. Section 2 provides a survey of the related literature. Here we describe the theoretical and empirical literature related to our results. In Section 3 we describe the institutional background of European equity markets, specifically focusing on the changes observed since MiFID was operationalized in November 2007. Section 4 presents the data and the filters applied to it, and also presents some descriptive statistics. It also examines the role of non-standard tick sizes in dark markets. The empirical methodology and the results are discussed in Section 5. Finally, we conclude in Section 6.

[2] As per ESMA (2015, p. 171), "*Both volume caps are measured against a rolling 12 month period with monthly updates published by ESMA, as well as updates published twice a month in certain circumstances.*"

2. Related Literature

Our paper is related to several strands of the literature. In this section we briefly review the literature on OTC trading, the literature on competition between trading venues and the fragmentation it entails, and the literature on dark trading.

The literature that explicitly analyzes OTC trading in equity markets is scant. Gomber et al. (2011) estimate that OTC trading accounts for about 40% of equity trading in Europe. This is much higher than the 17% OTC market share reported for the U.S. in Tuttle (2014). Fong et al. (2001) use data from Australia and show that off-market trading is driven by institutional trading interest and liquidity. Ang et al. (2013) consider the valuation of unlisted OTC-traded stocks. These are very small, illiquid stocks that are not listed on an exchange. This is a market segment which is very different from the blue chip stocks in our sample.

We analyze the co-existence of lit markets (regulated markets and new competitors) on one hand, and different types of dark markets on the other. Consequently, our paper is related to previous research on competition between equity markets. Several papers analyze the coexistence of identically organized markets and conclude that there is a tendency towards centralization (for example, Pagano (1989), Chowdhry and Nanda (1991)). Madhavan (1995) argues that, if trade disclosure is not mandatory, large traders and market makers benefit from a fragmented market; consequently, markets need not consolidate. Other papers focus on the relation between the upstairs and the downstairs market on the NYSE and argue that the non-anonymity of the upstairs market reduces adverse selection costs (Seppi (1990)), and allows dealers in the upstairs market to serve as a repository for unexpressed demand (Grossman (1992)). Empirical evidence provided by Madhavan and Cheng (1997) and Booth et al. (2002) suggests that adverse selection costs are indeed lower in the upstairs market.

Boehmer et al. (2007), Menkveld et al. (2016), and Degryse et al. (2016) examine traders' order routing choices to alternative trading mechanisms. Boehmer et al. (2007) find that publication of monthly execution reports by exchanges, Electronic Communication Networks (ECN), and NASDAQ dealers affects the subsequent order flow routed to these venues. In a study contemporaneous to ours, Menkveld et al. (2016) document a pecking order in terms of trading costs and immediacy determining traders' intraday order routing decisions to different lit and dark venues in the US. Degryse et al. (2016) examine the tradeoff between submitting hidden orders on otherwise public lit markets versus accessing off-book markets and find that they are imperfect substitutes of each other such that off-book venues do not appear redundant.

Competition between markets results in fragmentation. O'Hara and Ye (2011) analyze the fragmentation in US equity markets empirically. They conclude that fragmentation is not harmful, and that "while US equity markets are spatially fragmented, they are, in fact, virtually consolidated into a single market" (pp. 460-461). The latter statement is reminiscent of Harris (1993) who introduced the concept of segmented markets. Several other papers (e.g. Boehmer and Boehmer (2003) for the ETF market, Foucault and Menkveld (2008) for Dutch equities and Mayhew (2002) for the equity options market) confirm the beneficial role of competition. Hengelbrock and Theissen (2009) and Chlistalla and Lutat (2011) analyze the market entry of a new competitor and conclude that this event had a positive impact on liquidity in the main market. A growing body of literature analyzes the coexistence of an exchange and an off-book market (such as crossing network). Hendershott and Mendelson (2000), Degryse et al. (2009) and Dönges and Heinemann (2013) develop theoretical models of competition between a dealer market and a crossing network, and conclude that the welfare implications of introducing a crossing network are ambiguous. Ye (2011) adds a crossing network to the Kyle (1985) framework and finds that the crossing network reduces both price discovery and volatility. Buti et al. (2016) show that a crossing network, if introduced alongside a transparent limit order book, diverts order flow away from the limit order book. Zhu (2014) concludes that the relation between the degree of adverse selection and the market share of the dark crossing network is non-monotonic. Investors trade off the higher execution cost at the exchange against the higher execution risk at the crossing network. The probability of non-execution is higher for informed investors because they are more likely to be on the long side of the market. Therefore, the crossing network is relatively more attractive for uninformed traders. At low levels of adverse selection, an increase in that level attracts uninformed traders to the crossing network while informed traders still prefer to trade at the exchange. Beyond a certain threshold level of adverse selection, informed investors start to also use the crossing network. Uninformed traders then migrate back to the exchange. The second effect dominates the first and, consequently, the market share of the crossing network decreases.

The empirical evidence on the effects of off-book trading is inconclusive. Buti et al. (2011) find that dark pool activity has positive effects on liquidity but ambiguous effects on price efficiency. Gresse (2006) also finds that trading activity in a crossing network has a positive effect on liquidity. She attributes this positive effect to risk-sharing benefits from trading in the crossing network. Degryse et al. (2015) and Gresse (2016) differentiate between fragmentation across lit and dark markets and conclude that fragmentation across lit markets has positive effects on market quality. With respect to off-book volume, the two papers disagree. While Degryse et al. (2015) report that an increase in off-book volume has negative implications, Gresse (2016) concludes that both quoted spreads and depth increase, but that the combined effect on effective spreads is neutral. Hendershott and Jones (2005) analyze an episode of slightly more than a year during which the Island ECN chose to stop displaying quotes for three actively traded ETFs. They find that market quality in Island deteriorated. The setting that is analyzed in Hendershott and Jones (2005) is special, though, because Island was the dominant market for these ETFs.

Conrad et al. (2003) report that execution costs for trades in crossing networks (and even more so in Electronic Communication Networks) are lower than those in traditional markets. This result is consistent with findings by Hatheway et al. (2016) and Comerton-Forde and Putniņš (2015) who show that orders executing in dark trading venues are predominantly uninformed. As a consequence, adverse selection risk and bid-ask spreads in lit markets increase when the level of dark trading is high. A complementary result is reported by Garvey et al. (2016). They find that traders are more likely to execute orders in dark venues when the bid-ask spread in the lit market is high. Ready (2014), on the other hand, finds that institutional investors' usage of the crossing network is lower for stocks with higher adverse selection risk. The results of all these papers are consistent with the theoretical predictions in Zhu (2014). However, while the findings in Conrad et al. (2003), Hatheway et al. (2016), Comerton-Forde and Putniņš (2015) and Garvey et al. (2016) support the predictions the model makes for low levels of adverse selection, the cross-sectional results in Ready (2014) are consistent with the model's implications for high levels of adverse selection. The latter statement also applies to the results reported in Nimalendran and Ray (2014) who present evidence that informed investors split their trades across dark and lit venues. Boni et al. (2013) conclude that the extent of informed trading in a dark pool depends on the design of its trading protocol, and in particular on whether there are rules that limit or preclude the access of brokers and high-frequency traders to the system. In fact, while some dark pools, such as Liquidnet and POSIT, match trades of buy-side institutions without the intervention of a market maker, this is not true for other dark pools (Ready (2014)).

3. Institutional Background

In Europe until late 2007, the regulatory environment of securities trading was defined by the "Investment Services Directive (ISD)" established in 1993. Incumbent exchanges in many of the EU member states managed to sustain a quasi-monopolistic position in the "market for markets" for a long time as ISD allowed the member states to have concentration rules, which required all orders (in some cases above a certain size threshold) to be executed on the national exchange, or default rules, which required customers to explicitly choose to trade outside the listing exchange. For example, the concentration rules existed in Italy, Spain and France, and the default rule in Germany. A significant change in the competition for order flow in Europe was triggered by the European Commission enacting the Markets in Financial Instruments Directive (MiFID), with the objective of "*. . . enabling investors to trade securities at maximum efficiency and at minimum cost.*" (EC, 2004). This was to be achieved through increased transparency and accessibility of markets, better investor protection and market integrity, harmonization of European regulation, and creation of a level playing field among different types of trading venues to ensure competition and foster innovation. MiFID became operational in November 2007.

MiFID defines three categories of trading venues: "Regulated Markets (RM)", "Multilateral Trading Facilities (MTF)" and "Systematic Internalisers (SI)". RMs reflect the incumbent exchanges, whereas MTFs and SIs represent new categories in European securities legislation. While RMs and MTFs constitute multilateral trading, i.e. bringing together the trading intentions (orders) of multiple buyers and sellers, SIs are investment firms that execute client orders against their own account. Over the counter (OTC) trading, which also is a form of bilateral trading, is the residual category.[3] As per Recital 53 of MiFID, this category includes trades which are (i) performed on an ad-hoc and irregular bilateral basis, (ii) carried out with wholesale counterparties, (iii) part of a business relationship which is itself characterized by dealings above standard market size and (iv) carried out outside the systems usually used by the firm concerned for its business as an SI.[4]

As regulators saw the trade-off between the potential for transaction cost reductions and service improvements due to competition between trading venues on the one hand, and the potential adverse impact of order flow fragmentation on the efficiency of the price formation

[3]OTC trading is not classified by MiFID as a separate venue. In fact, it is only mentioned once in the entire MiFID text.

[4]MiFID uses a subjective criterion to identify SIs resulting in some internalizing brokers reporting their trades under the OTC category.

process on the other hand, they imposed best execution obligations for brokers and pre- and post-trade transparency requirements for each category of trading venues. In contrast to the US where best execution with respect to prices publicly quoted on exchanges is guaranteed through the order protection rule and the consolidated tape,[5] in the EU the responsibility to ensure best execution lies with the brokers. While establishing their best execution policies, brokers may consider dimensions such as speed, likelihood of execution and costs, in addition to price, while making a reasonable effort to obtain the best possible result for their clients.

The rules concerning pre- and post-trade transparency are similar for RMs and MTFs. Pre-trade transparency requires them to publish bid and offers and market depth for shares admitted to trading on an RM. The details on transparency depend on the market model of the system, i.e., whether it is a continuous trading system, a quote-driven trading system, a periodic auction trading system or any other trading system. Investment firms that are classified as SI also have to fulfill certain pre-trade transparency obligations. Concerning post-trade transparency, price, volume and time of trade have to be reported by RMs, MTFs, and all investment firms (including SIs) trading outside an RM or MTF as close to real-time as possible, but in any case within three minutes of the relevant transaction. However, while RMs and MTFs are required to provide the respective venue identification, SI trades can be reported with the general flag "SI" and other bilateral trades with the general flag "OTC" without disclosing the respective firm(s) that executed the transaction.

Competent authorities are able to waive pre-trade transparency obligations depending on the trading venue's market model, and the type and size of an incoming order. For example, a venue could use a widely published and reliable reference price imported from another trading venue for its own price determination and choose to not fulfil the pre-trade transparency obligations. This waiver, known as the reference price waiver, and other such waivers, allowed trading systems such as dark pools to exist.[6] "Regulated dark pools", are either registered as MTFs (for example, Posit, Liquidnet, and Turquoise Block Discovery) or RMs (for example, Xetra MidPoint), whereas "unregulated dark pools" or Broker Crossing Networks (BCNs) are operated by investment firms to execute customer (primarily institutional) and proprietary orders without any pre-trade transparency (Gomber et al., 2011). Although BCNs provide similar functionalities as regulated dark pools, they are not required to provide information on the re-

[5] A consolidated tape may be introduced in Europe with the implementation of MiFID II in 2018.

[6] Although the term dark pools is not defined in MiFID, it has become a common terminology for systems that use the MiFID pre-trade transparency waivers.

spective venue in post trading, resulting in their activity being reflected in the general OTC data stream. Another waiver provided by MiFID includes delaying the fulfilment of post-trade transparency obligations in case of trades above a certain size threshold. We discuss this point in the next section.

Gomber et al. (2011) and Gomber et al. (2015) provide an overview of the gains and losses in market share of different venues since the introduction of MiFID. As a result of MiFID, and in line with the US experience, a multitude of new MTFs have entered the marketplace and led to a highly fragmented European equity market. These new competitors have gained a market share of between 20% and 40% of total public lit trading in the main European indices. More than a dozen dark pools and SIs each have become operational. Yet, a large portion of trading activity still is reported under the residual OTC category, which retains a high and stable market share of around 30%.

4. Data and Summary Statistics

We use Thomson Reuters Tick History (TRTH) as the primary data source for this study. Our sample comprises all the constituents of the EURO STOXX 50, DAX 30, CAC 40, MDAX, and EURONEXT 100 indices as of 1 January 2013. We restrict our sample to stocks with a primary listing on Deutsche Börse, NYSE Euronext (Paris, Amsterdam or Brussels), Borsa Italiana, and Bolsa de Madrid. Essentially our sample includes the largest stocks in continental Europe plus midcap stocks listed on Deutsche Börse and NYSE Euronext. The time series covers all trading days between 1 January 2011 and 30 June 2013. Our coverage of venues includes the primary market for each stock, as well as the three largest MTFs, namely Chi-X, BATS and Turquoise.[7] For these venues, the data contains trades and order book updates at a millisecond precision.[8] TRTH additionally includes off-book trades reported to the Markit BOAT trade reporting platform.[9] These trades capture internalization activity by various broker-dealers, over-the-counter trades, and trades executed on eight regulated dark pools (Instinet, Liquidnet, Nomura MTF, POSIT, Blink, UBS MTF, BlockCross and Millenium). Our dataset captures more than 90% of lit activity, more than 99% of systematic internalization activity, and more

[7]In November 2011, BATS and Chi-X merged with each other to form BATS Europe, and started operating two integrated order books. Furthermore, they changed their status to a recognized investment exchange in May 2013.

[8]TRTH time stamps record the time when a trade or order book update arrives at Thomson Reuters, and hence is delayed when compared to actual exchange time stamps.

[9]In July 2014, BOAT was taken over by Cinnober.

than 80% of OTC activity reported by Fidessa in the respective stocks. We complement TRTH with data on free float, dividend dates and the VSTOXX implied volatility from Datastream, and earnings release dates from Compustat Global. The VSTOXX is an implied volatility index calculated from the prices of options written on the EURO STOXX 50. It is constructed similarly to the VIX in the US.

4.1 Data Filters

We apply several filters to the data. We exclude stocks with incomplete TRTH data and with a primary listing after 30 June 2012. This leaves us with 176 stocks. We eliminate all order book updates with a best bid or ask price equal to zero or a quoted bid-ask spread that is negative or greater than 10%. Next, we adjust all OTC trades for cancellations by first matching each cancelled trade with a corresponding trade (based on price and size) reported earlier, and then eliminating all matched pairs. If we cannot find a matching trade we simply eliminate the cancelled leg.

We further exclude all trades with a price greater (lower) than 150% (50%) of previous day's high (low), or with a size greater than 10% of the end-of-day free float or €50 million, whichever is lower. The price filter is meant to eliminate erroneous trades and the size filter is meant to eliminate very large trades which are unlikely to represent a meaningful economic exchange within the scope of this paper. Such trades include bookkeeping adjustments between different portfolios, trades executed pursuant to corporate events, give ups for settlement and clearing, etc.[10,11] Trades greater than €50 million, which we exclude, represent 0.002% of total trades and 15.8% of total volume.

Finally, MiFID allows market participants to delay the publication of large trades executed between an investment firm and its customer. The maximum permissible delay ranges from 60 minutes to the end of the third trading day after the trade, and is a function of the average daily volume of the stock and the trade size.[12] For a €50 million trade - the largest possible trade in our filtered dataset - the maximum permissible reporting delay for the stocks in our sample is the end of second trading day after the trade. We calculate the execution date of each trade eligible for delayed reporting based on the assumption that the maximum possible

[10] See Paragraph 8.1 of ESMA Discussion Paper (ESMA/2014/548) on MiFID II/MiFIR for more details on what constitutes a transaction (ESMA, 2014).

[11] Our results are robust to using different combinations of the price and size cutoffs.

[12] For a detailed description of the reporting delays see European Commission Regulation (EC) No 1287/2006 (EC, 2006).

delay is utilised by the market participants.[13] For our analysis, it is only important that we get the date of execution right and not the time. We identify the trading activity on different venues and trades eligible for delayed reporting based on the trade qualifier flag reported in the dataset.

4.2 Stock Characteristics

Panel A of Table 1 presents the characteristics of the stocks in our sample. The average price across all stocks is €41.1. However, with a standard deviation of €32.6 and a minimum (maximum) price of €1.4 (€229.7), price levels vary substantially in the cross-section. The same is true for the average daily free float during the sample period. Mean and median free float across all stocks are €11.0 billion and €4.6 billion, respectively. The average stock has a realized one-minute midpoint volatility of 8.5 bps. The average stock has a daily primary market time-weighted bid-ask spread of 10.7 bps and depth within 50 bps from the midpoint of almost €540,000. Again, we observe large cross-sectional variation with the most liquid stock having a spread (depth) of 3.1 bps (€4.9 million) while the corresponding values for least liquid stock are 46.6 bps (€49,000). Finally, in order to capture the extent to which the tick size constrains the quoted spread, we calculate the amount of time the quoted spread on the primary market is one tick for each stock-day. The average stock has a value of 12%, but the least and most constrained stocks have values of 1% and 87%, respectively.

[Insert Table 1 about here]

4.3 Volume by Trading Mechanisms and Trade Size

For each stock-day, we divide total volume into the following five trading mechanisms: Continuous Trading (CONT), Auctions (AUC), Dark Pools (DP), Systematic Internalizers (SI) and Over-the-Counter (OTC).[14] CONT trades include continuous trading activity on exchanges and MTFs between 09:00 and 17:30 CET. Trading activity in the opening auctions, closing auctions, scheduled intra-day auctions on Deutsche Börse, and auctions triggered by volatility interruptions is collectively referred to as AUC trading. The DP category includes trades executed on Deutsche Börse's Xetra MidPoint order book, the dark pools operated by Chi-X, BATS and

[13]Based on discussions with Deutsche Börse, we think that this is a reasonable assumption as operators' post-trade reporting systems are configured to automatically report trades by utilising the maximum permissible delay unless the reporting firm explicitly chooses to report earlier.

[14]We do not split continuous trading into primary market and MTFs because they operate largely similar trading protocols and we are interested only in the differences in trading activity across different trading mechanisms.

Turquoise, and the eight additional dark pools included in BOAT. The SI category includes internalized trades reported to BOAT, as well as trades internalized through Deutsche Börse's Xetra Best platform. Finally, the OTC category includes bilaterally negotiated trades reported to the primary markets, MTFs or BOAT.

Panel B of Table 1 describes the cross-sectional variation in the average daily € volume, as well as its break-up between the different trading mechanisms defined above. The average stock in the sample has a total daily volume of €139.5 million. The largest (smallest) stock has an average daily volume of €791.0 (€1.7) million. The CONT category makes the largest contribution to total trading with an average daily volume of €69.6 million, followed by the OTC category at €54.7 million and AUC at €10.2 million. SI and DP together account for a volume of almost €5 million.

Next, we split the total volume in each trading mechanism into large and small trades which are defined as follows: all trades which are less than the MiFID-defined large in-scale (LIS) threshold are categorized as small trades, and all trades greater than or equal to this threshold are categorized as large trades. The LIS threshold, which is relevant for the MiFID pre-trade transparency waiver and which ranges from €50,000 to €500,000, is calculated based on the average daily turnover of the stock and updated annually. Table 2 illustrates the market share of each trading mechanism for all trades, small trades and large trades respectively. In addition to reporting the cross-sectional statistics of the average daily market shares we also report the average standard deviation within a stock-quarter.

[Insert Table 2 about here]

The public lit venues jointly execute 64.7% of total volume. This is split up into trades during the continuous session (56.3%) and during auctions (8.4%). On the other hand all off-book venues contribute approximately 35.3% to the total volume, split into trades in the OTC (31.4%), DP (2.1%), and SI (1.8%) categories. Small trades account for 73.8% of the total volume, and most of these trades are executed in the continuous trading session (61.0%). On the other hand, large trades make up for 26.2% of total trading volume, with the vast majority of them being executed in the OTC market. This lends support to our argument that market participants simultaneously choose the trading mechanism and the size of their orders, and traders' preferred size sometimes constrains their choice of venue. DP and SI trading volume is quite small at approximately 2% each over our sample period, and most of it is concentrated in small trades. This is in contrast to the US, where dark pools make up for around 10% of total trading volume.[15] This may be because in Europe BCNs are categorized as OTC. While the mean and median market shares reported in Table 2 are very close to each other there is some variation in the cross-section of stocks in our sample. For example, the smallest (largest) market share for the continuous and OTC mechanisms are 35.9% (77.7%) and 12.7% (50.7%) respectively. However, the time series variation in the market shares of the different trading mechanisms is larger as is evidenced by the higher within stock-quarter standard deviation.

Finally, we illustrate the time series evolution of the market shares for all trading mechanisms and trade sizes in Figures 2, Figures 3, and 4.

[Insert Figures 2, 3, and 4 about here]

During our sample period, the OTC market, and, to a lesser extent, dark pools, have managed to steadily attract significant volume. On an overall basis, the share of OTC trades increased from approximately 30% in 2011 to around 40% in 2013. At the same time, the share of public lit markets decreased from around 55% to 45%. This effect is more pronounced for small trades, where the market share of off-book venues has doubled between 2011 and 2013.[16]

4.4 Tick Size Violations

In this section, we measure the extent of tick size violations to understand whether tick size is likely to be a relevant factor in explaining the market share of off-book markets. The tick size of a security affects the relative importance of price and time priority within and across venues. It determines the magnitude of price improvement necessary for limit order traders to obtain price priority (Chordia and Subrahmanyam, 1995) so as to overcome the time priority of existing orders sitting at the top of the order book. In contrast to the US, where price priority is also enforced across public lit venues,[17] brokers are responsible for ensuring best execution in the EU. Riordan et al. (2010) show that while there is strong price competition across alternative public lit venues in the UK, the amount of trade-throughs is quite substantial.[18]

[15] See Menkveld et al. (2016) and SEC (2010) for more details.

[16] In addition to losing market share to off-book markets, incumbent exchanges such as Deutsche Börse and NYSE Euronext, have lost significant market share to MTFs such as BATS Chi-X and Turquoise.

[17] The order protection rule requires exchanges to match the best available quote or route an order to the venue providing such a quote, subject to certain exceptions. This arrangement ensures that best quotes on public lit venues are protected from trade-throughs which potentially incentivizes liquidity providers to post more competitive quotes.

[18] However, their results should be interpreted with caution because of the inaccuracies in the time stamps in TRTH data (see the discussion above).

A uniform tick size regime across venues and a prohibition of tick size violations is a necessary pre-condition for price priority across venues to be meaningful. Since 2010, tick sizes on public lit trading venues in the EU have been harmonized pursuant to an arrangement brought about by the Federation of European Securities Exchanges (FESE). Under this arrangement, all such venues uniformly apply a price-contingent tick size, and refrain from under-cutting each other by offering excessively granular tick sizes.[19] However, not all off-book venues have subscribed to this arrangement, thus allowing traders to obtain economically small price improvements over prices offered on public lit markets. This may reduce competition between liquidity providers on public lit venues and may thus harm market quality. Hatheway et al. (2016) show that off-book venues in the US cream-skim uninformed order flow by offering sub-penny improvements over public prices.[20] Degryse et al. (2015) provide evidence of cream-skimming by off-book markets in the EU, although they do not focus on violations of tick sizes.

[Insert Table 3 about here]

Table 3 reports the percentage share of total volume in each trading mechanism-trade size bin where the trade price violates the FESE tick size. We report full-tick violations and half-tick violations. They are defined as follows. Assume the minimum tick size is one cent. Then any sub-cent price constitutes a full-tick violation, and any sub-cent price that does *not* end on 0.5 cents constitutes a half-tick violation. We use these definitions in order to eliminate tick size violations due to executions at the primary market midpoint. We use this approach due to imprecise time-stamps prohibiting us from exactly matching a transaction price with the primary market order book midpoint at the time of execution. However, due to this, the half-tick violations reported in Panel B should be interpreted as a lower bound for the number of tick size violations excluding midpoint executions. This is because a half-tick trade is not necessarily executed at the midpoint if the bid-ask spread is wider than one tick. Returning to the above example, a trade at 40.005 executed while the quoted bid and ask prices are 40.00 and 40.02, respectively, is not a midpoint trade, even though it executes at a half-tick.

Unsurprisingly, tick size in CONT is almost never violated, especially when we eliminate midpoint trades which can arise as a result of certain special orders types like pegged midpoint

[19] The current tick size tables for different markets in the EU are available at http://www.fese.eu/tick-size-regimes. In 2011, NYSE Euronext tried to unilaterally change the tick size of Dutch and French blue-chip stocks, but decided against it after protests from competitors.

[20] In the US, Reg-NMS Rule 612 mandates a minimum tick size of 1 cent for stocks priced above $1, and 0.01 cent for stocks priced below $1. However, off-book venues are exempted from this rule.

orders. In contrast, a substantial portion of volume in the three off-book mechanisms involves a tick size violation, suggesting that these venues frequently employ a more granular tick size to gain a competitive advantage over lit venues. 40.3% of DP executions involve a one-tick violation. However, this number drops to 0.9% for half-tick violations. This is consistent with most dark pools in our dataset predominantly operating a midpoint cross market model. The corresponding percentages for SI and OTC volumes which violate one tick are 29.3% and 24.8% respectively. These percentages drop to 22.4% in case of half tick violations. For small trades, the proportion of tick size violations increases with the trade size such that violations of relatively small magnitudes can potentially be economically significant.

5. Determinants of Market Share

5.1 Empirical Methodology

In this section we examine the determinants of traders' joint choices of venues and trade sizes. As we do not observe the routing decisions of individual market participants, we use the daily market share of each category in a grid of venues and trade sizes as the dependent variables. This is similar to Boehmer et al. (2007) who study routing decisions to the NYSE and competing ECNs for different order sizes for NYSE-listed stocks in the period from 2001 to 2004. He et al. (2015) apply the same idea, without differentiating between order sizes, in a study examining the international market entry of Chi-X. The underlying idea comes from Bell et al. (1975) who show that, under reasonable assumptions, the relative "attraction" of competitors in an industry is reflected in their market shares.

It is important to note that the competitive environment we study differs from that studied in Boehmer et al. (2007) and He et al. (2015), where the competing markets under analysis are relatively similar in structure. Therefore, their performance can be measured relatively easily based on realized transaction costs, liquidity measures, or execution speed. In contrast, the trading mechanisms we analyze are fundamentally different such that a direct comparison along one or several dimensions is infeasible. For example, we do not observe bid and ask prices during auctions and on certain off-book venues. However, prior literature (see Section 1 and 2) makes predictions on stock and market characteristics that determine the relative advantages and disadvantages investors face when considering the different trading mechanisms. In particular, we have argued that institutional trading interest, execution costs in the public lit markets, tick size constraints, the expected volatility, and the degree of anonymity and immediacy offered by the different trading venues affect traders' order routing decisions.

We therefore investigate the relationship between investors' preferences within the above trading venue-trade size grid as a function of the general market conditions, stock-specific activity, and characteristics of the trading environment. General market conditions include the expected market volatility as measured by the VSTOXX. In order to proxy for conditions on the public lit markets, we use three measures of liquidity based on trading activity on the listing venue: quoted bid-ask spread, quoted visible depth within 50 basis points of the order book midpoint, and the percentage of time when the quoted spread is equal to one tick. Additionally, we include lagged daily stock returns, separated into positive and negative returns. Past returns may explain trading activity motivated by portfolio re-balancing considerations or trend-following strategies. Finally, we include minute-by-minute midpoint volatility as an independent variable.

As our objective is to model market participants' choices, we use lagged values of these explanatory variables in order to mimic the traders' information set. This approach is similar to Boehmer et al. (2007). Besides the above variables, we add variables reflecting firm-specific events to the model. These include dummy variables for ex-dividend and earnings release dates, and for seven calendar days immediately before and after these dates. Earnings release dummies capture days when the level of asymmetric information in the market is high, whereas ex-dividend dummies capture days when there is a high level of uninformed trading in the market.

Our approach involves estimating the following panel regression for the dataset containing 176 stocks and all trading days from January 2011 to June 2013:

$$Y_{i,t}^{m} = \alpha + \beta \mathbf{X_{i,t-1}} + \gamma \mathbf{Z_{i,t}} + \epsilon_{i,t} \tag{1}$$

where $Y_{i,t}^{m}$ is the market share of trading mechanism m for stock i and day t, $\mathbf{X_{i,t-1}}$ denote the lagged regressors for stock i at time $t-1$, $\mathbf{Z_{i,t}}$ denote the contemporaneous regressors for stock i at time t, and $\epsilon_{i,t}$ is the error term. $\mathbf{X_{i,t-1}}$ includes the fraction of the day when the listing venue spread is one tick ($TICK\_CONSTRAINT_{i,t-1}^{PM}$), log of the time-weighted listing venue depth within 50bps of the order book midpoint ($DEPTH50_{i,t-1}^{PM}$), time-weighted listing venue quoted spread ($SPREAD_{i,t-1}^{PM}$),[21] standard deviation of one-minute order book midpoint re-

[21] We use liquidity measures on the listing venue as a proxy for liquidity during the continuous trading sessions in the public lit markets. Our results are qualitatively unaffected if we use the corresponding measures on one of the MTFs. While differences in liquidity across the public lit trading venues may lead to shifts in trading

turns ($VOLATILITY^{PM}_{i,t-1}$), log of the implied volatility index of EURO STOXX 50 constituent options ($VSTOXX_{t-1}$), the daily return if positive and zero otherwise ($RETURN^{+}_{i,t-1}$), and the daily return if negative and zero otherwise ($RETURN^{-}_{i,t-1}$). $\mathbf{Z_{i,t}}$ includes event dummy variables for earnings release date j ($EARNINGS_{i,t=j}$), for ex-dividend date k ($DIVIDEND_{i,t=k}$), and for one week before and after these events ($EARNINGS_{i,t\in[j-7,j-1]}$, $EARNINGS_{i,t\in[j+1,j+7]}$, $DIVIDEND_{i,t\in[k-7,k-1]}$, and $DIVIDEND_{i,t\in[k+1,k+7]}$). $Y_{i,t}$ and $\mathbf{X_{i,t-1}}$ are centered and standardized within stock and calendar quarter. β and γ are the coefficient vectors of interest. We cluster the standard errors by stock and day.

We estimate the first set of regressions for the different trading mechanisms combining all trade size categories. The market share $Y^{m}_{i,t}$ here is calculated as the total trading volume for stock i, day t, and trading mechanism m as a percentage of total trading volume for stock i and day t across all trading mechanisms. In the second and third set of regressions, we estimate the above regression for stock i, day t, and trading mechanism m for trades smaller than LIS and equal to or larger than LIS, respectively. Here we calculate the market share $Y^{m}_{i,t}$ as the sum of all trades below (above) LIS for stock i, day t, and trading mechanism m as a percentage of the total trading volume for stock i and day t across all trading mechanisms and trade size categories. We exclude auctions both in the numerator and the denominator in the second and third set of regressions as for some markets the data only reports the total auction volume.

5.2 Results

Tables 4, 5, and 6 reports the regression results for the first, second and third set of regressions, respectively.

[Insert Tables 4, 5, and 6 about here]

5.2.1 Bid-ask Spreads

The relationship between listing venue liquidity and the market share of the different trading mechanisms is likely dependent on market participants' connections to the different mechanisms, their willingness to split large orders, and their desire for immediacy. Traders connected to all trading mechanisms will optimally route their orders to those providing the best price and most suited to handle their preferred order sizes. For example, when listing venue liquidity is low, traders may move towards DP, which execute trades at the midpoint and thus allow traders to

volume between them, this is beyond the scope of this paper as we focus on traders choices across distinct trading mechanisms.

save on the bid-ask spread, or towards OTC/SI, which can violate the tick size regime of public lit markets and thereby provide improvements over primary market prices. On the other hand, traders constrained to trade in specific trading mechanisms and/or trade sizes will respond differently to changes in liquidity. For example, the OTC market attracts more than 95% of orders larger than LIS. Traders constrained to trade in such large sizes, to the extent they are patient and willing to compromise on immediacy and anonymity, may attempt to time their trades when liquidity is high to get better terms of trade.

Our results are consistent with both these explanations. The coefficient on $SPREAD_{i,t-1}^{PM}$ is negative and significant for CONT market share in all three regressions, suggesting that higher spreads predict a lower market share during continuous trading in the public lit markets. A one standard deviation increase in bid-ask spreads predicts a drop in overall CONT market share of 0.016 standard deviations, which approximately corresponds to a 0.16% drop in market share for every 1 bps increase in the bid-ask spread. This decrease in market share is observed for both small and large trades. Auctions, by matching buyers and sellers at a single clearing price, allow traders to save on the spread. Consistent with this we observe that a one standard deviation increase in spreads predicts a 1.8% increase in market share during auctions. The coefficients for all three off-book venues are negative and significant for large trades. This finding suggests that overall trade sizes across all trading mechanisms drop in response to higher spreads on the primary market. For small trades, on the other hand, the coefficients are positive across the three off-book venues but only significant for the OTC market whose market share increases by 1.9% for a one standard deviation increase in bid-ask spreads. This countervailing effect for large and small trades explains why the overall effect of the bid-ask spread on off-book market share is insignificant.

5.2.2 Tick Size Constraints

Traders' order routing choices are also likely affected by the extent to which the tick size constrains the bid-ask spread. Unlike the US which operates a fixed tick size for stocks priced above $1, tick sizes in the EU are stepwise price-contingent i.e., they are constant within a fixed price range. As the stock price crosses the upper (lower) price barrier of this range, the tick size increases (decreases). Large tick size constraints lead to large queues of standing limit orders on the limit order book and low execution probability for the marginal limit order trader. This may induce traders to move to dark pools which allow traders to by-pass such queues

(Buti et al., 2011; Kwan et al., 2015). Our results are consistent with this argument. Large $TICK\_CONSTRAINT_{i,t-1}^{PM}$ predicts a higher overall market share for all off-book mechanisms but a lower market share during continuous trading. A one standard deviation increase in tick size constraints predicts a 0.7%, 3.6%, and 2.5% increase in market share of OTC, DP and SI respectively, and a 0.5% decrease in CONT market share. The gains in market share for DP/SI (OTC) occur predominantly in small (large) trade sizes. We also observe that CONT market share goes up for large trades with $TICK\_CONSTRAINT_{i,t-1}^{PM}$. This is likely due to the positive correlation between tick size constraints and depth, especially at the top of the limit order book, in the public lit markets which induces market participants to submit (large) aggressive orders (Goettler et al., 2005; Parlour, 1998).

5.2.3 Depth

The relationship between $DEPTH50_{i,t-1}^{PM}$ and the market share in the different trading mechanisms is also likely affected by the need for traders to trade in large sizes. Large depth allows traders to execute a large order with minimum price impact. Consistent with this we observe that high $DEPTH50_{i,t-1}^{PM}$ is associated with low market share for small trades in OTC, SI and CONT mechanisms such that a one standard deviation increase in depth predicts a decrease of 0.3%, 0.9%, and 0.3% in their respective market shares. Conversely, the market share of large trades goes up by 1.3%, 2.9%, and 4.7% respectively. On an overall basis, OTC (CONT) market share is positively (negatively) associated with $DEPTH50_{i,t-1}^{PM}$. A one standard deviation increase in $DEPTH50_{i,t-1}^{PM}$ predicts a 0.8% increase in OTC market share and a 0.4% decrease in CONT market share. This is likely capturing dealers' liquidity supply response as a large depth in the continuous market allows them to unwind positions at low costs.

DP market share decreases across both trade size categories. Overall, a one standard deviation increase in depth results in a 1.0% decrease in DP market share. The DP offers anonymous execution at low implicit trading cost at the expense of high execution risk. When depth in the continuous market increases, the cost advantage of the DP becomes less important and the DP thus less attractive.

5.2.4 Volatility

Consistent with the theoretical predictions of Seppi (1990), we observe that a one standard deviation increase in stock-specific and market wide volatility predicts a decrease of 0.7% and

1.8% in OTC market share, and an increase of 1.0% and 1.3% in CONT market share. This result can be explained by investors' need for immediacy and by the increased risk faced by dealers in the OTC market that open positions experience an adverse change in value. OTC market share for small trades is predominantly driven by changes in $VOLATILITY^{PM}_{i,t-1}$, whereas for large trades $VSTOXX_{t-1}$ drives the results. This can be explained by the fact that high market volatility is generally associated with low funding liquidity (Brunnermeier and Pedersen, 2009), which more likely affects liquidity supply for large trades. For large trades, overall CONT market share is positively (negatively) associated with stock-specific (market) volatility. This implies that traders' demand for immediacy when stock-specific volatility is high dominates the negative effect on liquidity supply associated with market volatility, which generally leads to smaller trade sizes. While the signs of the coefficients for DP/SI are similar to those of the OTC market, they generally lack significance at conventional levels. Finally, we observe that a one standard deviation increase in $VOLATILITY^{PM}_{i,t-1}$ predicts a 2.5% decrease in AUC market share. This is consistent with Garbade and Silber (1979), who model a market comprising of a sequence of call auctions, and show that the optimal frequency of auctions is an increasing function of the equilibrium price volatility. In our case, where the number of auctions is fixed, higher volatility may induce traders who prefer to trade in auctions to choose alternative trading mechanisms.

5.2.5 Returns

Past returns can be relevant in explaining the venue preferences of investors employing heterogeneous investment strategies. Certain investors periodically re-balance their portfolios to align the weights of the constituent stocks with their targets. Active portfolio managers as well as individual investors also employ strategies based on past prices (DeLong et al., 1990; Hong and Stein, 1999). We observe that the magnitude of past returns generally has a positive effect on the market share of the CONT, SI and DP mechanisms and a negative effect on the market share of OTC and AUC mechanisms. This is consistent with active investors employing momentum/contrarian strategies preferring the immediacy offered by these relatively fast venues. On the other hand, portfolio rebalancing is likely to occur in the relatively slower OTC and AUC mechanisms. Of these two, the OTC market may be preferable because investors can negotiate a price for their entire portfolio (as opposed to trading individual stocks separately), potentially exploiting their reputation for uninformed trading in the non-anonymous environment.

The effect of past returns on market shares is more pronounced for negative returns, potentially due to a relatively stronger reaction of investors in response to losses. A one standard deviation increase in the magnitude of $RETURN^{-}_{i,t-1}$ predicts a 1.0%, 1.4%, and 0.6% increase in DP, SI, and CONT market share respectively and a 0.6% and 2.1% decrease in OTC and AUC market shares. The results for the magnitude of $RETURN^{+}_{i,t-1}$ are similar for AUC and CONT and insignificant for the other market mechanisms. Finally, the coefficients for small trades are larger than those for large trades.

5.2.6 Events Associated with Different Levels of Adverse Selection

Traders' preferences for the three off-book mechanisms are likely affected differently by changes in the level of adverse selection in the market. In order to understand the relative attractiveness of these mechanisms, we examine two stock-specific events: earnings release dates and ex-dividend dates. Typically, the period before and including the earnings release date is associated with a high level of information asymmetry. Even after the relevant information has been released, differences with respect to its interpretation are likely to keep adverse selection high (Kim and Verrecchia, 1991, 1994). On the other hand, trading around ex-dividend dates is likely associated with tax-induced differential valuations of dividends (Michaely and Vila, 1996), as opposed to differences in investors' information sets. Delta-neutral tax arbitrage strategies involving the underlying stocks and futures contracts are set-up and unwound by investors around these dates. These strategies generally involve large trade sizes.

The distribution of market share across the different mechanisms shifts significantly around both these events. OTC and AUC trading experiences a decreases of 2.5% and 22.5% on the earnings release date. The effect on CONT and DP market share is almost the exact opposite. These venues experience an increase in market share of 4.4% and 18.4%, respectively. Informed traders apparently show limited patience around earnings release dates due to the short-term nature of their information. Hence, continuous trading on public lit venues, which is associated with fast and certain execution in an anonymous environment, become more attractive to traders. For dark pools, two competing models of informed trading come to different conclusions. Zhu (2014) argues that, as the execution probability of informed trades is lower in the dark pool, informed traders route their order to the public lit venues. On the other hand, Ye (2011) argues that informed traders migrate to the dark pools allowing them to better hide their trades as they face high price impact costs (Kyle, 1985) in the public lit markets. However, both models only focus on the trade-off between a dark pool and a dealer market. Order routing decisions across multiple public lit and off-book venues are likely to be much more complex. Nevertheless, our results for dark pools are consistent with the predictions of Ye (2011). Interestingly, dark pools are the only market mechanism which experiences a statistically significant increase in market share (predominantly in small trades) before earnings release dates, a period likely associated with high levels of adverse selection. The impact of an earnings release on SI market share, while positive and significant, is driven by large outlier trades. The results for the week after the earnings release date for DP, AUC and CONT are broadly in the same direction as those on the earnings release date, although smaller in magnitude and sometimes less significant.

Around ex-dividend dates, the results are the exact opposite. OTC and SI market share increases by 19.6% and 36.9% respectively, and the market share of DP, AUC, and CONT decreases by 21.1%, 10.4% and 6.9% respectively, on the ex-dividend date. The results are similar for trading in the different mechanisms one week before and after the ex-dividend date. Dividend arbitrage strategies are likely implemented in large sizes. This is reflected in the large positive and strongly significant coefficients for large OTC trades.[22] On the other hand, the market share of public lit venues goes down because uninformed traders executing large trades stay away due to higher transaction costs in anonymous markets. DP market share also goes down around ex-dividend dates, predominantly due to a drop in market share of small trades. Auctions, being anonymous, do not allow traders to signal their trading motives, and hence experience a drop in market share.

The above results for the OTC market are consistent with the predictions of Seppi (1990) and Madhavan and Cheng (1997) who argue that traders prefer markets which allow them to credibly signal the uninformative nature of their trades in order to obtain better terms of trade. Demonstrating the absence of private information is difficult around earnings release dates and much easier around ex-dividend dates, especially when such trades are delta-neutral.

6. Conclusion

In this paper we empirically study investors' order-routing decisions and the determinants of the market share of different public lit and off-book venues in the European equity market.

[22] We also observe a similar effect for large SI trades. This suggests that such trades, while rare, are also negotiated and not implemented in an automated environment.

Our analysis is based on the premise that market participants simultaneously choose the trading venue and their trade size. On the off-book side, we consider OTC markets, systematic internalizers and dark pools, and on the public lit side we consider continuous trading in such markets as well as trading in call auctions. We split the activity in each of these categories into small and large trades. We find that the continuous trading sessions in public lit markets dominate trading in small sizes while the OTC market is the predominant venue for large trades. We further find that volatility and liquidity in the public lit markets have distinct effects on traders' trade size and venue choices.

We argue that differences in the level of anonymity and immediacy across the venues, as well as their absorptive capacities, explain the relative attraction of the different venues under specific market conditions and thus determine their market shares. The importance of anonymity and immediacy offered by different trading venues is illustrated by considering changes in market shares around earnings announcements and ex-dividend dates. Earnings announcements are associated with increased informational asymmetries. Informed traders prefer fast and anonymous execution. At the same time OTC market makers are less likely to be willing to take large positions in their books. Correspondingly, we find an increase in continuous trading on public lit markets and a decrease in OTC trading around earnings announcements. Ex-dividend dates, on the other hand, are associated with a surge in uninformed trading. Uninformed traders are likely to prefer a non-anonymous environment because this allows them to credibly signal their trading motives. Consistent with this view, we find an increase in OTC trading around ex-dividend dates.

Additionally, we find that the (non-)existence of rules constraining the choices of venue operators with respect to their trading protocols (such as minimum tick size requirements) also affect market participants' order routing choices. These rules may potentially create an uneven playing field with unintended consequences. For instance, we show that inconsistent application of minimum tick size rules across some of the off-book venues allows venue operators to trivially improve on public limit orders and thus undermine their priority. The likely motivation for this is cream-skimming which may have negative externalities for the market.

On a more general level our results suggest that, when analyzing the impact of off-book trading on market quality, differentiating between alternative off-book trading mechanisms as well as between different trade size categories is important. This is particularly true when the results of the analysis are used to derive policy implications.

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Table 1. Stock Characteristics

This table describes the summary statistics for the 176 stocks in our sample. We first calculate the daily values of each variable and report the cross-sectional statistics. Panel A reports the stock characteristics. Stock Price is the closing price, Free Float is the market value of the end-of-day free float, Realized Volatility is the standard deviation of one-minute midpoint returns, Bid-Ask Spread is the time-weighted listing venue quoted spread, Depth 50bps is the time-weighted listing venue depth within 50bps of the midpoint, and Tick Size Constraint is the fraction of the day when the listing venue quoted spread is one tick. Panel B reports the average daily volume across stocks and its break-up in the different venues defined in Section 4.3. For each statistics, we report the mean, standard deviation, median, minimum and maximum across stocks.

	Mean	**Std. Dev.**	**Median**	**Min**	**Max**
Panel A: Stock Characteristics					
Stock Price	41.1	32.6	33.8	1.4	229.7
Free Float (€ bn)	11.0	14.9	4.6	0.4	91.0
Realized Volatility (bps)	8.5	22.6	6.5	4.0	305.7
Bid-Ask Spread (bps)	10.7	7.1	7.9	3.1	46.6
Depth 50bps (€)	538,150	642,391	330,294	48,850	4,899,946
Tick Size Constraint (%)	12.0%	14.6%	7.0%	1.0%	87.0%
Panel B: Trading Volume (€ Million)					
TOTAL	139.5	171.6	65.2	1.7	791.0
CONT	69.6	85.4	34.3	1.3	446.0
AUC	10.2	12.8	4.6	0.2	67.6
DP	2.2	2.5	1.3	0.0	11.2
SI	2.7	3.8	1.4	0.0	21.9
OTC	54.7	73.2	25.1	0.2	381.4

Table 2. Market Share of Alternate Trading Mechanisms
This table describes the market shares of the different trading mechanisms for the 176 stocks in our sample. We calculate the average daily market share for each stock and report the cross-sectional mean, standard deviation, median, minimum and maximum values. In the last column we calculate the daily standard deviation for each stock-quarter and report its mean. Panel A reports the statistics for all trades and Panels B and C report the statistics for all trades below and above the LIS. Panels B and C exclude auctions as the individual trades resulting from auctions are not reported separately for all the markets.

	Mean	**Std. Dev.**	**Median**	**Min**	**Max**	**Std. Dev. Stock-Qtr**
Panel A: Market Share - All Trades						
CONT	56.3%	7.9%	56.3%	35.9%	77.7%	11.4%
AUC	8.4%	1.7%	8.3%	2.6%	12.3%	3.8%
DP	2.1%	0.8%	2.0%	0.3%	5.5%	2.1%
SI	1.8%	0.8%	1.8%	0.2%	3.8%	2.5%
OTC	31.4%	7.3%	31.5%	12.7%	50.7%	12.4%
Panel B: Market Share - Trades ≤ LIS						
TOTAL	73.8%	10.0%	74.7%	38.4%	97.3%	14.3%
CONT	61.0%	8.9%	61.5%	23.0%	83.4%	12.7%
DP	2.0%	0.7%	2.0%	0.3%	4.3%	1.8%
SI	1.1%	0.5%	1.1%	0.1%	3.4%	0.9%
OTC	9.7%	3.2%	9.4%	3.5%	20.1%	3.8%
Panel C: Market Share - Trades > LIS						
TOTAL	26.2%	10.0%	25.3%	2.7%	61.6%	14.3%
CONT	0.2%	0.1%	0.1%	0.0%	0.6%	0.5%
DP	0.3%	0.3%	0.2%	0.0%	2.2%	1.1%
SI	0.9%	0.7%	0.9%	0.0%	4.6%	2.3%
OTC	24.8%	9.8%	24.0%	2.4%	59.1%	14.0%

Table 3. Summary of Minimum Tick Size Violations

This tables reports the percentage of total volume executed in violation of the public lit venue minimum tick size in the different venue and trade size bins across all stocks over the sample period. Each trade is classified into the venues defined in Section 4.3. We exclude auction trades because these trades are executed in the listing venue and hence, by definition, never violate the tick size. Trades within each venue are further classified into the following bins based on trade sizes: less than €7,500, between €7,500 and €50,000, between €50,000 and LIS, and between LIS and €50 million. We report violations of one tick in Panel A and violations of one-half tick in Panel B.

Venue	**Trade Size (x)**				
	$\mathbf{x \leq 7,500}$	$\mathbf{7,500 < x \leq 50k}$	$\mathbf{50k < x \leq LIS}$	$\mathbf{LIS < x \leq 50M}$	**Total**
Panel A: Full-Tick Violations					
CONT	0.0%	0.1%	0.0%	0.1%	0.1%
DP	39.3%	38.9%	44.6%	47.7%	40.3%
SI	21.4%	26.0%	49.4%	29.6%	29.3%
OTC	31.6%	32.7%	53.9%	21.7%	24.8%
Total	2.8%	3.5%	16.8%	21.9%	11.8%
Panel B: One-Half Tick Violations					
CONT	0.0%	0.0%	0.0%	0.0%	0.0%
DP	0.6%	0.6%	2.6%	0.9%	0.9%
SI	7.9%	9.5%	39.0%	27.9%	22.4%
OTC	12.8%	15.8%	50.0%	20.6%	22.4%
Total	0.7%	1.1%	14.8%	20.6%	10.0%

Table 4. Market Share Regression: All Trades

This table reports the results from a stock-day panel regression of the daily market share for the different trading venues described in Section 4.3. $TICK\_CONSTRAINT^{PM}_{i,t-1}$ is the fraction of the day when the listing venue spread for stock i and day t is one tick, $DEPTH50^{PM}_{i,t-1}$ is the log of the time-weighted listing venue depth within 50bps of the mid-quote, $SPREAD^{PM}_{i,t-1}$ is the time-weighted listing venue quoted spread, $VOLATILITY^{PM}_{i,t-1}$ is the standard deviation of one-minute midpoint returns, $VSTOXX_{t-1}$ is the log of the implied volatility index of EURO STOXX 50 constituent options, and $RETURN^{+}_{i,t-1}$ ($RETURN^{-}_{i,t-1}$) is the daily return if positive (negative) and zero otherwise. $EARNINGS_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an earnings announcement date j and zero otherwise. $EARNINGS_{i,t\in[j+1,j+7]}$ ($EARNINGS_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the earnings announcement date j and zero otherwise. $DIVIDEND_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an ex-dividend date k and zero otherwise. $DIVIDEND_{i,t\in[j+1,j+7]}$ ($DIVIDEND_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the ex-dividend date k and zero otherwise. All dependent and independent variables except $VSTOXX_{t-1}$ and the dummy variables are standardized by within stock-quarter mean and standard deviation. $VSTOXX_{t-1}$ is standardized by within quarter mean and standard deviation. Standard errors are clustered by stock and day. t statistics are reported in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent respectively.

	(1) OTC	(2) DP	(3) SI	(4) AUC	(5) CONT
$TICK\_CONSTRAINT^{PM}_{i,t-1}$	1.758***	3.640***	1.821***	-0.885	-2.693***
	(3.18)	(6.36)	(3.26)	(-1.17)	(-4.37)
$DEPTH50^{PM}_{i,t-1}$	1.981***	-1.011**	0.566	-0.626	-1.798***
	(3.45)	(-2.00)	(1.15)	(-0.76)	(-2.65)
$SPREAD^{PM}_{i,t-1}$	0.209	-0.050	-0.572	3.893***	-1.586**
	(0.33)	(-0.07)	(-0.89)	(4.01)	(-2.16)
$VOLATILITY^{PM}_{i,t-1}$	-1.708**	-0.597	-0.113	-5.483***	5.003***
	(-2.41)	(-0.84)	(-0.22)	(-4.09)	(5.58)
$VSTOXX_{t-1}$	-4.529***	-0.400	-1.017	-3.620	6.311***
	(-4.41)	(-0.47)	(-1.34)	(-1.32)	(4.10)
$RETURNS^{+}_{i,t-1}$	0.194	-0.147	0.595	-3.823***	1.415*
	(0.34)	(-0.27)	(1.20)	(-3.30)	(1.95)
$RETURNS^{-}_{i,t-1}$	1.446**	-0.972**	-1.030**	4.606***	-2.792***
	(2.06)	(-2.10)	(-2.23)	(3.21)	(-3.05)
$EARNINGS_{i,t\in[j+1,j+7]}$	0.962	4.007	-1.803	-12.951***	6.166**
	(0.36)	(1.48)	(-0.87)	(-3.14)	(2.11)
$EARNINGS_{i,t=j}$	-6.229*	18.392***	14.017***	-49.833***	21.973***
	(-1.92)	(4.44)	(3.08)	(-10.24)	(5.37)
$EARNINGS_{i,t\in[j-7,j-1]}$	1.548	4.887*	-0.831	-4.881	-2.898
	(0.54)	(1.82)	(-0.32)	(-1.33)	(-0.87)
$DIVIDEND_{i,t\in[k+1,k+7]}$	52.249***	-14.970***	17.191***	-28.428***	-57.839***
	(12.29)	(-5.34)	(5.25)	(-6.29)	(-15.56)
$DIVIDEND_{i,t=k}$	49.518***	-21.082***	26.589***	-23.063***	-34.318***
	(6.06)	(-5.37)	(4.05)	(-3.65)	(-5.00)
$DIVIDEND_{i,t\in[k-7,k-1]}$	61.196***	-20.027***	7.374***	-32.720***	-53.031***
	(12.53)	(-7.38)	(2.79)	(-7.81)	(-10.78)
$CONSTANT$	-2.824***	0.639	-0.692	2.071	2.486**
	(-3.39)	(1.01)	(-1.09)	(0.99)	(2.08)
N	111,213	111,148	110,721	110,020	111,213

Table 5. Market Share Regression: Small Trades

This table reports the results from a stock-day panel regression of the daily market share of all trades with size less than LIS for the different trading venues described in Section 4.3. $TICK\_CONSTRAINT^{PM}_{i,t-1}$ is the fraction of the day when the listing venue spread for stock i and day t is one tick, $DEPTH50^{PM}_{i,t-1}$ is the log of the time-weighted listing venue depth within 50bps of the mid-quote, $SPREAD^{PM}_{i,t-1}$ is the time-weighted listing venue quoted spread, $VOLATILITY^{PM}_{i,t-1}$ is the standard deviation of one-minute midpoint returns, $VSTOXX_{t-1}$ is the log of the implied volatility index of EURO STOXX 50 constituent options, and $RETURN^{+}_{i,t-1}$ ($RETURN^{-}_{i,t-1}$) is the daily return if positive (negative) and zero otherwise. $EARNINGS_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an earnings announcement date j and zero otherwise. $EARNINGS_{i,t\in[j+1,j+7]}$ ($EARNINGS_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the earnings announcement date j and zero otherwise. $DIVIDEND_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an ex-dividend date k and zero otherwise. $DIVIDEND_{i,t\in[j+1,j+7]}$ ($DIVIDEND_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the ex-dividend date k and zero otherwise. All dependent and independent variables except $VSTOXX_{t-1}$ and the dummy variables are standardized by within stock-quarter mean and standard deviation. $VSTOXX_{t-1}$ is standardized by within quarter mean and standard deviation. Standard errors are clustered by stock and day. t statistics are reported in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent respectively.

	(1) OTC	(2) DP	(3) SI	(4) CONT
$TICK\_CONSTRAINT^{PM}_{i,t-1}$	0.729	3.764***	1.936***	-2.802***
	(1.37)	(6.64)	(3.85)	(-6.09)
$DEPTH50^{PM}_{i,t-1}$	-0.862**	-0.737*	-1.138**	-1.937***
	(-1.98)	(-1.76)	(-2.46)	(-4.41)
$SPREAD^{PM}_{i,t-1}$	4.855***	0.047	0.157	-1.609***
	(8.47)	(0.08)	(0.28)	(-3.08)
$VOLATILITY^{PM}_{i,t-1}$	-7.133***	-0.392	-0.556	4.986***
	(-16.73)	(-0.87)	(-1.30)	(12.25)
$VSTOXX_{t-1}$	-0.766	-0.126	-0.547	6.429***
	(-1.59)	(-0.28)	(-1.16)	(12.22)
$RETURN^{+}_{i,t-1}$	-0.298	-0.152	1.898***	1.367***
	(-0.78)	(-0.43)	(4.82)	(4.04)
$RETURN^{-}_{i,t-1}$	2.420***	-1.019***	-2.175***	-2.753***
	(6.57)	(-2.85)	(-6.30)	(-8.13)
$EARNINGS_{i,t\in[j+1,j+7]}$	-6.707**	4.120*	-1.637	5.732***
	(-2.50)	(1.65)	(-0.70)	(2.73)
$EARNINGS_{i,t=j}$	-42.546***	18.621***	3.418	19.876***
	(-10.95)	(4.66)	(0.82)	(5.34)
$EARNINGS_{i,t\in[j-7,j-1]}$	1.035	5.320**	0.176	-3.146
	(0.41)	(2.20)	(0.08)	(-1.30)
$DIVIDEND_{i,t\in[k+1,k+7]}$	-45.591***	-17.696***	-17.627***	-57.713***
	(-13.73)	(-6.64)	(-7.87)	(-17.76)
$DIVIDEND_{i,t=k}$	-49.649***	-20.727***	-8.295*	-34.791***
	(-9.08)	(-5.24)	(-1.71)	(-5.52)
$DIVIDEND_{i,t\in[k-7,k-1]}$	-56.919***	-22.806***	-17.029***	-54.461***
	(-15.78)	(-9.16)	(-7.64)	(-12.39)
$CONSTANT$	2.996***	0.773***	0.813***	2.542***
	(15.66)	(6.13)	(6.15)	(13.71)
N	111,213	111,148	110,595	111,213

Table 6. Market Share Regression: Large Trades

This table reports the results from a stock-day panel regression of the daily market share of all trades with size greater than LIS for the different trading venues described in Section 4.3.$TICK\_CONSTRAINT^{PM}_{i,t-1}$ is the fraction of the day when the listing venue spread for stock i and day t is one tick, $DEPTH50^{PM}_{i,t-1}$ is the log of the time-weighted listing venue depth within 50bps of the mid-quote, $SPREAD^{PM}_{i,t-1}$ is the time-weighted listing venue quoted spread, $VOLATILITY^{PM}_{i,t-1}$ is the standard deviation of one-minute midpoint returns, $VSTOXX_{t-1}$ is the log of the implied volatility index of EURO STOXX 50 constituent options, and $RETURN^{+}_{i,t-1}$ ($RETURN^{-}_{i,t-1}$) is the daily return if positive (negative) and zero otherwise. $EARNINGS_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an earnings announcement date j and zero otherwise. $EARNINGS_{i,t\in[j+1,j+7]}$ ($EARNINGS_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the earnings announcement date j and zero otherwise. $DIVIDEND_{i,t=j}$ is a dummy variable which takes a value of one on day t if it is an ex-dividend date k and zero otherwise. $DIVIDEND_{i,t\in[j+1,j+7]}$ ($DIVIDEND_{i,t\in[j-7,j-1]}$) is a dummy variable which takes a value of one if day t is within seven calendar days after (before) the ex-dividend date k and zero otherwise. All dependent and independent variables except $VSTOXX_{t-1}$ and the dummy variables are standardized by within stock-quarter mean and standard deviation. $VSTOXX_{t-1}$ is standardized by within quarter mean and standard deviation. Standard errors are clustered by stock and day. t statistics are reported in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent respectively.

	(1) OTC	(2) DP	(3) SI	(4) CONT
$TICK\_CONSTRAINT^{PM}_{i,t-1}$	1.784***	0.501	1.172***	1.946***
	(3.91)	(1.21)	(2.62)	(4.12)
$DEPTH50^{PM}_{i,t-1}$	2.383***	-0.934**	1.143***	1.888***
	(5.73)	(-2.28)	(3.03)	(4.03)
$SPREAD^{PM}_{i,t-1}$	-1.070**	-0.932*	-1.246***	-0.827*
	(-2.14)	(-1.93)	(-2.70)	(-1.68)
$VOLATILITY^{PM}_{i,t-1}$	-0.302	-0.403	0.518	1.382***
	(-0.77)	(-0.90)	(1.33)	(3.74)
$VSTOXX_{t-1}$	-3.802***	-0.108	-0.138	-2.560***
	(-7.87)	(-0.27)	(-0.33)	(-5.65)
$RETURNS^{+}_{i,t-1}$	0.453	0.410	-0.343	1.043***
	(1.31)	(1.06)	(-0.93)	(2.64)
$RETURNS^{-}_{i,t-1}$	0.397	-0.783**	0.286	-0.406
	(1.19)	(-2.06)	(0.81)	(-0.98)
$EARNINGS_{i,t\in[j+1,j+7]}$	1.117	0.541	-1.275	7.678***
	(0.50)	(0.24)	(-0.62)	(3.32)
$EARNINGS_{i,t=j}$	5.941	9.046*	20.202***	59.277***
	(1.60)	(1.92)	(3.51)	(7.77)
$EARNINGS_{i,t\in[j-7,j-1]}$	2.124	0.397	0.290	2.775
	(0.88)	(0.17)	(0.13)	(1.19)
$DIVIDEND_{i,t\in[k+1,k+7]}$	56.061***	1.726	19.369***	-7.199***
	(16.64)	(0.85)	(6.16)	(-3.43)
$DIVIDEND_{i,t=k}$	37.692***	-4.401	19.806***	7.013
	(5.98)	(-0.98)	(3.32)	(1.51)
$DIVIDEND_{i,t\in[k-7,k-1]}$	58.085***	-0.143	13.509***	10.626***
	(13.01)	(-0.07)	(4.97)	(3.55)
$CONSTANT$	-2.867***	-0.090	-0.908***	-0.584***
	(-14.69)	(-0.80)	(-6.74)	(-4.59)
N	111,085	93,977	96,084	101,327

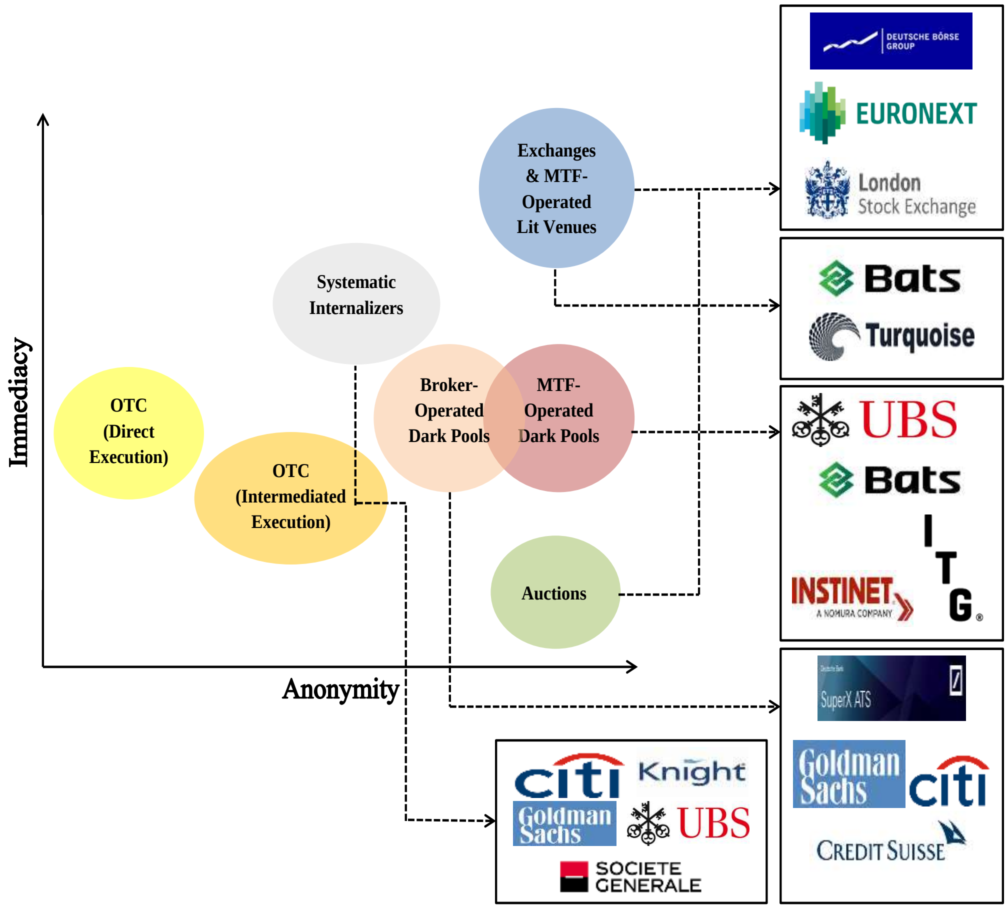

Figure 1. Immediacy Versus Anonmymity
We plot the different lit and dark markets along the two dimensions of immediacy and anonymity.

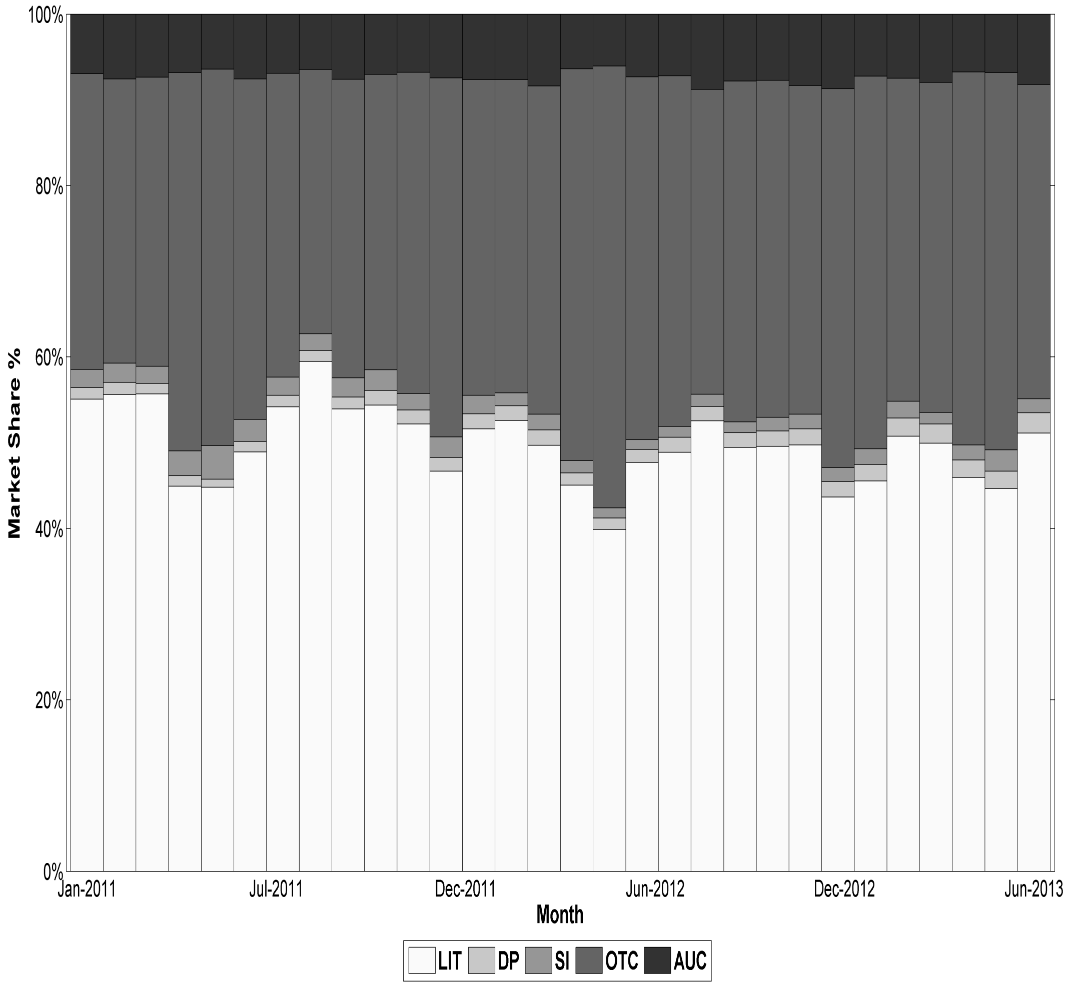

Figure 2. Market Share of Public Lit and Off-Exchange Venues

We plot the market share of the different venues defined in Section 4.3 between January 2011 and June 2013 for the 176 stocks in the sample.

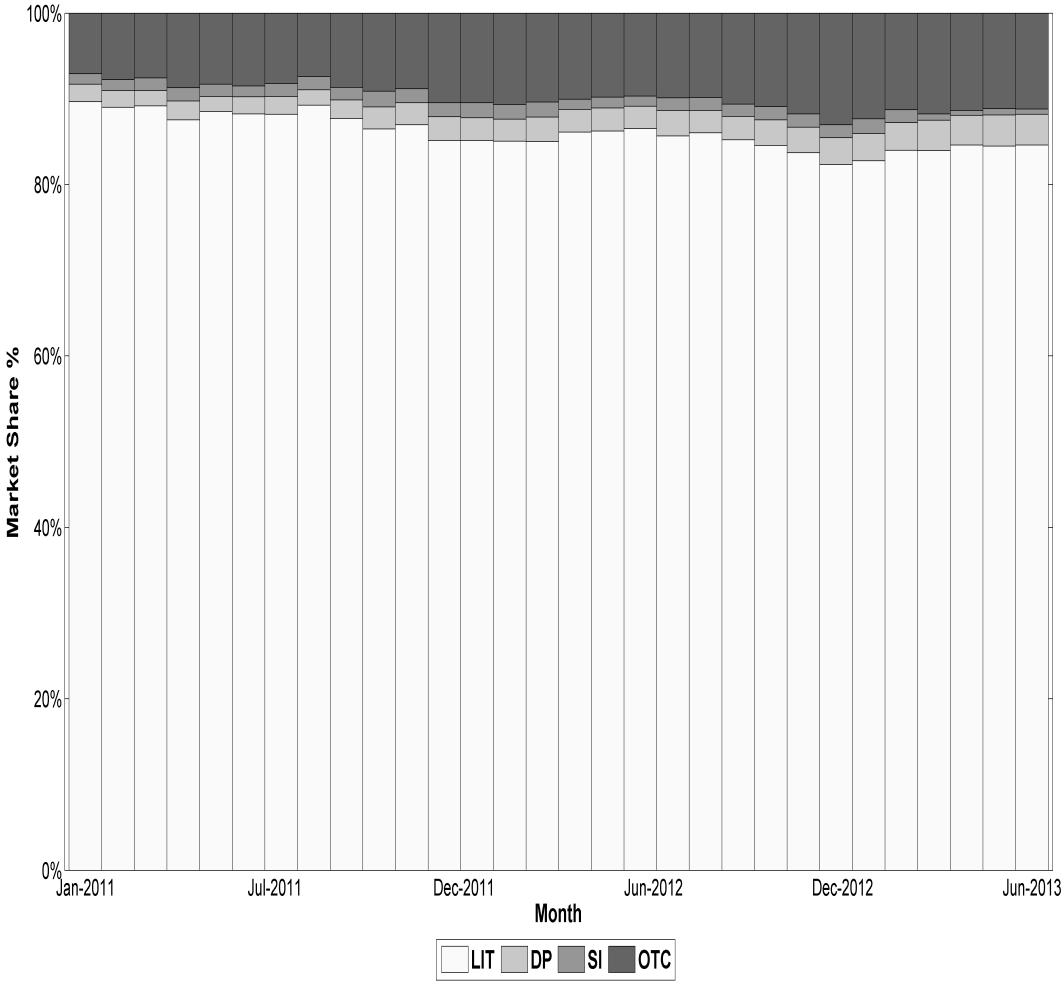

Figure 3. Market Share of Public Lit and Off-Exchange Venues for Small Trades
We plot the market share of the different venues defined in Section 4.3 for small trades i.e. trades below LIS, between January 2011 and June 2013 for the 176 stocks in the sample.

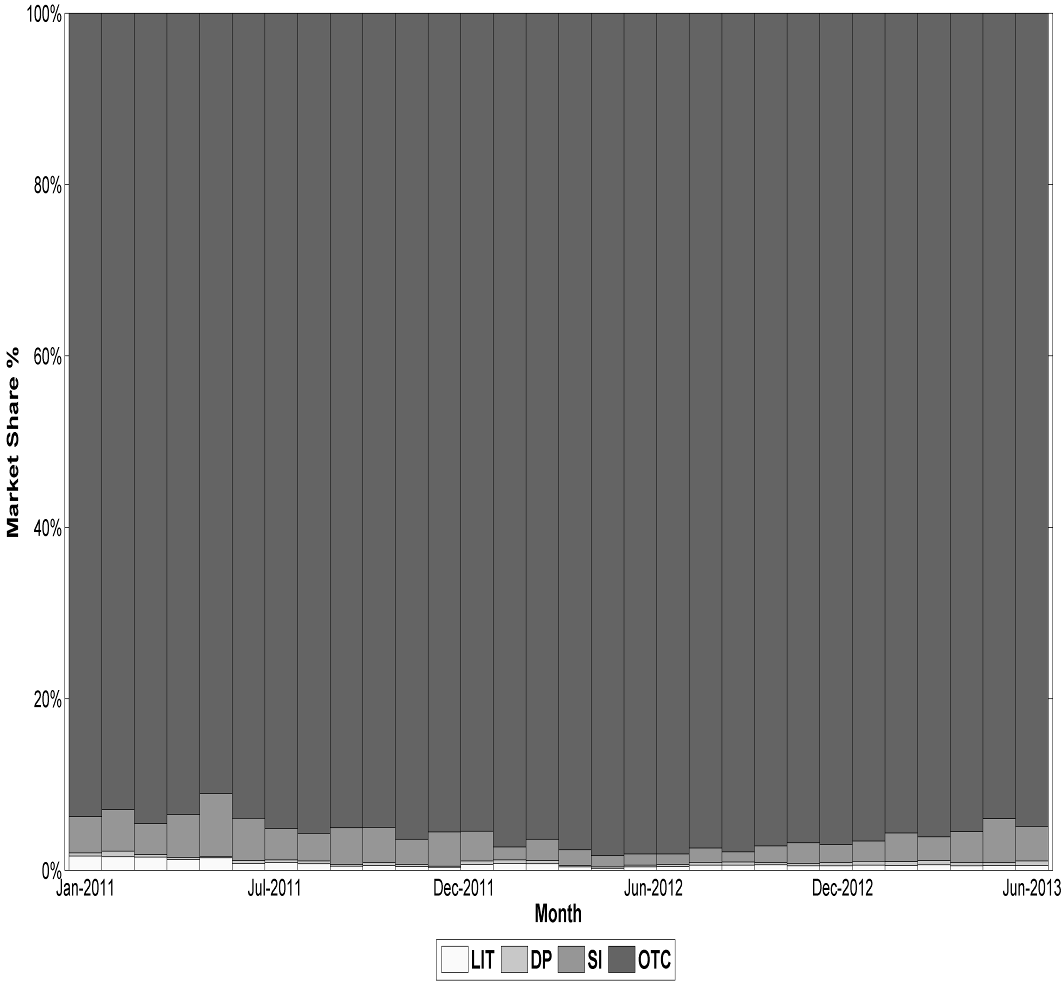

Figure 4. Market Share of Public Lit and Off-Exchange Venues for Large Trades
We plot the market share of the different venues defined in Section 4.3 for large trades i.e. trades above LIS, between January 2011 and June 2013 for the 176 stocks in the sample.

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