Off-exchange Trading in Modern Equity Markets

A Market Microstructure Perspective on Systematic Internalizers

Fatemeh Aramian
Abstract
Off-exchange trading has become a feature of the equity markets. This dissertation contains three articles that examine how off-exchange trading through systematic internalizers (SIs) affects inter-market competition and various features of market quality.

Article I studies SIs' characteristics and the impact of SI operations on price efficiency. Using high-frequency measures of price efficiency, the results show that SIs' activities improve the informativeness of prices on exchanges. The article further indicates that market making is an important factor in a firm's decision to operate as an SI and that the heterogeneity in the level of market making among SIs matters for market efficiency analysis. Efficiency is improved only through the activities of those SIs with the highest level of market making on exchanges.

Article II investigates the role of SIs run by HFTs in equity markets, with a focus on the impact of HFT SI operations on HFTs' inventory management behavior, their liquidity provision on exchanges, and, ultimately, market quality with respect to liquidity. The results show that the trading activity of HFT SIs leads HFTs to manage their inventory imbalances by taking liquidity and reducing their liquidity provision on exchanges. The exchanges' bid-ask spreads therefore widen and the order books become thinner.

Article III analyzes competition between SIs and exchanges, with a focus on the determinants of traders' choice of venue and trading costs. The findings indicate that SI trades are less informative than exchange trades, implying that uninformed traders are more likely to interact with SIs. Due to their ability to avoid trading with informed investors, SIs often undercut the exchange bid-ask spread when the spread is wide and the tick size is not binding. SIs can thus offer lower trading costs and gain a higher market share relative to exchanges.

Keywords: Systematic internalizers, Off-exchange trading, Equity markets, Price efficiency, Liquidity, Trading costs, High-frequency traders, Regulation, Dealers, Inventory management.
OFF-EXCHANGE TRADING IN MODERN EQUITY MARKETS

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Fatemeh Aramian
To my family
Acknowledgement

Looking back on these years, I cannot help but to find myself emotional. It has been a unique, challenging, yet rewarding experience. I am grateful to everyone who contributed to this journey.

Foremost, I would like to extend my sincere gratitude to my primary supervisor, Lars Nordén, for the excellent guidance he has given me throughout these years. Thank you, Lars, for your endless support and patience, for always being available to discuss my research and to answer my questions, and for filling me with positivity when I was feeling lost. I am also truly thankful to my co-supervisor, Lu Liu, for always providing me excellent comments and suggestions, especially on methodological issues, for reading my texts carefully, and for her kindness and care.

I owe a great deal of appreciation to Björn Hagströmer, who has been an outstanding discussant for my milestone seminars and always provided me invaluable feedback and questions. Thank you, Björn, not only for your support and guidance, but also for creating an inspiring working environment for microstructurers at SBS. I would also like to extend my appreciation to Gunther Wuyts, Talis Putnins, Kjell Jørgensen, and Markus Baldauf for their useful comments and suggestions at different stages of this dissertation. A huge thanks to David Michayluk for his help during my stay at University of Technology Sydney and Mia Hinnerich for her guidance in the beginning of my Ph.D. studies.

I am grateful to my colleagues and friends at SBS. Thank you, Abi, for your friendship, generosity and care and for making my stay at SBS an enjoyable one. And a huge thanks to my dear friend, Ester, for all the laughter and talks we had together and for her great hospitality during my time in Sydney. I also owe much gratitude to my other dear friends,
Chengcheng, Petter, Ian, Anton, Dong, Amir, Vahid, Anna Felicia, Emelie, Sara, Emma and Johan. I learned a lot from all of you guys—thank you. In addition, I am thankful to all the people at SBS who helped me with administrative tasks, which could be overwhelming. Thank you, Linnea, Helene, Oskar, Doris and Vanessa, for your help.

Finally, I am beyond grateful to my family. I cannot thank enough my amazing parents and my sister for their unconditional love, and my dearest Reza for all the encouragement, love, support, and help he has given me throughout this journey. This dissertation would not be possible without your support.

Fatemeh Aramian
Stockholm, November 2021
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Introduction

Equity markets facilitate interactions between traders by bringing them together either at physical trading floors or through electronic trading services. Each trading venue operates with a specific market structure (or trading mechanism), which is a set of trading rules dictated to traders. Market structures determine the order types traders are allowed to submit, order-matching procedures, the degree of information available to traders about other participants (e.g., information about orders, trades, or the identity of other traders), and trading fees. As discussed by Harris (2003) and Foucault, Pagano, Roell, and Röell (2013), these trading rules influence traders’ strategies, the association between different types of traders, and ultimately traders’ profitability.

The area of finance that analyzes the role of trading mechanisms in the price formation process is known as market microstructure. As noted by O’Hara (2001), market microstructure studies the process and results of exchanging assets under certain trading rules.

Understanding the role of each market structure is crucial, because it has implications for the well-functioning and quality of the market (Harris (2003)). This thesis focuses on the role of the trading mechanisms of off-exchange platforms in the form of systematic internalizers (SIs) in equity markets. An SI is a single-dealer platform, run by a trading firm, by which traders receive access to quoted prices from one dealer, and orders are executed against the dealer’s inventory outside exchanges. SIs have experienced a sharp growth in market share in the last few years. As a collection of three articles, the thesis investigates how SIs affect traders’ order routing decisions and various features of market quality.
Liquidity and price efficiency are the main features of market quality. A high-quality market is highly liquid and generates efficient prices. Liquidity refers to a market’s ability to execute an order in a short time frame when needed, without causing large price changes (Black (1971)). As noted by Kyle (1985), the tightness of bid–ask spreads (the difference between the best bid and ask prices), depth, and resiliency are the three dimensions of liquidity. Tightness represents the cost of transacting a stock over a short period, depth accounts for the available volume to buy (or sell) at different price levels, and resiliency refers to the speed of the recovery of prices from a liquidity shock. A liquid market generates tight bid–ask spreads, is deep so that transacting a relatively large volume does not lead to noticeable movements in prices, and is resilient enough so that prices recover from liquidity shocks and move back to their underlying values relatively quickly.

Price efficiency refers to the informativeness of prices about fundamental values, which are the estimates of future cash flows (Foucault et al. (2013)). More informative prices help traders to make more informed investment decisions. Under the efficient market hypothesis, at any point in time, prices should reflect all available information and returns should not be serially correlated. Information about fundamental values originates from two sources: public and private. Information obtained from macroeconomic news and announcements about a company’s performance is publicly available to all traders. With the arrival of news and announcements, traders update their beliefs, and prices adjust accordingly. The other source of information is private, where so-called informed traders acquire information prior to its availability to other market participants. This information is incorporated into prices by the activities of informed traders.

Traditionally, quote-driven and order-driven markets are the two prototypical trading mechanisms operated by exchanges. In a quote-driven market, or a dealership
market, multiple dealers who operate as market makers on the exchange set the prices at which they are willing to buy and sell. Traders interact only with dealers and buy from (sell to) a dealer at the quoted ask (bid) price. In contrast, in an order-driven market, also called a limit order book market, all traders set the prices and the volumes they intend to trade. Traders trade directly with each other and their buy and sell orders are executed accordingly. While order-driven markets provide traders the ability to choose whether to supply or demand liquidity, dealers are the only liquidity providers to liquidity demanders in quote-driven markets.

Equity exchanges initially started as physical venues where traders would gather and trade on the exchange’s trading floor. Equity markets, however, have undergone several radical changes since their introduction. Technological developments and the evolution of electronic trading have modernized the trading landscape and reduced the need for trading floors. Many exchanges now conduct trading through electronic services, and most exchanges run order-driven markets.¹ Traders are, however, heterogeneous with respect to their objectives, and thus the existence of diverse trading mechanisms can help meet every trader’s needs. Regulatory reforms in equity markets have led to the proliferation of new trading venues with unique trading mechanisms that serve different types of traders.

The Regulation National Market System (Reg NMS) in 2005 and Markets in Financial Instruments Directive I (MiFID I) in 2007 resulted in extreme market fragmentation in the U.S. and European equity markets, respectively, in which venues compete with each other in attracting order flow. Market fragmentation has increased the importance of order routing decisions, since liquidity is now scattered across several

¹Some exchanges, such as the New York Stock Exchange (NYSE), conduct trading using both electronic services and trading floors. Although electronic trading has brought about numerous advantages to the trading landscape, floor trading seems to still be beneficial in special situations. For instance, Brogaard, Ringgenberg, and Roesch (2021) find that the NYSE’s suspension of floor trading due to COVID-19 deteriorated market quality by reducing (increasing) liquidity (pricing errors). The authors suggest that floor trading can complement algorithmic trading in complex situations.
venues and traders need to source it from those venues that provide them with the best execution. An unintended consequence of the regulations has been the significant rise in trading on off-exchange platforms, which execute orders away from the limit order books of exchanges, that is, lit markets. The activities of off-exchange platforms have always been at the core of debates, since regulators are concerned about the potential adverse effects of trading away from lit markets on market quality. The effects of off-exchange trading are not yet fully understood, and the research has not arrived at a unanimous conclusion on how it affects market quality.

An important distinction between lit and off-exchange markets is the extent to which they provide pre-trade transparency. Lit markets offer full pre-trade transparency, whereas off-exchange platforms provide either no or limited pre-trade transparency. Does pre-trade transparency have implications for market quality? Baruch (2005) finds that pre-trade transparency increases liquidity by promoting competition between liquidity providers. Boehmer, Saar, and Yu (2005) also empirically provide evidence that an increase in pre-trade transparency improves market quality by increasing liquidity and the information efficiency of prices. The full visibility of orders in lit markets helps market participants to learn from the order flow and update their beliefs about the fundamental value, since limit and market orders carry information, according to Kaniel and Liu (2006) and Rosu (2010).

On the other hand, Boulatov and George (2013) show that hiding orders, particularly liquidity-providing orders, leads to more aggressive competition among informed traders in liquidity provision and improves price discovery. Along the same lines, Madhavan, Porter, and Weaver (2005) find that the visibility of limit orders reduces

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2 Pre-trade transparency refers to the level at which information about quoted prices (the prices that buyers and sellers are willing to pay and receive, respectively) and quoted sizes (the volumes at quoted prices) is publicly available to market participants.

3 Pagano and Röell (1996) show that pre-trade transparency enhances price informativeness and reduces trading costs for uninformed traders.
liquidity. The authors argue that a high degree of pre-trade transparency reduces traders' tendency to post limit orders due to the cost of “free” options.

Apart from the role of transparency, order fragmentation across venues can affect market quality. On the one hand, the migration of liquidity takers to off-exchange platforms in the hopes of obtaining low transaction costs could reduce competition among liquidity providers on lit markets and thus harm liquidity. On the other hand, fragmentation promotes competition across venues to attract more order flow. Foucault and Menkveld (2008) and Colliard and Foucault (2012) show that the increased competition across venues results in lower transaction costs and increases liquidity.

Algorithmic trading has also been a game changer in equity trading and can be viewed as a feature of modern markets. In algorithmic trading, every part of the trading process—including order submission and order management after submission, such as order modification, cancellation, and execution—is handled using computer algorithms.4 When a stock is traded on multiple venues, algorithmic traders use computer algorithms and employ a smart order routing system to decide where to submit orders (e.g., Foucault and Menkveld (2008)). A subcategory of algorithmic traders that rely on high speed and sophisticated programs for all trading activities are high-frequency traders (HFTs). HFTs are proprietary trading firms that also acquire colocation services offered by exchanges to obtain information faster than other participants (SEC (2010)).

The speed of obtaining, processing, and reacting to information is a trademark of HFTs. When acting as liquidity providers, HFTs use their speed advantage to update their quotes to avoid being adversely selected by slow informed traders (e.g., Hoffmann

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4Computer algorithms decide on the price, volume, and timing of an order submission and constantly track market conditions across different stocks and trading venues. Determining trading strategies (whether to trade passively by submitting limit orders or actively by submitting market orders or employing a mixed strategy of active and passive trading) and order splitting are also processed by algorithms.
They also use this speed to recognize trading opportunities faster than others and subsequently take liquidity, imposing higher adverse selection costs to slow liquidity providers (e.g., Foucault, Hombert, and Roșu (2016)). Although HFTs provide low transaction costs for retail traders by tightening spreads, Korajczyk and Murphy (2019) and Van Kervel and Menkveld (2019) find evidence that they impose higher transaction costs on large institutional investors by detecting their orders, learning from them, and ultimately trading in the same direction as these orders.

HFTs are active in both multilateral trading-based venues, such as exchanges, and in bilateral trading off exchange. They engage in bilateral trading off exchange mainly by operating single-dealer platforms in the form of electronic liquidity providers (ELPs) and SIs in the United States and Europe, respectively.5 Our understanding of single-dealer platforms run by HFTs, with respect to their strategies and effects in equity markets, is limited, partly due to their recent growth and a lack of granular data.

The articles of this thesis contribute to the microstructure literature by being the first to explore SIs’ activities in equity markets from various perspectives. The articles also contribute to different strands of the literature on off-exchange trading, high-frequency trading, market fragmentation, and dealership markets, which are described in more detail in Section 3 and in the articles.

Article I studies SIs’ characteristics and the impact of SI operations on price efficiency. Using high-frequency measures of price efficiency, the results show that SIs’ activities improve the informativeness of prices on exchanges. The article further indicates that market making is an important factor in a firm’s decision to operate as an SI and that the heterogeneity in the level of market making among SIs matters for market efficiency analysis. Efficiency is improved only through the activities of those

5ELPs and HFT SIs operate under two distinct trading mechanisms. For instance, ELPs operate with no pre-trade transparency obligations, whereas SIs are obliged to provide limited pre-trade transparency.
SIs with the highest level of market making on exchanges.

Article II investigates the role of SIs run by HFTs in equity markets, with a focus on the impact of HFT SI operations on HFTs’ inventory management behavior, their liquidity provision on exchanges, and, ultimately, market quality with respect to liquidity. The results show that the trading activity of HFT SIs leads HFTs to manage their inventory imbalances by taking liquidity and reducing their liquidity provision on exchanges. The exchanges’ bid-ask spreads therefore widen and the order books become thinner.

Article III analyzes competition between SIs and exchanges, with a focus on the determinants of traders’ choice of venue and trading costs. The findings indicate that SI trades are less informative than exchange trades, implying that uninformed traders are more likely to interact with SIs. Due to their ability to avoid trading with informed investors, SIs often undercut the exchange bid-ask spread when the spread is wide and the tick size is not binding. SIs can thus offer lower trading costs and gain a higher market share relative to exchanges.

The remainder of the introduction chapter is organized as follows. Section 1 describes the regulation in European equity markets and compares the regulatory frameworks in Europe and the United States. Section 2 explains the empirical setting of the thesis, including the institutional details of SIs. The introduction chapter ends by summarizing the three articles.
1. Institutional Background

1.1. Regulation in European equity markets

MiFID I encouraged diversity in trading mechanisms, and consequently trading systems such as multilateral trading facilities (MTFs), dark pools, and SIs emerged. An MTF is a trading system that eases the exchange of financial instruments between multiple third parties, and a dark pool is a trading system that matches buy and sell orders with no pre-trade transparency.

The existence of new trading platforms alongside regulated markets (RMs)\(^6\) has promoted competition for order flow across venues. The objective of MiFID I was to set a unified regulatory framework for all European markets that protects investors by providing a fair, liquid, and efficient market while promoting competition across venues. MiFID I required RMs and MTFs (i.e., exchanges) to continuously report information on bid and ask prices and their corresponding sizes in their limit order books, to harmonize pre-trade transparency and to reduce the potential drawbacks of order fragmentation.

MiFID I also provided waivers from pre-trade transparency obligations, including reference price, large-in-scale (LIS), negotiated price, and order management facility waivers. When a trading system executes orders at reference prices—prices determined by another trading system where the prices have been publicly displayed—the venue is exempt from pre-trade transparency requirements. Dark pool operations rely on the reference price waiver. Under the LIS waiver, orders equal to or larger than the minimum LIS threshold can be executed without any pre-trade transparency. The ne-

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\(^6\)An RM is a multilateral trading system in which multiple third parties selling and buying interests interact with each other. While MTFs are operated by investment firms or market operators, RMs are run only by market operators. Unlike RMs, MTFs do not impose listing requirements.
gotiated price waiver is applicable when a trade is executed bilaterally through private negotiation between traders at the execution price determined by conditions other than the current market price of the share or is executed at or within the current volume-weighted spread. The order management facility waiver is applied to orders detained by exchanges prior to disclosure to the market, such as iceberg orders and hidden orders. The pre-trade transparency waivers together with rapid technological developments (e.g., the emergence of high-frequency trading) resulted in a sharp growth in dark trading during MiFID I.

The rapid rise in dark trading, high market fragmentation, the speed of technological changes combined with concerns raised about the accountability of the regulatory framework following the global financial crisis in 2008–2009 motivated regulators to follow up on MiFID I. The objective was to create a more robust regulatory legislation that enhances investors' protection by increasing transparency and boosting market functionality, ensuring market efficiency and liquidity. Therefore, European equity markets experienced a big shake-up again as MiFID II was instituted on January 3, 2018.\(^7\)

One of the most radical changes brought about by MiFID II is related to dark trading, since regulators were aiming to regulate off-exchange trading, essentially moving it to more transparent venues.\(^8\) To fulfill this goal, regulators imposed a number of trading obligations. First, rules restricted trading in dark pools through the double volume cap (DVC). The DVC permits a stock’s market share to be at most 4% in a single dark pool and 8% across all dark pools during the most recent 12 months of trading activities in that stock. Second, the scope of the reference price waiver was

\(^7\)The focus of MiFID I was mainly on equity instruments. MiFID II, however, extended the scope of MiFID to a wide variety of asset classes, including non-equity instruments.

\(^8\)The harmonized tick size regime is another important change in MiFID II. Accordingly, all European stock markets should follow the same tick size regime, in which tick size is determined based on price and the liquidity band of the stock. A large number of active stocks experienced a reduction in tick size following the launch of MiFID II.
changed. While reference price trades were authorized at both the midpoint and the best quotes (the best bid and ask prices) under MiFID I, they are now allowed only at the midpoint price. Third, the regulation modified the minimum size threshold for trades executed under the LIS waiver by increasing (decreasing) the minimum threshold for high-volume (low-volume) stocks.\(^9\) Fourth, broker crossing networks that would execute clients’ orders off exchange with no pre-trade transparency were banned under MiFID II.\(^10\)

In terms of share trading, regulators also imposed the share trading obligation (STO) rule. STO requires trades in shares admitted to trading on a European RM to take place on an RM, MTF, SI, or a third country’s trading venue evaluated as equivalent under MiFID II. However, the STO makes exceptions and still allows over-the-counter (OTC) trading, provided that the trades are non-systematic, infrequent and irregular, and ad-hoc or the trades do not contribute to the price discovery process, and occur between eligible and/or professional counterparties.\(^11\)

One major outcome since the implementation of MiFID II has been the rapid growth in SI trading. Dark trading rules promoted SIs as qualified execution platforms. Various types of trading firms, including banks, investment banks, and HFTs, have chosen to operate as SIs in post-MiFID II. These rules have also induced traders to comply with trading obligations and source liquidity from alternative venues, including SIs. Therefore, the number of SIs (their market share) in equity trading increased from 13 (almost 2\%) in 2017 to 73 (almost 20\%) in 2019 (ESMA (2020a)).

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\(^9\)The minimum qualifying sizes for LIS orders under MiFID II are presented in Table 1, Annex II, Regulatory Technical Standards 1(RTS1; see https://eur-lex.europa.eu/eli/reg_del/2017/587/oj). The minimum LIS threshold is determined based on a share’s average daily turnover.

\(^10\)Broker crossing networks would execute clients’ orders off exchange with no pre-trade transparency by matching them against their own flow or through client-to-client order matching.

\(^11\)Following Brexit in 2020, UK and Europe regulatory frameworks started to diverge. For instance, the United Kingdom has suspended STO and DVC rules and lowered the minimum threshold for the LIS waiver.
1.2. *Lit, dark and partially transparent trading*

Today, stock trading in Europe is possible through several trading systems, including lit markets, SIs, traditional call auctions, periodic auctions, dark venues (LIS platforms and dark pools), and OTC markets (only if trades fulfill STO requirements for OTC trading). Lit markets, adopted by exchanges, run electronic limit order books and offer full pre-trade transparency by continuously providing real-time information about bid and ask prices and their corresponding sizes at several levels. In limit order books, orders interact with each other anonymously, and a trade occurs when a limit order is reached by a market order or a marketable limit order.

An SI is a single-dealer platform where the SI acts as a dealer and executes orders off exchange against its own inventory. SIs are considered partially transparent trading systems, since they offer limited pre-trade transparency. Each SI publicly displays quotes only for sizes up to the standard market size (SMS). SIs do not execute orders at a reference price obtained from a lit market; instead, they generate execution prices based on their own internal books. The institutional details of SIs, which are the focus of this thesis, are described in Section 2.

Traditional call auctions acquired by most primary exchanges take place at predetermined times during a trading day, mainly at the opening and closing of the market. In addition to the opening and closing calls, some markets operate an intraday call auction at a scheduled time once a day. Traders indicate their trading interests during the call’s non-trade batching period, followed by uncrossing in which orders are simultaneously executed at a single price that balances liquidity supply and demand. Traditional call auctions publish only indicative prices and volumes that show the conditions at which trades would be executed if the auction were to uncross at that time.
Periodic auctions have been adopted by some MTFs, such as BATS Europe, in response to dark trading rules, and they resemble traditional call auctions with some differences. The timing of periodic auctions is not predetermined, and they can happen several times during a trading day. A periodic auction usually takes place every time there are opposite orders that can be matched. The duration of the auction phase is shorter than for traditional calls and is usually less than one second, during which indicative prices and volumes are displayed. Traditional call auctions and periodic auctions can be considered partially transparent venues, since they do not provide full pre-trade transparency as in the case of lit markets.

Dark venues provide no information about the price and size of orders before trades take place. LIS platforms, such as BATS Europe LIS, Turquoise Plato Block Discovery, and Euronext Block, are dark platforms initiated in response to dark trading rules under MiFID II. They rely on the LIS waiver, execute large block orders with no pre-trade transparency at all, and are not subject to the DVC. Dark pools rely on the reference price waiver and do not use an internal order book to generate execution prices. They mainly execute orders at the midpoint price of the best quotes publicly displayed in the limit order books of exchanges. Unlike LIS platforms, dark pools execute orders of all sizes and are subject to the DVC.

1.3. Regulatory frameworks in the U.S. and Europe

Similar to MiFID, Reg NMS aimed to create a liquid and efficient market for investors while encouraging competition across venues and easing trader interactions in a unified trading framework. Reg NMS made the U.S. equity market extremely fragmented. By the end of May 2021, there were 16 exchanges (57.6% market share), approximately...
223 wholesale market makers\textsuperscript{12} (29.2\% market share), and 32 dark venues, including 27 alternative trading systems\textsuperscript{13} (9.5\% market share) and five ELPs (3.7\% market share) (Rosenblatt Securities (2021)).

Despite similar objectives, Reg NMS and MiFID have several important differences. First, in the United States, the consolidated tape collects information on all trades and the best quotes from all venues in the U.S. equity market and disseminates it. The consolidated tape provides market participants with a complete picture of market activities and is an essential tool to ensure higher reliability for best execution. For instance, it provides market participants with the National Best Bid and Offer (NBBO), which represents the best bid and ask prices across all public venues. The use of the NBBO secures the execution price of off-exchange trades, particularly in dark pools that execute orders at the midpoint price, since it guarantees that the midpoint price has been determined based on all venues, and not just one (Comerton-Forde (2021)).

In contrast to the U.S. market, the consolidated tape does not currently exist in Europe, although Europe is moving toward its implementation. The adoption of a consolidated tape would benefit European equity markets. For instance, a real-time consolidated tape that provides all quotes at the time of each trade can help traders assess their execution against the European Best Bid and Offer instead of the best quotes of the primary exchange. It can also assist the market become more resilient during an outage of the primary exchange by making the European Best Bid and Offer the reference price rather than the best bid and offer of the primary exchange (Comerton-Forde (2021)). In addition, a real-time post-trade consolidated tape, for example, would provide traders a more reliable and comprehensive view of the prices and the volume traded. This will increase the reliability of the estimation of the

\begin{footnotesize}
\begin{itemize}
\item\textsuperscript{12}Wholesale market makers purchase retail orders from retail brokers in the form of payment for order flow and internalize the orders off exchange.
\item\textsuperscript{13}Alternative trading systems are electronic trading systems that execute orders electronically without providing pre-trade transparency. All alternative trading systems in the United States are dark pools.
\end{itemize}
\end{footnotesize}
average daily trading volume executed on and off exchange, which can improve trading
decisions (Comerton-Forde (2021); Plato Partnership (2021)).

Second, Reg NMS imposes the order protection rule/trade-through rule, which proh-ibits order execution at prices worse than those published on other venues. Although
no trade-through rule exists under MiFID, European traders state that they are un-
likely to send orders to venues executing orders at inferior prices, unless their execution
cost analysis shows a benefit (Comerton-Forde (2021)).

The third difference is related to the way MiFID and Reg NMS treat internaliza-
tion, in which a broker–dealer executes a client’s orders against its own inventory off
exchange. Internalization has always been a controversial concept in securities trading.
Its opponents argue that internalizing retail orders away from lit markets harms liquid-
ity, whereas its proponents claim that it improves liquidity by increasing the number of
broker-dealers competing to execute order flow. To prevent any unintentional adverse
effects of internalization, MiFID introduced the concept of SI, in which broker–dealers
that systematically and frequently internalize their clients’ orders must operate as SIs.
SIs are more regulated than internalizers in the United States, their main distinc-
tion being in pre-trade transparency. As mentioned earlier, SIs have limited pre-trade
transparency obligations, whereas internalizers in the United States are exempt from
them.

Finally, the U.S. equity market permits the use of payment for order flow. Payment
for order flow refers to a practice in which dealers executing trades make cash or non-
cash payments to brokers to route their clients’ retail orders to them. Retail orders are
usually uninformed and, hence, profitable to dealers. Payment for order flow is widely
used by wholesale market makers and some ELPs, and its effects on market quality
have always been of concern. For instance, Eaton, Green, Roseman, and Wu (2021)
find that ELPs’ payment for order flow has a harmful effect on the liquidity of the U.S. market. Payment for order flow can create a conflict of interests between traders and their brokers. A broker can be motivated to send a client’s order to a dealer that does not provide the best execution for the client. In Europe, however, MiFID II’s rule in the context of best execution is interpreted as a de facto ban on payment for order flow.

2. Empirical Setting of the Thesis

The empirical setting of the thesis is the Swedish stock market. The sample comprises the trading activities of the 45 large-cap Swedish stocks with the highest average daily turnover in 2018. The studies focus on the activities on SIs and on the most important exchanges, namely, Nasdaq Stockholm (the primary exchange) and MTFs (BATS Europe, Chi-X, Turquoise, and Aquis).

Table 1 presents descriptive statistics for the stocks in the sample. Market capitalization is based on the closing price of December 29, 2017, expressed in millions of Swedish kronor (MSEK). The average (median) stock in the sample has a market capitalization of 104,885.10 MSEK (68,025.10 MSEK). The stock–day average price is 229.35 SEK, which is higher than the median price of 186.82 SEK. A similar pattern is observed for the relative tick size, which is the tick size divided by the midpoint quote in the consolidated limit order book observed at the end of every minute, expressed in basis points. The stock–day average and median relative tick size are 3.45 and 3.26 basis points, respectively. In addition, Table 1 reports an average stock–day volatility (the realized volatility of one-minute midpoint logarithmic returns in the consolidated order book) of around 1.27% and a median of 1.13%.
Table 1: Descriptive statistics

This table reports descriptive statistics (mean, median and standard deviation) for the 45 large-cap Swedish stocks with the highest average daily turnover in 2018. Market capitalization is based on the closing price of December 29, 2017, expressed in millions of Swedish kronor, or MSEK. The relative tick size is the tick size divided by the midpoint quote in the limit order book consolidated over exchanges, observed at the end of every minute, expressed in basis points. Volatility is the realized volatility of one-minute midpoint logarithmic returns in the consolidated order book. All variables except for the market capitalization are calculated across the stocks from January 3 to December 28, 2018. The exchanges are Nasdaq Stockholm, BATS Europe, Chi-X, Turquoise, and Aquis.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market capitalization (MSEK)</td>
<td>104,885.10</td>
<td>68,025.10</td>
<td>96,967.2</td>
</tr>
<tr>
<td>Price (SEK)</td>
<td>229.35</td>
<td>186.82</td>
<td>25.28</td>
</tr>
<tr>
<td>Relative tick size (bps)</td>
<td>3.45</td>
<td>3.26</td>
<td>0.41</td>
</tr>
<tr>
<td>Volatility (%)</td>
<td>1.27</td>
<td>1.13</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Nasdaq Stockholm is the listing exchange for Swedish stocks and is an RM offering a traditional call auction mechanism and continuous trading. Trading takes place continuously in a limit order book from 9:00 AM to 5:25 PM. The execution priority of the submitted limit orders is set based on price, internal, visibility, and time. Trading is open every weekday, except for Swedish public holidays. On a weekday before a Swedish public holiday, the market is open for half the day and closes early, at 1:00 PM. Each trading day, Nasdaq also offers an opening call auction (with the uncrossing at 9:00 AM), a closing call auction (with the uncrossing at 5:30 PM), and a scheduled intraday call auction (with the uncrossing at 1:35 PM). On half-days, when the market closes at 1:00 PM, the scheduled intraday call auction is omitted, and the market closes with the closing call auction uncrossed at 1:00 PM.

The MTFs are pan-European exchanges. Chi-X was the first pan-European exchange, launched in 2007, and BATS Europe, Turquoise, and Aquis soon followed. MTFs usually do not offer traditional call auctions, and trading days start directly with a continuous trading session. MTFs’ trading hours are in line with the trading hours of the continuous trading session of the RM (i.e., Nasdaq Stockholm). The ex-

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14 Internal priority means the internalization of orders within a trading firm. If a trading firm submitting a market order also has a limit order posted in the book at the same price level, that limit order has priority, even if other limit orders at the same price level were posted earlier.
ecution priority of all MTFs’ limit order books is based on price, visibility, and time, except for Aquis, whose limit order book follows price and time priority.

Trading is also possible through SIs. While exchanges facilitate trading by allowing the interaction of multiple third-party buying and selling interests, SIs conduct bilateral trading and execute orders against their own inventories. The European Securities and Markets Authority (ESMA) emphasizes that, under the market structure of SIs, trading is characterized by risk-taking activity, according to which each SI is obliged to take positions in transactions and to execute orders against its own inventory, which influences its profit and loss account (ESMA (2020c)).

SIs are obliged to continuously publish real-time two-way quotes only for liquid stocks during the continuous trading session of the most relevant market in terms of these stocks’ liquidity. The pre-trade transparency obligation is, however, limited to orders with sizes up to the SMS, which is EUR 10,000 for all Swedish stocks in the sample, except for one stock whose SMS is EUR 30,000. SIs are also required to post quotes with sizes greater than or equal to 10% of the SMS. They should make quotes public through one of the Approved Publication Arrangement (APA) reporting services. SIs can choose any APA, but most opt to use the main one, namely, the Cboe trade reporting service (BXTR), which accounts for the majority of SIs active in European equities. The pre-trade transparency obligation is waived for orders larger than the SMS for both liquid and illiquid stocks, and quotes are provided upon request. Different from SIs, limit order books of exchanges are obliged to provide pre-trade transparency for all stocks (liquid and illiquid) and for all order sizes.

Regarding post-trade transparency, similar to exchanges, SIs are required to make

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15 According to Article 4 of RTS1, the most relevant market in terms of liquidity for a stock is the trading venue with the highest turnover within all European markets for that stock. Nasdaq is the most relevant market for the sample of stocks in this thesis, except for two, for which Chi-X and the London Stock Exchange are the relevant markets.
each trade’s information public as close to real time as technically possible, following Article 6 of Markets in Financial Instruments Regulation (MiFIR) and Article 14 of RTS1. ESMA emphasizes this further that a level playing field in post-trade transparency is required, since SIs compete directly with other trading venues for customers’ order flow. Hence, according to the rules, “trading venues and SIs using similar technology and systems should process transactions for post-trade publication at the same speed” (ESMA (2021), 24).

The regulation provides a degree of flexibility for SIs to decide whom they trade with (for all order sizes) based on their commercial policies, such as counterparties’ credit status or counterparty risk. For instance, for orders up to the SMS, when SIs make their quotes public through an APA, the quotes are visible to everyone, but it is not possible for an investor to interact with the APA quotes, since, for this, they need direct trading connectivity to the SI. This process normally involves both an order entry connection and a market data connection. Via the market data connection, the investor receives quotes from the SI which it can trade with by sending orders via the order entry connection. It is via this direct connectivity that SIs operate their commercial discretion regarding the counterparties with which to trade. Quotes for orders above the SMS are also accessible through market data connections upon request, and then SIs use their commercial discretion regarding whether to trade with the counterparty.

When it comes to the minimum price improvement (tick size), although exchanges must follow the MiFID II tick size regime for orders of all sizes, SIs’ quotes, price improvements, and execution prices must comply with the tick size regime for orders up to the minimum LIS threshold. This requirement came into force in June 2020, and previously SIs were advised to follow the tick size regime only for orders up to the

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16 This flexibility is based on Article 17 of MiFIR. According to this article, SIs are also allowed to limit the number of transactions with the same counterparty, to reduce the risk of exposure to multiple transactions from the same client.
SMS. Specifically, although there was no written rule for SIs to follow the MiFID II tick size regime prior to June 2020, ESMA (2020c) clarifies that price improvements on quoted prices can only be justified when they reflect the minimum tick size applicable to the same stock traded on an exchange.

SIs and exchanges have different trading fee structures, with diversity within each group as well. For an exchange trade, a broker pays a trading fee directly to the exchange (the exchange fee), a fee to the central clearing party (either directly or via their clearer) for clearing the trade, and then a settlement fee. SIs generally do not charge a platform fee or other connectivity costs for sessions that exchanges charge, and they also do not normally charge for market data. SI counterparties, however, still need to cover their own costs for clearing and settling trades.

If an investor interacts with an SI through its broker, the investor does not pay the clearing and settlement fees, which is similar to trading on exchanges. In other words, the investor pays the broker a commission on each trade and the broker then pays all the costs, including clearing and settlement fees. Hence, in such cases, there should normally be no difference in the costs from interacting with an SI or an exchange for the end investor.

Nasdaq Stockholm and MTFs also differ in their applied trading fee models. MTFs usually have a make-take fee model, in which the exchange pays a rebate to liquidity providers for making the market and charges liquidity takers a fee. However, Nasdaq Stockholm does not have a make-take fee model.
3. Summary of the Thesis

This thesis contains three articles that examine the impacts of SIs on traders' order routing strategies and the quality of equity markets from different perspectives.

Article I: Anatomy of Systematic Internalizers and Price Efficiency

Systematic internalizers have taken on an important role in European equity markets. The proliferation of SIs and the growth in their market share have made the equity market more fragmented (ESMA (2020b)). An understanding of SIs' characteristics and whether SI trading influences market quality is therefore relevant and of interest.

Each SI acts as a stand-alone trading platform and competes with other venues in attracting order flow. Although SIs are run by two distinct groups of trading firms, namely, HFTs and banks (banks and investment banks), firms within each group are also heterogeneous with respect to their strategies (Hagströmer and Nordén (2013); Benos, Brugler, Hjalmarsson, and Zikes (2017)). Article I investigates SIs' characteristics, the impact of SI operations on price efficiency, and, ultimately, diversity among SIs and its effects on market efficiency.

The findings indicate that exchanges' liquidity providers are more likely to operate single-dealer platforms. This is consistent with the conjecture that running dealer platforms helps SIs maintain better control over adverse selection and inventory risks. This is because of the non-anonymous nature of trading under the SI regime and the possibility of being involved in inter-dealer trading. The results also show that trading firms operating as SIs are heterogeneous with respect to the level of liquidity supply.
on exchanges, measured as the fraction of a firm’s activity through principal passive trading (liquidity supply ratio).

I examine the impact of SI trading on price efficiency using high-frequency metrics based on return autocorrelations and variance ratios. I find evidence that the trading activity of SIs improves the informativeness of prices on exchanges. The improved price efficiency is closely related to the segmentation of informed and uninformed orders across SIs and exchanges documented by Aramian and Nordén (2021a), that is, Article III. Aramian and Nordén (2021a) show that SI trades are less informative than exchange trades and suggest that liquidity traders are more likely to interact with SIs, whereas informed traders are concentrated on exchanges. The finding that the segmentation by SIs is associated with better price efficiency supports the prediction by Zhu (2014) that the presence of liquidity traders on off-exchange platforms, while informed traders are concentrated on exchanges, reduces noise in prices and thus boosts price discovery.

Article I also investigates diversity among SIs and its effects on price efficiency by analyzing how order execution on SIs with different levels of market making on exchanges affects the speed of convergence to price efficiency. The results show that the improved efficiency is driven by high–market making SIs—that is, SIs with the highest level of market making on exchanges—and that these SIs lead to the faster incorporation of information into prices. High–market making SIs on exchanges are more exposed to adverse selection costs than other SIs. Therefore, they are more motivated to avoid interactions with informed traders on their SI platforms to compensate for the adverse selection costs on exchanges. This strategy results in the greater segmentation of informed and uninformed orders and thus more informative prices on exchanges.

This study contributes to the literature that links off-exchange trading and market
quality. While previous research has examined the aggregate measures of off-exchange trading, to my knowledge, this study is the first to analyze diversity in off-exchange platforms and its effects on price efficiency. In addition, the literature has focused on off-exchange trading in markets with no pre-trade transparency (e.g., Larrymore and Murphy (2009); Comerton-Forde and Putniņš (2015); Foley and Putniņš (2016); Hatheway, Kwan, and Zheng (2017)). Different from these studies, I contribute to the literature by exploring how off-exchange platforms offering partial pre-trade transparency influence price efficiency.

Article II: High-Frequency Traders and Single-Dealer Platforms

Market fragmentation and developments in technology and electronic trading have created an environment for HFTs to grow and to become essential players in equity markets. HFTs have attracted a great deal of attention from researchers and regulators because of, for example, their reliance on high speed and very short time frames for trading activities.

The literature has developed a good understanding of HFTs’ strategies and their market quality effects when they are active in multilateral trading–based venues. HFTs engage in diverse strategies, including market making, liquidity taking by trading on information or predicting order flow, and being active in arbitrage across assets and markets (e.g., Hagströmer and Nordén (2013); Menkveld (2013); Dahlström, Hagströmer, and Nordén (2020); Hirschey (2021)). The literature also shows that HFTs’ activities improve liquidity and price efficiency (e.g., Carrion (2013); Brogaard, Hendershott, and Riordan (2014); Brogaard, Hagströmer, Nordén, and Riordan (2015)).
HFTs’ activities, however, are not limited to exchanges or dark pools, and they also engage in off-exchange trading in a bilateral trading setting, where we know less about the role of HFTs. Among the few studies, for instance, Battalio, Hatch, and Saglam (2018) examine the bilateral interactions of large institutional orders and ELPs, or market making HFTs, in the U.S. equity market with respect to trading costs. The authors show that the exposure of parts of a parent order by ELPs imposes a higher transaction cost on the entire order, due to information leakage. The promotion of single-dealer platforms in the form of SIs by MiFID II in Europe led to the emergence of HFT SIs in 2018. Article II, co-authored with Lars Nordén, studies the impacts of HFT SI operations on HFTs’ inventory management behaviors, their liquidity supply on exchanges, and, ultimately, on different dimensions of market liquidity.

The results show that the activity of HFT SIs deteriorates liquidity on the primary exchange by increasing the quoted spread and reducing the depth, while the actual trading cost remains virtually unchanged. The findings also indicate that HFT SIs’ activities are associated with a reduction in their liquidity provision on exchanges. We argue that there are two channels for the reduction in liquidity provision. HFT SIs manage their inventory imbalances that arise from their SI trades by taking liquidity on the exchanges, and, at the same time, reducing their liquidity supply. Another possible channel is related to potential HFT SIs’ preference for supplying liquidity on their own dealer platforms to reduce their adverse selection costs.

Moreover, Article II provides evidence that the activity of HFT SIs is associated with a reduction in the number of times HFTs change their inventory positions. This suggests that operating as SIs helps HFTs to have better control over inventory costs. In addition, larger dealer volumes, that is, larger inventory positions, are associated with lower end-of-day inventory, indicating that larger inventory positions prompt HFT SIs to manage their inventories more carefully.
This study contributes to the HFT literature by exploring HFTs’ strategies and their market quality effects in the context of bilateral trading off exchange, whereas the focus of previous research has been mainly on HFTs’ activities in multilateral trading venues. The article also contributes to the literature on dealership markets by being the first to analyze the trading behaviors of specific types of dealers, namely, HFT SIs, since this literature has examined dealers’ activities only at the aggregate level.

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

In today’s fragmented market, diverse trading mechanisms help various types of investors to trade on venues that fulfill their trading objectives. Competition between venues to attract order flow affects traders’ order routing decisions, trading costs, and the distribution of orders across venues. Article III, co-authored with Lars Nordén, examines three research questions: What are the determining factors in traders’ selection between dealers and exchanges? What determines the costs to trade on dealer platforms? In the current electronic market setting, are informed or uninformed traders seeking out dealers?

To explore the determinants of traders’ choice of venue and trading costs, the study focuses on small trades—trades with sizes up to the SMS—since SIs have pre-trade transparency obligations for small trades. Analyzing small trades helps in conducting valid analysis, since liquidity demanders can observe quotes on both SIs and exchanges and choose where to trade. The results suggest that SIs and exchanges are substitutes for each other. Traders are more likely to choose SIs over exchanges when the spread...
is large and volatility is low on exchanges and the tick size is not binding in the exchange’s limit order book. Large spreads on exchanges impose a higher transaction cost for liquidity takers and motivate them to route their orders to a platform offering lower costs. The findings are also consistent with the hypothesis that, in times of high volatility, traders prefer to trade on large venues, since these have concentrated liquidity and can guarantee execution at a reasonable cost.

When it comes to trading costs, the study provides evidence that SIs frequently improve on the exchange’s best bid and ask prices. A large percentage of SI trades are executed at prices better than the best bid and ask prices on exchanges. After employing the Heckman correction model to account for the potential endogeneity that can arise due to traders’ choice of venue, the findings indicate that trading costs on SIs increase with volatility and trade size, whereas these are lower when the tick size is not binding in the exchange’s limit order book.

Article III also shows that both small and large SI trades have significantly lower price impacts than exchange trades. This means that SI trades carry less private information about a stock’s fundamental value and are thus more likely to be initiated by uninformed (or liquidity) traders. This finding is consistent with the hypothesis that trading with SIs helps uninformed traders to signal themselves as traders for liquidity, and not information, in the hopes of facing lower transaction costs. Informed traders, on the other hand, might be less willing to interact with SIs, since the non-anonymous nature of trading on SIs exposes informed traders’ identities, which can lead to information leakage and thus higher trading costs.

This article contributes to the literature in two ways. Previous research has mainly focused on the market quality effects and market share determinants of dark markets (e.g., Degryse, Van Achter, and Wuyts (2009); He and Lepone (2014); Buti, Rindi,
and Werner (2016); Buti, Rindi, and Werner (2017)). Different from these studies, Article III analyzes inter-market competition from the perspective of trading costs and by examining an off-exchange platform with limited pre-trade transparency. The study also contributes to the literature on dealership markets by investigating competition between exchanges, which run fully electronic limit order books, and SIs that act as dealers in the context of today’s fragmented markets.
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