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Title:
Closing Mechanisms in European Equities

Date:
2023-06-01

Citation:
Aramian, F. & Comerton-Forde, C. (2023). Closing Mechanisms in European Equities. The University of Melbourne.

Persistent Link:
https://hdl.handle.net/11343/336902


THE UNIVERSITY OF
MELBOURNE

Faculty of Business
and Economics

# Closing Mechanisms in European Equities

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June 2023

# Contents

# Executive summary

This paper examines end-of-day trading mechanisms in European equity markets. Over the period January 2021 to September 2022, closing mechanisms account for around 18% of consolidated Euro volume in STOXX 600 stocks. Only continuous lit trading accounts for a larger fraction of activity. The high share of activity at the close is attributed to a range of factors including increases in assets under management in index and quantitative investment strategies and in Exchange Traded Funds. Closing mechanisms exhibit notably higher market share on rebalance and month-end days. The market share of closing mechanisms increases to 40% and 30% on rebalance and month-end days, respectively. These increases are likely due to benchmarking practices of index and other institutional traders. The market share of closing mechanisms decreases significantly on volatile and less liquid days.

Increased activity in closing auctions has focused attention on the typically higher cost of trading in primary exchange closing auctions. Alternative closing mechanisms have emerged to compete with primary exchange auctions. Despite the emergence of competing venues, primary exchange closing auctions continue to capture the lion's share of closing volume, representing about 84% of all closing activity. Alternative closing mechanisms, which compete for volume with the primary exchange, include Systematic Internalisers offering a guaranteed closing price (SI guaranteed close), Aquis Market-at-Close (MaC), Turquoise Plato Trade-at-Last (TPT@L), Cboe Closing Cross (3C), and the primary exchange Trade-At-Last (TAL) mechanisms. Among these, the SI guaranteed close and Aquis MaC have gained the largest market share, accounting for around 11% and 4.3%, respectively.

Closing mechanisms vary in the price formation process, pre-trade transparency, matching priority for execution, and duration. The primary exchange closing auction provides a price discovery mechanism, executing orders at a single price determined by volume-maximising and volume imbalance-minimising algorithms. In contrast, alternative closing mechanisms typically reference the primary exchange closing auction price for order execution. One exception is the 3C auction mechanism which is designed to offer price discovery and executes orders at a price that maximises the executed volume of limit orders in the 3C book. However, in practice, 99% of 3C trades occur at the primary exchange closing auction price after the uncross, suggesting that little to no price formation actually occurs on 3C.

European closing mechanisms provide pre-trade transparency, with the exception of SI guaranteed close, TPT@L, and the primary exchange TAL mechanisms. The degree of pre-trade transparency also varies among transparent mechanisms. The 3C mechanism discloses information on each order, whereas closing auctions only display indicative auction prices and volumes. Aquis MaC shares information on total MaC volume on each side, the first five MaC orders, and the primary exchange closing auction's indicative prices. The mechanisms also differ on a range of other dimensions including matching priority for execution and duration.

Why have alternative closing mechanisms failed to attract significant trading volume despite offering cheaper services? And why have some alternative mechanisms been more successful than others? The answers to these questions lie in the differing perspectives of market participants about the potential impact of fragmentation at the close, the ability to capture the benefits of the lower fees, and differences in the market structure of the mechanisms.

**Closing auctions versus alternative closing mechanism:** Opponents of alternative closing mechanisms, which include some index funds and institutional traders, argue that the migration of market orders from the primary exchange auction to alternative mechanisms may hinder the price formation process, resulting in less reliable closing prices. For this group of participants, cost-saving is not the main concern as they typically pay a flat fee to brokers. On the other hand, proponents of alternative closing mechanisms, such as brokers and more cost-sensitive traders, highlight the importance of competition at the close from a trading fee perspective. They argue that the alternative closing mechanisms can operate alongside closing auctions without negatively affecting the price formation process. In their view, the migration of orders primarily influences the auction's total executed volume rather than the price, as only market orders migrate to the alternative closing mechanisms. Further empirical research is required to resolve the question of how alternative mechanisms impact price formation.

**Alternative closing mechanism:** Differences in the market structure of alternative closing mechanisms have caused some to be more successful than others. Execution certainty, the possibility of changing orders up to the time of execution, and typically offering zero-fee trading have made SI guaranteed close more appealing than other mechanisms. However, the operation of post-close mechanisms and the presence of a cut-off time in other alternative mechanisms have made some traders less willing to participate due to potential operational risks.

The paper also offers a policy recommendation, encouraging regulators to monitor trading fees charged by primary exchanges. The gap between the trading fees of closing auctions and continuous trading sessions might undermine the closing auction's price formation process by restricting participation in closing auctions to specific groups.

# 1. Introduction

The market close is a critical time in the trading day. The closing price is determined at the end of the day when trading intensity increases due to, for example, traders wanting to get set at the closing price and closing their positions to avoid overnight risk. The closing price is the most important price in equity markets and a crucial reference price for market participants. It is used, among others, to compute portfolio returns, to price mutual fund shares, and as a benchmark price for institutional traders when reporting performance. The closing call auction mechanism adopted by primary exchanges has shown to be helpful in setting an efficient closing price and providing liquidity at the close for market participants (e.g., **Schwartz (2001)**; **Pagano and Schwartz (2003)**).

Global equity markets have seen a significant rise in closing auction activity over recent years. For instance, in France, the market share of the closing auction increased from 8% in 2015 to 14% in late 2019 (Autorité des Marchés Financiers (2019)).[1] This growth can be attributed to various factors, such as the rise of index investing, the growing use of quantitative investment strategies benchmarked to the close, a surge in Exchange Traded Funds (ETF), and increased emphasis on best execution imposed by MiFID II (JP Morgan (2019); Autorité des Marchés Financiers (2019); BlackRock (2020); Bogousslavsky and Muravyev (2020); Comerton-Forde and Rindi (2022)). Additionally, the concept of "liquidity begets liquidity" has played a role in this increase. The closing auction is a key liquidity event. As the volume grows, its liquidity is enhanced, attracting traders seeking liquidity, such as active funds, and opportunistic traders.[2]

Primary exchanges' closing auctions were once the exclusive trading mechanism at market close. This monopoly has allowed primary exchanges to charge higher fees for the auction than in the continuous trading session.[3] Some market participants raised concerns about the higher fees in their response to ESMA's recent consultation paper (ESMA (2020)). Due to the importance of the close, some market participants advocated for alternative closing mechanisms to promote competition and reduce trading fees. As a result, the closing auction is no longer the sole mechanism where trading at the close is possible. For example, in Europe, some systematic internalisers (SIs) offer *SI guaranteed close* in which the SI guarantees the execution of orders at the primary exchange's closing auction price. Several other trading venues also offer alternative closing mechanisms. Despite their lower explicit fees for trading at the closing price, some traders are cautious about using these alternative closing mechanisms due to concerns about fragmenting the price discovery process at the close.

This paper reviews the trading landscape for closing mechanisms in European equity markets. We describe the primary exchange call auction mechanism, the structure of the alternative closing mechanisms, provide details of the level of trading activity on these mechanisms, and discuss their strengths and weaknesses. We also examine determinants of trading activity on the different closing mechanisms. We conclude with some policy recommendations.

1 Market share of closing auctions in the U.S. market also increased from 4% in 2013 to 11% at the end of 2019 (Bogousslavsky and Muravyev (2020)).

2 Other factors also contributed to the rise of closing auction volume. Post-crisis regulation increased brokers' willingness to close their positions at the close as holding positions overnight would be costly. In addition, traders unwilling to interact with high-frequency traders (HFTs) increased their closing auction participation since HFTs are less likely to trade in closing auctions (Autorité des Marchés Financiers (2019)).

3 For instance, Euronext Paris and Amsterdam, and Nasdaq Stockholm charge higher fees for auction trades in one of their pricing schemes.

# 2. Market-on-close trading landscape in Europe

European market operators offer multiple mechanisms where trading at the close can take place. These include the primary exchange closing auction and alternative closing mechanisms: SI guaranteed close, Aquis Market-at-Close (MaC), Turquoise Plato Trade-at-Last (TPT@L), Cboe Closing Cross (3C), and the primary exchange Trade-At-Last (TAL). Table 1 provides an overview of the different features of the primary exchange closing auction and each of the alternative closing mechanisms.

**Table 1: Closing mechanisms in European equity markets**

| | Primary exchange closing auction | Alternative closing mechanisms | | | | |
|---|---|---|---|---|---|---|
| | | Aquis Market-at-Close | Turquoise Plato Trade-at-Last | Cboe Closing Cross | SI guaranteed close | Primary exchange Trade-At-Last* |
| **Execution price** | market closing price | market closing price | market closing price | determined by its auction | market closing price | market closing price |
| **Price formation** | volume-maximising price | none | none | volume-maximising price | none | none |
| **Matching priority** | varies depending on the market | member (size)/ time | member/size/time | member/price/ size/time | – | time |
| **Execution risk** | yes | yes | yes | yes | no | yes |
| **Pre-trade transparency** | transparent | transparent | non-transparent | transparent | non-transparent | non-transparent |
| **– Level** | indicative auction prices and volumes | the first five orders, MaC volume on each side, primary exchange indicative auction prices | – | individual order price & volume | – | |
| **Trading fee** | varies depending on the market and fee schedule** | a monthly fee for unlimited message traffic (£30,000)*** | 0.3 bps | 0.075 bps **** | zero | varies depending on the market |
| **Clearing** | CCP | CCP | CCP | CCP | varies depending on the SI | CCP |
| **Settlement** | CSD | CSD | CSD | CSD | varies depending on the SI | CSD |
| **Duration** | 5 minutes***** | matches primary market's auction duration | 15 minutes | 25 minutes | – | 5–10 minutes ****** |

* Only some of the European primary exchanges offer the Trade-At-Last mechanism.

** Basis points fees for auction trades range from 0.2bps to 0.95bps, and some exchange also charge a fixed per message fee.

*** Aquis offers a basis point fee for new members. During their first year of trading, new members can be charged 0.1 basis points on traded value instead of the flat fee.

**** Traders with self-matched execution on 3C are charged a fee of 0.075 basis points, while other execution types have zero trading fees.

***** Switzerland is an exception operating a 10-minute call phase.

****** The primary exchange TAL mechanism's duration varies depending on the market but usually lasts not more than 10 minutes.

The primary exchange's closing auction price is determined based on a volume-maximising and volume-imbalance-minimising algorithm. Aside from 3C, other mechanisms execute orders at the market closing price set by the primary market closing auction. In contrast, 3C does not reference the closing auction price for order executions. Instead, it uses an auction mechanism where the execution price is set based on an algorithm designed to maximise the volume of executed limit orders within the 3C order book.

The mechanisms are different in terms of order matching priority for execution. In closing auctions, market orders take priority over limit orders. All limit orders with better prices than the auction price are executed, while orders with worse prices are not. In case of imbalance, primary exchanges apply specific matching priorities for limit orders with prices equal to the auction price, which vary by market. Except for SI guaranteed close, where matching priority is not applicable (due to bilateral execution), Aquis MaC, TPT@L, 3C, and the primary exchange TAL match orders using member (size) /time, member/size/time, member/price/size/time, and time priorities, respectively. Consequently, orders submitted on all closing mechanisms are subject to execution risk, except for SI guaranteed close, where the SI ensures execution of counterparties' orders at the closing price upon mutual agreement.

The mechanisms also vary with respect to the level of pre-trade transparency. Closing auctions, Aquis MaC, and 3C provide some pre-trade transparency, while TPT@L, SI guaranteed close, and the primary exchange TAL mechanisms do not, making submitted orders invisible to the rest of the market. In addition, the degree of pre-trade transparency differs among pre-trade transparent mechanisms. Closing auctions only display indicative auction prices and volumes, while Aquis MaC reveals the first five orders, MaC volume on each side (buy/sell), and primary exchange indicative auction prices. In contrast, 3C offers complete pre-trade transparency at the order level by showing the price and volume of each order.

Trading fees vary across the different mechanisms. All closing mechanisms charge trading fees, except for the SI guaranteed close, which typically offers zero-fee trading. Trading fees charged by closing auctions vary depending on the market's primary exchange. The fees are either per executed order or based on the traded value. Aquis MaC typically charges a fixed monthly fee for unlimited message traffic for MaC orders[4], while TPT@L and 3C charge fees based on traded volume. The trading fee amount on the primary exchange TAL mechanism varies depending on the market's primary exchange. Clearing and settlement are conducted through Central Clearing Counterparties and the local Central Securities Depository. Some SIs also utilise alternative options, such as the Delivery versus Payment method.

Closing mechanisms also differ in terms of duration. Closing auctions, which include the auction phase and the uncross, typically last for five minutes, with an additional thirty seconds of randomization to prevent traders from gaming the auction. Aquis MaC has the same duration as closing auctions and follows the primary exchange's closing auction timeline. In contrast, TPT@L and 3C have durations of fifteen and twenty-five minutes, respectively, both commencing at the same time as the auction phase of closing auctions. The primary exchange TAL mechanism starts immediately after the uncross of the primary exchange closing auction. It usually lasts 5 to 10 minutes, in which submitted dark orders are executed at the closing auction price. [5]

A shared characteristic among all these mechanisms is order size restrictions. None of the closing mechanisms restrict order size, allowing traders to submit orders of any magnitude. However, orders smaller than the Large-in-Scale size submitted to TPT@L and TAL are subject to the MiFID II Double Volume Cap (DVC) rules, as they are dark venues that execute orders at a reference price (i.e., the closing auction price).[6]

The following two sub-sections describe the structures of the primary market closing auction and alternative closing mechanisms, respectively, in greater detail.

4 Aquis also offers a basis point fee schedule for new members. During the first year of trading, new members can be charged 0.1 basis points on traded value instead of the fixed fee.

5 The primary exchange TAL mechanism's duration varies depending on the market but usually lasts not more than 10 minutes.

6 Post-Brexit these rules only apply to EU stocks.

## 2.1 The primary exchange closing auction

European markets utilise a closing auction mechanism to establish an efficient closing price. This mechanism is featured on each market's primary exchange. The closing auction begins immediately after the end of continuous trading session, with a call phase typically lasting five minutes.[7] During this phase, traders can submit, modify, or cancel orders, but no automatic order matching or transactions occur. The call phase is followed by an uncross phase with a 30-second randomisation period to deter traders from manipulating the auction. At the uncross, orders are executed in a single batch and at a single price. This price is established by an algorithm designed to maximise the executed volume and minimise volume imbalances.

In closing auctions, market orders take priority in execution over limit orders. All limit orders with better prices than the auction price are executed, while orders with worse prices are not. In case of imbalance, primary exchanges apply specific matching priorities for limit orders with prices equal to the auction price, which is typically time priority.[8] The mechanism offers a restricted level of pre-trade transparency. Specifically, the primary exchange discloses only indicative auction prices and volumes.

Primary markets use a range of different fee structures for closing auctions including fees per executed order, fees based on the traded value, or both. Some exchanges charge higher fees for closing auctions than for continuous trading. Cataloguing all of these differences is beyond the scope of this paper, but we provide an example for illustrative purposes. Euronext offers three alternative fee schedules. Option 1 charges the same fees for all trading mechanisms comprising €0.15 per executed order and a basis point fee ranging from 0.45bps to 0.95bps depending on the euro value traded. Option 2 charges a different fee schedule for auction trades. These fees vary depending on the customers' minimum monthly trading commitment, but for customers with no minimum trading commitment (Option 2B) they are charged €1.3 and 0.8bps for auction trades and €1 and 0.2bps for continuous trades (Euronext (2023)). Clearing and settlement of closing auction trades are the same as other trades on the corresponding primary exchange through the Central Clearing Counterparty and Central Securities Depository.

Like Europe, the U.S. market also features a specific closing mechanism on its major exchanges. Although the objectives for providing the closing mechanisms are similar, the market structures in the U.S. and Europe differ. This paper does not intend to explore the U.S. market's closing landscape in detail. Nevertheless, we offer a brief overview of the U.S. closing auction's structure in the box labeled "Closing auctions in the U.S. market" for comparative purposes.

### Closing auctions in the U.S. market

The U.S. market has experienced a significant increase in closing auctions, with the market share rising from 4% in 2013 to 11% in 2019 (**Bogousslavsky and Muravyev (2020)**). Like Europe, the U.S. closing mechanism executes orders at a predetermined time and a single price. An algorithm determines the closing auction price by (i) maximising the number of executed shares and (ii) minimising volume imbalances if multiple prices satisfy the primary objective (i).

Rather than the call auction mechanism used in Europe, the U.S. exchanges operate a market-on-close facility. There are some important differences between the two types of mechanisms. First, in the U.S., continuous trading occurs alongside the on-close facility and ends with the closing uncross at 16:00. In Europe, continuous trading ends when the primary exchange closing auction call phase commences. Second, U.S. on-close facilities have a cut-off time for submitting, canceling, or altering orders. For example, orders can be submitted at the New York Stock Exchange until 15:50, and no changes are permitted afterward.[a] In Europe, however, traders can submit/modify/cancel their orders anytime before the auction uncross. Finally, European auctions disclose information about indicative prices and volumes when the call phase begins. In the U.S., these data are published immediately after the cut-off time, providing details about order imbalances and indicative prices.

a The New York Stocks Exchange changed its cut-off time from 15:45 to 15.50 in January 2019. Nasdaq also changed it from 15:50 to 15:55 in October 2018.

7 Switzerland is an exception, where the call phase lasts for ten minutes.

8 Nasdaq Nordic executes such orders based on price/internal/visibility/time priority. Internal priority happens when a trading firm submitting a market order has also submitted a limit order. In this case, the limit order has priority, even if other limit orders at the same price level were posted earlier.

## 2.2 Alternative closing mechanisms

In Europe, some market operators run alternative closing mechanisms. These include SI guaranteed close, Aquis MaC, Turquoise Plato Trade-at-Last, Cboe Closing Cross, and primary exchange Trade-At-Last mechanisms. This sub-section describes the structure of Aquis MaC, TPT@L, and 3C in greater detail, as their features are generally less well-known than those of SIs and TAL mechanisms.

We again provide a brief overview of the alternative closing mechanisms in the U.S. market in the box labeled "Alternative closing mechanisms in the U.S. market" for comparative purposes.

### Alternative closing mechanisms in the U.S. market

In the U.S. market, high trading fees in primary exchanges' market-on-close facilities have contributed to fragmentation at the close. This has led to the launch of trading mechanisms that execute market-on-close (MoC) orders at the primary exchange closing price with lower fees. Today, traders can execute their MoC orders off-exchange via Alternative Trading Systems operated by broker-dealers or on-exchange via Cboe Market Close.

Off-exchange guaranteed close, offered by broker-dealers such as Morgan Stanley, Goldman Sachs, Credit Suisse Group AG, and UBS Group AG, ensures the execution of traders' buy/sell orders at the primary exchange closing price at lower fees. As a result, the market share of guaranteed close doubled from 16% to 32% between 2015 and 2018 (**The Wall Street Journal (2018)**). This arrangement is similar to the guaranteed close offered by SIs in Europe, with one difference: in the U.S., broker-dealers can act as agents or principals in trades, while in Europe, SIs always act as principals.

On March 6, 2020, Cboe Market Close, introduced another alternative closing mechanism in the U.S. It allows traders to trade non-Cboe listed stocks at the primary exchange closing price. Traders can submit, cancel, or modify MoC orders until 15:49, the cut-off time, after which no changes are permitted. After that, orders are matched based on time priority, and unmatched orders are canceled. After the matching, the total size of matched orders is published on the Cboe Auction feed and the Multicast PITCH feed.

The growth of guaranteed close and the introduction of the Cboe Market Close raised concerns from primary exchanges like the New York Stock Exchange (NYSE) and Nasdaq. They argued that executing MoC orders away from the primary exchange closing auction negatively affects the auction's price formation process. As a result, to reduce the migration of MoC orders, NYSE reduced its closing auction fee for MoC orders, effective January 2, 2018. Utilising this event, **Hu, Liu, and Yu (2021)** examined the impact of guaranteed close on price informativeness and found that guaranteed close trading activity away from the exchange improves closing price efficiency.

**Aquis Market-at-Close**. Aquis introduced its Market-at-Close (MaC) order type in 2015 to offer trading at the closing price. The MaC order book operates simultaneously with the closing auction of the primary exchange. As a result, the MaC order book's timeline for each European stock market depends on the closing auction's timeline on the corresponding primary exchange. Execution of Aquis MaC orders involves four sequential phases (Aquis Exchange (2022a)). Figure 1 displays the Aquis MaC order execution phases for the U.K. stock market.

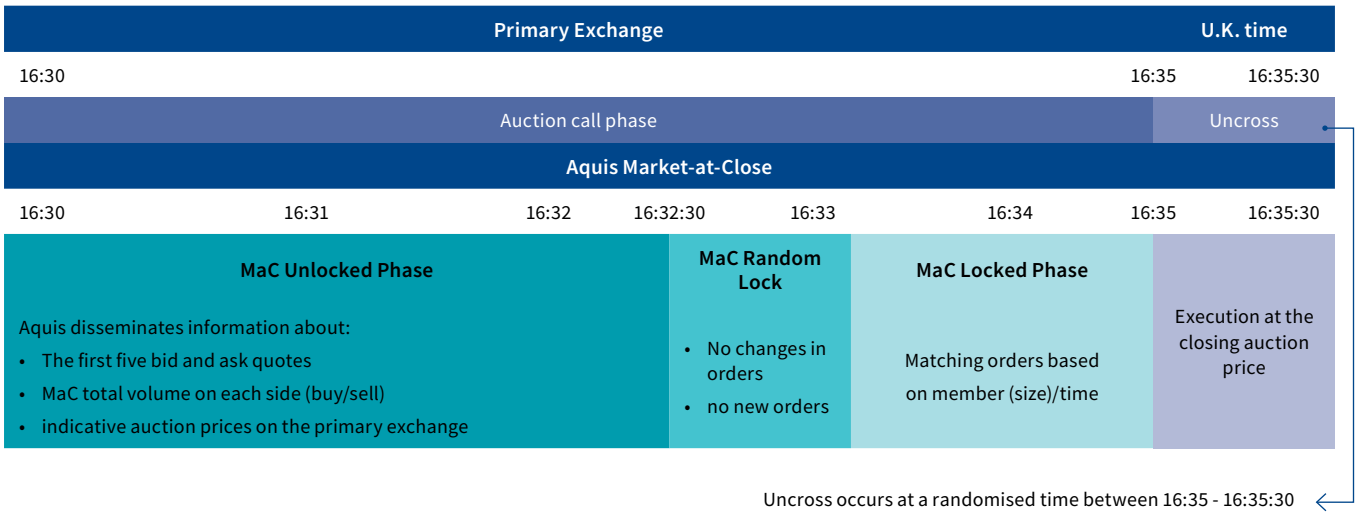
The first phase, MaC Unlocked Phase, starts when the closing auction phase commences on the primary exchange. In this phase, lasting two and a half minutes, traders can submit, amend and cancel their market orders. Aquis does not impose any restrictions on MaC order size. During this phase, Aquis disseminates market data information continuously and in realtime. The information includes Aquis's first five bid and ask orders (time priority) received for each stock, the total MaC volume on each side (buy/sell) for each stock, and the indicative closing auction prices on the primary exchange. The second phase, MaC Random Lock Phase, starts immediately after the completion of the first phase. In this phase, at a random point during the 30 second window, the MaC is locked; no new orders are accepted, and submitted orders are locked from modification in order size or cancelation.

Aquis MaC matches orders for execution in the third phase, MaC Locked Phase, lasting two minutes (two and a half minutes if the closing auction is subject to a 30-second randomisation). The matching is based on member[9], in which self matched orders are prioritised by smallest size first, in order to maximise number of orders matched, and then time priority (Aquis Exchange (2022a)). Once orders are matched, the matched members receive confirmation, and unmatched MaC orders are canceled. The last phase relates to the execution of MaC orders. Immediately after the uncross of the primary exchange closing auction and publication of the closing price, the matched MaC orders are executed at the closing auction price.

In case of any delay, extension, or cancelation of the primary exchange closing auction, all MaC orders are canceled, and no execution occurs at the closing price (Aquis Exchange (2022a)). Although Aquis uses a reference price (the closing auction price) for the execution of MaC orders, these orders are not subject to MiFID II DVC restriction related to the Reference Price Waiver because Aquis MaC meets the MiFID II pre-trade transparency requirements (Aquis Exchange (2022a)).

Aquis does not typically charge a basis point fee. Instead, it charges a trading fee according to traders' generation of message traffic. For MaC orders, traders are charged a monthly fee of £30,000 which allows for unlimited message traffic (Aquis Exchange (2022b)). However, new members can be charged a 0.1 basis points on traded value fee during the first year of trading. Clearing and settlement of executed MaC orders are the same as other trades on Aquis through the Central Clearing Counterparty and Central Securities Depository (Aquis Exchange (2022a)).

### Fig. 1. Aquis Market-at-Close for the U.K. stock market




9 Member priority applies when a member submit both buy and sell MaC orders. In this case, the member has matching priority over any third party member's orders.

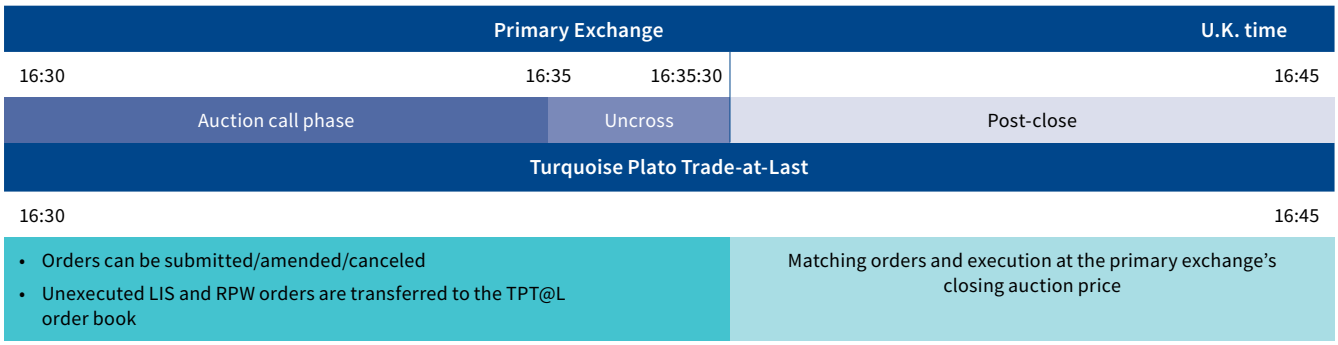
**Turquoise Plato Trade-at-Last**. Turquoise Plato launched its post-close trading service, Turquoise Plato Trade-at-Last, in October 2020, wherein orders are executed at the market closing price. TPT@L is one of the Turquoise Plato order books (non-pre-trade transparent and price-referencing order books) that uses the market closing price as a reference price for execution.[10] For each stock, traders can submit their limit and market orders in the TPT@L order book once the closing auction phase on the corresponding primary exchange commences (Turquoise Exchange (2021)). There is no order size restriction for trading on TPT@L, and traders can submit any order size, including Large-in-Scale orders. However, since TPT@L is a dark order book and uses a reference price for execution, orders are subject to the MiFID II DVC rule (Turquoise Exchange (2021)). Orders unexecuted in the Turquoise Plato order books' regular trading hours are automatically transferred to TPT@L unless canceled. Figure 2 displays the structure of the TPT@L mechanism for the U.K. stock market.

Turquoise Plato Trade-at-Last does not match orders during the primary exchange auction phase. Once the closing auction has ended, and the closing price is publicly available, TPT@L commences matching submitted orders and executes them at the closing price. It matches orders based on member/size/time priority (Turquoise Exchange (2021)).[11]

TPT@L matches and executes orders only if the primary exchange has made its uncross closing auction price public within ten minutes after the regular time for the end of the closing auction (e.g., 16:45 U.K. time for the U.K. market). If the primary exchange does not publish its closing auction price before that time for any reason, TPT@L cancels all submitted orders, and no execution takes place.

All trades executed in the Turquoise Plato order books, including those in the TPT@L, are charged an execution fee of 0.30 basis points, and TPT@L does not charge any incremental costs to use the service (Turquoise Exchange (2022)). In addition, the clearing and settlement of executed orders are the same as other trades on Turquoise through the Central Clearing Counterparty and Central Securities Depository, respectively (Turquoise Exchange (2021)).

## Fig. 2. Turquoise Plato Trade-at-Last for U.K. stock market




10 Turquoise Plato order books use the Reference Price Waiver and the Large-in-Scale Waiver for executing orders. They execute orders at the Primary Market Midpoint Price for orders during the exchange hours and at the Primary Market Closing Price on the Turquoise Plato Trade-at-Last (Turquoise Exchange (2021)).

11 Firms wishing to increase the probability of matching with themselves can register their firms for Member Priority Matching.

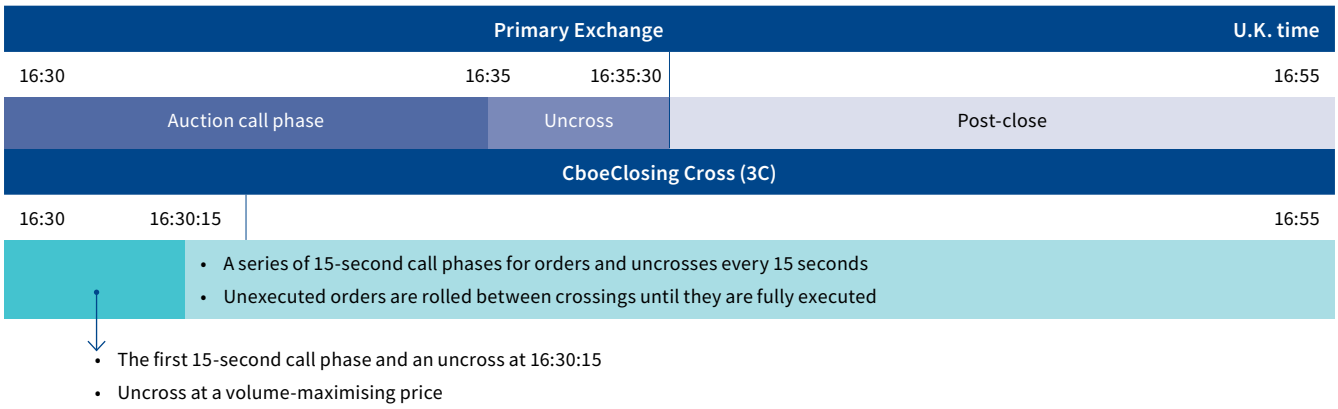
**Cboe Closing Cross**. Cboe Closing Cross is a trading service based on an auction mechanism operated on Cboe BXE (from August 2019) and Cboe DXE (from November 2020). Unlike Aquis MaC and TPT@L, 3C allows traders to trade at their desired prices after the continuous trading session. Specifically, traders can only submit limit orders, and their orders are executed only at the specified limit price. For each stock, 3C starts immediately after the end of the continuous trading session on BXE and DXE order books, simultaneously with the commencement of the primary exchange's closing auction phase. Figure 3 displays the Cboe Closing Cross mechanism for the U.K. stock market.

When the 3C order book commences, traders can submit their limit orders, and any other order type is rejected. Similar to the other closing mechanisms, 3C does not impose size restrictions for order submission and trading. Although 3C starts at the same time as the closing auction phase on the primary exchange, its timeline and pricing model is independent of the closing auction. Cboe Closing Cross lasts 25 minutes with an uncross every 15 seconds, where matched orders are executed at a single price (Cboe (2022a)).[12] Each uncross price is determined based on the volume-maximising algorithm. When more than one price maximises the executable volume, 3C chooses the price closest to the last traded price on the Cboe continuous session. Failing that, the highest price in the 3C book is chosen as the execution price (Cboe (2022a)). While on paper 3C offers a price discovery mechanism, in practice around 99% of trades are executed at the primary market closing auction price.[13]

Cboe Closing Cross offers the highest level of pre-trade transparency compared to the other alternative closing mechanisms. 3C publicly displays the price and size of each order during each 15-second call phase. It does not operate any lock phase; submitted orders can be canceled or modified at any time during the 15-second call period. The execution allocation is based on member/price/size/time priority, and orders are executed with no price improvement (Cboe (2022a)).[14] Unexecuted orders in each uncross typically roll between crossings until fully executed. However, traders can face execution risk in the 3C order book since orders only get executed if the uncrossing price meets the limit price specified by the trader. Traders also face price risk as the execution price may differ from the closing auction price on the primary exchange.

Cboe Closing Cross did not charge traders trading fees until the end of 2019. However, since 2020, traders with self-matched execution on 3C have been charged a fee of 0.075 basis points, while other execution types continue to be free until further notice (Cboe (2022b)). The clearing and settlement of 3C trades are the same as those executed on other Cboe order books through Central Clearing Counterparty and Central Securities Depository, respectively.

### Fig. 3. Cboe Closing Cross mechanism for U.K. stock market




12 When Cboe Closing Cross was introduced, it would run for 15 minutes with an uncross every minute. However, in March 2020, Cboe changed the 3C duration to 25 minutes with an uncross every 15 seconds. More recently Cboe has adjusted the start times in some markets as they have earlier closes (Cboe (2022a)).

13 There is some variation in the fraction of trades at the closing price by country. The UK has the highest fraction of trades away from the closing price at 1.37% and Germany has the lowest at 0.06%.

14 Member priority takes place if "Broker Preferencing" is enabled.

# 3. Trading activity of closing mechanisms

Next, we examine the trading activity of each closing mechanism. We focus on stocks included in the STOXX 600 Europe from January 1, 2021, to September 30, 2022, and collect all trades in these stocks from BMLL Technologies. We only consider markets with more than ten stocks in the STOXX 600 Europe index and only stocks that remain in the index for the duration of the sample period. We also exclude stocks from the Oslo Stock Exchange, Milan Stock Exchange, and Bolsa de Madrid as we do not have access to these data via BMLL.

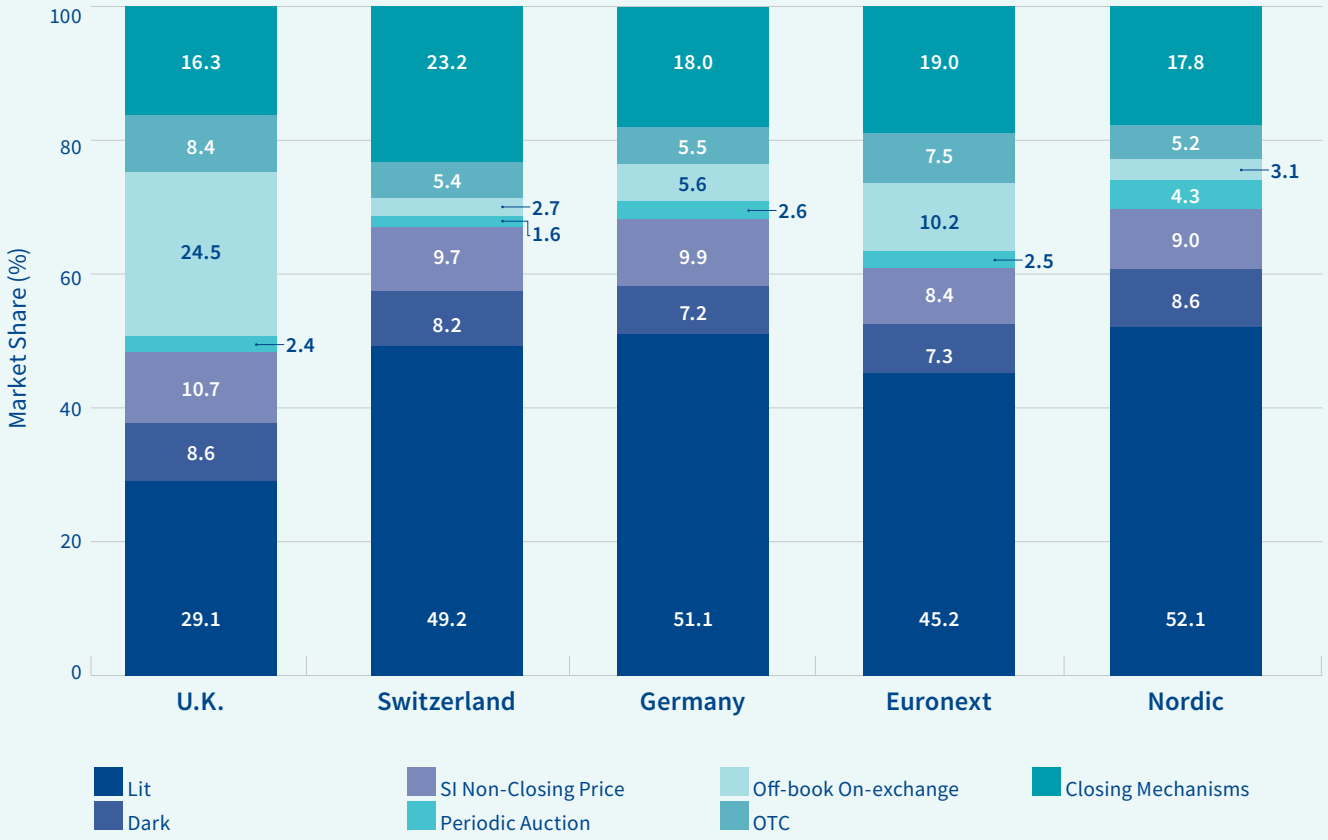
The final sample consists of 503 stocks traded in the U.K. (148 stocks), France (76 stocks), Sweden (68 stocks), Germany (67 stocks), Switzerland (51 stocks), the Netherlands (32 stocks), Denmark (25 stocks), Finland (19 stocks), and Belgium (17 stocks). Through BMLL, we obtain information on each trade, including the trade price, volume, time of execution, and the executing platform. We also collect the order book data (at the top of the book) on the primary exchanges and MTFs (i.e., Cboe DXE, Aquis Europe, and Turquoise Europe) for the analysis presented in the next section. The data include information on best bid and ask prices, corresponding sizes, and timestamps. We construct a consolidated order book for each market from the data for the primary exchanges and MTFs.[15] Table A1 in Appendix A provides descriptive statistics for stocks in the sample for various metrics, including Euro trading volume, quoted spread, relative tick size, and volatility.

Figure 4 displays the market share of each trading mechanism for the markets in the sample. The market share is the Euro volume traded on each mechanism as a percentage of the total Euro volume traded on all mechanisms. Lit contains all continuous lit trades in the limit order books and trades in the opening and intraday auctions. Closing mechanisms represent trades in the closing auctions and alternative closing mechanisms. Finally, SI Non-Closing Price refers to all SI trades not in the SI guaranteed close category. Euronext contains French, Dutch, and Belgian markets, and Nordic includes the Swedish, Danish, and Finnish markets. Figure 4 shows that, in all markets, Lit captures the highest market share, and the closing mechanisms follow it except for in the U.K., where off-book on-exchange trades rank second in terms of market share.

Figure 5 demonstrates the market share of different closing mechanisms by market. The market share is the Euro volume traded on each mechanism as a percentage of the total Euro volume traded on all closing mechanisms. We observe that closing auctions have the highest market share in all markets. SI guaranteed close is the next largest with the highest market share in Switzerland. We also note that other alternative closing mechanisms have had limited success in attracting order flow as they capture only 5% of the total closing Euro volume in each market. Aquis MaC's market share accounts for around 4.3%, while TPT@L, 3C, and the primary exchange TAL mechanisms capture minimal market share.

15 We also collect daily exchange rates from Refinitiv to convert all currencies to Euros.

## Fig. 4. Market share for different mechanisms by market




## Fig. 5. Market share for different closing mechanisms by market

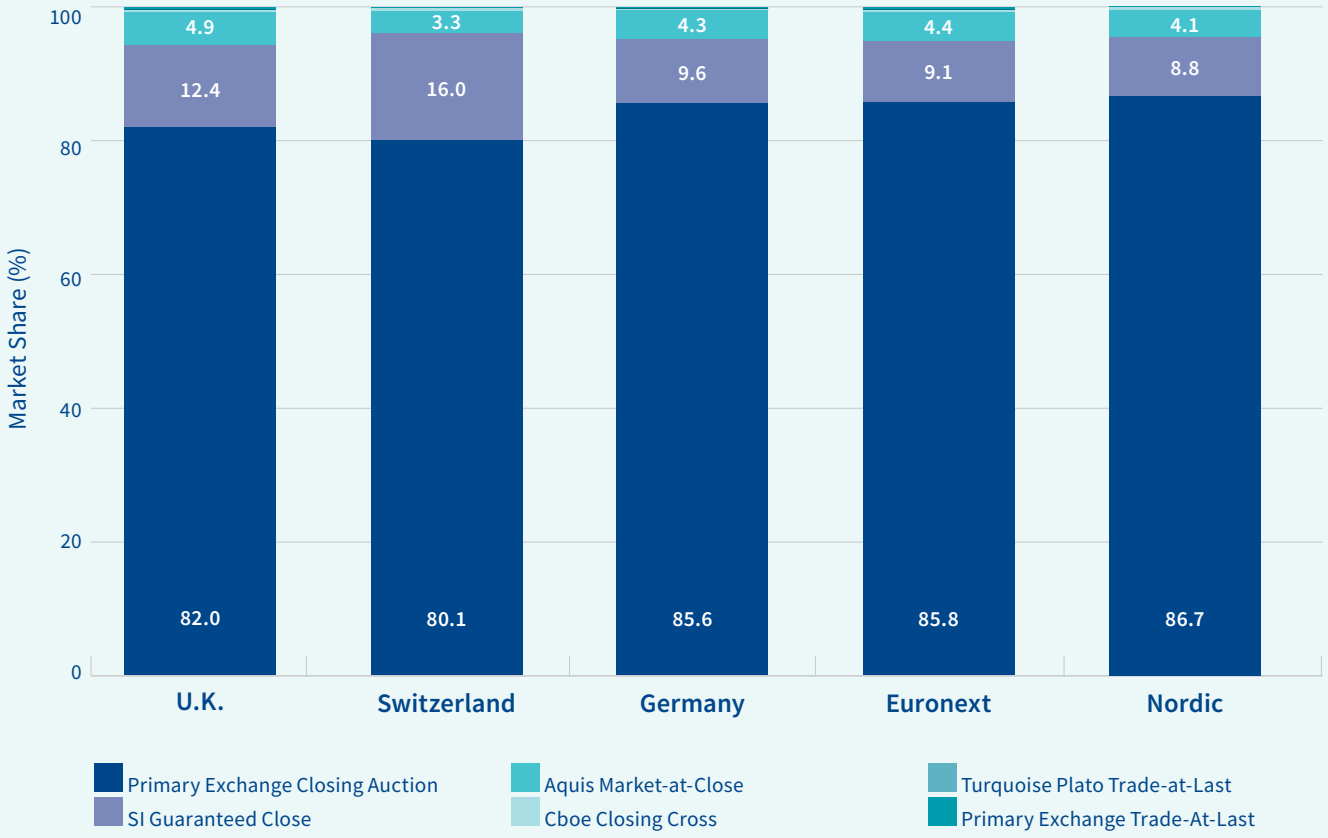


Figure 6 illustrates the market share of closing mechanisms, defined in Figure 4, from January 2021 to September 2022. The figure indicates that closing mechanisms represent approximately 18% of the total Euro volume in January 2021, peaking at 32.5% in May 2022 and stabilising at around 19% for the rest of the sample period. Furthermore, all the spikes in the market share occur on index rebalance days and/or month-end days. This implies that closing mechanisms' trading volumes increase significantly on these days.

Figure 7 presents the market share of three closing mechanisms (defined in Figure 5): closing auctions (solid teal line), Aquis MaC (teal dashed line), and SI guaranteed close (navy dashed line). The figure demonstrates that these mechanisms maintained stable trading activities throughout our sample period. Since all three mechanisms experienced higher trading volumes on index rebalance days and/or month-end days compared to other days, we do not observe significant spikes in the market share plots. Due to their extremely low levels, we do not display the plots for TPT@L, 3C, and the primary exchange TAL mechanisms.

**Fig. 6. Market share of closing mechanisms**

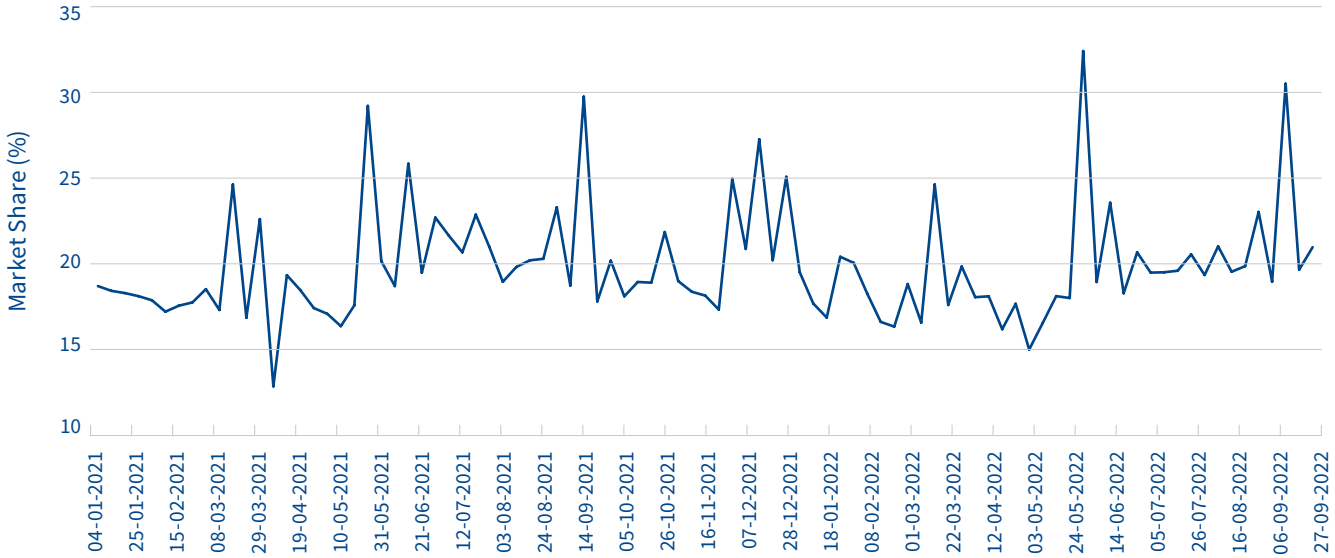
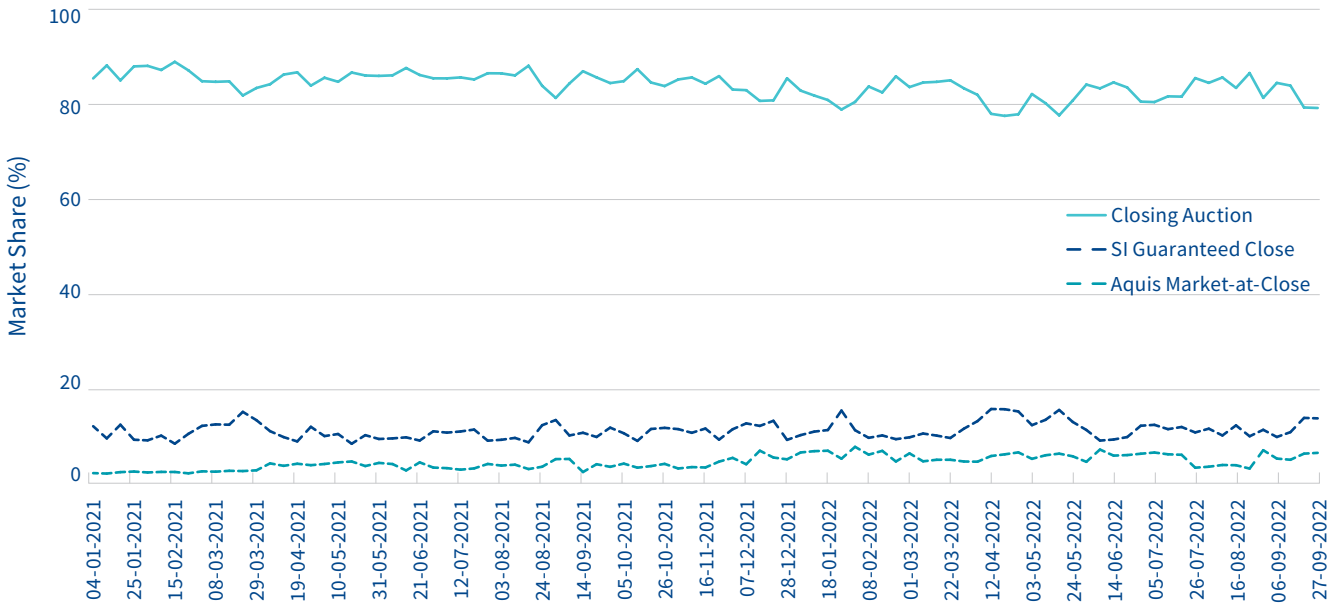



**Fig. 7. Market share of different closing mechanisms**



Next, in Figure 8, we demonstrate the difference in market share of closing mechanisms on rebalance days versus non-rebalance days. The figure indicates that the market share of closing mechanisms, as defined in Figure 4, is more than twice as large on rebalance days compared to non-rebalance days in all markets.

We also illustrate the ratio of the Euro volume traded on closing mechanisms to the Euro volume of lit trades in the primary exchanges' continuous trading sessions in Figure 9.

The figure shows that the volume of closing mechanisms is, on average, 45% of the volume of continuous lit trades, peaking at 91%. The ratio spikes on rebalance days and/or month-end days. This implies that closing mechanisms (and market closing time) are as important as the primary exchanges' continuous trading sessions and even more critical on certain occasions, like rebalance days, where the ratio peaks at 91%.

**Fig. 8. Market share of closing mechanisms: rebalance versus non-rebalance days**

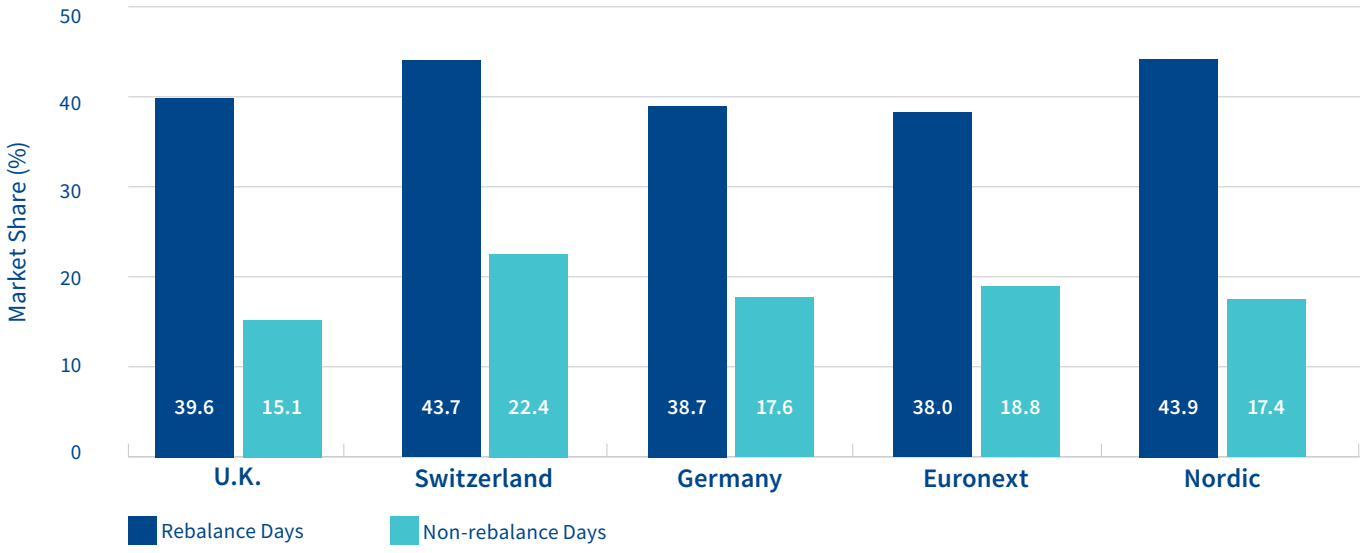
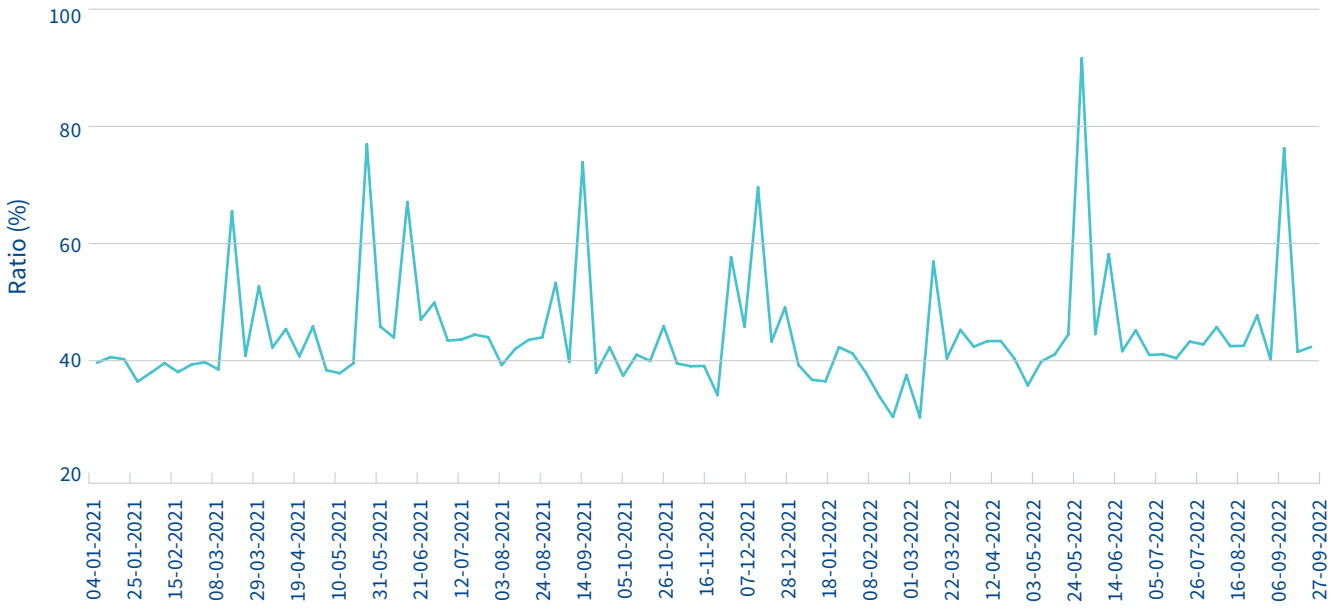



**Fig. 9. Close to continuous lit trades ratio**



# 4. Determinants of closing mechanisms' market share

This section presents empirical analyses of the determinants of market share of different closing mechanisms in Europe. The emphasis is on closing auctions, SI guaranteed close, and Aquis MaC since the other mechanisms have yet to attract much volume. We analyse the time series and cross-sectional variation in the market share of these mechanisms.

We start by examining the variation in the market share of each closing mechanism in time series. To do this, we regress the market share of each mechanism on a set of control variables in stock-day regressions. For each closing mechanism, the market share is the Euro volume traded on the mechanism as a percentage of the total Euro volume traded on all trading mechanisms except for the OTC mechanism, as it is not relevant for the analysis of market share determinants.[16] We control for stock-specific variables with Volatility, Quoted Spread, and Total Volume (transformed into natural logarithm), defined in Appendix A. We also include two dummy variables for index rebalancing days and month-end days to investigate index investing and seasonality, respectively. The dummy variable for rebalance days takes the value one on index rebalancing days and zero otherwise. Similarly, the dummy equals one on month-end days and zero otherwise. Each regression is run with stock fixed effects to control for time-invariant stock-specific elements, and standard errors are double clustered by stock and date.

Table 2 reports the results of the regressions for each mechanism. The results show that volatility is significantly and negatively associated with the market share of all closing mechanisms. Specifically, the market share of closing auctions, SI guaranteed close, and Aquis MaC are significantly lower on days with high volatility. A one percent increase in volatility decreases the average market share of closing auctions by almost 75.36% (from 19.23% to 4.82%). This finding is consistent with the evidence provided by Comerton-Forde and Rindi (2022) on the association between volatillity and auction market share. Such an increase in volatility also decreases the market share of SI guaranteed close, and Aquis MaC by 100% (from 2.52% to -0.28% for SI guaranteed close and from 0.99% to -0.32% for Aquis MaC).

**Table 2: Determinants of closing mechanism market share in the time-series**

| | Market Share | | |
|---|---|---|---|
| | **Primary exchange closing auction** | **SI guaranteed close** | **Aquis MaC** |
| **Volatility** | -14.40*** (2.61) | -2.80* (1.47) | -1.31*** (0.41) |
| **Quoted Spread** | -0.40*** (0.08) | -0.05** (0.02) | 0.00 (0.01) |
| **Total Volume** | -4.03*** (0.66) | -0.16** (0.08) | -0.21*** (0.03) |
| **Rebalancing Days** | 22.44*** (0.87) | 2.73*** (0.42) | 0.65** (0.28) |
| **Month End** | 9.08*** (1.44) | 1.75*** (0.26) | 0.38*** (0.13) |
| **Constant** | 91.91*** (6.11) | 5.45*** (0.82) | 4.84*** (0.26) |
| **Adj. $R^2$** | 0.49 | 0.14 | 0.13 |
| **Fixed Effect** | Stock | Stock | Stock |
| **# Observation** | 210,483 | 210,483 | 210,483 |

16 Table A2 in Appendix A presents the market share of the mechanisms, in all sample markets, for all days, rebalance, and non-rebalance days.

The results show that the association between volatility and closing mechanisms is stronger for SI guaranteed close and Aquis MaC than for closing auctions. In times of high volatility, SIs may be less willing to offer guaranteed close due to the potentially increased inventory risk. Although we focus only on SI trades executed at the market closing price, the negative association between the trading activity of SI guaranteed close, and volatility supports findings of Comerton-Forde and Rindi (2022) and Aramian and Nordén (2023) that show a negative correlation between SI volume and volatility. Additionally, on volatile days, traders are more likely to concentrate on closing auctions as they offer higher concentrated liquidity. Traders can track changes in the auction price up to the closing auction uncross and cancel or modify their orders if the price moves in the opposite direction of their desired price level. However, on Aquis, MaC orders are locked around halfway into the MaC order book, and traders cannot make any changes afterward if the primary auction closing price moves in the wrong direction. Consequently, on volatile days, primary exchange closing auctions are likely to experience a smaller decrease in their market share compared to the other two closing mechanisms.

We also find that the market share of closing auctions and SI guaranteed close is statistically significantly lower on days with low liquidity (large quoted spread), but the association is not economically significant. A one basis point increase in quoted spread reduces the average market share of closing auctions and SI guaranteed close by 2.08% (19.23% to 18.83%) and 2.38% (from 2.52% to 2.58%), respectively. However, there is no significant relation between the quoted spread and Aquis MaC's market share. Table 2 also shows a significantly negative association between the total traded volume and the market share of the three closing mechanisms. This indicates that on highly liquid days, traders are more likely to trade on other mechanisms, particularly lit markets, reducing the market share of these closing mechanisms.

The results also show that all three closing mechanisms experience a significantly higher market share on rebalancing days. On rebalancing days, the market share of closing auctions and SI guaranteed close increases by 100% (from 19.23% to 41.67% for closing auctions and from 2.52% to 5.25% for SI guaranteed close). On these days, Aquis MaC's market share is also higher by 65.65% (from 0.99% to 1.64%) compared to non-rebalance days. In fact, when a trader is aware that they need to buy or sell a specific stock in the index (as they are indextracking funds), they will execute the transaction when there is a change in the index, and other index trackers will do the same. As a result, we observe a spike in the activity level at the close on rebalancing days. Generally, index traders usually rebalance their portfolios only when their benchmark index changes. As a result, index funds' trading activities is expected to be concentrated on rebalance days. Our results support the findings of Bogousslavsky and Muravyev (2020) and Comerton-Forde and Rindi (2022) on the association between closing auction volume and rebalancing days in the U.S. and European markets, respectively.

We document a similar association between closing mechanisms' market shares and the month-end variable. Table 2 shows that the market share of closing auctions, SI guaranteed close, and Aquis MaC is significantly higher on month-end days, and the magnitude is economically significant. This result is consistent with findings of Bogousslavsky and Muravyev (2020) on the link between closing volume and month-end days. The higher market share of closing mechanisms on month-end days is likely due to institutional traders' portfolio reports benchmarked against month-end prices.

Next, we investigate the cross-sectional variation of each closing mechanism using Fama and MacBeth (1973) cross-section regression method with each closing mechanism's market share as the dependent variable. We consider Volatility, Total Volume (transformed to natural logarithm), and Market Cap. (transformed to natural logarithm) as control variables. Table 3 reports the estimated coefficients.

Table 3 demonstrates that the market share of closing auctions decreases with the total traded volume, while SI guaranteed close experiences the opposite effect. In other words, the market share of SI guaranteed close is higher for more liquid stocks. SIs are likely to offer guaranteed close in more liquid stocks to reduce inventory costs through efficient inventory management. After a guaranteed close transaction, the SI may need to manage its inventory by unwinding its position to return it to the desired level. In this case, offering guaranteed close in less liquid stocks makes finding counterparties for unwinding the position more challenging, potentially increasing the risk of holding the position overnight.

On the other hand, less liquid stocks are more likely to participate in closing auctions since it represents an important liquidity event during the trading day, potentially increasing the chances of being matched and executed in the closing auction compared to the continuous trading session. As a result, the market share of closing auctions is higher for low-liquidity stocks. However, Table 3 shows no significant association between the Aquis MaC market share and a stock's liquidity.

We also find that the market share on closing auctions, SI guaranteed close, and Aquis MaC is significantly higher in large stocks, in line with the result provided by Bogousslavsky and Muravyev (2020) and significantly lower in volatile stocks.

**Table 3: Determinants of closing mechanism market share in the time-series**

| | Market Share | | |
|---|---|---|---|
| | **Primary exchange closing auction** | **SI guaranteed close** | **Aquis MaC** |
| **Volatility** | -55.75*** (8.35) | -1.34* (5.73) | -3.01*** (4.46) |
| **Market Cap.** | 0.52*** (11.02) | 0.34*** (9.01) | 0.16* (8.01) |
| **Total Volume** | -0.42*** (6.06) | 0.11*** (8.03) | 0.01 (1.01) |
| **Constant** | 28.30*** (6.44) | -0.28*** (5.75) | 0.71*** (3.29) |

# 5. Discussion

**Closing auctions versus alternative closing mechanisms.** In Europe, the primary exchange closing auction was once the sole trading mechanism at the market close. This monopoly allowed primary exchanges to charge higher fees in the auction than in the continuous trading session. Given the importance of closing auctions for traders, some market participants have advocated for alternative closing mechanisms to promote competition at the close and reduce trading fees. Lower explicit costs have been the main driver for alternative closing mechanisms. However, as demonstrated in Section 3, during our sample period, the primary exchange closing auction still captures the bulk of closing mechanism volume, with alternative mechanisms accounting for only 16% of traded volume. Why have these mechanisms failed to attract considerable order flow, despite the substantial cost savings? The answer to this question lies in the differing perspectives of market participants on fragmentation at the close and the ability to capture the benefits of the lower fees.

Index funds and other institutional traders who use the closing auction price as a benchmark are the main participants in closing auctions. Many of these traders prefer closing auctions over alternative closing mechanisms due to a belief that fragmentation at the close and the migration of market orders to alternative closing mechanisms may affect the price formation at the close, making the closing price less reliable. Additionally, institutional traders typically pay a flat fee to brokers for transactions. As a result, there is no cost-saving for them to encourage the adoption of alternative closing mechanisms. Their primary concern is obtaining the closing price and ensuring it is an efficient price.

Brokers and cost-sensitive traders are the leading proponents of competition at the close due to the cost-saving potential. Since brokers are responsible for covering all explicit costs, including trading fees, they can bypass the high fees of the primary exchange closing auction by using alternative mechanisms while still executing client orders at the market closing price. Brokers can benefit from the cost-saving options provided by alternative mechanisms, especially in certain situations. For instance, when a broker has market orders on both the buy and sell sides, they can submit these orders to Aquis MaC rather than the primary market. If submitted to the auction, some of these orders would be executed against each other, resulting in the broker paying fees for both sides. In contrast, on Aquis MaC, these orders are pre-matched during the Aquis MaC matching period and executed at the closing price. From this group of participants' perspective, limit orders are the main factor in determining the auction price rather than market orders. Consequently, the migration of market orders should primarily affect the total executed volume at the auction without necessarily influencing the final auction price.

The introduction of alternative closing mechanisms has led to concerns among primary exchanges and large buy-side firms about their potential impact on the efficiency of the auction closing price. In a study, Euronext (2021) demonstrates that a smaller market order buffer (the fraction of market orders matched against each other in the closing auction relative to the auction's total executed volume) results in higher auction volatility. Based on this finding, they conclude that executing market orders away from the primary exchange closing auction harms the auction price.

However, a study conducted by J.P.Morgan (2021) disputes this claim, arguing that a reduction in the fraction of offsetting market orders (i.e., market order buffer) is not the cause of increased auction volatility but rather a consequence of it. They show that a rise in intraday and auction volatility is linked to an increase in the executed volume of limit and market orders in the closing auction while negatively correlated to the fraction of offsetting market orders. Additionally, they reveal that the rate of increase in the quantity of executed limit orders is greater than the increase in market orders. In general, during periods of high volatility, traders tend to submit more limit orders than market orders to protect themselves from unfavorable price movements.

Addressing the potential impact of alternative closing mechanisms on the closing auction price requires an investigation of their causal effect on the auction price formation process, which is absent in the existing studies. However, this remains an empirical question, as the low volume of alternative mechanisms prevents us from assessing their impact. That said, it is important to note that the closing auction price is determined based on a volume-maximising algorithm. Hence, any shift in the balance of supply and demand in the auction book can alter the closing auction price. Further, since market orders have priority over limit orders, they play a crucial role in establishing the auction price. As a result, the activity of alternative mechanisms may influence the auction price if the migration of market orders from the closing auction is sufficiently large.

**Alternative closing mechanisms.** The trading volume on alternative closing mechanisms is primarily dominated by SI guaranteed close and Aquis MaC, with the former having the largest market share. The variation in activity levels across these mechanisms, as shown in Section 3, stems from their differing market structures and operational methods, making some more appealing to traders than others.

SI guaranteed close has three key features that make it more attractive to traders than other mechanisms. Foremost, it ensures the execution of orders at the closing price, whereas traders face execution risk on other mechanisms, potentially leaving their orders unfilled. Second, SI guaranteed close typically offers the most affordable execution, as most SIs do not charge traders any trading fees. Finally, through SI guaranteed close, traders can modify or cancel their orders at any time before the uncross of the primary exchange closing auction. In contrast, with other mechanisms (except for 3C), submissions, cancellations, or modifications are locked once the matching process begins. For example, Aquis MaC's Locked phase restricts traders from canceling or modifying orders approximately two minutes before the primary exchange closing auction uncrosses.

Moreover, traders prefer SI guaranteed close and Aquis MaC mechanisms because they operate during the pre-close period of the market, while other mechanisms primarily provide post-close liquidity after the primary exchange closing auction has ended. As noted in Section 3, TPT@L, 3C, and the primary exchange TAL account for a small fraction of volume at the close. Utilising a post-close mechanism exposes traders to operational risks, as their orders may not be executed due to insufficient liquidity. In such cases, they cannot find liquidity elsewhere since the market has closed. In contrast, with Aquis MaC, orders are matched for execution approximately halfway through the call phase of the primary exchange closing auction. Traders with unmatched orders still have the opportunity to send their orders to another mechanism, such as the primary exchange closing auction for execution.

However, if sufficient liquidity exists on these mechanisms, TPT@L and the primary exchange TAL offer benefits beyond cost-saving, catering to traders with specific trading needs. As non-pre-trade transparent mechanisms, they attract traders who want to trade at the close while minimising information leakage and price impact. For example, traders wishing to execute large orders at the close price may set a participation cap when submitting orders to the closing auction due to concerns about potential price impact. This can leave them with unexecuted orders at the end of the day. By using TPT@L and the primary exchange TAL mechanisms, traders can submit their remaining orders to them for execution without exposing themselves to information leakage.

In response to concerns about the price impact of large orders when placed in the auction, the Swiss Stock Exchange launched a new order type called Auction Volume Discovery (AVD) in May 2023. AVD is a dark order type designed to aggregate capped liquidity without the risk of information leakage or price impact. Traders can submit AVD orders simultaneously with the call auction phase. The orders will not influence the auction price formation process and are matched for execution based on size/time priority, supporting minimum execution quantity. At the uncross, AVD orders are executed at the auction price. They are first executed against any remaining non-AVD orders in the auction and then against other AVD orders. Any unexecuted AVD orders are canceled or transferred to the primary exchange TAL mechanism.

# 6. Policy Implications

The closing auction mechanism plays a crucial role in well-functioning equity markets. It serves as a vital source of liquidity and price discovery. The deep liquidity pool in the closing auction offers traders high execution certainty when trading at the close. The auction design improves the auction's price formation process and price discovery. In particular, the aggregation and simultaneous execution of orders at a single price enhances the incorporation of information into prices, leading to a more efficient closing price price (Madhavan (1992); Pagano and Schwartz (2003)).

Closing auctions have attracted significant attention from regulators and market participants as a considerable amount of trading has shifted from continuous trading to this mechanism in recent years. Various factors have contributed to this change in closing auction volume. The substantial growth in market share has led regulators to question whether this trend could disrupt market functionality and if regulatory intervention is necessary. Research has found no evidence of a disruptive impact of European closing auctions on the market quality of the continuous trading session (Comerton-Forde and Rindi (2022)), which contrasts with findings in the U.S. market (Bogousslavsky and Muravyev (2020)). In response to ESMA's inquiries about the growth in closing auctions, different market participants have also expressed that they do not see a need for regulatory intervention.

Nevertheless, while regulatory action may not be necessary to influence the growth of closing auctions, regulators might need to consider another aspect of closing auctions: the trading fees. Some primary exchange closing auctions charge high trading fees, which can be significantly higher than fees in continuous trading sessions in some markets. Despite the presence of alternative closing mechanisms offering substantially lower fees, primary exchange closing auctions remain the dominant mechanism. This monopolistic service increases the risk of primary exchanges raising their closing auction fees even further if closing auction volume continues to grow.

Some market participants have also expressed this concern, urging ESMA to require primary exchanges to charge the same trading fees in auctions as they do in the continuous trading session. Regulators must monitor trading fees charged by primary exchanges closely. A significant fee difference between the auction and continuous trading sessions can limit closing auction participation to certain market participants willing to bear the cost or result in higher brokerage fees for traders demanding brokers to trade in closing auctions. Restricting closing auction participation to specific participants may undermine the auction's price formation process.

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# Acknowledgements

We thank Chris Andrew, Paul Battams, Mike Bellaro, Nicholas Craze, Daniel Mayston, Tom Medland, Matt Wertheim, Edward Wicks and Mark Wilcox for valuable comments and discussions.

# About the sponsor

This research was sponsored by the Plato Partnership, a not-for-profit company comprising asset managers and broker-dealers who are collaborating to bring creative solutions and efficiencies to today's complex marketplace. Through their Market Innovator MI3 they financially support independent research aimed at improving European market structure. This research reflects the views of the authors and does not necessarily reflect the views of the Plato Partnership or its members.

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# Appendix A Sample statistics

**Table A1** presents stock-day averages of different metrics for stocks in the sample. Relative Tick Size is measured as the tick size divided by the midpoint, expressed in basis points. Quoted Spread is the difference between the best ask and bid prices, divided by the midpoint, expressed in basis points.[17] Volatility is the one-minute standard deviation of midpoint log returns, expressed in percentage.

### Table A1: Descriptive Statistics

The table displays descriptive statistics for stocks in the STOXX 600 Europe index from January 2021 to September 2022. Euronext includes stocks in the French, Dutch, and Belgium markets. Nordic represents stocks in the Swedish, Danish, and Finnish markets. We only consider markets with more than ten stocks in the STOXX 600 Europe index and stocks that remain in the index during the sample period. Although Oslo Stock Exchange, Millan Stock Exchange, and Bolsa de Madrid have more than ten stocks in STOXX 600 Europe, we exclude them from the analysis due to our lack of access to these markets through BMLL Technology.

| | All | Germany | Euronext | Nordic | U.K. | Switzerland |
|---|---|---|---|---|---|---|
| **Euro Volume (Million)** | 88.10 | 115.93 | 108.15 | 46.78 | 79.15 | 99.99 |
| **Number of Shares (Million)** | 5.2 | 2.8 | 2.9 | 2.5 | 11.5 | 1.5 |
| **Relative Tick Size (bps)** | 4.86 | 3.15 | 3.62 | 3.94 | 4.12 | – |
| **Quoted Spread (bps)** | 8.40 | 6.79 | 7.03 | 8.75 | 9.32 | 10.39 |
| **Volatility (%)** | 0.006 | 0.003 | 0.003 | 0.006 | 0.009 | 0.007 |

**Table A2** displays the Euro volume traded on closing auctions, SI guaranteed close and Aquis MaC, in all markets in the sample, as a percentage of the total Euro volume executed on all trading mechanisms except for the OTC mechanism, for all days, reblanace day and non-rebalance days. Table A2 reveals that during the sample period, closing auctions accounted for 19.23% of the total Euro volume, with 39.54% on rebalance days and 18.61% on non-rebalance days. SI guaranteed close captured 2.52% of the total Euro volume, which increased to 5.24% on rebalance days and decreased to 2.44% on nonrebalance days. Aquis MaC also sees an increase in market share on rebalance days, with the market share rising from 0.99% to 1.44%.

### Table A2: Market share of closing mechanisms

The table presents the market share of closing auctions, SI guaranteed close, and Aquis MaC, in all sample markets, for all days, rebalance, and non-rebalance days.

| | Market Share | | |
|---|---|---|---|
| | **All days** | **Rebalance days** | **Non-rebalance days** |
| **Primary exchange closing auction** | 19.23 | 39.54 | 18.61 |
| **SI guaranteed close** | 2.52 | 5.24 | 2.44 |
| **Aquis MaC** | 0.99 | 1.44 | 0.98 |

17 For each stock, the tick size is determined based on the stock price and its liquidity band. The liquidity band is determined based on the stock's average daily number of transactions in the preceding calendar year. The average daily number of transactions is calculated by ESMA (for European stocks), FCA (for U.K. stocks), and FINMA (for Swiss stocks). Due to issues regarding the reliability of the average number of transactions for Swiss stocks in our sample, we do not present the statistic for the Relative Tick Size for this market.


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