Shifting Volumes to the Close: Consequences for Price Discovery and Market Quality

Abstract

Due to the rise in passive investments and regulatory changes, equity markets worldwide have witnessed substantial shifts of trading volumes to the close. Based on three major European markets, where closing auctions account for more than one third of daily trading volume, we analyze whether such high-volume closing auctions have negative implications for price discovery at the close and market quality during continuous trading. We find evidence for significant distortions of the closing price with 23% of the closing auction return being systematically reversed over night. Our results also show that intraday liquidity decreases due to the shift of trading volumes to the close while volatility improves. Thus, our findings on the effects of high-volume closing auctions are in contrast to the positive effects of closing auctions for price discovery and liquidity predicted by theory.

Keywords: Market Microstructure, Stock Market Quality, Price Efficiency, Closing Auction
JEL: G10, G14

1. Introduction

Closing auctions are the standard procedure of most exchanges to close equity markets at the end of the trading day. In contrast to continuous trading, where a trade occurs at a specific price whenever bid and offer match, a call auction accumulates buy and sell orders for each stock and simultaneously executes them in a batched trade at a single uniform price. This aggregation of orders at the end of the day comes with several advantages as it reduces execution costs for individual participants, decreases information asymmetry, improves price discovery, and exacerbates manipulation of the closing price (Madhavan, 1992; Comerton-Forde and Rydge, 2006). The potential benefits of closing auctions are particularly important because of the significance of the closing price. It is the most commonly quoted price and not only used for portfolio evaluations but also for daily margining and the settlement of derivatives contracts at expiration.

Due to the rise in passive investments and regulatory changes, equity markets worldwide witnessed substantial increases in trading interest and trading activity at the close. Thus, closing auctions have become an important liquidity event in global equity markets and substantially increased their share of overall trading volume relative to continuous trading. In the US, closing auctions reached about 10% of daily volume in 2019, which means that their share more than tripled from 3% in 2010 (Jegadeesh and Wu, 2022). In European markets, the share of trading volume executed in the closing auction is even higher and accounts for striking 20% to 40% of daily trading volume (Comerton-Forde and Rindi, 2021). This immense shift of volume to the close raises the question whether this comes at the cost of negative effects for market quality during continuous trading. Moreover, the mostly liquidity-driven trading interest of participants in the closing auction (e.g., passive investors trying to minimize their tracking error) might lead to distortions of the closing price and deviations from the fundamental value due to short-term supply and demand imbalances caused by, e.g., one-sided order flow from index tracking funds.

Therefore, this study aims to shed light on whether high closing auction volumes have negative implications for the efficiency of stock markets in terms of price discovery at the close and intraday market quality. Theoretical predictions and empirical studies on the introduction of closing auctions provide strong evidence for the positive effect of closing auctions on price discovery (see, e.g., Kandel et al., 2012). Based on three major European markets, where the average closing auction accounts for more than one third of daily trading volume, we find opposing results. Our analysis provides evidence that the high-volume closing auctions in the underlying sample lead to closing auction returns that are, at least partially, systematically reversed over night. Specifically, we find that 23% of the closing auction return are reversed over night and that this reversal also persists during the first half hour of continuous trading. For the largest closing auctions in our sample that account for on average half of total daily trading volume, the price distortion even persists for almost two hours after the opening auction on the next day. Bogousslavsky and Muravyev (2021) and Jegadeesh and Wu (2022) find similar but even stronger support for distortions of closing prices in the US stock market although closing auction shares are much lower than in European markets. Specifically, both studies find that closing auction returns are almost entirely reversed overnight or at least within the next few days. In contrast, Comerton-Forde and Rindi (2021), who analyze the European market, find only limited evidence for distortions of closing prices despite the large closing auction volumes relative to overall daily trading volume.

Besides implications for price discovery, we analyze whether high-volume closing auctions adversely affect liquidity and volatility during the rest of the day. This could result from trading volume that shifts away from continuous trading to the closing auction. Again, most theoretical models predict that closing auctions improve intraday market quality, which is also confirmed by empirical studies on the introduction of closing auctions (e.g., Kandel et al., 2012). In line with those studies, we find that high-volume closing auctions are beneficial for market quality in the sense that they are associated with reductions of intraday volatility. However, opposed to most studies on the introduction of closing auctions, we find that increasing closing auction volumes lead to a reduction of intraday liquidity in terms of higher relative spreads and lower order book depth. This adverse effect on liquidity is not limited to the last 30 minutes before the start of the closing auction but is observable for the entire continuous trading phase. Bogousslavsky and Muravyev (2021) also find adverse effects of high closing auction volumes on relative spreads but only within the first 30 minutes of the next trading day. Moreover, they find no effect on intraday volatility. Comerton-Forde and Rindi (2021) find no adverse effects of high closing auction volumes on liquidity.

The remainder of this study is organized as follows: Section 2 reviews the literature on closing auctions and their impact on price discovery and market quality. It also discusses the reasons for increasing closing auction volumes in recent years and potential implications of this development. Section 3 explains the institutional details of the analyzed markets, describes our data set, and provides descriptive statistics. In Section 4, we analyze whether high-volume closing auctions negatively affect price discovery at the close. Section 5 investigates whether the shift of trading volumes to the close comes with negative implications for intraday liquidity and volatility. Section 6 concludes.

2. Literature review

2.1. The impact of closing auctions on price discovery and market quality

Theoretically, call auctions provide lower volatility and higher price efficiency than any other type of market structure in securities trading, especially when large volumes and a large number of market participants are involved (Madhavan, 1992). Due to the importance of the closing price and the high trading interest at the close, many stock exchanges introduced closing auctions as a mechanism to close markets at the end of the day in the late 1990s and in the early 2000s.[1] With this development, also the academic interest in closing auctions increased and studies approached the effects of closing auctions both theoretically and empirically.

Table 1 provides an overview of these studies. From a theoretical point of view, the vast majority of models predict a positive effect of closing auctions on liquidity, volatility, and price discovery. With respect to volatility, all models agree that the introduction of a closing auction reduces volatility, e.g., due to traders becoming more patient (Kaniel and Liu, 2006; Foucault et al., 2005). Concerning liquidity, again most studies predict positive effects since, e.g., liquidity demanders submit less market orders during continuous trading knowing that they can also trade within the closing auction so that liquidity suppliers react by posting more aggressive limit orders (Foucault et al., 2005; Roşu, 2009). However, Admati and Pfleiderer (1988, 1991) argue that the liquidity in the closing auction will attract uninformed traders that would otherwise have traded during the day. That in turn increases the share of informed order flow in the continuous trading phase and, thus, adverse selection costs for liquidity providers. Consequently, bid-ask spreads will increase if uninformed order flow shifts to the closing auction. When looking at the effects of a closing auction mechanism on price discovery, the theoretical predictions are mixed. On the one hand, Kaniel and Liu (2006) predict that informed traders become more patient when closing auctions are present, which makes information becoming incorporated into prices more slowly. On the other hand, Hillion and Suominen (2004) show that closing auctions are a powerful mechanism to reduce price manipulation at the end of the day.

The first empirical studies on closing auctions use their introduction as an event to analyze their impact on market quality and price discovery. Pagano and Schwartz (2003) analyze the introduction of a closing auction at Euronext Paris and find

[1] E.g., closing auctions have been introduced at the German Stock Exchange Xetra and the Australian Stock Exchange in 1997, at the Paris Bourse (today Euronext Paris) in 1996/1998, at the London Stock Exchange (LSE) and the Singapore Stock Exchange in 2000, at the Borsa Italiana (today Euronext Milan) in 2001, and at the Nasdaq and the Toronto Stock Exchange in 2004.

Table 1: Overview of theoretical predictions and empirical findings regarding the impact of closing auctions (CA) on price discovery and stock market quality (based on Kandel et al., 2012).

Paper	Intuition/Findings	Spread	Volatility	Price Discovery
Theoretical Predictions				
Admati and Pfleiderer (1988, 1991)	If volume moves from the end of the continuous phase to the CA, then the CA becomes the new pool of liquidity. The end of the continuous phase loses uninformed traders, thus liquidity providers face worse information asymmetry.	↑	↓	↓
Kaniel and Liu (2006)	CA introduction increases the horizon of informed traders, who become more patient.	↓	↓	↓
Foucault et al. (2005) and Roşu (2009)	Liquidity demanders become less impatient at the end of the continuous phase and submit less market orders. Liquidity suppliers react by posting more aggressive limit orders.	↓	↓	↑
Hillion and Suominen (2004)	Price manipulation decreases.	↓	↓	↑
Empirical Findings (Introduction of Closing Auctions)				
Pagano and Schwartz (2003)	CA introduction at Euronext Paris in 1996 (illiquid stocks) and 1998 (liquid stocks) had mostly insignificant effects on market quality. Price Discovery sharpened.	→	→	↑
Comerton-Forde and Rydge (2006)	Analyze changes in the CA set-up at ASX in 2002. Study highlights importance of call auction algorithm.	-	↓	↑
Comerton-Forde et al. (2007)	CA introduction in Singapore in 2000. Find CA is more important for less liquid stocks.	-	-	↑
Chang et al. (2008)	CA introduction in Singapore in 2000 led to higher market quality and better price discovery. Liquid stocks benefit more than illiquid stocks.	-	↓	↑
Chelley-Steeley (2008, 2009)	CA introduction in London in 2000 on average improved price discovery. Less liquid securities experience the greatest improvements while the effect is neutral for highly liquid stocks.	-	-	↑
Aitken et al. (2005)	CA introduction in Australia in 1997 consolidated liquidity at a single point in time without having any adverse effect on intraday liquidity and volatility.	→	→	–
Pagano et al. (2013)	CA introduction at NASDAQ in 2004. CA significantly reduced both spreads and volatility for all market capitalization groups.	↓	↓	→
Kandel et al. (2012)	CA introduction at Borsa Italiana (2001) and Euronext Paris (1998). They find find that while the CA has no effect during most of the day, its effect on the last minutes of trading is dramatic.	↓	↓	↑
Effect of Increasing Closing Auction Volumes				
Bogousslavsky and Muravyev (2021)	CA returns in US stocks are almost completely reversed over night. Liquidity deteriorates at the open.	↑	→	↓
Jegadeesh and Wu (2022)	21% (43%) of the closing auction return is reversed at the NYSE (Nasdaq) overnight and accumulates to 61% (85%) over the next days.	-	-	↓
Comerton-Forde and Rindi (2021)	Rising CA volumes in Europe do not negatively affect intraday liquidity. Overnight price reversals are relatively small and not persistent.	→	-	→
This Study				
FTSE 100 (LSE)		↑	↓	↓
CAC 40 (Euronext Paris)		↑	↓	↓
DAX 30 (Xetra)		↑	↓	↓

that the closing auction significantly enhanced price discovery and the quality of the closing price. Also, they find that the introduction of the auction has no meaningful effect on intraday spreads, volatility, and trading volume. The positive effect of closing auctions on end-of-day price discovery is supported by empirical analyses for the Australian Stock Exchange (Comerton-Forde and Rydge, 2006), the Singapore Stock Exchange (Comerton-Forde et al., 2007; Chang et al., 2008), and the LSE (Chelley-Steeley, 2008, 2009). Relating to Hillion and Suominen (2004), the first three studies also find that closing price manipulation is significantly reduced with the introduction of closing auctions.

With respect to effects on intraday market quality, Aitken et al. (2005) find that the closing auction benefits investors by consolidating liquidity at a single point in time and that this does not come with any negative effects for liquidity during the rest of the trading day. Pagano et al. (2013) use data from Nasdaq to investigate the impact of closing auctions on market quality across the whole trading day. They find that Nasdaq's closing auction has significantly reduced both spreads and volatility independent of the stocks' market capitalization. Besides, they do not find a significant effect of the closing auction on the pattern of trading volume in the continuous trading phase. Kandel et al. (2012) use data from Borsa Italiana and Euronext Paris and find that the introduction of a closing auction affects only the last minutes of continuous trading while it has no effect on the rest of the trading day. Within the last minutes of the continuous trading phase, the authors observe a significant reduction in quoted spreads, volatility, and trading volume. Kandel et al. (2012) note that their results provide strong empirical support for the theoretical models that account for the (im)patience of traders (Kaniel and Liu, 2006; Foucault et al., 2005) but less so for the predictions of models that focus on effects driven by information asymmetry (Admati and Pfleiderer, 1988, 1991).

In summary, the vast majority of empirical studies finds that closing auctions enhance price discovery at the close although theory offers predictions in both directions. Moreover, the results suggest that closing auctions do not come with adverse effects for intraday liquidity and volatility since studies either find no effect on intraday market quality or actually find improvements in line with most theoretical predictions. Yet, it remains unclear whether these positive effects still hold when closing auctions absorb a significant share of daily trading volume as seen in today's equity markets. Moreover, also the price discovery process in the closing auction might be affected by the large amount of passive order flow, which can lead to supply and demand imbalances due to one-sided flow from index tracking strategies. This liquidity-driven imbalance can then result in distorted closing prices.

2.2. The growing importance of closing auctions

According to Raillon (2020), there are four main reasons contributing to the recent increase in closing auction volumes on trading venues worldwide and in particular in European markets: (1) the rapid and strong growth in passive investments, (2) the introduction of MiFID II, (3) market participants trying to avoid being executed against high-frequency trading (HFT) arbitrageurs, and (4) the fact that liquidity attracts liquidity.

First of all, the large investments in passively managed funds are one of the main contributors for increasing closing auction volumes. Passive equity fund managers seek to minimize the tracking error between their current portfolio and the index they are trying to replicate. Since only closing prices are used for the evaluation of the tracking error, trading in the closing auction is highly attractive for passive strategies whereas intraday trading becomes less important. Bogousslavsky and Muravyev (2021) find that closing auction volumes peak on index rebalancing days, when passive equity funds managers have to trade more than on other days in order to reflect these changes in their portfolio. The amount of passive investments and index rebalancing days as major drivers of high closing auction volumes are also confirmed by Jegadeesh and Wu (2022) and Comerton-Forde and Rindi (2021).

Besides the growth in passive investments, the introduction of the revised European Markets in Financial Instruments Directive (MiFID II) accelerated closing auction volumes by limiting over-the-counter and dark pool trading, which is confirmed in an event study of the French regulator (Gallon, 2019). Moreover, the avoidance of HFT arbitrageurs provides a third explanation for increasing closing auction volumes since HFTs trade substantially less in (closing) auctions (European Securities and Markets Authority, 2014). Thus, trading in the closing auction can mitigate the risk of being confronted with these traders. A fourth explanation for rising closing auction volumes is the comprehensively researched "liquidity begets liquidity"-effect (e.g., Admati and Pfleiderer, 1988; Chowdhry and Nanda, 1991), which might have amplified the impact of the other three factors.

First studies already analyze the impact of rising closing auction volumes on price efficiency (shown in the lower Panel of Table 1). Based on data for the US market, Jegadeesh and Wu (2022) and Bogousslavsky and Muravyev (2021) find temporary distortions in closing prices due to rising closing auction volumes. The analysis of Jegadeesh and Wu (2022) shows that 21% (43%) of the closing auction return is reversed at the NYSE (Nasdaq) overnight. The reversal continues over the following trading days leading to a cumulative reversal of about 61% (85%) of the price change induced by the closing auction. Bogousslavsky and Muravyev (2021) find that closing prices contain almost no incremental information relative to the last quote midpoint of the continuous trading phase because closing auction returns almost completely reverse overnight (85%). Half of this reversal already occurs in the after trading hours right after the auction. Moreover, they find that increasing closing auction volumes are associated with a deterioration of liquidity at market opening while volatility at the open remains unchanged. Based on European data, Comerton-Forde and Rindi (2021) find little reason to be concerned about growing closing auction volumes. Although they find evidence for a shift in trading volume away from the last 30 minutes of continuous trading with rising closing auction volumes, their results show that this shift does not worsen liquidity or price efficiency during continuous trading. In contrast to the studies based on US data, Comerton-Forde and Rindi (2021) also find no evidence for closing price distortions driven by demand and supply imbalances due to the increased trading interest at the close. The authors conclude that the differences between their results and those of Jegadeesh and Wu (2022) and Bogousslavsky and Muravyev (2021) may result from the different auction designs implemented in Europe and in the US and that further research is necessary.

Therefore, this study adds further evidence to the discussion on the impact of the enormous closing auction volumes in Europe. Based on three major European markets and a recent data set covering strong variations in closing auction shares including the temporary decline in closing auction volumes during the 2020 stock market turmoil caused by the outbreak of the COVID-19 pandemic, we analyze whether high-volume closing auctions affect the efficiency of closing prices and intraday market quality.

3. Institutional details & data

3.1. Institutional details

We analyze stocks of the three leading European blue chip indices CAC 40, DAX 30, and FTSE 100, which are primarily traded on the venues Euronext Paris (CAC stocks), Xetra (DAX stocks), and the LSE (FTSE stocks). Apart from trading at the main venues, investors can buy and sell these stocks also on other stock exchanges. During our observation period, most of the trading volume (63% to 75%) of the analyzed stocks was executed at the main venues analyzed in this study.[2]

The trading models of the three venues are highly comparable. Trading takes place in standard open limit order books offering continuous trading with auctions

[2] According to Fidessa (https://fragmentation.fidessa.com/), the three main venues had the following share in overall lit trading in the analyzed period: CAC stocks (63.38%), DAX stocks (74.95%), and FTSE stocks (67.29%).

at the open, midday (excluding Euronext Paris) and close. In addition to natural order flow, also market makers are active in the book. The call phase of the opening auction at Euronext Paris starts at 6:15 GMT, while it starts at 7:50 GMT at Xetra and the LSE. For all venues, the opening auction ends at 8:00 GMT with a random uncrossing period of up to 30 seconds. The subsequent continuous trading phase lasts from 8:00 GMT to 16:30 GMT and is only interrupted at XETRA and LSE by a midday auction, which lasts from 12:00 GMT to 12:02 GMT (plus a random end of 30 seconds). At 16:30 GMT, the closing auction starts on all three venues and ends five minutes later at 16:35 GMT, again with a random uncrossing period of up to 30 seconds. During auctions, the venues calculate and disseminate indicative prices and volumes, i.e., the price and volume at which the call would cross conditional on all the orders submitted to the system at the specific point in time.

3.2. Data

The data used in this study is retrieved from the BMLL database maintained by BMLL Technologies Limited. In order to analyze the impact of high closing auction volumes on price discovery and market quality, we analyze stocks of the three blue chip indices CAC 40, DAX 30, and FTSE 100 in the period from January 1, 2018 to December 31, 2021. Due to data availability in the BMLL database, the time series for DAX constituents traded at Xetra starts on February 1, 2019.[3] Furthermore, to avoid potential biases from index effects, the data set contains only those stocks which were continuously part of their index over the whole observation period resulting in a total of 131 stocks (CAC: 32; DAX: 26; FTSE: 73). We retrieve trades and order book data from BMLL, which are time stamped to the nearest millisecond. Daily market capitalization of the stocks is retrieved from Datastream. We convert all non-EUR values to EUR based on daily exchange rates.

To analyze the impact of high-volume closing auctions on price discovery, we calculate daily *closing auction returns* and *overnight returns* (in %). Thereby, the closing auction return is measured as the log return of the last midpoint of the continuous trading phase right before auction start and the closing price determined in the closing auction. The overnight return is measured as the log return of the closing price and the opening price of the next day.

In order to quantify the impact of increasing closing auction volumes on market quality, all trades and order book snapshots are aggregated to five minute intervals, starting from 8:00 GMT after the end of the opening auction period. The last five

[3]In subsequent robustness tests, we show that the different starting points of the observation period for the three indices does not bias or change our results.

minute interval ends at 16:30 GMT, when the closing auction starts. All market quality measures are aggregated by taking the mean except for trading volume and number of trades, for which the sum is calculated. Since the midday auction takes place only at LSE and Xetra between 12:00 GMT and 12:02 GMT and there is no midday auction at Euronext Paris, the five minute interval starting at 12:00 GMT is excluded from the analysis. This helps to avoid any spillover effects from the midday auction affecting our results and to compare the stocks traded on the three different venues without a bias from the (non-)existence of a midday auction. We also exclude the 8:00 GMT five minute interval to avoid spillover effects from the opening auction on the continuous trading phase and to cope with extended opening auctions that delay the start of continuous trading.

3.3. Descriptive statistics

Within this study, we rely on the closing auction share to investigate the volume shift towards the close and to measure the size of each closing auction. The closing auction share is calculated by dividing the trading volume that was executed in the closing auction by the entire trading volume in a specific stock on the same day including all auctions and the continuous trading phase. The advantage of the closing auction share compared to the absolute trading volume in the auction is that it controls for general variations in trading activity that influence both the volume in the closing auction and the trading volume that is executed during the rest of the day. Figure 1 shows the development of the average closing auction share for the 131 stocks analyzed in this study over time aggregated to quarterly observations for each index. The figure shows a growing average closing auction share for FTSE stocks over the entire observation period from 23% at the beginning of 2018 to nearly 45% at the end of 2021. The average closing auction share of stocks in the other two indices fluctuates between between 33% and 43% (CAC stocks) and between 27% and 35% (DAX stocks). Furthermore, a drop in the average closing auction share can be observed across the full sample for the first quarter of 2020, which can be explained by excessive (continuous) trading during the market turbulence caused by the outbreak of the COVID-19 pandemic. Similar developments are observed when dividing the sample into thirds according to closing auction share (see Figure A.1 in the appendix). Consequently, the stocks and the analyzed time period offer both high levels of closing auction shares and significant fluctuations of closing auction shares over time as well as in the cross-section, which provides a suitable basis for our subsequent analyses.

Confirming the findings of previous studies on the drivers of closing auction volumes (Comerton-Forde and Rindi, 2021; Bogousslavsky and Muravyev, 2021; Raillon,

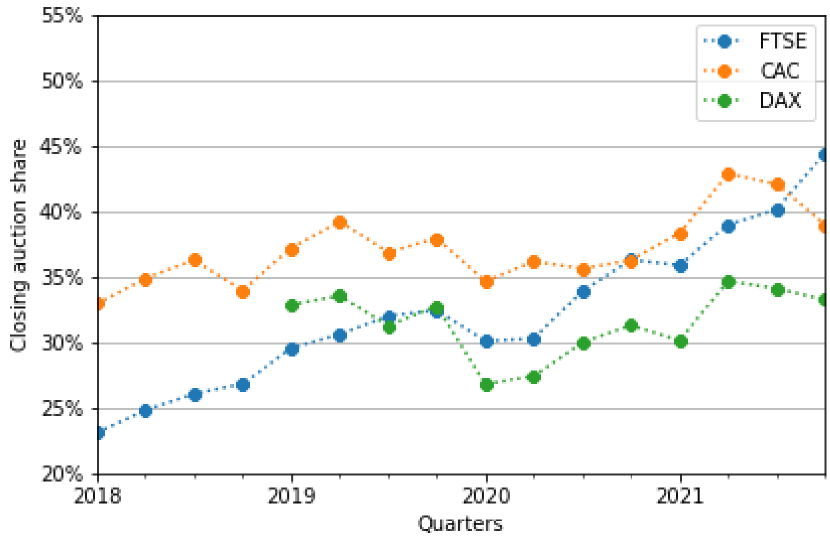

Figure 1: Development of average closing auction shares over time for each stock index

This figure plots the average quarterly closing auction shares for all stocks in each index over our observation period from January 2018 to December 2021 (February 2019 to December 2021 for DAX stocks).

2020), MSCI rebalancing and derivatives expiry days are major drivers for closing auction volumes. Figure A.2 in the appendix shows that MSCI rebalancing days and quarterly expiry days of derivative products clearly differentiate from other trading days with substantially higher closing auction shares on these days relative to total trading volume during continuous trading. Moreover, the figure proves the negative relation between closing auction shares and trading volume during continuous trading, providing further evidence for the shift of volumes towards the close with increasing relevance of the closing auction.

Table 2 shows the daily descriptive statistics for the full sample of 131 stocks. Thereby, each variable has a total of 120,586 observations. The average (median) closing auction share accounts for 33.46% (32.62%) of the overall trading volume on a given day. The average daily trading volume in the full sample is EUR 43.382 million, while the mean (median) of the number of trades is 7,698 (5,822) per day. The descriptive statistics of liquidity measures show an average relative spread of 4.93 bps with its median being slightly lower (4.60 bps). The mean quoted depth at the top of the order book (L1-volume) amounts EUR 59,840 and is slightly larger than its median value of EUR 43,250. The volatility measures show an average of

12.05 (16.43) bps for return vola (range vola), while the average market capitalization of the stocks included in the sample is EUR 35.47 bn.

Table 2: Descriptive statistics

This table provides daily descriptive statistics for the full sample of 131 stocks. *CA share* is calculated by dividing the trading volume that was executed in the closing auction by the aggregate trading volume on the same day including all auctions and continuous trading. Market quality measures are based on five-minute intervals during continuous trading and aggregated on a daily basis by taking the sum for market activity measures (*trading volume*, *number of trades*) and by taking the mean for liquidity (*relative spread*, *L1-volume*) and volatility measures (*return vola*, *range vola*). *Market cap* is retrieved from Datastream on a daily basis.

	Unit	N	Mean	Std	Min	25%	50%	75%	Max
CA share	%	120,586	33.46	11.45	3.50	25.26	32.61	40.50	93.99
Trading volume	k EUR	120,586	43,382	44,131	1,045	12,446	28,553	59,198	422,870
Number of trades	-	120,586	7,698	6,080	583	3,516	5,822	9,978	56,900
Relative spread	bps	120,586	4.93	2.32	1.42	3.18	4.60	6.03	19.50
L1-volume	k EUR	120,586	59.84	51.15	6.85	24.91	43.25	77.23	354.15
Return vola	bps	120,586	12.05	6.40	4.74	8.23	10.37	13.63	50.93
Range vola	bps	120,586	16.43	9.47	1.37	10.77	13.92	18.83	94.51
Market cap	bn EUR	120,586	35.47	36.71	2.42	10.34	22.2	47.62	370.85

Since we analyze the impact of closing auction volumes based on different time periods and subsamples, Table A.1 in the appendix reports descriptive statistics per year and index. The closing auction share peaks for the three index subsamples in the last observation year 2021 and is on average highest for CAC stocks followed by DAX and FTSE constituents. In addition, Panel A and Panel B report the average market quality parameters during the entire continuous trading phase and for the last 30 minutes of trading right before the start of the closing auction. We see similar trends concerning trading activity, liquidity, and volatility in the different samples and also for the two panels.

To understand the impact of high closing auction volumes on price discovery, we analyze deviations in prices between continuous trading (i.e., the last midpoint) and the closing auction using *closing auction returns*. Table 3 reports descriptive statistics for the full sample and for the three index subsamples. The price deviations in the full sample and the three index subsamples are relatively large. The average closing auction return for the full sample is 16.38 bps, while FTSE stocks show the largest deviation with 16.76 bps and DAX stocks the lowest with 14.62. These closing auction returns are substantially larger than those for the US markets as reported by Bogousslavsky and Muravyev (2021). The aforementioned authors also emphasize that auction trades are not necessarily executed at the midpoint and, therefore,

Table 3: Descriptive statistics concerning closing auction returns

This table reports statistics for the closing auction return, half spread and price impact. The absolute closing auction return (abs. AR) is decomposed in the half spread and price impact components. The decomposition follows: abs. AR = half spread + price impact. Abs. AR is calculated as the return of the last midpoint and the closing auction price. The half spread component is calculated as the distance of the last bid and the last ask right before the closing auction divided by two. Statistics are reported for the full sample and across indices.

Sample	**Measure**	**Count**	**Mean**	**Std**	**Median**
Full	Abs. AR	120,586	16.38	15.95	12.14
	Half spread	120,586	2.07	0.94	1.95
	Price impact	120,586	14.33	15.79	10.22
FTSE	Abs. AR	71,064	16.76	16.30	12.22
	Half spread	71,064	2.28	1.00	2.15
	Price impact	71,064	14.48	16.12	10.12
CAC	Abs. AR	30,496	16.61	16.02	12.78
	Half spread	30,496	1.80	0.76	1.70
	Price impact	30,496	14.82	15.91	11.03
DAX	Abs. AR	19,026	14.62	14.28	10.99
	Half spread	19,026	1.69	0.73	1.55
	Price impact	19,026	12.94	14.15	9.35

decompose the absolute deviation into the components *half spread* (measured by the bid-ask quote right before the auction) and *price impact*. We follow their analysis and report the descriptive statistics of the components in Table 3. The average half spread accounts with 2.07 bps only for 12.64% of the closing auction return in the full sample. FTSE stocks show the largest half spread with an average of 2.28 bps accounting for 13.60% of the closing auction return, while DAX stocks show a slightly lower half spread of 1.69 bps accounting for 11.56% of the closing auction return. Hence, we observe only small microstructure frictions (i.e., low spreads) but considerable price impact that accounts for the majority of the closing auction return both in the full sample and across the three index subsamples.

4. Implications for Price Discovery

4.1. Methodology

The efficiency of closing prices is of high importance for many market participants because of their relevance for portfolio evaluations and derivative settlement. However, the shift of a large share of total trading volume to the close could lead to a distortion of the closing price. Such a distortion might, for example, stem from a temporary and non-fundamentally justified price change resulting from demand and supply imbalances due to one-sided uninformed order flow submitted to the closing auction. In order to investigate whether closing prices are distorted leading to systematic reversals of the closing auction return over night, we estimate the following regression that reveals the relationship between closing auction return and overnight return (Equation (1)):

$$\textit{Overnight return}_{i,t} = \alpha + \beta_1 \textit{Closing auction return}_{i,t} + \epsilon_{i,t} \quad (1)$$

where *Overnight return* is defined as the log return of the closing auction price and the opening price of the next day for stock i on day t and *Closing auction return* is defined as the log return of the last midpoint in continuous trading before the closing auction and the price of the closing auction for stock i on day t. We re-estimate the regression using the average midpoint of the five minute intervals after the market open to calculate the overnight return (e.g., the log return of the closing auction price and the average midpoint of the five minute interval from 8:00 to 8:05). This enables us to control for potentially distorted opening prices and to investigate how long the price distortion of the closing price persists in continuous trading on the next day. We estimate the regression with standard errors clustered by stock and day. If closing auction prices are systematically distorted by order imbalances due to the high trading interest at the close, these transitory deviations from the fundamental price should be reversed overnight. The results of this analysis are presented in the following.

4.2. Results

In case of a price distortion during the closing auction, the price of the closing auction will be reverted at the opening price the next day indicated by a negative β_1-coefficient when estimating Equation (1). If the closing auction does not distort or even improve price discovery, the opening price should not systematically deviate from the closing price. A positive β_1-coefficient would indicate that the price change from the last midpoint to the closing auction is accelerated over night. Table 4 shows the regression results regarding the relationship between closing auction and overnight returns. Since all variables are log returns, the regression coefficients can be interpreted as elasticities.

Starting with the full sample, we find an overall price reversal of 23% with a significance at the 1%-level. Running the regression analysis for each index separately, we find significant overnight price reversals for each index ranging from 20% to 36%, with the highest price reversal for DAX stocks. Hence, we find a systematic and significant price distortion across all indices. In addition, we analyze when the price reversal caused by the closing price distortion diminishes during continuous trading on the next day. For the full sample and the three index subsamples, we find that

Table 4: Closing price reversals on full sample and major European indices

This table shows the regression results for the analysis of potential distortions of the closing price. Specifically, the estimated β_1-coefficient of Equation (1) is provided for the full sample as well as for different index subsamples (FTSE, CAC, DAX). Closing auction return (AR) is calculated as the log return of the last midpoint in continuous trading and the closing price. Overnight return (OR) is calculated as the the log return of the closing price and the opening price on the next day or the average midpoints of the five minutes intervals from 8:00 until 8:40 on the next day. Standard errors are double-clustered by stock and day and reported in parentheses.

	Overnight Return (OR)								
Stocks	**Open Price**	**08:05**	**08:10**	**08:15**	**08:20**	**08:25**	**08:30**	**08:35**	**08:40**
AR Full	-0.23***	-0.23***	-0.21***	-0.16**	-0.14*	-0.15*	-0.14*	-0.15	-0.15
	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.10)	(0.11)
AR FTSE	-0.21***	-0.21***	-0.21***	-0.14**	-0.11	-0.11	-0.09	-0.10	-0.10
	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.10)	(0.10)
AR CAC	-0.20**	-0.19**	-0.18**	-0.13*	-0.14*	-0.15*	-0.16*	-0.18*	-0.18
	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.10)	(0.11)
AR DAX	-0.36**	-0.38**	-0.33*	-0.32*	-0.32*	-0.35*	-0.37*	-0.34	-0.34
	(0.18)	(0.16)	(0.17)	(0.17)	(0.18)	(0.19)	(0.19)	(0.21)	(0.22)

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

the reversal effect is eliminated after 40 minutes in continuous trading at the latest. Thereby, the degree of the price reversal is decreasing during continuous trading which is shown by an almost monotonically decreasing coefficient across all samples as well as by the coefficient becoming less significant. The price correction is quickest for stocks included in the FTSE with an insignificant reversal coefficient already 20 minutes after the opening auction, while the reversal effect for CAC stocks remains significant until 35 minutes after the opening. For robustness, we re-estimate this regression setup including closing auction returns and overnight returns adjusted by half the spread to control for market frictions which could also be a reason for price deviations. The half spread adjusted regression results are presented in Table A.2. For the full sample, we find with a reversal of 17% a slightly lower but still significant price reversal for the opening price as well as for the first 10 minutes in continuous trading. The index subsamples show a similar picture. However, the regression results with half spread adjusted returns show a faster elimination of the price reversal with insignificant reversal coefficients after 15 minutes at latest compared to 40 minutes in the standard regression setup (CAC: 10 minutes; DAX: 10 minutes; FTSE: 15 minutes).

To analyze variations in price distortions according to different levels of closing auction share, we sort all auctions by closing auction share and divide them into quintiles. Table 5 shows the regression results for the five quintile subsamples. We find that closing auctions in the smallest quintile with an average closing auction

Table 5: Closing price reversals according to level of closing auction share

This table shows the regression results for the analysis of potential closing price distortions according to the level of closing auction share. Specifically, the estimated β_1-coefficient of Equation (1) is provided for stocks of the full sample which a sorted in five sub-samples according to their level of closing auction share. Closing auction return (AR) is calculated as the log return of the last midpoint in continuous trading and the closing price. Overnight return (OR) is calculated as the the log return of the closing price and the opening price at the next day as well as the average midpoints of the five minutes intervals from 8:00 until 8:30 at the next day. Standard errors are double-clustered by stock and day and reported in parentheses.

	Overnight Return (OR)								
Quintiles	**Open Price**	**08:05**	**08:10**	**08:15**	**08:20**	**08:25**	**08:30**	**Ø CA**	**Ø Vola.**
<20%	-0.37*	-0.30*	-0.34*	-0.28	-0.29	-0.31	-0.27	18.60	14.67
	(0.20)	(0.16)	(0.19)	(0.18)	(0.19)	(0.20)	(0.22)		
20%-40%	-0.21**	-0.19**	-0.14	-0.06	-0.05	-0.04	-0.02	26.80	12.67
	(0.11)	(0.09)	(0.10)	(0.10)	(0.11)	(0.12)	(0.11)		
40%-60%	-0.22**	-0.21**	-0.21**	-0.16**	-0.13	-0.14	-0.13	32.60	11.61
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.10)		
60%-80%	-0.19***	-0.20***	-0.17**	-0.13*	-0.10	-0.10	-0.10	38.80	10.88
	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)		
>80%	-0.17***	-0.23***	-0.22***	-0.17**	-0.14**	-0.15**	-0.16**	50.50	10.36
	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)		

Note: $^{*}\,p < 0.1$; $^{**}\,p < 0.05$; $^{***}\,p < 0.01$. The largest quintile (>80%) becomes insignificant from 09:45 onwards.

share of 18.6% show a price reversal of 37% being significant at the 10%-level. The reversal effect in this quintile is already eliminated after 15 minutes of continuous trading on the next day. Closing auctions included in quintiles with higher closing auction shares show a lower price reversal of around 20% (significant at the 5%- or 1%-level). However, the price distortion persists longer on the next day. This is especially pronounced for stocks included in the quintile with the highest closing auction share (average closing auction share of 50.5%), where the coefficient indicating the reversal becomes insignificant after 1:45 hours of continuous trading at 9:45. In addition, we find that an increasing closing auction share is related with lower volatility. More specific, while auctions included in the quintile with the lowest closing auction share show on average volatility of 14.67 bps, the average daily volatility decreases with increasing closing auction shares and is lowest for the quintile including stocks with highest closing auction share (50.5% of overall daily trading volume). Summarizing, we find a significant price reversal with similar magnitude across all quintiles, whereby the reversal effect persists longer for the closing auctions with the largest share of overall trading volume.

In a third analysis, we investigate the price reversal effects according to different periods for the full as well as for the different index subsamples. The overnight return in this step is calculated based on the standard setup, i.e., closing and opening prices. The results are shown in Table 6.

Table 6: Closing price reversals in different time periods

This table shows the regression results for the analysis of potential closing price distortions according to different periods. Specifically, the estimated β_1-coefficient of Equation (1) is provided for stocks of the full sample in 2018, 2019, 2020, 2021, during the COVID-19 outbreak, and on MSCI rebalancing/derivative expiry days. Closing auction return (AR) is calculated as the log return of the last midpoint in continuous trading and the closing price. Overnight return (OR) is calculated as the the log return of the closing price and the opening price. Standard errors are double-clustered by stock and day and reported in parentheses.

Period	Stocks	Coefficient	Std. Error	Ø CA	Ø Vola.
2018	**Full**	-0.10	0.11	27.83	9.88
	FTSE	-0.12	0.12	25.24	10.00
	CAC	-0.03	0.16	34.57	9.55
2019	**Full**	-0.36***	0.07	33.11	10.06
	FTSE	-0.39***	0.09	31.23	10.40
	CAC	-0.26***	0.09	37.80	9.42
	DAX	-0.37***	0.12	32.59	9.91
2020	**Full**	-0.27*	0.14	32.76	16.56
	FTSE	-0.21*	0.13	32.86	17.04
	CAC	-0.28*	0.14	35.72	16.82
	DAX	-0.50*	0.30	28.93	14.93
2021	**Full**	-0.07	0.08	38.73	11.13
	FTSE	-0.09	0.09	39.92	11.66
	CAC	-0.05	0.11	40.69	10.62
	DAX	-0.01	0.13	33.08	10.30
Corona	**Full**	-0.76**	0.34	28.30	27.42
	FTSE	-0.62**	0.32	26.90	27.23
	CAC	-0.68**	0.27	34.62	28.84
	DAX	-1.36**	0.61	24.31	26.24
MSCI/ Derivatives	**Full**	-0.32	0.31	51.33	13.27
	FTSE	-0.14	0.27	51.58	13.31
	CAC	-0.21	0.27	54.02	13.17
	DAX	-1.08	0.80	46.12	13.30

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Running the regression setup only for specific years, we find that the reversal effect is significant in 2019 and 2020 across the three index subsamples and the full sample. However, we do not observe significant closing price distortions in 2018 and 2021. Furthermore, the period from February 2020 to May 2020 indicating the market turbulence during the outbreak of the COVID-19 pandemic shows very high and significant price distortions with a price reversal of 136% for DAX stocks while the full sample shows a significant price reversal of 76%. Interestingly, we find no significant price reversal effects on days when MSCI rebalancing and derivatives expiry take place despite the high closing auction shares on these days. Concluding, the reversal effect varies over time, was very prominent during the outbreak of COVID-19, and does not occur on MSCI rebalancing and derivatives expiry days. Hence, the reversal effect is especially pronounced in times of market uncertainty but independent of anticipated index flow such as on MSCI rebalancing days.

Overall, we find evidence for systematic distortions of closing prices and that closing auction returns partly reverse overnight across all major European indices and the full sample. Thereby, the duration to eliminate the price distortion in the continuous trading phase on the next day varies across the indices and takes between 20 (FTSE) to 40 minutes (CAC). While we find significant distortions of closing prices for all auctions in our sample, the price reversal effect is more persistent with rising closing auction shares. For the largest closing auctions in our sample, it takes almost two hours on the next day until the price reversal vanishes. Analyzing different periods, the price reversal effect was strongest during the outbreak of COVID-19 with an almost entire reversal of closing auction returns.

5. Implications for Intraday Market Quality

5.1. Methodology

In addition to the negative impact rising closing auction shares can have on price discovery, there might be a potential adverse effect on intraday market quality as well. In our analysis, we focus on intraday liquidity and volatility being the most prominent measures of stock market quality. We estimate several regressions to exploit the variations in closing auction shares revealed by the descriptive statistics to examine the impact of rising closing auction shares on intraday market quality. To obtain robust results, we apply two different measures for each dimension of market quality. To capture different dimensions of liquidity, we analyze implications of high-volume closing auctions for relative spreads and depth at the top of the order book (L1-volume). The impact of high closing auction shares on volatility is investigated based on return volatility and range volatility. Since intraday market quality and closing auction turnover are endogenously determined, we make use of a two stage least square regression approach with the lagged closing auction share of the previous day as an instrumental variable for the closing auction share on day t. Equation (2) shows the first stage regression where the closing auction share is explained by the instrumental variable (lagged closing auction share) together with control variables (same as in the second stage regression):

$$\begin{aligned} CA\ share_{i,t} = \ & \alpha + \beta_1 CA\ share_{i,t-1} + \beta_2 X_{i,t} + \beta_3 Expiry_t + \beta_4 MSCI_t + \beta_5 COVID_t \\ & + \sum_{d=6}^{9} \beta_d Weekday_t + \sum_{a=10}^{12} \beta_a Year_t + \sum_{d=13}^{14} \beta_d Venue_i + \epsilon_{i,t} \end{aligned} \tag{2}$$

This instrumental variable is then used as an explanatory variable in Equation (3).

$$\begin{aligned} Y_{i,t} = \ & \alpha + \beta_1 CA\ share\ (IV)_{i,t} + \beta_2 X_{i,t} + \beta_3 Expiry_t + \beta_4 MSCI_t + \beta_5 COVID_t \\ & + \sum_{d=6}^{9} \beta_d Weekday_t + \sum_{a=10}^{12} \beta_a Year_t + \sum_{d=13}^{14} \beta_d Venue_i + \epsilon_{i,t} \end{aligned} \tag{3}$$

where $Y_{i,t}$ denotes the respective normalized market quality measure of stock i on day t. Specifically, we normalize all liquidity and volatility measures by their average across the previous 21 trading days (i.e., one month) to control for changes in liquidity and volatility over time and other potential unobserved changes in market quality over the relatively long period of our panel data set. Thereby, t either refers to the whole continuous trading phase on day t or the last 30 minutes of continuous trading before the closing auction. *CA share (IV)* is the instrumented closing auction share from Equation (2). $MSCI_t$ and $Expiry_t$ are dummy variables being one for MSCI rebalancing and derivative expiry days, respectively. Moreover, $COVID_t$ is a dummy variable being one between February 2020 and May 2020 to control for the market turbulence during the outbreak of the COVID-19 pandemic. We include $Weekday_t$ dummy variables to control for differences between weekdays and $Year_t$ dummies to control for year specific developments. In the full model covering all stocks, we also include $Venue_i$ dummies to control for differences across the three trading venues in our sample. Finally, $X_{i,t}$ controls for each stock's daily *return vola* or *relative spread* depending on whether $Y_{i,t}$ measures liquidity or volatility, i.e., we control for the level of volatility when analyzing the impact of rising closing auction shares on intraday liquidity and vice versa. All non-binary regression variables are transformed by taking the natural logarithm so that the results can be interpreted as elasticities. We apply robust standard errors as suggested by White (1980) and cluster standard errors by stock and day to account for potential correlations across days and between stocks in our panel data set.

5.2. Liquidity

To analyze the impact of increasing closing auction volumes on intraday liquidity, we estimate the regression shown in Equation (3) using *relative spread* and *L1-volume* as dependent variables. The results of this analysis are provided in Table 7. We find a robust negative impact of increasing closing auction shares on liquidity for both measures and across the different index subsamples. This effect holds for the entire continuous trading phase as well as for the last 30 minutes before the start of the closing auction.

Specifically, our results show that a one percent increase in the closing auction share increases the relative spread of the full sample during the whole continuous trading day (last 30 minutes) by 0.050% (0.035%) and lowers L1-volume by 0.045% (0.056%). Hence, the effect of increasing closing auction shares on intraday liquidity is comparable for the whole trading day and for the last 30 minutes of trading. Additionally, all results are significant at the 1%-level. Comparing the two different indicators of market liquidity, the impact of increasing closing auction volumes seems to be similar for the spreads and the L1-volume in both panels. This effect is also meaningful from an economic perspective. Consider a stock whose closing auction share rises from the lowest quintile (18.60% average closing auction share) to the highest quintile (50.50%, increase of 271%). This increase in closing auction volumes leads to an increase of the intraday relative spread by 13.55% and a reduction of depth at the top of the order book by 12.25%.

Looking at the index subsamples, we find that the negative impact of increasing closing auction shares on liquidity is robust across all venues both for the entire continuous trading day and the last 30 minutes of trading. This result is also independent of the liquidity dimension being analyzed. Across the three index subsamples, the impact of a one percent increase in the closing auction share leads to an increase of the intraday relative spread by 0.044% (FTSE) to 0.147% (DAX) and a reduction of L1-volume by 0.042% (FTSE) to 0.101% (DAX). Similar but slightly smaller effects can be observed for the last 30 minutes of continuous trading. Here, the impact of a one percent increase in the closing auction share ranges between 0.036% and 0.104% (relative spread) and 0.058% and 0.068% (L1-volume), all being significant at the 1%-level.

The remaining four control variables in Table 7 show the expected results. Higher volatility and the market turbulence caused by the outbreak of the COVID-19 pandemic are associated with lower levels of liquidity, i.e., increased spreads and lower order book depth. The increased trading activity on derivative expiry and MSCI rebalancing days shows mostly positive effects on liquidity, although not always being significant, which is particularly true for the last 30 minutes of the continuous trading phase.

The analysis of potential implications of high-volume closing auctions for intraday liquidity leads to three major findings: First, liquidity significantly decreases with increasing closing auction shares both in terms of higher relative spreads and lower order book depth. Second, this adverse effect on liquidity is consistent across the three index subsamples analyzed in this study. Third, the decrease in liquidity is not only limited to the last 30 minutes prior to the start of the closing auction but is observable for the entire continuous trading phase. Therefore, high-volume closing auctions come with negative consequences for intraday market quality leading to a decrease in liquidity, thus making trading throughout the day more costly for investors.

Comparing our findings with the theoretical predictions outlined in Table 1, the effects of high-volume closing auctions on intraday liquidity are in line with the predictions of Admati and Pfleiderer (1988, 1991) expecting a decrease in liquidity due to the reduction of information in continuous trading. However, the majority of theoretical predictions and empirical studies on the introduction of closing auctions finds no or a positive effect on liquidity in form of smaller spreads (e.g., Foucault et al., 2005; Pagano and Schwartz, 2003). The difference in our findings to the theoretical and empirical literature could result from the level of the closing auction share being analyzed. While most literature investigates the impact of closing auctions on liquidity when closing auctions are being introduced, hence, have a relatively small share on overall trading volume, our analyses examine the effect of high closing auction shares. This is supported by the recent study of Bogousslavsky and Muravyev (2021) who also analyze rising closing auction volumes and find that liquidity deteriorates in the 30 minutes of continuous trading after the open. We find not only a deterioration in liquidity in this period but a reduction of liquidity during the entire continuous trading day. Therefore, we conclude that closing auctions per se can be beneficial for market liquidity. However, the effect depends on the level of closing auction volumes. High-volume closing auctions that account for a relevant share of overall trading volume actually harm intraday liquidity in form of increased spreads and a reduction of order book depth.

Table 7: Two-stage least squares regression results for liquidity

This table shows the regression results for the impact of increasing closing auction volumes on stock market liquidity during the entire continuous trading phase (*Panel A*) and the last 30 minutes of continuous trading (*Panel B*) based on Equation (3). The dependent variables measuring liquidity are *relative spread* and *L1-volume*. As independent variables we use the *closing auction share (CA share)*, *return volatility* and dummy variables for *derivative expiry days*, *MSCI rebalancing days* and the *COVID-19 outbreak*. Additionally, we add dummy variables to control for *year*, *weekday*, and *venue*. All non-binary regression variables are transformed by taking the natural logarithm. Standard errors are clustered by stock and day.

Panel A: Daily	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.4746***	-0.4391***	-0.5340***	-0.9923***	0.3933***	0.3329***	0.5915***	0.7487***
CA share	0.0497***	0.0444***	0.0691***	0.1473***	-0.0452***	-0.0420***	-0.0841***	-0.1006***
Return vola.	0.1210***	0.1143***	0.1180***	0.2069***	-0.1032***	-0.0814***	-0.1319***	-0.1807***
Expiry	0.0039	-0.0101**	0.0103	-0.0043	0.0228***	0.0164**	0.0443***	0.0631***
MSCI	-0.0302***	-0.0382***	-0.0213***	-0.0651***	0.0287***	0.0384***	0.0319***	0.0284*
COVID	0.0298***	0.0544***	0.0240**	-0.0572***	-0.1360***	-0.1547***	-0.1516***	-0.0348***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0914	0.0993	0.0757	0.1034	0.0706	0.0639	0.0930	0.0799
N	117,966	69,569	29,891	18,506	117,966	69,569	29,891	18,506

Panel B: Last 30min	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.3579***	-0.3536***	-0.3357***	-0.7469***	0.4660***	0.4758***	0.5212***	0.5594***
CA share	0.0352***	0.0359***	0.0376***	0.1038***	-0.0563***	-0.0680***	-0.0659***	-0.0580***
Return vola.	0.0931***	0.0888***	0.0823***	0.1645***	-0.1245***	-0.1109***	-0.1404***	-0.1682***
Expiry	-0.0002	-0.0129**	0.0144	-0.0118	0.0158**	0.0068	0.0450***	0.0338*
MSCI	0.0036	-0.0086	0.0222***	-0.0178	0.0321***	0.0602***	0.0109	-0.0118
COVID	0.0359***	0.0566***	0.0312***	-0.0322***	-0.1687***	-0.1950***	-0.1871***	-0.0637***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0405	0.0391	0.0363	0.0549	0.0532	0.0465	0.0735	0.0612
N	117,920	69,523	29,891	18,506	117,920	69,523	29,891	18,506

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

5.3. Volatility

In order to examine the impact of increasing closing auction shares on market volatility, we estimate Equation (3) using return volatility and range volatility as dependent variables. Table 8 provides the results of this analysis for the full sample as well as for each index subsample. We find a positive impact of increasing closing auction shares, independent of the measure of market volatility, the venue, and the time of the continuous trading phase (whole trading day or last 30 minutes).

Analyzing the entire continuous trading phase, *Panel A* shows that both return volatility and range volatility decrease for the full sample due to an increase in the closing auction share. Considering the full sample, a one percent increase of the closing auction share leads to a 0.099% (0.134%) decrease of the return volatility (range volatility). This effect remains similar during the last 30 minutes of the continuous trading, where a one percent increase of the closing auction share lowers the return volatility of the full sample by 0.094% and the range volatility by 0.131% all being significant at the 1%-level. Again, these results are economically meaningful. Thinking of a stock whose auction volume shifts from the lowest quintile to the largest quintile, this stock experiences a reduction of intraday return volatility by 26.83% (25.47% in the last 30 minutes of trading). Dividing the stocks in the three index subsamples confirms the aforementioned results. Only the magnitude of the volatility reduction differs slightly across the different venues with a stronger effect for CAC and DAX stocks than for FTSE stocks.

The remaining regressors in Table 8 all show the expected sign and are all highly significant. Increasing relative spreads lead to an increase in market volatility. The same is true for expiry days of derivative contracts and MSCI rebalancing days where large volumes are traded fostering volatility. Furthermore, the market turbulences in spring 2020 caused by the outbreak of the COVID-19 pandemic are associated with higher volatility.

In summary, we find that increasing closing auction volumes lead to a decrease in volatility. This effect is of similar magnitude for the entire continuous trading session as well as for the last 30 minutes of trading before the close. The result is also independent from the measure of market volatility, since both return volatility and range volatility decrease with increasing closing auction volumes. This is in line with theoretical predictions and empirical studies investigating the closing auction introduction in Table 1. Consequently, our results show that also high-volume auctions retain the beneficial effect of closing auctions on intraday volatility.

Table 8: Two-stage least squares regression results for volatility

This table shows the regression results for the impact of increasing closing auction volumes on volatility during the entire continuous trading phase (*Panel A*) and the last 30 minutes of continuous trading (*Panel B*) based on Equation (3). The dependent variables measuring volatility are *return vola* and *range vola*. As independent variables we use the *closing auction share (CA share)*, *relative spread* and dummy variables for *derivative expiry days*, *MSCI rebalancing days* and the *COVID-19 outbreak*. Additionally, we add dummy variables to control for *year*, *weekday*, and *venue*. All non-binary regression variables are transformed by taking the natural logarithm. Standard errors are clustered by stock and day.

Panel A: Daily	return vola				range vola			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	0.2650***	0.1777***	0.3706***	0.3592***	0.4133***	0.3185***	0.5546***	0.5126***
CA share	-0.0988***	-0.0832***	-0.1224***	-0.1439***	-0.1342***	-0.1176***	-0.1663***	-0.1849***
Rel. spread	0.0724***	0.0647***	0.0693***	0.1106***	0.0604***	0.0537***	0.0515***	0.0990***
Expiry	0.1496***	0.1363***	0.1709***	0.1663***	0.1716***	0.1609***	0.1887***	0.1925***
MSCI	0.1381***	0.1357***	0.1366***	0.1592***	0.1605***	0.1705***	0.1443***	0.1653***
COVID	0.1023***	0.1170***	0.1199***	0.0345**	0.1083***	0.1242***	0.1185***	0.0484***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0740	0.0661	0.0891	0.0983	0.1002	0.0952	0.1137	0.1210
N	117,966	69,569	29,891	18,506	117,966	69,569	29,891	18,506

Panel B: Last 30min	return vola				range vola			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	0.2718***	0.1860***	0.4023***	0.4087***	0.3450***	0.1965***	0.5452***	0.5630***
CA share	-0.0935***	-0.0753***	-0.1251***	-0.1485***	-0.1313***	-0.1023***	-0.1764***	-0.2125***
Rel. spread	0.0586***	0.0502***	0.0573***	0.0959***	0.0951***	0.0897***	0.0838***	0.1375***
Expiry	0.1478***	0.1324***	0.1728***	0.1713***	0.1756***	0.1618***	0.1908***	0.2117***
MSCI	0.1343***	0.1310***	0.1356***	0.1587***	0.3155***	0.3114***	0.3250***	0.3302***
COVID	0.1093***	0.1238***	0.1282***	0.0391***	0.1408***	0.1616***	0.1406***	0.0785***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0693	0.0604	0.0880	0.0968	0.0663	0.0639	0.0684	0.0851
N	117,963	69,566	29,891	18,506	117,963	69,566	29,891	18,506

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

5.4. Robustness tests

To ensure robustness of our results, we perform several additional tests where we change certain parameters of our analysis. First of all, since the data availability differs for the three analyzed venues, we repeat our analysis by starting in February 2019 where the necessary data is equally available for all analyzed stocks. Tables A.3 and A.4 in the appendix report the results of this analysis. Our findings remain the same and the coefficients are highly comparable. In addition, all coefficients remain highly significant.

Since the descriptive analysis has revealed that MSCI rebalancing days and derivatives expiry days are major drivers of high closing auction volumes, we repeat our analysis by explicitly excluding these days although we control for them in our main analysis. The results remain nearly identical so that we do not tabulate them. That gives further evidence to our results, making them more independent from the exact regression specification.

As a third robustness test, we vary the way how we normalize liquidity and volatility measures. Besides of our normalization of the liquidity and volatility measures by dividing them through their 21 previous trading days average (i.e., roughly one month), we repeat our analysis by considering the previous 30 and 42 trading days instead. By doing so, the not tabulated results remain very similar and the effects are even slightly stronger.

Last, we change our measure of high closing auction volumes. Instead of taking the percentage of the closing auction volume relative to the overall trading volume in a stock on a given day, we simply take the natural logarithm of the closing auction volume. Thereby, we do not control for the general level of trading activity on a given day. Again, our results concerning relative spreads remain the same (see Table A.5 in the appendix). Concerning order book depth, the results are less clear although we also see a decrease in the available volume for two of the three index subsamples. Due to the high correlation of trading activity and volatility, we only use this alternative measure of closing auction volume for the liquidity analysis. Since the absolute closing auction volume does not control for the general level of trading activity, the closing auction share is the better measure to analyze the impact of high-volume closing auctions on intraday volatility.

6. Conclusion

Driven by the rise in passive investments and the high trading interest of investors at the close, global equity markets witnessed an enormous increase in closing auction volumes in recent years, especially in Europe. In the three major European markets analyzed in this study, the closing auction on average accounts for one third of total daily trading volume. Although closing auctions have proven as well-functioning mechanisms to close markets, which was also confirmed by empirical studies analyzing the introduction of closing auctions (e.g., Kandel et al., 2012; Pagano et al., 2013), it remains unclear whether closing auctions are still efficient and beneficial for price discovery and market quality when huge volumes, mainly driven by passive investments, are executed at a single uniform price.

Based on our sample of high-volume closing auctions, we find evidence for systematic distortions of the closing price. Specifically, we observe that 23% of the closing auction return are reversed over night. This reversal also persists during the first 30 minutes of trading on the next day. For the largest closing auctions in our sample that account more than 50% of daily trading volume, the price distortion even persists for almost two hours after the opening auction on the next day. Short-term supply and demand imbalances in the closing auction caused by one-sided order flow from passive index tracking strategies can serve as an explanation for the price distortion. Although contrasting with the empirical literature on the introduction of closing auctions, our results are in line with recent papers based on the US market. While closing auction shares in the US are substantially lower compared to those in European markets, Jegadeesh and Wu (2022) find that 21% to 43% of the closing auction return are being reversed the next day, depending on whether NYSE or Nasdaq auctions are analyzed. Bogousslavsky and Muravyev (2021) even find that closing auction returns are almost completely reversed the next day. Yet, Comerton-Forde and Rindi (2021), who also analyze price discovery of European closing auctions, find only limited evidence for distortions of closing prices.

Concerning intraday market quality, we document that the immense shift of trading volumes to the close adversely affects liquidity in terms of higher relative spreads and lower order book depth. This result not only holds for the last minutes of the continuous trading phase but for the entire trading day, which increases implicit transaction costs for investors. Again, this finding contrasts with the literature on the introduction of closing auctions. Our results indicate that high-volume closing auctions indeed lead to shifts of uninformed order flow (e.g., order flow from index tracking strategies) to the liquidity pool at the close thereby increasing adverse selection costs for liquidity providers during the continuous trading phase as predicted by theoretical models (Admati and Pfleiderer, 1988, 1991). Thus, while the mere existence of a closing auction with decent volume increases liquidity due to increased patience of traders as noted by Kandel et al. (2012), volume shifts and increased information asymmetry seem to dominate this positive effect in case of high-volume closing auctions. Besides adverse affects on intraday liquidity, we find beneficial effects of increasing closing auction volumes on intraday volatility also for the high-volume auctions analyzed in this study. Again, this effect holds not only for the last 30 minutes of trading before the auction start but for the entire continuous trading phase. In line with existing theories on the impact of closing auctions, we find that high-volume closing auctions still lead to this beneficial effect for intraday market quality. Besides the reasons elaborated on by theoretical models, this volatility dampening effect might result from the volume shifts to the close and the correlation between trading volume and volatility.

In summary, our findings demonstrate that the increase in closing auction volumes worldwide should receive more attention from regulators, exchange operators, and researchers as they come with negative consequences for market efficiency. First, our results provide evidence for distortions of closing prices due the high volumes being executed in closing auctions and resulting supply and demand imbalances from one-sided, uninformed order flow. Because of the importance of closing prices for investors' trading decisions, portfolio evaluations, and many more applications in financial markets, this development should be investigated further in future research. Second, we find that the shift of investors' trading interest to the close negatively affects liquidity during the rest of the day. Although we observe a dampening effect of increasing closing auction volumes on intraday volatility, this development needs to be watched by regulators and exchange operators since it not only increases transaction costs for investors during the trading day but might amplify the trend of trading at the close in the sense of the "liquidity-begets-liquidity"-effect (Admati and Pfleiderer, 1988). Regulators should also carefully design and evaluate new regulatory actions so that they do not further accelerate the trend of increasing closing auction volumes. To ensure efficient closing auction prices despite the large trading interest of uninformed, index-tracking order flow that often comes in the same direction, exchange operators could implement and expand matching facilities that allow order execution at the closing price after the closing auction without market impact and the possibility to distort the closing price.

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Appendix

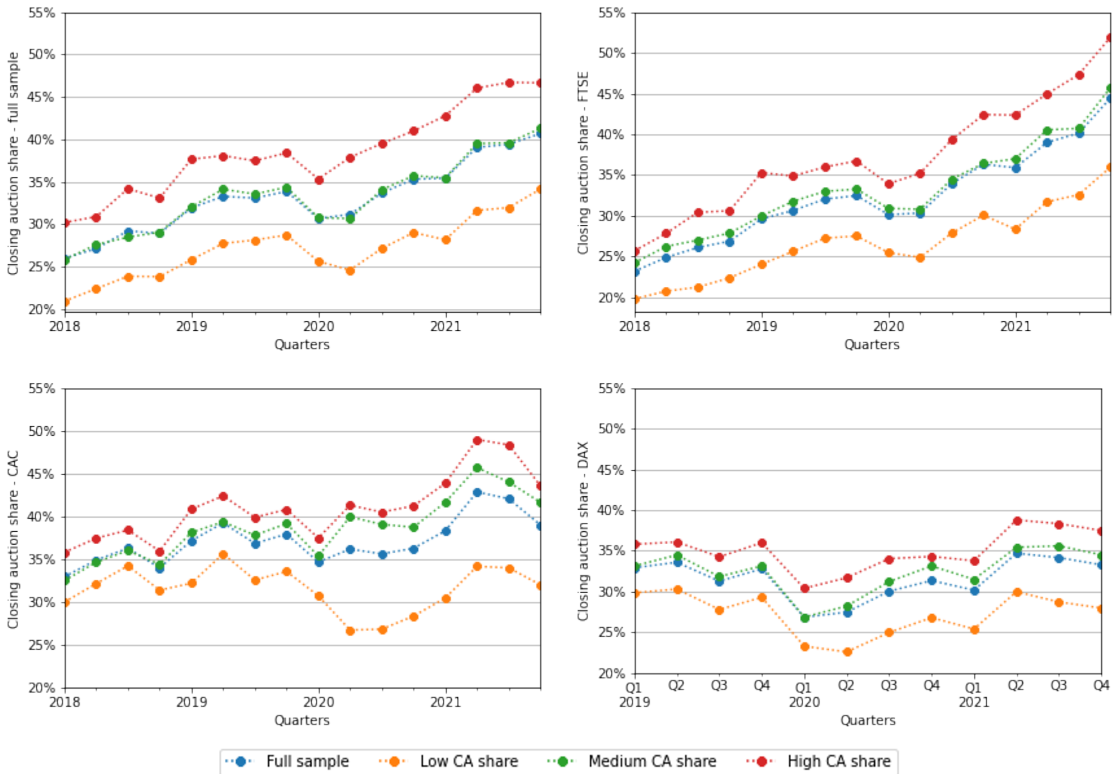

Figure A.1: Quarterly averages of the closing auction share for different subsets

This figure plots the average quarterly closing auction shares for subsamples dividing the data set into thirds based on closing auction share for all indices as well as for each index separately.

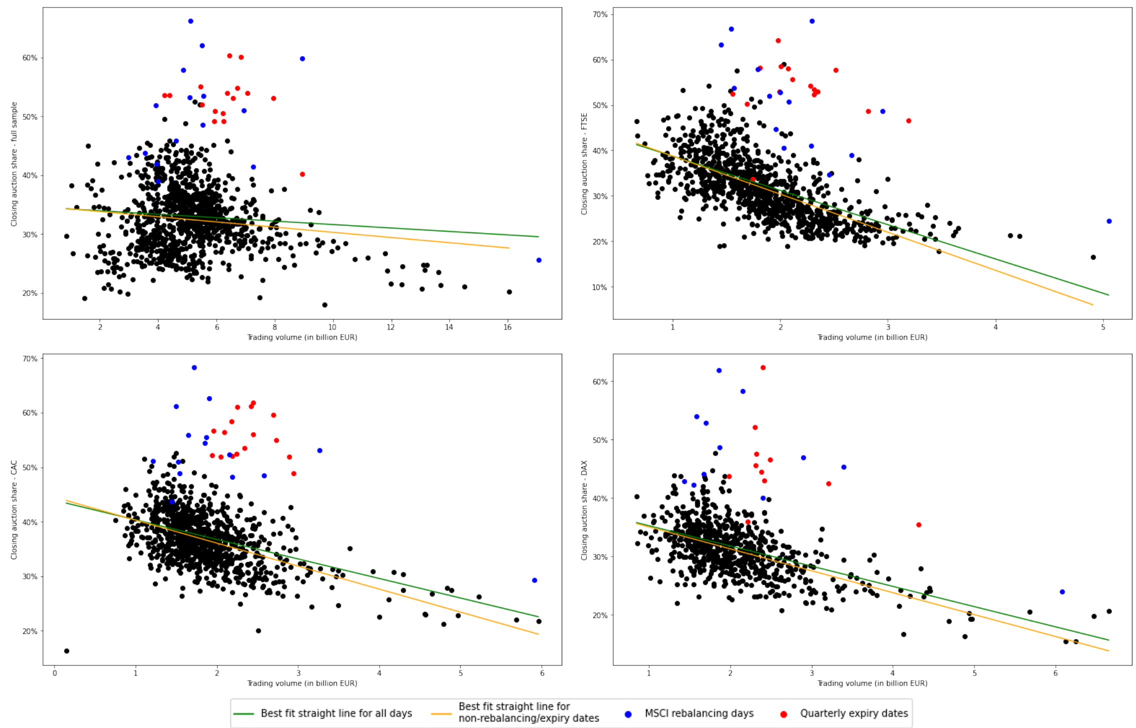

Figure A.2: Relation of trading volume during continuous trading and closing auction share

This figure plots the closing auction share for every stock and day relative to trading volume in EUR during continuous trading. MSCI rebalancing days and derivatives expiry days are indicated in blue and red, respectively. The estimated fit straight line indicates that the relationship between trading volume in the continuous trading phase and the share of the closing auction relative to total daily trading volume are negatively related, i.e., trading volume shifts from continuous trading to the close with rising closing auction shares.

Table A.1: Descriptive statistics per year, index, and time during continuous trading

This table shows descriptive statistics for the full sample and subsamples for each index for each year during the observation period. Panel A provides the daily means of the analyzed market quality measures for the whole continuous trading phase whereas Panel B shows the means for the last 30 minutes of continuous trading directly before the start of the closing auction.

	Full				FTSE				CAC				DAX		
Panel A: Daily	2018	2019	2020	2021	2018	2019	2020	2021	2018	2019	2020	2021	2019	2020	2021
Trading volume	42,715.5	42,918.2	48,360.8	39,435.4	33,522.2	26,598.8	24,088.0	20,883.7	66,520.2	56,681.1	65,576.6	52,854.5	73,833.4	93,816.6	73,205.5
Number of trades	7.10	6.64	9.11	7.77	6.52	5.48	6.42	5.5	8.59	7.76	12.26	10.73	8.64	12.68	10.32
Relative spread	4.54	4.42	6.14	4.47	4.78	4.99	7.18	5.42	3.92	3.82	5.10	3.26	3.50	4.59	3.42
L1-volume	68.81	73.22	49.07	51.05	51	42.80	25.91	27.73	114.78	114.81	66.55	61.23	109.26	90.84	101.03
Return vola	9.88	10.06	16.60	11.14	10.00	10.39	17.11	11.70	9.56	9.43	16.85	10.62	9.91	14.94	10.30
Range vola	13.54	13.39	23.16	14.99	13.51	13.29	22.61	14.96	13.61	12.92	24.73	15.18	14.33	22.76	14.83
Panel B: Last 30min															
Trading volume	4,961.87	4,459.06	5,041.13	3,901.65	4,034.86	3,033.52	2,851.71	2,337.55	7,362.22	5,712.74	6,705.7	5,102.47	7,091.53	9,007.58	6,663.46
Number of trades	0.80	0.66	0.94	0.76	0.75	0.59	0.74	0.61	0.92	0.74	1.20	0.99	0.78	1.16	0.89
Relative spread	3.86	3.69	4.77	3.62	3.98	4.01	5.37	4.24	3.54	3.43	4.19	2.82	3.03	3.83	2.91
L1-volume	91.42	98.85	65.51	64.17	71.18	63.16	36.94	38.46	143.83	147.64	88.40	77.56	141.66	115.86	117.31
Return vola	9.88	10.06	16.59	11.14	10.00	10.39	17.09	11.68	9.56	9.42	16.85	10.61	9.91	14.94	10.30
Range vola	14.85	12.94	23.6	14.2	14.81	13.05	23.4	14.68	14.96	12.58	24.79	13.83	13.08	22.74	13.37
Both panels															
Number of stocks	105	131	131	131	73	73	73	73	32	32	32	32	26	26	26
CA share	27.84	33.1	32.74	38.65	25.23	31.19	32.83	39.81	34.56	37.79	35.71	40.68	32.58	28.93	33.07
Market cap	33.29	35.74	32.43	40.22	28.87	28.56	23.69	28.97	44.70	47.61	44.79	57.00	41.50	41.30	49.76

Note: Trading volume and number of trades are daily (30 minute) sums, the other daily (30 minute) means.

Table A.2: Closing price reversals with half spread adjusted returns

This table reports the results of the regression of overnight returns on closing auction returns adjusted for the half spread. Specifically, the estimated β_1-coefficient of Equation (1) is provided for the full sample as well as for the different index subsamples (FTSE, CAC, DAX). The adjusted closing auction return (Adj. AR) is calculated as the log return of the last midpoint in continuous trading and the closing price adjusted by the half-spread. The adjusted overnight return (Adj. OR) is calculated as the the log return of the closing price and the opening price at the next day as well as the average midpoints of the five minutes intervals from 8:00 until 8:40 at the next day all adjusted by the half-spread. Standard errors are double-clustered by stock and day and reported in parentheses.

	Adjusted Overnight Return								
Stocks	**Open Price**	**08:05**	**08:10**	**08:15**	**08:20**	**08:25**	**08:30**	**08:35**	**08:40**
(Adj. AR) Full	-0.17**	-0.17**	-0.16*	-0.11	-0.08	-0.09	-0.08	-0.09	-0.09
	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.11)	(0.12)
(Adj. AR) FTSE	-0.16**	-0.16**	-0.15*	-0.08	-0.05	-0.04	-0.02	-0.03	-0.03
	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)	(0.08)	(0.11)	(0.11)
(Adj. AR) CAC	-0.14*	-0.13*	-0.12	-0.08	-0.08	-0.09	-0.1	-0.12	-0.12
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.10)	(0.11)	(0.11)
(Adj. AR) DAX	-0.32*	-0.34*	-0.28	-0.27	-0.27	-0.31	-0.34	-0.29	-0.29
	(0.18)	(0.17)	(0.18)	(0.18)	(0.19)	(0.20)	(0.20)	(0.22)	(0.23)

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table A.3: Two-stages least squares regression results for liquidity with the data starting in 2019

This table shows the regression results for the impact of increasing closing auction volumes on stock market liquidity during the entire continuous trading phase (*Panel A*) and the last 30 minutes of continuous trading (*Panel B*) based on Equation (3). The dependent variables measuring liquidity are *relative spread* and *L1-volume*. As independent variables we use the *closing auction share (CA share)*, *return volatility* and dummy variables for *derivative expiry days*, *MSCI rebalancing days* and the *COVID-19 outbreak*. Additionally, we add dummy variables to control for *year*, *weekday*, and *venue*. All non-binary regression variables are transformed by taking the natural logarithm. Standard errors are clustered by stock and day.

Panel A: Daily	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.5083***	-0.4556***	-0.5486***	-0.9923***	0.3639***	0.2748***	0.4946***	0.7487***
CA share	0.0553***	0.0454***	0.0714***	0.1473***	-0.0423***	-0.0319***	-0.0712***	-0.1006***
Return vola.	0.1277***	0.1196***	0.1209***	0.2069***	-0.0968***	-0.0720***	-0.1098***	-0.1807***
Expiry	0.0164***	0.0041	0.0278**	-0.0043	0.0115*	-0.0029	0.0282**	0.0631***
MSCI	-0.0191***	-0.0209***	-0.0104	-0.0651***	0.0211***	0.0264***	0.0269**	0.0284*
COVID	0.0263***	0.0513***	0.0217**	-0.0572***	-0.1394***	-0.1578***	-0.1669***	-0.0348***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0940	0.1041	0.0768	0.1034	0.0737	0.0661	0.0966	0.0799
N	91,299	50,393	22,400	18,506	91,299	50,393	22,400	18,506

Panel B: Last 30min	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.3743***	-0.3611***	-0.3254***	-0.7469***	0.4235***	0.4209***	0.4206***	0.5594***
CA share	0.0375***	0.0354***	0.0357***	0.1038***	-0.0499***	-0.0580***	-0.0500***	-0.0580***
Return vola.	0.0972***	0.0920***	0.0811***	0.1645***	-0.1180***	-0.1023***	-0.1212***	-0.1682***
Expiry	0.0125**	0.0034	0.0298**	-0.0118	0.0095	-0.0047	0.0340**	0.0338*
MSCI	0.0119**	0.0033	0.0307***	-0.0178	0.0357***	0.0733***	0.0082	-0.0118
COVID	0.0336***	0.0546***	0.0319***	-0.0322***	-0.1717***	-0.1980***	-0.2003***	-0.0637***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0418	0.0406	0.0375	0.0549	0.0567	0.0505	0.0779	0.0612
N	91,274	50,368	22,400	18,506	91,274	50,368	22,400	18,506

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table A.4: Two-stage least squares regression results for volatility with the data starting in 2019

This table shows the regression results for the impact of increasing closing auction volumes on volatility during the entire continuous trading phase (*Panel A*) and the last 30 minutes of continuous trading (*Panel B*) based on Equation (3). The dependent variables measuring volatility are *return vola* and *range vola*. As independent variables we use the *closing auction share (CA share)*, *relative spread* and dummy variables for *derivative expiry days*, *MSCI rebalancing days* and the *COVID-19 outbreak*. Additionally, we add dummy variables to control for *year*, *weekday*, and *venue*. All non-binary regression variables are transformed by taking the natural logarithm. Standard errors are clustered by stock and day.

Panel A: Daily	return vola				range vola			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	0.3010***	0.2272***	0.3407***	0.3592***	0.4445***	0.3669***	0.4948***	0.5126***
CA share	-0.1126***	-0.1037***	-0.1160***	-0.1439***	-0.1469***	-0.1374***	-0.1523***	-0.1849***
Rel. spread	0.0800***	0.0760***	0.0675***	0.1106***	0.0669***	0.0637***	0.0493***	0.0990***
Expiry	0.1467***	0.1291***	0.1722***	0.1663***	0.1793***	0.1699***	0.1949***	0.1925***
MSCI	0.1668***	0.1728***	0.1663***	0.1592***	0.1991***	0.2291***	0.1741***	0.1653***
COVID	0.0967***	0.1082***	0.1210***	0.0345**	0.1032***	0.1156***	0.1202***	0.0484***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0800	0.0741	0.0870	0.0983	0.1056	0.1046	0.1064	0.1210
N	91,299	50,393	22,400	18,506	91,299	50,393	22,400	18,506

Panel B: Last 30min	return vola				range vola			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	0.3125***	0.2361***	0.3733***	0.4087***	0.4119***	0.2900***	0.4964***	0.5630***
CA share	-0.1086***	-0.0951***	-0.1198***	-0.1485***	-0.1540***	-0.1352***	-0.1669***	-0.2125***
Rel. spread	0.0668***	0.0612***	0.0585***	0.0959***	0.1047***	0.1033***	0.0841***	0.1375***
Expiry	0.1459***	0.1255***	0.1750***	0.1713***	0.1975***	0.1896***	0.2105***	0.2117***
MSCI	0.1637***	0.1683***	0.1660***	0.1587***	0.3477***	0.3625***	0.3423***	0.3302***
COVID	0.1033***	0.1152***	0.1278***	0.0391***	0.1327***	0.1487***	0.1408***	0.0785***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0758	0.0684	0.0868	0.0968	0.0730	0.0727	0.0707	0.0851
N	91,297	50,391	22,400	18,506	91,297	50,391	22,400	18,506

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table A.5: Two-stage least squares regression results for liquidity with absolute closing auction volume

This table shows the regression results for the impact of increasing closing auction volumes measured by absolute closing auction volume (CA absolute) on stock market liquidity during the entire continuous trading phase (*Panel A*) and the last 30 minutes of continuous trading (*Panel B*) based on Equation (3). The dependent variables measuring liquidity are *relative spread* and *L1-volume*. As independent variables we use the *closing auction volume (CA absolute)*, *return volatility* and dummy variables for *derivative expiry days*, *MSCI rebalancing days* and the *COVID-19 outbreak*. Additionally, we add dummy variables to control for *year*, *weekday*, and *venue*. All non-binary regression variables are transformed by taking the natural logarithm. Standard errors are clustered by stock and day.

Panel A: Daily	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.3807***	-0.3464***	-0.4034***	-0.5002***	0.1966***	0.1083***	0.3152***	0.4387***
CA absolute	0.0121***	0.0100***	0.0179***	0.0151***	-0.0004	0.0049***	-0.0105***	-0.0129***
Return vola.	0.1068***	0.1049***	0.0911***	0.1459***	-0.0891***	-0.0696***	-0.0988***	-0.1388***
Expiry	0.0153***	0.0026	0.0223***	0.0472***	-0.0013	-0.0146**	0.0154	0.0312**
MSCI	-0.0191***	-0.0275***	-0.0082	-0.0107	0.0090*	0.0137**	0.0074	-0.0066
COVID	0.0265***	0.0473***	0.0333***	-0.0497***	-0.1366***	-0.1528***	-0.1675***	-0.0393***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0881	0.0945	0.0747	0.1065	0.0627	0.0546	0.0854	0.0779
N	117,966	69,569	29,891	18,506	117,966	69,569	29,891	18,506

Panel B: Last 30min	relative spread				L1-volume			
	Full	FTSE	CAC	DAX	Full	FTSE	CAC	DAX
Constant	-0.3232***	-0.3014***	-0.3103***	-0.4365***	0.2243***	0.1622***	0.3037***	0.4001***
CA absolute	0.0116***	0.0104***	0.0141***	0.0143***	-0.0008	0.0028*	-0.0081***	-0.0094**
Return vola.	0.0834***	0.0817***	0.0679***	0.1211***	-0.1070***	-0.0929***	-0.1144***	-0.1439***
Expiry	0.0040	-0.0058	0.0154	0.0198	-0.0138**	-0.0364***	0.0222*	0.0179
MSCI	0.0087**	-0.0023	0.0260***	0.0176	0.0079	0.0255***	-0.0084	-0.0304*
COVID	0.0325***	0.0501***	0.0345***	-0.0278**	-0.1693***	-0.1902***	-0.1996***	-0.0659***
Year and Weekday	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Venue dummy	Yes	-	-	-	Yes	-	-	-
Adj. R-squared:	0.0406	0.0385	0.0372	0.0642	0.0519	0.0450	0.0720	0.0623
N	117,920	69,523	29,891	18,506	117,920	69,523	29,891	18,506

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$