Costs and Benefits of Trading with Electronic Stock Dealers: The Case of Systematic Internalizers

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Abstract

Stock dealers are investment firms that trade out of their own inventories by internalizing the trades off exchanges. We analyze the extent to which traders' stock transactions occur with dealers and the associated costs. Traders face a choice between exchanges' anonymous trading and high transparency and dealers' negotiation ability and low transparency. The choice hinges on the trade-off between avoiding price impact and paying low costs for liquidity supply. Our results show that dealer trades have lower price impact, but cost more, than exchange trades. Hence, traders might choose dealers over exchanges to avoid price impact, but end up paying higher liquidity supply cost in the process. In our analyses, we look to Systematic Internalizers (SIs), who are dealers with slack regulation relative exchanges when it comes to transparency and minimum tick size. We show that dealers' comparative advantages matter for attracting trade flow.

Key Words: Equity Markets, Dealers, Exchanges, Trading Costs, Systematic Internalizers

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1 Introduction

The traditional organization of equity markets used to be a trading floor in a centrally located stock exchange building. With this market structure in place, the main liquidity suppliers were dealers, who were physically present on the trading floor, trading out of their own inventories. Today, equity markets are electronic and fragmented across exchanges, dark pools, crossing networks, and independent dealers, with different trading costs and market structure on each trading venue (O'Hara, 2015). In this market setting, traders supply and demand liquidity on the electronic multiple-venue "trading floor".

The coexistence of independent dealers and exchanges provides the opportunity for traders to choose venues based on their trading needs. Lower pre- and post-trade transparency, and the possibility of individual negotiation, make dealer platforms potentially attractive to traders who want to limit the exposure of their trading intentions. Others, in particular investors who trade on information or trade in small sizes, might prefer the anonymity and high transparency offered by exchanges, respectively. In general, traders seek to minimize their trading costs by optimally choosing the venue that matches their trading needs for transparency and anonymity (Harris (1993)).[2]

What determines traders' selection between independent dealers and exchanges? How costly is the opportunity to source liquidity from independent dealers? In the current

[2] In recent years, off-exchange trading, including broker/dealer internalization and dark pools, has grown significantly. In the U.S., un-displayed trading away from exchanges accounts for approximately 31% of consolidated volume as of March 2012 (Preece (2012)). In Europe, off-book trades account for about 26% of European equity trading volume in 2018, according to Fidessa. Fidessa is a trading technology vendor, and we use their Fragulator website for obtaining an overall picture of the fragmentation across trading venues. See https://fragmentation.fidessa.com/fragulator/

electronic market setting, are informed or uninformed traders seeking out independent dealers? We investigate these research questions in the European equity market, where regulatory reforms particularly highlight the competition between exchanges and independent dealers. Our focus is on trading costs. In our analyses, we decompose total trading cost, measured by the effective spread, into liquidity supply cost and price impact cost and we recognize a potential tradeoff between the components. In this respect, some traders might be willing to pay a higher cost to a liquidity supplier in order to avoid price impact, while others might not.

Regulators always attempt to keep up with equity market innovation and to initiate the way for development. In Europe, the first Markets in Financial Instruments Directive (MiFID I) in 2007 opened up for competition between traditional exchanges, multilateral trading facilities (MTFs), dark pools, and systematic internalizers (SIs).[3] An SI is an investment firm, registered by the European Securities and Market Authorities (ESMA) that deals through its own account when executing clients' orders outside traditional exchanges and MTFs. Regulators followed up with the MiFID II in 2018, with the main intention to increase the transparency of equity trading. Key regulatory reforms in MiFID II are the banning of broker crossing networks and restrictions in dark pool trading.[4] Following the implementation of MiFID II, SIs' market share of trading in European stocks increased from about 2% to more than 20%, according to Fidessa.[5] SIs operate as dealers

[3] In the US, also in 2007, the Regulation National Market System (Reg NMS) brought similar changes. Multilateral Trading Facilities (MTFs) are lit trading venues facilitating trading of different securities among multiple parties.

[4] Broker crossing networks (BCNs) are investment firms matching clients' orders outside the regulated markets and multilateral trading facilities without any pre-trade transparency. MiFID II limits dark trading by the double volume cap rule. Accordingly, the rule allows trading in a stock up to 4% of its volume during the past 12 months in a single dark pool and 8% across all dark pools.

[5] Just prior to the implementation of MiFID II on January 2, 2018, the ESMA registered more than 50 investment firms as SIs. By April 19, 2018, (June 18, 2019) the number of registered SIs was 103 (207). See https://registers.esma.europa.eu/publication/searchRegister?core=esma_registers_upreg for the current number of registered SIs.

with the pre-trade transparency obligation to publish bid and offer quotes continuously. As such, SIs compete directly with traditional stock exchanges and MTFs for order flow.[6] We investigate our research questions using data on transactions in Swedish stocks during the first quarter of 2018. The data identify and detail transactions on both SIs and exchanges.

Interestingly, the current European market regulation favors SIs relative exchanges in a number of ways. First, while SIs are obliged to make quotes public for orders up to the standard market size (SMS), which, according to the MiFID regulation, is about EUR 10,000 for most European shares, there is no pre-trade transparency for orders above the SMS. Exchanges have a pre-trade transparency requirement for quotes of all order sizes. Second, SIs are exempt from the harmonized tick size regime under MiFID II for orders above the SMS.[7] Exchanges must follow the minimum price improvement regime imposed by MiFID II for all order sizes. Third, SIs possess a certain flexibility in post-trade transparency. Specifically, they may delay the publishing of each trade's information while exchanges must publish information about a trade immediately following the trade.[8]

Our empirical results show that traders are more likely to choose independent dealers over exchanges when the spread is wide, depth is high and tick size is binding in the

[6] Henceforth, we refer to traditional stock exchanges and MTFs simply as "exchanges".
[7] ESMA states that for SI quotations for orders up to the SMS, "price improvements on quoted prices are only be justified when they are meaningful and reflect the minimum tick size applicable to the same financial instrument traded on a trading venue" (Question 23 in Questions and Answers on MiFID II and MiFIR market structures topics, ESMA70-872942901-38).
[8] According to the *Article 10* of MiFIR, market operators and investment firms operating a trading venue shall make details of all such transactions public as close to real-time as is technically possible. Moreover, the ESMA adds the following: "trading venues and systematic internalizers using similar technology and systems should process transactions for post-trade publication at the same speed and as close to real time as technically possible" (Question 8, Questions and Answers on MiFID II and MiFIR transparency topics, ESMA70-872942901-35).

exchange limit order book. The results also reveal that dealers, on average, offer traders almost the same execution cost as exchanges for small trade sizes.[9] Moreover, after controlling for traders' endogenous selection to trade on exchanges or with dealers, we find evidence that an average dealer trade is more costly than a corresponding exchange trade when the spread is binding, and when volatility is high on the exchanges' limit order books. On the contrary, the results show that traders with higher trading volume get a lower trading cost on dealer platforms than on exchanges.

Focusing on the tradeoff between liquidity supply costs and price impact, we decompose total trading cost (effective spread) into liquidity impact (liquidity supply cost) and price impact (adverse selection cost) components. Our results show that dealer trades on average contain a lower adverse selection cost, and carry less information, than exchange trades. The results are consistent with independent dealers being successful in minimizing the price impact of the trades, for which they charge a relatively high liquidity supply cost. Informed and/or liquidity traders might choose to trade through dealers rather than exchanges in their ambition to avoid order exposure or price impact, and they might be prepared to pay the relatively high liquidity supply cost of doing so. Put differently, dealer revenues from trades, in particular for trades larger than SMS, are on average higher than corresponding revenues for liquidity suppliers on exchanges.

This study contributes to the literature on dealer markets and their competition with other trading systems. Degryse, Van Achter and Wuyts (2009) theoretically analyze traders' choice of venue between crossing networks and dealer markets. They document that traders with strong willingness to trade are more motivated to be present in the

[9] With small trade sizes, we mean those that are below the standard market size stipulated by the European Securities and Market Authorities (ESMA).

dealer market as it guarantees the execution while the crossing network does not. With respect to execution cost, in their theoretical model, Pagano and Röell (1996) examine trading cost between auction and dealer markets by focusing on their difference in transparency. The authors show that higher transparency in auction markets leads to lower average trading costs for uninformed traders. Along the same lines, Huang and Stoll (1996) empirically find that execution cost in a dealer market (NASDAQ) is twice the size of that in the auction market (NYSE). They argue that the higher cost might be partially due to the internalization, order preferencing, and the presence of alternative interdealer systems, which reduce dealers' willingness to narrow the spread, and result in higher costs on dealer markets.

Seppi (1990), Pagano and Röell (1992) and Easley, Kiefer and O'Hara (1996) argue that dealers are more likely to trade with uninformed traders since the lack of anonymity and limited transparency in dealer markets help them to screen informed traders. This paper differs from previous studies on dealer markets in two ways. First, we analyze the competition between exchanges, which run fully electronic limit order book markets, and dealer markets with respect to the traders' choice of venue and execution cost. Second, while most of the studies on the competition between dealer and auction markets go back to the time when the market was not fragmented, we address our research questions in the context of today's fragmented equity markets. Our study also contributes to the literature on internalization. Grammig and Theissen (2005) show empirically that internalized trades contain less information and carry lower adverse selection cost. Moreover, Chung, Chuwonganant and McCormick (2006) and Larrymore and Murphy (2009) show that internalization harms overall market quality, while Kam,

Panchapagesan and Weaver (2003) conclude that the market quality effect of dealer internalization is benign.

We also contribute to the growing studies on SIs. Gomber and Zimmermann (2014) find that a large fraction of SI trades of the STOXX 50 index in the year 2009 are at better prices compared to the primary market. Conducting an event study, Aramian (2018) shows that SIs' trading volume is higher when the tick size is binding on exchanges, and that SI trading driven by stocks with higher tick size harms market quality by increasing the quoted and effective spreads on exchanges. Johann, Putniņš, Sagade and Westheide (2019) analyze the market share and market quality effects of the ban on dark pools after the implementation of MiFID II. The authors document that a fraction of dark pools' order flows migrates to SIs following the implementation of the double volume cap, and that the liquidity effect of this migration is benign. Different from these studies, we address traders' order routing strategies, their trading costs and the information asymmetry between SIs and exchanges.

Our study is also relevant to the literature on market fragmentation. The initiation of new trading venues with different market structures (e.g., MTFs and dark venues) resulted in studies analyzing the driving elements of market share between different trading systems. These studies show mixed results. He and Lepone (2014) provide evidence from the Australian stock market showing that low exchange liquidity shifts trading from this venue to its exchange operated dark pool. On the other hand, Buti, Rindi and Werner (2010) theoretically show that the dark market share is higher when the exchange spread is narrow, and, thus, liquidity is high. Regarding competition between exchanges, He, Jarnecic and Liu (2015) examine the competition between Chi-X and the primary market for different countries. We add to this literature by analyzing traders' venue choices on a

trade-by-trade basis, and trading cost between transparent (exchanges) and partially transparent (SIs) trading mechanisms.

The empirical results presented in this paper are relevant to regulators, market operators and traders. Investigating the competition between SIs and exchanges during the post-MiFID II period is important to regulators when they evaluate the outcomes of the new regulation, and provides insights for future regulatory policies. Our findings might also be informative to dealers and exchanges for assessing their trading structures and analyzing their strengths and weaknesses in the competition against each other. Finally, our study is of interest and relevance to traders. It helps them to understand which factors result in a better execution quality across dealers and exchanges.

The paper continues as follows. Section 2 sets out the literature review and hypotheses development. Section 3 contains an overview of the institutional details and data. Section 4 presents the analyses and the empirical results. Section 5 provides concluding remarks.

2 Literature Review and Hypotheses Development

In this section, we present previous research that will help us answering our research questions posed in the introduction. First, we jointly discuss the hypotheses for the questions of "*What determines traders' selection between independent dealers and exchanges?*" and "*How costly is the opportunity to source liquidity from independent dealers?*" preparing for the analyses of venue choice and trading costs. Second, we turn to the hypothesis for the question of "*In the current electronic market setting, are informed or uninformed traders seeking out independent dealers?*".

2.1 Venue Choice and Trading Costs

Execution quality is an important element that affects traders' order routing decisions. Market participants increase the quality of their transactions by being present on a trading venue offering a low transaction cost or fast fill (Bessembinder and Venkataraman (2004) and Boehmer, Jennings and Wei (2007)). Inter-market competition together with technological innovations provide traders with smart order routing systems the opportunity to source liquidity across different trading venues and choose where to trade.

The choice between dealers and exchanges depends on different factors. The situation with dealers (SIs) being able to set prices within the exchange bid-ask spread is similar to the theoretical model in Buti, Consonni, Rindi, Wen and Werner (2015). Their model has a limit order book, which faces competition from a sub-penny venue that allows trades within the minimum tick size constrained spread (a penny). They predict that traders will choose to queue jump to the sub-penny venue when the limit order book is constrained, i.e., when the bid-ask spread equals the minimum tick size. Moreover, the authors argue that when the tick size is binding, traders are more likely to submit market orders than limit orders. As a result, the migration of marketable orders to the sub-penny venue is more concentrated during this condition of the order book. We transform the theoretical result from Buti et al. (2015) into a prediction of the inter-market competition between dealers and exchanges. Accordingly, we expect to see a larger trading activity at SIs when the bid-ask spread on exchanges is binding in the sense that it equals the minimum tick size.

Liquidity measures such as bid-ask spread and order book depth are factors that might affect traders' choice of venue. Spread and depth vary across dealers and exchanges as they operate under different market structures. When the exchange bid-ask spread is

wide, liquidity-taking traders are more likely to migrate to a venue with tighter spread to reduce their transaction costs. He et al. (2015) examine the determinants of market share between two exchanges (Chi-X and the corresponding traditional exchange). The authors document that the spread is an important determinant for traders' routing decisions. The literature on off-exchange markets also emphasizes the importance of the spread in competition between trading venues. He and Lepone (2014) provide evidence that the dark market share increases when there is a large quoted spread on the primary exchange. On the contrary, though, Buti et al. (2010) indicate that dark pools experience higher trading volume when the exchange spread is narrow.

When the exchange limit order book is deep, it is possible to trade large orders without moving the price. However, high order book depth causes longer waiting time for limit orders to be executed. As a result, traders with short-lived information might find it optimal to cross the exchange spread or move to dealer platforms depending on which venue is providing the lowest cost. Hence, the decision on where to trade boils down to a trading cost decision, i.e., a comparison of venue spreads. Buti et al. (2010) and He and Lepone (2014) address the association between dark trading activity and depth by documenting that large depth in the limit order book results in the higher dark trading volume. To this end, we expect that traders shift trading to SIs when the spread and depth are large on exchanges.

Volatility affects both venue choice and trading cost. In times of high volatility, liquidity providers quote wider bid-ask spreads to protect themselves from, e.g., trading with informed traders. In addition, at times of high volatility, traders might be willing to be present on venues with high concentrated liquidity to guarantee their execution at a reasonable cost. He et al. (2015) show that the Chi-X volume share is lower relative to

volume on the primary exchange when volatility is high. Along the same line, He and Lepone (2014) and Ye (2010) find a negative relationship between dark pool trading activity and the volatility of the limit order book. As a result, we expect a higher SI trading cost than on exchanges when volatility is high, as exchanges are more likely to provide a stable liquidity, and subsequently a lower execution cost than dealers.

2.2 Price Impact of Large Trades

In the internalization process, dealers execute customers' orders against their own inventories through negotiation, without sending them directly to other venues, e.g., the exchanges. Information content of dealer trades, which is reflected in each trade's permanent price impact, is driven by the distribution of informed and uninformed order flows on dealer platforms. The dynamics of trading strategies by dealers, informed, and uninformed traders, is affected by the degree of transparency and anonymity offered by dealer platforms and exchanges. Indeed, dealers' flexibility with respect to pre- and post-trade transparency, and their non-anonymous trading system might attract various types of traders.

Informed traders who trade on their private information usually trade in large sizes to maximize their profit (e.g., Blau, Van Ness, and Van Ness (2009)). As noted in Grossman (1992), exposing large orders on transparent markets like exchanges imposes the risk of being front run by other traders or the risk of being picked off if the market conditions change. Hence, informed traders might be willing to interact with dealers to limit the exposure of their orders.

On the other hand, informed traders are better off in an anonymous market structure since they are able to hide their identities. Otherwise, it is hard for them to find

counterparties to trade with, as other traders know that they are informed (e.g., Harris (1993)). Grammig, Schiereck and Theissen (2001) show that the probability of informed trading is higher on the anonymous electronic trading system of the Frankfurt Stock Exchange than its non-anonymous floor-based exchange. As a result, informed traders face a tradeoff between trading on exchanges, which offer high transparency and anonymity, and dealer platforms. Trading with a dealer might limit the order exposure but might result in a higher total trading cost. In fact, dealers increase their spread (Glosten and Milgrom (1985), or charge a higher premium to informed traders to mitigate their loss in those trades.

The lack of pre-trade transparency also motivates uninformed traders to interact with dealers as they can control the risk of being picked off by predatory traders. In his theoretical study, Zhu (2014) argues that liquidity traders are willing to trade on venues with no pre-trade transparency (dark pools) to reduce the adverse selection cost. In addition, liquidity traders willing to trade large blocks of orders might benefit from trading with dealers. Specifically, the non-anonymous trading offered by dealers provides liquidity traders with the possibility to reveal their identities to show that they trade for liquidity purposes in hopes of getting a lower transaction cost, so-called "sunshine trading".

The theoretical and empirical studies on the co-existence of anonymous and non-anonymous trading systems conclude that information asymmetry, which is reflected in permanent price impact and adverse selection cost, does not play a big role in the non-anonymous markets due to the possibility of screening information-based trades (e.g., Seppi (1990); Smith, Turnbull, and White (2001); Booth, Lin, Martikainen (2001)).

From the dealers' perspective, based on their theoretical models, Chordia and Subrahmanyam (1995) and Easley, Kiefer, and O'Hara (1996) show that dealers are more likely to internalize trades with uninformed traders. They argue that dealers actively choose to trade with uninformed traders to avoid the adverse selection costs. In other words, trade internalization with customers who have superior information causes dealers to lose in those transactions and make their trades less profitable. Along the same line, Grammig and Theissen (2005) find that internalized trades contain less information and carry lower adverse selection cost.

Regarding the post-trade transparency, dealers have the possibility to delay the publication of each trade. When dealers internalize trades, by taking on customers' trades, they earn the bid-ask spreads but face the risks associated with the stock positions. This flexibility might provide dealers with the opportunity to offload stock positions acquired in a trade before the trade becomes publicly known.

SIs operate as dealers with certain flexibility in the pre- and post-trade transparency relative the exchanges, and might internalize their clients' orders through negotiation, without sending them directly to the exchanges. Based on previous research, we hypothesize that SI trades convey less information and carry less adverse selection cost than trades on exchanges. Whether the relatively low adverse selection is a result from dealers' skills in working large orders or their avoidance dealing with informed traders is an open question that we cannot answer with the data at hand.

3 Institutional Details and Data

This section provides a description of the institutional details for the venues on which it is possible to trade Swedish stocks. The main emphasis is on the independent dealers (the

SIs), and the exchanges. The section also contains a presentation of the data and some summary statistics of trading activity on the dealer platforms and exchanges.

3.1 Institutional Details

The empirical setting is the Swedish stock market. Today, it is possible to trade Swedish stocks on several trading platforms including exchanges, dark venues and SIs. We focus on trading activity of the OMXS 30 index stocks on SIs and the most important exchanges (Nasdaq OMX Stockholm and the MTFs).

Nasdaq OMX Stockholm is a regulated market (RM) offering an auction mechanism and continuous trading. The continuous trading takes place in a limit order book from 9:00 AM to 5:25 PM. The execution priority of submitted limit orders is set based on price, internal, visibility, and time.[10] Trading is open every weekday except for Swedish public holidays. On a weekday before a Swedish public holiday, the market closes early at 1:00 PM. The MTFs are pan-European exchanges that initiated equity trading following the introduction of MiFID I in 2007. Chi-X was the first pan-European exchange launched in 2007 and Bats Europe, Turquoise and Acquis soon followed. The exchanges (RMs and MTFs) are venues providing full pre-trade transparency for visible limit order book trading. The execution priority of limit orders on the MTFs follows price, visibility and time.

Stock trading is also possible on independent dealer platforms (SIs), which are different from the exchanges in a number of respects. First, SIs trade bilaterally with their clients' orders outside the exchanges. In other words, while exchanges facilitate trading by

[10] Internal priority means internalization of orders within a trading firm. If a trading firm who submits a market order also has a limit order posted in the book at the same price level, that limit order gets priority even if other limit orders at the same price level were posted earlier.

allowing the interaction of multiple third party buying and selling interests, SIs execute clients' orders against their own books. According to the European Securities and Markets Authorities' Questions and Answers (ESMA's Q & A) on the SI networking issue on April 5, 2017, "*SI activity is characterized by risk facing transactions that impact the profit and loss account for them".* It is also stated that rules *"prevent SIs from operating any system that would bring together third party buying and selling interest in a functionality similar to a trading venue"*.

Second, SIs are obliged to make quotes public for liquid stocks while quotes for less liquid stocks are only required to be published upon request. Third, while SIs are required to make quotes public up to the Standard Market Size (SMS), which is EUR 10,000 for the OMXS 30 stocks, pre-trade transparency is waived for orders larger than the SMS. Fourth, SIs possess more flexibility than exchanges regarding post-trade transparency by being allowed to publish a trade's information with a delay up to one minute after the execution time. Moreover, the MiFID II post-trade transparency regime for equity trading stipulates that investment firms dealing with their own accounts can report trades above a certain size (very large trades) with an even longer delay. The time deferral depends on the trade size and varies from 60 minutes, 120 minutes, until the end of the trading day, or until the end of the next trading day.[11] Thus, for trades in this category with a possible informational signal value, SIs might find it optimal to delay the reporting time in order to hide the information of the trade as long as possible.

The fifth and final distinction between SIs and exchanges relates to tick size. While

[11] The minimum qualifying size for public deferral is specified in Table 4 in ANNEX II, RTS1 (https://eur-lex.europa.eu/eli/reg_del/2017/587/oj). These trades are identified using the ESMA's Transitional Transparency Calculation (TTC) file. In this file, the average daily turnovers (ADT) of ISINs are estimated over the fixed period between January 4 and September 12, 2017. With the ADT and Table 4, it is possible to obtain the minimum qualifying size for delaying and the accepted delay time for each stock.

exchanges must follow the harmonized tick size regime for orders of all sizes, SIs have flexibility with respect to the minimum price improvement for orders above the SMS.

3.2 Data and Summary Statistics

The data consist of all trades and quotes in the OMXS 30 stocks recorded in the Refinitiv Tick History (RTH) database between January 3 and March 23, 2018 (58 trading days).[12] The RTH database allows us to identify trades on SIs and on exchanges. We confine the analyses to the SI trades that are reported to the CBOE trade reporting service, BXTR.[13] According to Fidessa, BXTR is the reporting venue for more than 98% of the SI trades in the OMXS 30 stocks during the sample period.[14] We also confine the analyses to trades reported during the regular exchange continuous trading hours.

The SI trade data contain information on trade price, size, the reporting time (to the fraction of microseconds), and flags (indicating if it is a SI, dark or over-the-counter trade).[15] However, we cannot identify the specific SI that is responsible for each trade. Moreover, SIs may delay the trade information after the execution time. Hence, we may not ascertain that the reporting time of a trade is the same as the actual trade execution.

The RTH database also holds microsecond-stamped data on all trades and quotes on exchanges during the sample period. We define the exchanges where the OMXS 30 stocks

[12] Previously known as *Thomson Reuters Tick History* (*TRTH*). See https://www.refinitiv.com/en/financial-data/market-data/tick-history.

[13] Under MiFID II, SIs should report both pre- and post-trade information through a new data reporting service called Approved Publication Arrangement (APA). Currently, there are eight registered APA reporting services for SIs. The eight APAs for SIs are CBOE Trade Reporting Service (BXTR), TRADEcho, Nasdaq MiFID II APA service, Tradeweb, Trax, Deutsche Boerse, Bloomberg and NEX Regulatory Reporting. However, RTH only has the three reporting systems of CBOE trade reporting services, TRADEcho and Nasdaq APA service.

[14] See https://fragmentation.fidessa.com/fragulator/?fim=.OMXS30.ST

[15] We removed three SI trades from our sample, as their trade prices were out-of-scale. Specifically, three stocks had one trade with a price less than SEK 1, which seem to be a mistake in the reporting. All three trades took place on the same day and around the same time.

trade as Nasdaq Stockholm, Bats Europe, Chi-X, Turquoise and Acquis.[16] Through RTH, we obtain information on each trade including trade price, size, and time of the execution. For the exchange trades, we only consider transparent trades taking place in the limit order books. In other words, non-standard trades, dark trades and those that are negotiated outside the exchanges are excluded from the sample. All exchanges are required to report trades immediately after execution.

The RTH data give us access to limit order book data from all exchanges, i.e., bid-ask prices and corresponding sizes for the best level on both sides of each order book. To avoid potential issues related to the opening and closing of trading on the exchanges, quotes reported during the first and last five minutes of the continuous trading session are removed from the sample. From the data of each exchange, we construct a consolidated limit order book in real time, which is the order book that sums liquidity over all exchanges.

[Insert Table 1 Here]

Table 1 presents summary statistics for measures of trading activity on SIs and exchanges. The RTH sample contains 11.19 million trades, whereof 0.51 million trades (4.6%) occur on SIs and the rest on exchanges. These trades amount to a total SEK volume of almost 573 billion for a total number of 4.61 billion shares. The SI market share is almost 23% of both the total SEK volume and the total number of traded shares. Evidently, SI trades occur less frequently than exchange trades, but some SI trades are very large. In Table 1, when we categorize the trading activity measures with respect to trade size, we note that the largest trades (those with a size in excess of 5,000 shares) on SIs are only 2.23% of all

[16] According to Fidessa, these five venues account for more than 99% of all lit limit order book trades in the OMXS 30 stocks during our sample period.

SI trades, but account for almost 80% of the SI volume. On the exchanges, the largest trades account for 0.15% of the number of trades, and around 2% of the volume. Evidently, SIs seem to attract larger trades than exchanges.

Table 1 also categorizes each trading activity measure with respect to time of the day, displaying the fraction of trades, volume and shares traded during morning (9:00 AM to 12:00 noon), midday (12:00 noon to 3:00 PM), and afternoon (3:00 PM to 5:25 PM) hours. Trading activity on SIs increases throughout the day, with around 45% of the activity going on during afternoons. On exchanges, the morning hours see almost 38%, midday hours about 26%, and the afternoon hours around 36% of the trading activity. To illustrate the different intraday trading activity patterns at SIs and exchanges, we plot the percentage number of trades, for each type of trading venue, on a half-hour basis throughout the trading day. For exchanges, we observe the usual U-shaped pattern in the number of trades, while the corresponding pattern for SIs is more J-shaped. Thus, in a relative sense, traders are less prone to choose SIs in the beginning of the trading day, and, reversely, more inclined to choose SIs towards the end of the day.

[Insert Figure 1 Here]

4 Analysis

We now turn to our analysis of the research questions. To answer our first research question: "*What determines traders' selection between independent dealers and exchanges?*" we first focus on trades smaller than the SMS (henceforth, small trades). Since dealers (SIs) are obliged to have the pre-trade transparency only for small trades, focusing only on transparent trades helps us to conduct reasonable analyses of the competition between SIs and exchanges. Indeed, performing the analyses only on small

trades helps us to determine the driving elements of traders' choice of venue in a condition where they observe quotes from both types of platform. Moreover, these trades are not subject to the post-trade publication deferral.

In a first stage, we estimate the selection between SIs and exchanges as a function of expected trading costs. Then, in a second stage, we estimate the trading cost at each trading venue type, while controlling for venue selection. The purpose of the second stage analysis is to answer our second research question: "*How costly is the opportunity to source liquidity from independent dealers?*". We look at how valuable SIs are from a liquidity demander's point of view; if s/he can get lower trading costs on SIs than on exchanges, and, if so, for which trades.

Finally, we focus on the trades larger than SMS (henceforth, large trades) to deal with our third research question "*In the current electronic market setting, are informed or uninformed traders seeking out independent dealers?*". In particular, we estimate the price impact of large trades to address how informative dealer trades are.

4.1 Venue Selection and Trading Cost

Sample of Small Trades and Descriptive Statistics

In the analysis of venue selection and trading cost, we set aside the large trades and randomly draw a sample of 300,000 small trades reported between 9:05 AM and 5:20 PM. We exclude data from the first and the last five minutes of continuous trading in order to avoid potential issues related to the opening and closing of trading on the exchanges. Table 2 reports descriptive statistics for the sample trades. The sampling procedure results in 13,610 SI trades (4.5%) and 286,390 exchange trades (95.4%). The percentage

number of SI trades is roughly 5% in both the small trade sample and the sample containing all trades. However, the percentage SI share of the SEK trading volume is much smaller in Table 2 relative to Table 1. This is due to the removal of the large trades, which contain larger volume on SIs than on exchanges.

[Insert Table 2 Here]

Table 2 shows that trading differs between SIs and exchanges when it comes to the spread binding condition prevailing in the order book consolidated across exchanges. Roughly 45% of the SI trades and only 34% of the exchange trades occur when the bid-ask spread equals the minimum tick size in the order book (*Zero Tick*). That is, trading on SIs is relatively more likely when the tick size is binding than when it is not binding.

We measure the cost of each trade as the signed difference between the trade price relative a benchmark price at the time of the trade (t), expressed in basis points. As the benchmark price, we use the midpoint quote in the consolidated exchange limit order book for both exchange trades and SI trades, at the time of each trade. In this way, the cost measure is the effective spread, which is extensively used to measure trading costs in the literature (see, e.g., Bessembinder, 2003). We refer to this cost as the *Effective Cost* and use it for measuring the cost of trades on both SIs and exchanges:

$$Effective\ Cost(t) = \left(\frac{Trade\ Price(t) - Midpoint(t)}{Midpoint(t)}\right) \times Trade\ Sign(t), \qquad (1)$$

where *Trade Sign* identifies the trade direction, taking the value of +1 for a buyer-initiated and -1 for a seller-initiated trade.

We use the Lee and Ready (1991) technique to estimate *Trade Sign* in Equation (1) by matching each trade price to the midpoint quote in the consolidated exchange limit order book at the time of the trade. Accordingly, a trade is seller-initiated if the traded price is below the midpoint and buyer-initiated if the price is above the midpoint. For trades at the midpoint, we follow the tick test method presented in Lee and Ready (1991), in which the direction of each trade is inferred by comparing its price to the price of preceding trades. According to this technique, a trade is buyer-initiated (seller-initiated) if its trade price is higher (lower) than the price of the previous trade. Consequently, *Trade Sign* takes the value zero for the cases when we are not able to infer the trade direction from data.

We also decompose the effective cost into liquidity impact (liquidity supply cost) and price impact (adverse selection cost). We define *Liquidity Impact* as the signed relative difference between the trade price and the exchange midpoint quote τ = 15 seconds after the reported time of the trade:

$$Liquidity\ Impact(t) = \left(\frac{Trade\ Price(t) - Midpoint(t+\tau)}{Midpoint(t)}\right) \times Trade\ Sign(t). \quad (2)$$

Moreover, we define *Price Impact* as the signed relative difference between the midpoint quote τ = 15 seconds after the reported time of the trade and the midpoint quote at the time of the trade:

$$Price\ Impact(t) = \left(\frac{Midpoint(t+\tau) - Midpoint(t)}{Midpoint(t)}\right) \times Trade\ Sign(t). \quad (3)$$

Table 3 presents volume-weighted averages for the three cost measures for the sample of

300,000 small trades. From the first row of Table 3, we note that the average effective cost equals 2.98 basis points for SI trades and 2.86 basis points for exchange trades. Hence, the one-way cost of trading on SIs is on average 0.12 basis points higher than on exchanges. The average liquidity impact of SI trades is 2.52 basis points (84.6% of the effective cost) while the average price impact of SI trades is only 0.46 basis points (15.4% of the effective cost).[17] For exchange trades, the pattern is different with an average liquidity impact of 0.82 basis points (28.6% of the effective cost), and an average price impact of 2.04 basis points (71.4%). Evidently, the SI trades carry only modest price impacts, but relatively high liquidity impacts. This result is consistent with dealers being successful in avoiding adverse selection, and earning high revenues for their liquidity supply.

[Insert Table 3 Here]

Other values in Table 3 than in the first row represent the average volume-weighted cost conditional on the levels for the same variables as in Table 2. The conditions *Small* and *Large* refer to below and above the variable median. When the consolidated exchange bid-ask spread (*Spread*) is large, i.e., when the exchange liquidity is low, the average effective cost is 2.91 basis points for SI trades, and 3.89 basis points for exchange trades. This indicates that it might be worthwhile to choose to trade on dealer platforms when the exchanges experience low liquidity. However, when the tick size is binding (*Zero Tick*), the average SI effective cost is higher than the corresponding average exchange cost. In fact, the effective cost is on average slightly smaller on SIs than exchanges when the tick

[17] We also measure liquidity impact and price impact for the time horizon equal to 30 and 60 seconds. The use of a longer time horizon does not affect the results. Hence, we present only subsequent results from using the 15 second time horizon.

size is not binding (> *Zero Tick*).

Effective cost on SIs as well as on exchanges is higher when volatility is high rather than low. *Volatility* is the realized volatility of one-second returns (changes in the midpoint quote in the consolidated exchange limit order book) during the five-minute period preceding each trade. Moreover, the difference between trading cost on SIs and exchanges is larger when volatility is high. Hence, it seems that dealers on average require a higher markup than liquidity suppliers on exchanges to compensate for higher volatility.

We expect to find increasing trading costs with larger trade size. This is the case for exchange trades, for which effective cost, liquidity impact and price impact increase with trade size. Large trades could be more costly in the consolidated limit order book as they might need to walk the book in order to be filled. Moreover, large trades might be likely carriers of information and then incur large adverse selection. SI trades also exhibit an increasing price impact with trade size. However, the effective cost for SI trades is not increasing with trade size. Instead, the liquidity impact decreases as a function of trade size. These observations indicate that dealers accept lower liquidity supply revenues when trade size becomes larger. In particular, for trades larger than 1,000 shares, the average effective cost on SIs is 3.05 basis points, while the corresponding average cost for exchange trades is 4.19 basis points. Hence, for trades smaller than the SMS, traders experience a lower execution cost on SIs than on exchanges when they trade more than 1,000 shares.

We also measure the undercutting cost distribution for the small SI trades in the sample. Table A1, in the appendix, reports descriptive statistics for the undercutting cost measure. *Within Spread* (*Outside Spread*) presents the percentage of SI trades priced within (outside) the bid-ask spread prevailing in the consolidated order book across exchanges

at the reported time of each trade. *At the Best* is the percentage of SI trades executed at the best quotes in the consolidated book at the reported time of each trade.

The first row in Table A1 shows that SIs undercut the exchange spread for around 43% of trades. In addition, we note that 32% of SI trades are priced at the best quotes of the exchanges while 24% of them receive inferior prices relative the best quotes. Other values in Table A1 than in the first row present the undercutting distribution conditional on the levels for the same variables as in Table 3. We note that SIs mainly undercut the spread and offer better trading costs when the exchanges spread is large, and the spread is not binding with the tick size.

Endogenous Venue Selection

The descriptive statistics on dealer and exchange trading costs must be interpreted as conditional on self-selection of trading venue. In other words, a bias in trading cost might arise when traders choose the venue that provides the lowest trading cost. Our goal is to obtain measures of trading costs that correct for the self-selection of trading venue, and we use the two-stage estimation procedure, originally proposed by Heckman (1979), to achieve this goal. Several studies use the two-stage approach to compare trading costs across different venues. Madhavan and Cheng (1997) and Bessembinder and Venkataraman (2004) apply the approach in the selection between upstairs and downstairs trading of stocks. Conrad, Johnson and Wahal (2003) use it in the analysis of the drivers of execution quality between electronic communication networks (ECNs) and traditional brokers, Hendershott and Madhavan (2015) in the selection between auction and over-the-counter trading of bonds, and Degryse, De Jong and van Kervel (2015) in the analysis of trading costs of stocks on dark and visible trading venues.

The first stage of the procedure helps us to provide evidence for the determinants of dealer trades, and we estimate the selection between trading on dealer platforms and on exchanges with a probit regression. Then, in the second stage, we estimate trading costs at each venue type while correcting for self-selection.

Determinants of the Choice between Dealer Platforms (*SIs*) *and Exchanges*

The dependent variable in the probit regression model is a dummy variable that is equal to one for an SI trade and zero for an exchange trade. For the explanatory variables, we follow the literature, which argues that a trader will select the venue with the lowest expected trading cost (e.g., Bessembinder and Venkataraman (2004) and Boehmer, Jennings and Wei (2007)). In our setting, this means that trading cost will depend on the liquidity in the limit order book consolidated across exchanges. We use the bid-ask spread and depth in the consolidated exchange order book as empirical proxies for the level of liquidity. Specifically, we estimate the spread as half the relative quoted spread prevailing in the consolidated order book at the reported time of each trade. Depth is the average SEK volume available at the best bid price and the best ask price in the consolidated order book at the reported time of the trade.

Moreover, we hypothesize that the spread binding condition at the exchanges affects the choice between SIs and exchanges. Hence, we include a dummy variable that is equal to one when the tick size is binding, and zero otherwise, as an explanatory variable in the probit regression. In addition, as Hendershott and Madhavan (2015), we include trade size and volatility as determinants of the venue choice.

As instrumental variables in the first stage regression analysis, we follow Degryse et al. (2015) and use the time in minutes between each trade and its previous trade, and a

dummy variable indicating whether each previous trade occurs on an SI or not. According to Degryse et al. (2015), a long time between consecutive trades indicates that trading on exchanges is inactive since the majority of trades occur on exchanges, and that an SI trade is more likely to occur. Moreover, a recent SI trade indicates SI trading interest, which increases the likelihood that the following trade also occurs on an SI.

Table 4 presents the results from the probit regression. The regression is estimated with maximum likelihood, and standard errors are clustered on stock. We also demean the continuous explanatory variables. Alongside each estimated coefficient, and each associated standard error, Table 4 also shows the marginal effect of each explanatory variable. We define the marginal effect as the change in probability of trading on an SI when there is a shock in each explanatory variable. For each dummy variable, the shock is a change from 0 to 1. For the continuous variables, the shock is a one standard deviation increase. In addition, we include stock fixed effects by adding a dummy variable for each stock, except for one.

[Insert Table 4 Here]

Consistent with expectations, the likelihood of trading on an SI is increasing significantly with the exchange bid-ask spread (*Spread* in Table 4). This result is in line with a substitution effect, according to which traders are more likely to select SIs when the exchange liquidity is low. Moreover, the marginal effect of a one standard deviation increase in the exchange spread equals 0.89%. The results also show that the exchange depth (*Depth* in Table 4) is positively associated with traders' willingness to trade on SIs. The marginal effect of depth is 2.53% and it is statistically and economically significant. This finding is in line with empirical results of He and Lepone (2014) and Buti et al.

(2010), who document the determinants of dark market shares with respect to the depth in limit order markets in Australia and U.S., respectively.

The results also confirm that the spread binding condition is an important determinant for venue selection. The likelihood of selecting SIs is significantly larger when the tick size in the exchange order book is binding than when the tick size is not binding. The coefficient for the dummy variable *Zero Tick* is significantly positive, and its marginal effect equals 3.21%. Considering that the unconditional likelihood of an SI trade is 4.50%, the marginal effect of going from a situation with a non-binding tick size to when it is binding is quite large, and, we argue, economically significant.[18]

In addition, Table 4 shows that SI trades are less likely when volatility (*Volatility*) is high. This is in line with our expectation based on the notion that traders prefer to be present on exchanges, with high concentrated liquidity, in times of high volatility. It is also consistent with the empirical work of He and Lepone (2014), who find that dark trading activity is higher when the volatility of the central limit order book (in Australia) is lower. Moreover, SI trades are less likely if the trade size (*Trade Size*) is high. Thus, when we consider small trades, i.e., lower than SMS, traders are significantly more likely to use SIs for the execution of their low volume trades. However, the marginal effects from *Trade Size* and *Volatility* on venue selection are very small, which makes the economic significance of these two variables limited.

The instrumental variables (*SI Lag* and $\Delta minute$) are both associated with significantly positive coefficients. Following the argumentation of Degryse et al. (2015), this means

[18] The unconditional likelihood of an SI trade during midday trading hours is obtained from Table 2 as the fraction of SI trades to all trades in the sample of 300,000 trades.

that the variables are strong predictors of observing an SI trade. Based on its marginal effect of 3.26%, we argue that *SI lag* is the most important instrumental variable.

Cost Estimation for trades on Dealer Platforms and Exchanges

In the second stage, we formulate regressions for effective trading cost, defined in Equation (1), on SIs ($Cost^s$) and exchanges ($Cost^e$) separately, conditional on the venue selection, in the following way:

$$E[Cost^s|x, z, S = 1] = x'\beta_s + \alpha_s MR_s(z'\gamma), \quad (4)$$

$$E[Cost^e|x, z, S = 0] = x'\beta_e + \alpha_e MR_e(z'\gamma), \quad (5)$$

where S represents the dummy variable for venue selection that is equal to 1 for an SI trade and 0 for an exchange trade, x contains the variables affecting trading costs, z contains the variables affecting the venue selection, and MR is short for the inverse Mill's ratio. The inverse Mill's ratios are obtained from the first stage probit regression as: $MR_s(z'\gamma) = \varphi(z'\gamma)/\Phi(z'\gamma)$ and $MR_e(z'\gamma) = -\varphi(z'\gamma)/[1 - \Phi(z'\gamma)]$, where $\varphi(z'\gamma)$ is the standard normal density function, $\Phi(z'\gamma)$ is the cumulative standard normal distribution, and γ contains the estimated coefficients from the probit regression.

We interpret the terms on the right hand side of each expression in Equations (4) and (5) in a similar way as Bessembinder and Venkataraman (2004). In Equation (4), the first term on the right-hand side is the unconditional effective cost of a random SI trade that is not strategically taking into account venue self-selection, while the second term adjusts the trading cost for the self-selection of SIs. If traders strategically select to trade on SIs, the effective SI trading cost will be lower than the unconditional cost. As a result, we

expect the coefficient α_s to be negative. The same argument applies for the effective exchange trading cost in Equation (5). However, we expect the coefficient α_e to be positive.

Apart from the instrument variables (*SI Lag* and $\Delta minute$), we include all explanatory variables (except for *Spread*) from the first stage regression as explanatory variables for the effective trading cost. We delete the *Spread* variable from the SI and exchange cost regressions due to its high correlation with the *Zero Tick* variable. The high correlation was not an issue in the first stage when we had the combination of both SI and exchange trades in the regression. In addition, each second stage regression equation includes the associated inverse Mill's ratio.

Table 5 contains the results from the two regressions with effective cost as dependent variable. Each regression is estimated with ordinary least squares, with the same type of stock fixed effects and clustering of standard errors on stocks, and demeaning of the continuous explanatory variables, as in the first stage. The coefficient for the inverse Mill's ratio in the SI cost regression is significantly negative on the 1% level, and the corresponding coefficient in the exchange cost regression is significantly positive on the 1% level. These results are in line with expectations, and imply that traders strategically select the type of venue that provides the lowest trading cost.

[Insert Table 5 Here]

The results show that the depth coefficient is negative and significant, at the 1% level, in each second stage regression equation. Hence, a deep consolidated exchange order book is associated with low trading costs at both exchanges and SIs. This result indicates a

complementarity between SI and exchange liquidity, and is similar to the empirical finding in Degryse et al. (2015) regarding dark and visible equity market liquidity.

The results also reveal that the spread binding condition is a driver of the SI trading cost, as the coefficient for the *Zero Tick* variable is negative and statistically significant at the 5% level. Moreover, the spread binding condition leads to a lower exchange trading cost as the *Zero Tick* coefficient is negative and significant at the 1% level in the exchange cost equation. The fact that the *Zero Tick* coefficient is more negative in the exchange equation than in the SI equation, confirms the results from the descriptive statistics of trading costs from Table 3, that trading costs on SIs are larger than the corresponding costs on exchanges when the tick size is binding.

In the SI cost regression, the coefficient for volatility is significantly positive on the 1% level. This is in line with expectations, and consistent with the view that SIs quote higher costs when they face higher risk, e.g., the risk of being adversely selected by informed traders. The coefficient for volatility is also significantly positive, at the 1% level, in the exchange cost regression. However, the volatility coefficient in the SI regression is more than two times larger than the corresponding coefficient in the exchange regression. Hence, the relatively higher sensitivity of SI trading costs to volatility implies that SIs adjust their liquidity supply more to risk compared to liquidity suppliers on the exchanges. This result is consistent with previous studies, which provide evidence that when volatility is high, larger venues are more able to provide stable liquidity and subsequently, a lower trading cost than small venues (e.g., He and Lepone (2014); He et al. (2015)).

Moreover, we note a positive coefficient, significant on the 1% level, for *Trade Size* in the regression equation for exchange trading cost. Accordingly, the exchange trading cost is

increasing in trade size, which is consistent with the descriptive statistics in Table 3. On the other hand, the corresponding coefficient in the equation for SI trading cost is negative and significant on the 5% level. Hence, even after controlling for self-selection of trading venue, the result from Table 3 that effective SI trading cost is not increasing in trade size prevails.

4.2 Price Impact of Large Trades on Dealer Platforms

We next turn to the analysis of our third research question "*In the current electronic market setting, are informed or uninformed traders seeking out independent dealers?*" with the focus on trades with a volume larger than the SMS (henceforth, large trades). To address this question, we investigate how informative trades on dealer platforms and exchanges are by focusing on price impact of trades.

Dealers (SIs) and exchanges compete in order to attract different types of traders and order flows. The absence of anonymous trading and pre-trade transparency on SIs with respect to large trades is tempting for uninformed traders as they can reduce the risk of being picked-off by predatory traders on exchanges. Specifically, an uninformed trader might be willing to trade a large block of orders with SIs rather than trading a sequence of small transactions on exchanges to control the risk of being picked off. Informed traders may also be motivated to interact with SIs to decrease the risk of being front run by other informed traders on exchanges. The lack of anonymous trading on SI platforms, however, might impose a higher cost to informed traders as SIs might know that they are interacting with an informed trader.

On the other hand, SIs' trading strategies and their views on what type of clients they are willing to trade with also affect the distribution of informed and uninformed orders

across SIs and exchanges. To make their trades more profitable, SIs needs to interact with order flows that carry low adverse selection risk. When SIs trade with counterparties who have superior information, they lose in those transactions to informed traders, although they can compensate the losses by passing it along to uninformed traders or charging informed traders a higher cost. As a result, SIs might deliberately limit their trading activities to uninformed traders to make their trades more profitable.

Sample of Large Trades and Descriptive Statistics

We start by presenting an overview of large trades on dealer platforms (SIs) and exchanges. Table 6 presents descriptive statistics for the measures of trading activity for large trades in our sample. The data contain 838,440 trades with volume larger than the SMS, whereof 90,910 (10.8%) take place on SIs and 747,530 (89.2%) on exchanges. Although the number of large trades on exchanges is roughly eight times more than SIs, their total trading volume is almost equal to SIs' total trading volume in the sample of large trades.

[Insert Table 6 Here]

The differences between large trades executed on SIs and exchanges become more visible when we classify trades into different trade sizes. Table 6 shows that while only about 8% of all large SI trades have a volume larger than 10,000 shares; they capture almost 85% of the SI trading volume. On the contrary, on exchanges, trades with a volume more than 10,000 shares account for 0.44% of all large exchange trades and with a percentage SEK volume of 2.44%. We also measure trading activities with respect to time of the day, and we notice similar patterns as the ones presented in Table 1, and Figure 1. The trading

activity of large SI trades exhibit a kind of J-shaped pattern throughout the trading day, while the corresponding pattern for large exchange trades is more U-shaped.

[Insert Table 7 Here]

Table 7 reports the average cost measures for all large trades on SIs and exchanges, and conditional on the levels for the same variables as in Table 3. We measure the three cost measures according to Equations (1) to (3). From the first row, we observe that the average price impact is 2.31 basis points for exchange trades and only 0.31 basis points for SI trades. Table 7 also shows that the large difference between the price impact for exchange trades and SI trades carry through with respect to all variable categories. When it comes to the trade size distribution, we note that there is a positive association between the price impact and trade size on exchanges. However, we do not observe a similar pattern for SI trades. An increase in the size of SI trades does not result in a higher price impact and the average values of price impacts are similar for all trade sizes.

The results in Table 7 are consistent with the notion that SI trades carry less information than exchange trades, which in turn is consistent with previous studies showing that dealers actively choose to trade with liquidity traders to reduce the risk of loss to informed traders (e.g., Chordia and Subrahmanyam (1995); Easley, Kiefer, and O'Hara (1996); Grammig and Theissen (2005)). In particular, previous studies argue that the information asymmetry is not an issue on venues with non-anonymous trading due to the ability of screening the information-based trades. In addition, from Table 7, we see that dealers earn almost ten basis points in liquidity impact on an average large trade, while the corresponding number for exchange liquidity providers is 0.91 basis point. Evidently, the avoidance of price impact comes at high costs. On average, large SI trades incur a total cost of 9.82 basis points while large exchange trades cost 3.22 basis points. This is

consistent with the studies in the dealer literature documenting that dealers charge higher cost than auction markets as they are internalizing trades and face risk (e.g., Huang and Stoll (1996)).

[Insert Table 8 Here]

In the next stage, we examine the drivers of permanent price impact from dealer trades and exchange trades. Our empirical approach involves two methods, a Heckman correction regression; similar to the one used in the analysis of small trades, and an ordinary least squares (OLS) regression. We use the Heckman correction regression to check whether there is an endogeneity issue with respect to large trades and price impact. In our analysis, the selection bias might arise if traders condition their choice of venue on the price impact characteristics. Addressing the effect of dark trading on price discovery, Comerton-Forde and Putniņš (2015) argue and show that selection bias is an important concern when analyzing the causality between dark trading and liquidity rather than its relation with information effects. The authors also mention that in the absence of the endogeneity issue, the one-stage OLS regression is preferable because of its higher precision and statistical power. Therefore, we employ the one-stage OLS regression to observe the possible differences.

Table 8 holds the results from the first stage probit regression analysis of the selection between trading on SIs or exchanges for large trades. The coefficients for the variables *Spread*, *Depth*, and *Volatility* have the same signs as the corresponding coefficients in Table 4. However, it is noted that *Depth* (Spread) and *Volatility* have larger (smaller) marginal effects for large trades relative the corresponding marginal effects for small trades. Hence, these variables are similar predictors for the venue choice of small and large trades. For large trades, the coefficient for the variable Zero Tick is significantly

negative on the 1% level. This result is the opposite of the one for small trades in Table 4, for which we obtain a significantly positive coefficient. Apparently, a large SI trade is less likely to occur when the exchange bid-ask spread is binding than when it is not binding. This result is consistent with SIs not competing with quotes within the exchange bid-ask spread for large trades. In fact, SIs are not obliged to be pre-trade transparent in their quoting of large trades.

In Table 8, the coefficient for the variable *Trade Size* is significantly positive and has a large marginal effect. Thus, unlike for small trades (according to the results in Table 4), large trades are more likely to occur on SIs when they are "very large". Evidently, traders prefer the dealer platforms when they want to trade very large trades, presumably in order to avoid walking the exchange order books. The results in Table 8 also show that *SI Lag*, the dummy variable that is equal to one if the previous trade occurs on an SI, is a significant predictor (at the 1% level) for venue choice of large trades, with a large marginal effect, and, thus is a good first stage instrument. However, the other instrumental variable $\Delta Minute$, the time in minutes between a trade and the previous trade, is not significantly different from zero, and, thus, not a proper instrument for the analysis of large trades. Given that one of the instrumental variables is significant in the first stage, we cannot rule out some degree of trading venue self-selection.

[Insert Table 9 Here]

Table 9 presents the results of the one-stage OLS regression and the second stage of the Heckman regression with price impact for large trades obtained from Equation (3) as dependent variable. Regressions include stock fixed effects and standard errors that are clustered across stocks. We use the same set of independent variables as in Table 5. The table contains results for SI trades and exchange trades in separate columns.

For the SI trades, the results for the second stage of the Heckman regression show that the selection bias is not much of an issue when dealing with price impact characteristics, as the coefficient for the inverse Mill's ratio is not statistically significant. In addition, the Heckman and OLS regression results are very similar. We note that there is a negative and statistically significant association between *Trade Size* and the price impact of SI trades. However, the coefficient is rather small and significantly negative only at the 10% level in the Heckman regression. SIs conduct non-anonymous trading and know whom they are trading with. This feature helps them to control the adverse information effect arising from institutional trades better, which subsequently results in a negative relationship between adverse selection cost and trade size on SIs.

Table 9 also shows that the coefficient for the volatility is positive and statistically significant at the 1% level. This means that the price impact of SI trades increases with volatility. In addition, the results reveal that there is no association between the price impact of SI trades and the variables *Zero Tick* and *Depth*, as the associated coefficients are not significantly different from zero.

For the exchange trades, the Heckman regression results are mostly similar to the ones obtained in the OLS regression except for the *Trade Size*. One noteworthy difference is the significantly negative coefficient for the *Trade Size* variable in the Heckman regression, while it is not significant in the OLS version. The result from the Heckman regression shows that when adjusting for venue self-selection, the price impact of large exchange trades is actually decreasing in trade size. This result is consistent with that traders are rewarded with a relatively low price impact when they self-select to trade large size orders on exchanges.

5 Concluding Remarks

Recent regulatory reforms and technology enhancements have fundamentally changed the equity market landscape and promoted competition between different trading mechanisms. Despite the dominance of electronic trading on exchanges, off-exchange trading through broker-dealer internalization and internalized dark pools attracts substantial trading volume. The flexibility in the pre-trade and post-trade transparency and the possibility of negotiation motivate traders with different trading needs to seek out dealer platforms. In this paper, we examine the competition between dealers and exchanges from traders' points of view and analyze their order routing strategies between these two trading mechanisms. To conduct the analyses, we focus on the European equity market, where regulatory reforms particularly highlight the competition between exchanges and independent dealers called systematic internalizers (SIs).

Our results show that liquidity is an important element in traders' choice of venue between exchanges and dealers. Specifically, dealers attract more trading volume when the tick size is binding, the spread is wide, and the limit order books are deep on exchanges. We note that dealers, on average, offer traders almost the same execution cost as exchanges for small trade sizes.[19] Moreover, after controlling for traders' endogenous selection to trade on exchanges or with dealers, we find that the trading cost is higher on dealer platforms than on exchanges when the spread is binding, and when volatility and depth are high on the exchanges' limit order books. On the contrary, the results show that

[19] With small trade sizes, we mean those that are below the standard market size stipulated by the European Securities and Market Authorities (ESMA).

traders with higher trading volume get a lower trading cost on dealer platforms than on exchanges.

We further analyze the distribution of informed and uninformed order flows across dealer platforms and exchanges. Our results show that dealer trades are less informative and carry less price impact than trades on exchanges. On the one hand, it is possible to interpret this result as that liquidity traders are more likely to interact with dealers to avoid the risk of being ripped off by informed traders on exchanges. This is consistent with the dealer internalization literature, which shows that dealers deliberately avoid trading with traders who have valuable information to reduce their inventory risks (e.g., Chordia and Subrahmanyam (1995) and Easley, Kiefer and O'Hara (1996)). On the other hand, the low price impact of dealer trades might partially emanate from the fact that dealers intentionally use their flexibility with respect to post-trade transparency and delay the reporting of trades with informed traders long enough to reduce the price impact, while charging a relatively high liquidity supply cost.

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Table 1: Trading Activity on SIs and Exchanges

	SIs			Exchanges		
	Trades	Volume	Shares	Trades	Volume	Shares
Trading Activity	0.51 (4.6%)	130.04 (22.7%)	1.04 (22.6%)	10.68 (95.4%)	442.44 (77.3%)	3.57 (77.4%)
Trade Size Distribution (%)						
<=500 Shares	75.16	7.36	4.99	81.64	58.95	39.99
500-1,000	12.63	4.86	4.35	12.39	22.97	26.76
1,000-5,000	9.98	7.89	9.21	5.82	16.28	29.14
> 5,000	2.23	79.89	81.45	0.15	1.80	4.11
Time of Day Distribution (%)						
9:05 AM - 12:00 Noon	27.77	19.21	21.05	37.36	37.81	38.57
12:00 Noon - 3:00 PM	27.47	34.29	31.57	26.17	25.36	25.33
3:00 PM - 5:25 PM	44.76	46.50	47.38	36.47	36.83	36.10

The table displays descriptive statistics for the number of trades (*Trades*), SEK trading volume (*Volume*) and the number of shares traded (*Shares*) on SIs and exchanges for all trades in the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. The numbers in the first row are the total number of trades (millions), total trading volume (billions SEK), and total number shares traded (billions) on SIs and exchanges respectively. Numbers within parentheses are the percentage shares of the trading activity measures for SIs and exchanges, respectively. Other values in the table than in the first row represent the percentage of trades and SEK volume for each *Trade Size* (the number of stocks in each trade) and *Time of Day* category.

Table 2: Trading Activity of Small Trades on SIs and Exchanges

	SIs		Exchanges	
	Trades	Volume	Trades	Volume
Trades and Volume	13,610 (4.5%)	0.35 (3.5%)	286,390 (95.4%)	9.40(96.5%)
Spread Distribution (%)				
Small	49.76	47.24	48.58	47.88
Large	50.24	52.76	51.42	52.12
Spread-Binding Distribution (%)				
Zero Tick	45.60	44.06	33.32	34.11
> Zero Tick	54.40	55.94	66.68	65.89
Volatility Distribution (%)				
Small	51.15	49.30	49.51	48.68
Large	48.85	50.70	50.49	51.32
Trade Initiation Distribution (%)				
Buyer Initiated	50.58	50.66	49.29	48.62
Seller Initiated	47.76	47.60	49.16	49.52
At Midpoint	1.66	1.74	1.55	1.86
Trade Size Distribution (%)				
<=500 Shares	89.05	71.66	85.83	73.27
500-1000	8.07	20.42	10.63	20.16
> 1000	2.88	7.92	3.54	6.57
Time of day Distribution (%)				
9:05 AM - 12:00 Noon	27.77	29.41	37.37	37.21
12:00 Noon - 3:00 PM	28.91	27.63	27.13	26.78
3:00 PM - 5:25 PM	43.32	42.96	35.50	36.01

Table 2: Trading Activity of Small Trades on SIs and Exchanges

The table displays descriptive statistics for the number of trades (*Trades*) and trading volume in billion SEK (*Volume*) on SIs and exchanges for a sample of small trades in the OMXS 30 stocks. A small trade means a trade with a trade size smaller than or equal to the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The sample consists of 300,000 trades, randomly drawn from all small trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. The numbers in the first row are the total number of trades and total trading volume on SIs and exchanges, respectively. Other values in the table than in the first row represent the percentage of trades and SEK volume for each variable as follows. The conditions *Small* and *Large* refer to below and above variable median. *Spread* is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Spread Binding* means the spread binding condition prevailing in the consolidated order book at the reported time of the trade. *Zero Tick* means that the bid-ask spread equals the minimum tick size in the order book, and *> Zero Tick* means that there is one or more than one tick available between the bid price and the ask price in the order book. *Tick Size* equals the minimum tick size allowed at the exchanges at the reported time of each trade. *Volatility* is the realized volatility of one-second midpoint returns (in the consolidated order book) during the five-minute period preceding each trade. *Trade Initiation* means if a trade is buyer or seller initiated, or if the trade occurs at the midpoint quote in the consolidated order book. *Trade Size* is the number of stocks in each trade.

Table 3: Trading Costs for Small Trades on SIs and Exchanges

	SIs			Exchanges		
	Cost	Liquidity Impact	Price Impact	Cost	Liquidity Impact	Price Impact
Overall Average	2.98	2.52	0.46	2.86	0.82	2.04
Spread Distribution						
Small	3.05	2.72	0.33	1.72	0.42	1.30
Large	2.91	2.34	0.57	3.89	1.17	2.72
Spread-Binding Distribution						
Zero Tick	2.81	2.44	0.37	1.54	0.48	1.06
> Zero Tick	3.10	2.58	0.52	3.52	0.98	2.54
Volatility Distribution						
Small	2.49	2.21	0.28	2.36	0.76	1.60
Large	3.46	2.82	0.64	3.32	0.86	2.46
Trade Initiation Distribution						
Buyer Initiated	2.94	2.76	0.18	3.06	0.73	2.33
Seller Initiated	3.12	2.35	0.77	2.75	0.92	1.82
Trade Size Distribution						
<=500 Shares	3.08	2.89	0.19	2.26	0.81	1.45
500-1000	2.70	2.12	0.58	2.92	0.76	2.16
> 1000	3.05	2.05	1.00	4.19	0.89	3.29
Time of day Distribution						
9:05 AM - 12:00 Noon	3.12	2.60	0.52	3.54	0.82	2.72
12:00 Noon - 3:00 PM	2.66	2.43	0.23	2.47	0.82	1.65
3:00 PM - 5:20 PM	3.09	2.52	0.57	2.41	0.81	1.60

Table 3: Trading Costs for Small Trades on SIs and Exchanges

The table displays average trading cost for a sample of small trades on SIs and exchanges in the OMXS 30 stocks. A small trade means a trade with a trade size smaller than or equal to the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The sample consists of 300,000 trades, randomly drawn from all small trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. *Cost* is the signed difference between each trade price and the midpoint quote in the order book consolidated over exchanges at the reported time of the trade, divided by the midpoint quote, expressed in basis points. *Liquidity Impact* is the signed difference between the trade price and the midpoint quote in the consolidated order book 15 seconds after the reported time of the trade, divided by the midpoint quote, expressed in basis points. *Price Impact* is the signed difference between the midpoint quote in the consolidated order book 15 seconds after the reported time of the trade and the midpoint quote at the time of the trade, divided by the midpoint quote at the time of the trade, expressed in basis points. The first row presents the volume-weighted average trading cost for all sample trades (*Overall Average*). Other values in the table than in the first row represent the volume-weighted average cost conditional on the levels for each variable as follows. The conditions *Small* and *Large* refer to below and above variable median. *Spread* is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Spread Binding* means the spread binding condition prevailing in the consolidated order book at the reported time of the trade. *Zero Tick* means that the bid-ask spread equals the minimum tick size in the order book, and *> Zero Tick* means that there is one or more than one tick available between the bid price and the ask price in the order book. *Tick Size* equals the minimum tick size allowed at the exchanges at the reported time of each trade. *Volatility* is the realized volatility of one-second returns (in the consolidated order book) during the five-minute period preceding each trade. *Trade Initiation* means if a trade is buyer or seller initiated, or if the trade occurs at the midpoint quote in the consolidated order book. *Trade Size* is the number of stocks in each trade.

Table 4: Venue Selection, Stage I Probit Regression (Small Trades)

	Coefficient (St. Error)	Marginal Effect
Constant	-2.8502*** (0.0636)	
Spread	0.1010*** (0.0102)	0.0089
Depth	0.2871*** (0.0171)	0.0253
Zero Tick	0.3631*** (0.0641)	0.0321
Trade Size	-0.0920*** (0.0096)	-0.0081
Volatility	-0.0097** (0.0058)	-0.0010
SI Lag	0.3688*** (0.0181)	0.0326
$\Delta Minute$	0.0065*** (0.0010)	0.0010
Stock Fixed Effects	Yes	
Observations	300,000	

The table displays results from the first stage probit regression models for the binary choice between trading at SIs and at exchanges for small trades. A small trade means a trade with a trade size smaller than or equal to the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The sample consists of 300,000 trades, randomly drawn from all small trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. The dependent variable equals one if an SI is selected and zero if an exchange is selected. Independent variables include the *Spread*, which is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Depth* is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. *Zero Tick* equals one if the bid-ask spread equals the minimum tick size in the consolidated order book at the reported time of the trade and zero otherwise. *Trade Size* is the SEK value of the volume in each trade. *Volatility* is the realized volatility of one-second returns during the five-minute period preceding each trade. *SI Lag* equals one if the previous trade occurs on an SI and zero if it occurs on an exchange. $\Delta minute$ is the time difference in minutes between each trade and its previous trade. The continuous independent variables are demeaned. Stock Fixed Effects are represented by stock-specific dummy variables. Standard errors are in parentheses and are clustered on stock. *** and ** denote significance at the 1% and 5% level, respectively. Marginal Effect is the change in probability of trading on an SI when there is a shock in each explanatory variable. For each dummy variable, the shock is a change from 0 to 1. For the continuous variables, the shock is a one standard deviation increase.

Table 5: Cost, Stage II Regression for Small SI and Exchange Trades

	SI Trades	Exchange Trades
Constant	4.6219***	5.8203***
	(0.5104)	(0.2420)
Zero Tick	-0.3231**	-1.9415***
	(0.1617)	(0.1229)
Volatility	0.7665***	0.2940***
	(0.1525)	(0.0506)
Depth	-0.6473***	-1.1171***
	(0.1644)	(0.0963)
Trade Size	-0.1326**	0.4361***
	(0.0652)	(0.0397)
Inverse Mill's Ratio	-1.6483***	25.2246***
	(0.5588)	(1.7997)
Stock Fixed Effects	Yes	Yes
Adjusted R-Squared	0.0446	0.3291
Observations	13,610	286,390

The table displays results from the second stage least squares regression models for the cost of trading at SIs and at exchanges, for small trades, controlling for the endogenous selection of trading venue. A small trade means a trade with a trade size smaller than or equal to the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The sample consists of 300,000 trades, randomly drawn from all small trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. Dependent variable is the *Effective Cost* measure, which equals the signed difference between each traded price and the midpoint quote in the order book consolidated over exchanges at the reported time of the trade, divided by the midpoint quote, expressed in basis points. Independent variables include the *Depth*, which is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. *Zero Tick* equals one if the bid-ask spread equals the minimum tick size in the consolidated order book at the reported time of the trade and zero otherwise. *Trade Size* is the SEK value of the volume in each trade. *Volatility* is the realized volatility of one-second returns during the five-minute period preceding each trade. The *Inverse Mill's Ratio* is the selectivity adjustment variable associated with the trading choice on SIs and exchanges respectively. The continuous independent variables are demeaned. Stock Fixed Effects are represented by stock-specific dummy variables. Standard errors are in parentheses and are clustered on stock. ***, **, * denotes significance at the 1%, 5%, 10% level, respectively.

Table 6: Trading Activity of Large Trades on SIs and Exchanges

	SIs			Exchanges		
	Trades	Volume	Shares	Trades	Volume	Shares
Trading Activity	90.91 (10.8%)	118.89 (49.9%)	0.95 (51.4%)	747.53 (89.2%)	119.58 (50.1%)	0.90 (48.6%)
Trade Size Distribution (%)						
<=1,000 Shares	45.44	4.71	2.67	61.18	50.65	30.01
1,000-5,000	42.17	7.91	8.14	37.15	42.87	56.11
5,000-10,000	4.35	3.27	2.93	1.23	4.04	7.13
10,000-50,000	4.91	14.52	10.80	0.43	2.31	5.99
> 50,000	3.13	69.59	75.46	0.01	0.13	0.76
Time of Day Distribution (%)						
9:05 AM - 12:00 Noon	29.71	18.23	20.23	38.28	39.03	40.06
12:00 Noon - 3:00 PM	26.25	35.09	32.11	24.05	23.88	23.75
3:00 PM - 5:25 PM	44.04	46.68	47.66	37.67	37.09	36.19

The table displays descriptive statistics for the number of trades (*Trades*), SEK trading volume (*Volume*), and the number of shares traded (*Shares*) on SIs and exchanges for large trades in the OMXS 30 stocks. A large trade means a trade with a trade size larger than the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. The numbers in the first row are the total number of trades (thousands), total trading volume (billions SEK), and total number shares traded (billions) on SIs and exchanges, respectively. Numbers within parentheses are the percentage shares of the trading activity measures for SIs and exchanges, respectively. Other values in the table than in the first row represent the percentage of trades and SEK volume for each *Trade Size* (the number of stocks in each trade) and *Time of Day* category.

Table 7: Trading Costs for Large Trades on SIs and Exchanges

	SIs			Exchanges		
	Cost	Liquidity Impact	Price Impact	Cost	Liquidity Impact	Price Impact
Overall Average	9.82	9.51	0.31	3.22	0.91	2.31
Spread Distribution						
Small	9.59	9.34	0.25	2.41	0.50	1.91
Large	10.05	9.68	0.37	4.02	1.31	2.71
Spread-Binding Distribution						
Zero Tick	9.16	8.84	0.32	2.67	0.63	2.04
> Zero Tick	10.04	9.74	0.30	3.54	1.07	2.47
Volatility Distribution						
Small	8.97	8.78	0.19	2.78	0.86	1.92
Large	10.66	10.24	0.42	3.65	0.96	2.69
Trade Initiation Distribution						
Buyer Initiated	11.14	10.83	0.31	3.40	0.87	2.53
Seller Initiated	9.36	9.02	0.34	3.15	0.98	2.17
Trade Size Distribution						
<=1,000 Shares	3.38	3.06	0.32	3.18	0.89	2.29
1,000-5,000	6.80	6.48	0.32	3.17	0.93	2.24
5,000-10,000	26.48	26.31	0.17	5.19	0.95	4.24
10,000-50,000	48.55	48.20	0.35	6.43	0.81	5.62
> 50,000	57.37	57.18	0.19	9.74	2.72	7.02
Time of day Distribution						
9:05 AM - 12:00 Noon	6.67	6.42	0.25	3.34	0.89	2.45
12:00 Noon - 3:00 PM	14.66	14.38	0.28	3.37	0.92	2.45
3:00 PM - 5:20 PM	8.92	8.56	0.36	2.99	0.92	2.07

Table 7: Trading Costs for Large Trades on SIs and Exchanges

The table displays average trading costs for the large trades on SIs and exchanges in the OMXS 30 stocks. A large trade means a trade with a trade size larger than the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. *Cost* is the signed difference between each trade price and the midpoint quote in the order book consolidated over exchanges at the reported time of the trade, divided by the midpoint quote, expressed in basis points. *Liquidity Impact* is the signed difference between the trade price and the midpoint quote in the consolidated order book 15 seconds after the reported time of the trade, divided by the midpoint quote, expressed in basis points. *Price Impact* is the signed difference between the midpoint quote in the consolidated order book 15 seconds after the reported time of the trade and the midpoint quote at the time of the trade, divided by the midpoint quote at the time of the trade, expressed in basis points. The first row presents the average trading cost for all large trades (*Overall Average*). Other values in the table than in the first row represent the average cost conditional on the levels for each variable as follows. The conditions *Small* and *Large* refer to below and above variable median. *Spread* is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Spread Binding* means the spread binding condition prevailing in the consolidated order book at the reported time of the trade. *Zero Tick* means that the bid-ask spread equals the minimum tick size in the order book, and *> Zero Tick* means that there is one or more than one tick available between the bid price and the ask price in the order book. *Tick Size* equals the minimum tick size allowed at the exchanges at the reported time of each trade. *Volatility* is the realized volatility of one-second returns (in the consolidated order book) during the five-minute period preceding each trade. *Trade Initiation* means if a trade is buyer or seller initiated, or if the trade occurs at the midpoint quote in the consolidated order book. *Trade Size* is the number of stocks in each trade.

Table 8: Venue Selection, Stage I Probit Regression (Large Trades)

	Coefficient (St. Error)	Marginal Effect
Constant	-2.3085*** (0.0250)	
Spread	0.0290*** (0.0071)	0.0045
Depth	0.2197*** (0.0187)	0.0341
Zero Tick	-0.3172*** (0.0327)	-0.0492
Trade Size	0.5432*** (0.0258)	0.0844
Volatility	-0.0644*** (0.0123)	-0.0100
SI Lag	0.7411*** (0.0234)	0.1151
$\Delta Minute$	-0.0020 (0.0013)	-0.0003
Stock Fixed Effects	Yes	
Observations	838,440	

The table displays results from the first stage probit regression models for the binary choice between trading at SIs and at exchanges for large trades. A large trade means a trade with a trade size larger than the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The data are all large trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. The dependent variable equals one if an SI is selected and zero if an exchange is selected. Independent variables include the *Spread*, which is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Depth* is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. *Zero Tick* equals one if the bid-ask spread equals the minimum tick size in the consolidated order book at the reported time of the trade and zero otherwise. *Trade Size* is the SEK value of the volume in each trade. *Volatility* is the realized volatility of one-second returns during the five-minute period preceding each trade. *SI Lag* equals one if the previous trade occurs on an SI and zero if it occurs on an exchange. $\Delta minute$ is the time difference in minutes between each trade and its previous trade. The continuous independent variables are demeaned. Stock Fixed Effects are represented by stock-specific dummy variables. Standard errors are in parentheses and are clustered on stock. *** and ** denote significance at the 1% and 5% level, respectively. Marginal Effect is the change in probability of trading on an SI when there is a shock in each explanatory variable. For each dummy variable, the shock is a change from 0 to 1. For the continuous variables, the shock is a one standard deviation increase.

Table 9: Price Impact of Large Trades

	SI Trades		Exchange Trades	
	Heckman	OLS	Heckman	OLS
Constant	0.3567***	0.3857***	2.3744***	2.2550***
	(0.0510)	(0.0231)	(0.0400)	(0.0273)
Volatility	0.5595***	0.5609***	0.3518***	0.3419***
	(0.0699)	(0.0696)	(0.0318)	(0.0306)
Trade Size	-0.0274*	-0.0383***	-0.1959***	-0.0327
	(0.0159)	(0.0112)	(0.0427)	(0.0267)
Zero Tick	-0.0136	-0.0053	-0.1460***	-0.2224***
	(0.0446)	(0.0422)	(0.0338)	(0.0406)
Depth	-0.0274	-0.0329	0.3927***	0.4451***
	(0.0249)	(0.0218)	(0.0338)	(0.0357)
Inverse Mill's Ratio	0.0331		0.9480***	
	(0.0491)		(0.1993)	
Stock Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-Squared	0.0066	0.0066	0.0224	0.0221
Observations	87,904	87,904	707,346	707,346

The table displays results from the ordinary least square (OLS) regression and the second stage least squares regression models (the Heckman correction model) for the price impact of large trades at SIs and exchanges. A large trade means a trade with a trade size larger than the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis. Dependent variable is the *price impact* measure, which equals the signed difference between the midpoint quote in the consolidated order book 15 seconds after the reported time of the trade and the midpoint quote at the time of the trade, divided by the midpoint quote at the time of the trade, expressed in basis points. Independent variables include *Trade Size*, which equals the SEK value of the volume in each trade. *Volatility* is the realized volatility of one-second returns during the five-minute period preceding each trade. *Zero Tick* equals one if the bid-ask spread equals the minimum tick size in the consolidated order book at the reported time of the trade and zero otherwise. *Depth* is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. The *Inverse Mill's Ratio* is the selectivity adjustment variable associated with the trading choice on SIs and exchanges, respectively. The continuous independent variables are demeaned. Stock Fixed Effects are represented by stock-specific dummy variables. Standard errors are in parentheses and are clustered on stock. ***, **, * denotes significance at the 1%, 5%, 10% level, respectively.

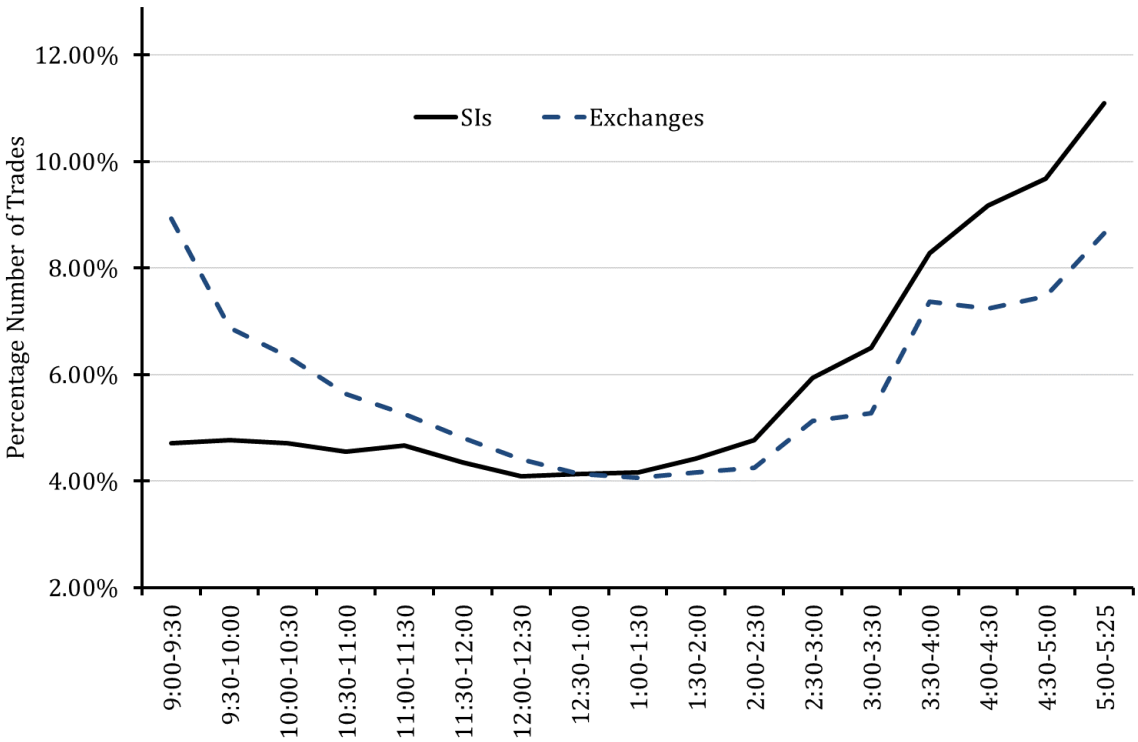

Figure 1: Number of Trades on SIs and Exchanges

The figure displays the intraday 30-minute percentage number of trades on SIs and exchanges for all trades in the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis.

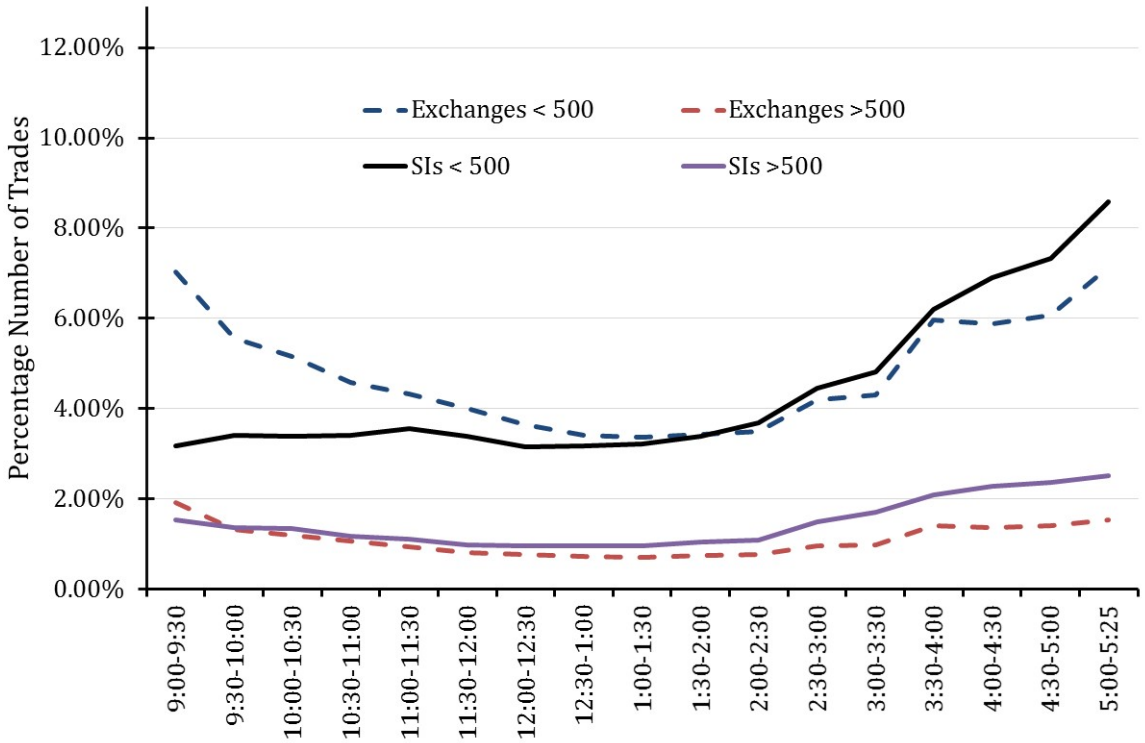

Figure 2: Number of Trades on SIs and Exchanges with respect to Trade Size

The figure displays the intraday 30-minute percentage number of trades on SIs and exchanges for all trades in the OMXS 30 stocks, with trade size larger and smaller than 500 shares. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis.

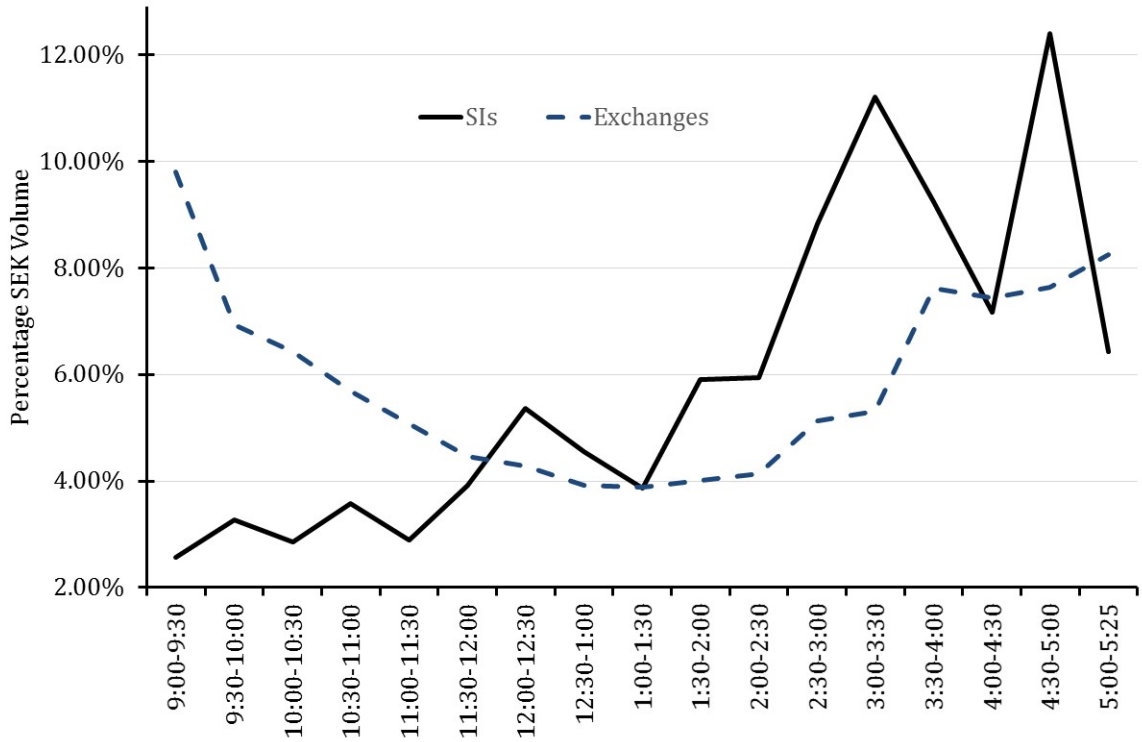

Figure 3: Trading Volume on SIs and Exchanges

The figure displays the intraday 30-minute percentage SEK volume on SIs and exchanges for all trades in the OMXS 30 stocks. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis.

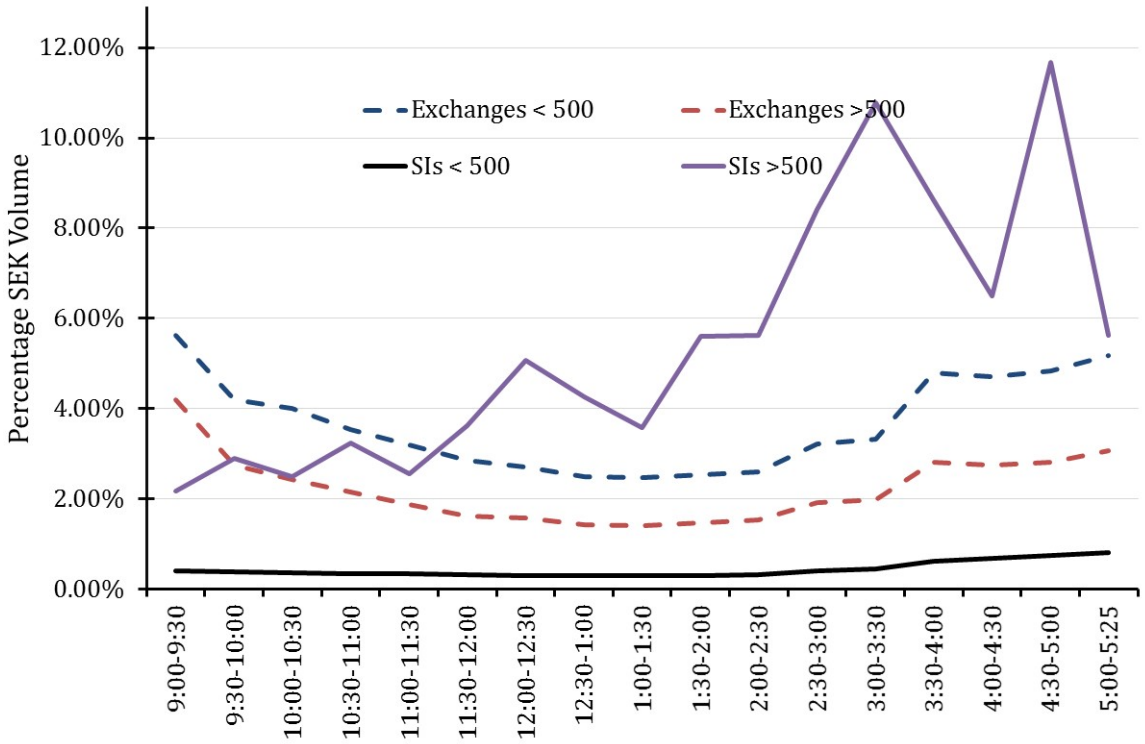

Figure 4: Trading Activity on SIs and Exchanges with respect to Trade Size

The figure displays the intraday 30-minute percentage SEK volume on SIs and exchanges for all trades in the OMXS 30 stocks, with trade size larger and smaller than 500 shares. The trades are from the period January 3-March 23, 2018, between 9:00 AM and 5:25 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). Trades on *Exchanges* are the ones occurring in the respective limit order book, and in the continuous trading session, on Nasdaq, Chi-X, Bats, Turquoise and Aquis.

Appendix

Table A1: Undercutting Cost of Small Trades on SIs

	SIs		
	Within Spread	At the Best	Outside Spread
All Trades (%)	43.38	32.93	23.69
Spread Distribution (%)			
Small	31.54	67.51	58.45
Large	68.46	32.49	41.55
Spread-Binding Distribution (%)			
Zero Tick	23.04	68.92	54.48
> Zero Tick	76.96	31.08	45.52
Depth Distribution (%)			
Small	48.52	50.69	50.82
Large	51.48	49.31	49.18
Volatility Distribution (%)			
Small	51.80	53.59	46.57
Large	48.20	46.41	53.43
Trade Size Distribution (%)			
<=500 Shares	87.73	87.68	93.36
500-1000	9.18	8.79	5.02
> 1000	3.09	3.53	1.62
Time of day Distribution (%)			
9:05 AM - 12:00 Noon	28.31	24.56	31.26
12:00 Noon - 3:00 PM	28.87	30.43	26.88
3:00 PM - 5:20 PM	42.82	45.01	41.86

Table A1: Undercutting Cost of Small Trades on SIs

The table displays descriptive statistics for the undercutting cost of SI small trades in the sample of all small trades (SIs and exchanges) in the OMXS 30 stocks. A small trade means a trade with a trade size smaller than or equal to the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The sample of all small trades consists of 300,000 trades, which SIs account for 13,610 trades. The sample is randomly drawn from all small trades during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). *Within Spread* presents trades executed at prices within the quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *At the Best* represents trades executed at the best quotes prevailing in the order book consolidated over exchanges at the reported time of each trade. *Outside Spread* presents trades occurred outside the quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. The numbers in the first row are the percentage of trades. Other values in the table than in the first row represent the percentage of trades conditional on the levels for each variable. The conditions *Small* and *Large* refer to below and above variable median. *Spread* is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Spread-Binding* means the spread binding condition prevailing in the consolidated order book at the reported time of the trade. *Zero Tick* means that the bid-ask spread equals the minimum tick size in the order book, and *> Zero Tick* means that there is one or more than one tick available between the bid price and the ask price in the order book. *Tick Size* equals the minimum tick size allowed at the exchanges at the reported time of each trade. *Depth* is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. *Volatility* is the realized volatility of one-second midpoint returns (in the consolidated order book) during the five-minute period preceding each trade. *Trade Size* is the number of stocks in each trade.

Table A2: Undercutting Cost of Large Trades on SIs

	SIs		
	Within Spread	At the Best	Outside Spread
All Trades (%)	55.77	19.99	24.24
Spread Distribution (%)			
Small	40.78	67.56	56.34
Large	59.22	32.44	43.66
Spread-Binding Distribution (%)			
Zero Tick	18.69	40.32	27.86
> Zero Tick	81.31	59.68	72.14
Depth Distribution (%)			
Small	50.39	48.34	50.45
Large	49.61	51.66	49.55
Volatility Distribution (%)			
Small	49.65	51.94	49.19
Large	50.35	48.06	50.81
Trade Size Distribution (%)			
<=1,000 Shares	51.11	51.63	26.64
1,000-5,000	44.04	42.61	37.38
5,000-10,000	2.98	2.63	9.04
10,000-50,000	1.44	1.75	15.91
> 50,000	0.43	1.38	11.03
Time of day Distribution (%)			
9:05 AM - 12:00 Noon	30.33	30.60	26.05
12:00 Noon - 3:00 PM	25.05	25.96	32.89
3:00 PM - 5:20 PM	44.62	43.44	41.06

Table A2: Undercutting Cost of Large Trades on SIs

The table displays descriptive statistics for the undercutting cost of SI large trades in the OMXS 30 stocks. A large trade means a trade with a trade size larger than the standard market size (SMS), which is EUR 10,000 for the OMXS 30 stocks. The SI trades are during the period January 3-March 23, 2018, between 9:05 AM and 5:20 PM. Trades on *SIs* are the ones reported to the CBOE Trade Reporting Services (BXTR). *Within Spread* presents trades executed at prices within the quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *At the Best* represents trades executed at the best quotes prevailing in the order book consolidated over exchanges at the reported time of each trade. *Outside Spread* presents trades occurred outside the quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. The numbers in the first row are the percentage of trades. Other values in the table than in the first row represent the percentage of trades conditional on the levels for each variable. The conditions *Small* and *Large* refer to below and above variable median. *Spread* is half the relative quoted spread prevailing in the order book consolidated over exchanges at the reported time of each trade. *Spread-Binding* means the spread binding condition prevailing in the consolidated order book at the reported time of the trade. *Zero Tick* means that the bid-ask spread equals the minimum tick size in the order book, and *> Zero Tick* means that there is one or more than one tick available between the bid price and the ask price in the order book. *Tick Size* equals the minimum tick size allowed at the exchanges at the reported time of each trade. *Depth* is the average SEK volume available at the best bid and the best ask prices in the order book consolidated over exchanges at the reported time of the trade. *Volatility* is the realized volatility of one-second midpoint returns (in the consolidated order book) during the five-minute period preceding each trade. *Trade Size* is the number of stocks in each trade.