J. Finan. Intermediation 21 (2012) 23–49

Contents lists available at ScienceDirect

J. Finan. Intermediation

journal homepage: www.elsevier.com/locate/jfi

The effect of a closing call auction on market quality and trading strategies

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A R T I C L E I N F O

Article history:
Received 29 May 2008
Available online 1 April 2011

JEL classification:
G14
G15
G18

Keywords:
Market design
Reference price
Closing auction
Closing price
Market quality
Price discovery
Liquidity provision

A B S T R A C T

We study the effects of the introduction of a closing auction (CA) on the microstructure on the continuous trading phase in Borsa Italiana and Paris Bourse. We postulate and compare several empirical predictions based on both standard Kyle-type models and more recent models of limit order book. We find that while the CA has no effect during most of the day, its effect on the last minutes of trading is dramatic. We document a sharp decline in volume, associated with a significant reduction in spread and volatility, and an increase in aggressiveness of liquidity suppliers during the last minutes. We show that the differences in the Reference Price algorithm between Milan and Paris have a significant effect: the CA attracts greater volumes when the Reference Price is equated to the CA price.

1. Introduction

Exchanges and regulators around the world pay much of attention to the process that determines the opening and the closing prices of securities traded in continuous electronic limit order markets. While an efficient opening mechanism is important for the price discovery process at the beginning of the trading day, an equally efficient mechanism of price formation is also necessary to guarantee

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1042-9573/$ - see front matter
doi:10.1016/j.jfi.2011.03.002

Table 1
Market closing method and Reference Price algorithm in equity markets around the world in 2006.

Exchange	Closing call auction	Reference price determination	Comments
US and North America			
NYSE	Partly[a]	Last trade	
Nasdaq	Yes[b]	Closing Cross price	Cross introduced in April 2004
Toronto	No	Last trade	
Europe			
Bolsa in Madrid	Yes	Closing auction price	
Borsa Italiana	Yes	Weighted Average	VWAP of the last 10% of the daily volume including the CA
Paris Bourse (Amsterdam, Brussels, Lisbon, Paris)	Yes	Closing auction price	
London Stock Exchange (SETS)	Yes	Closing auction price	
Deutsche Boerse (Xetra)	Yes	Closing auction price	
OMX – Stockholm	Yes	Closing auction price	
OMX – Copenhagen	No	Last Trade	
OMX – Helsinki	No	Last Trade	
Oslo	Yes	Closing auction price	
Wien Börse	Yes	Closing auction price	
Zurich	Yes	Closing auction price	
Other countries			
Tokyo	Yes	"Itayose" method	Orders can be submitted from 12:05 to 14:59:59 and have no time priority
Hong Kong	No	Median	Uses the median of the last five transaction prices in the last minute of trading
Tel Aviv Stock Exchange	Yes	Weighted average	Chooses the smaller of: the weighted average of the transaction prices in the last half-hour of trading, and the weighted average of the prices of the pre-specified volume at the end of the day

[a] At the NYSE the closing price is set by the specialist who collects market-on-close orders sent him in advance both by the Opening Automatic Report System (OARS), and by floor brokers. The OARS calculates trading volume and imbalances at each available price and the specialist chooses the clearing price that minimizes the market imbalance. The specialists can also post proprietary orders, or in case of price changes that look anomalous with respect to the previous closing price, he can halt trading and publicize information on the imbalance to attract new order flow. Notice that following the merger with Archipelago, NYSE stocks closing prices are also set at the NYSE Arca closing auction. The design of the Arca closing auction differs slightly from the European one as the closing price is set to maximize executable volume and if more than one price achieves this goal, than the system chooses the price that is closest to the previous closing price (http://www.archipelago.com/traders/auction.asp).

[b] There are two differences between the design of the Nasdaq closing cross and the European closing auction: firstly, on the Nasdaq the pre-closing phase overlaps with the continuous auctions, whereas in Europe the pre-auction phase starts when the continuous section finishes; secondly, while the first two principles governing the price formation algorithm are the same as the European ones, the third and last one aims to minimize the distance of the equilibrium closing price with the prevailing best bid-ask midpoint.

that the closing price is as reflective of the fundamental value as possible. The closing price is important because it serves as the Reference Price (RP) for the settlement of financial contracts. Mutual and provident funds' NAV calculations, option expirations, and the entry of stocks into various indexes are generally based on the RP, as are most compensation contracts. Thus exchanges and regulators strive to ensure that the price formation mechanism at the end of the trading day is efficient and manipulation-resistant.[1]

While most equity markets around the world are predominantly organized today as a continuous Limit Order Book (LOB), there is no uniformity in their closing mechanisms. Table 1 presents four basic mechanisms for closing the market and calculating the RP: some markets end the trading day with the last trade of the continuous phase, in which case the RP can be calculated as the price of the last trade,

[1] The closing prices are also of crucial importance for researchers using daily data in empirical Asset Pricing.

or the weighted average price of some proportion of the daily volume. Alternatively, the market closes with a Call Auction (CA) in which case the RP can be calculated either as the CA price, or again as a weighted average of some proportion of volume towards the end of the day including the CA volume.[2]

Many markets around the world introduced the CA in the last 10 years. This event, while endogenous for the exchange as an organization, is exogenous for the market participants (almost a natural experiment), who must adjust their behavior to the new environment. This feature allows us to test the effects of the introduction of the CA on the quality of the continuous auction market and on the trading strategies of market participants. In particular, we would like to learn whether the CA's effect mainly works through the information asymmetry channel, or through the liquidity provision channel. To this end we utilize the introduction of the CA in the Italian market in 2001 as well as the 1998 introduction of the CA in the Paris Bourse. The two exchanges are fairly similar, except that Paris Bourse started calculating the RP as the CA price, while Milan continued to use the weighted average method. Hence we also compare two different RP calculation algorithms.

We postulate empirical predictions based on several especially relevant papers: Admati and Pfleiderer (1988, 1991) as representative of the Kyle-type models with impatient informed and uninformed traders; Kaniel and Liu (2006), who allow informed traders to be more patient, and supply liquidity as well as demanding it; Foucault et al. (2005) and Rosu (2009) as representatives of the recent literature on immediacy provision in order-driven markets, without information asymmetry; and Foucault (1999) and Buti and Rindi (2009) as LOB models with picking-off risk. We study the effects on volume allocation, spreads, volatility, trade size, price discovery and order submission strategies. We also compare the effects of the two methods for calculating the Reference Price across the two exchanges.

The results show that the introduction of the CA in Milan and in Paris had very little effect on the market throughout most of the day except the very last minutes, where the effect was very dramatic. This suggests that comparing the measures of market quality over the longer time intervals may not reveal the full impact of the introduction of the CA. Following the adoption of this mechanism, a significant portion of daily volume moves to the CA, associated with a significant decline in volume, spreads and volatility in the last minutes of the continuous phase. At the same time, trade size decreases, price discovery improves, and limit orders become more aggressive right before the close.

While the reduction of volatility may follow from all the models mentioned above, the reduction in spreads and the improvement in price discovery contradict the predictions of the Admati and Pfleiderer (1988) model, which is representative of a large body of literature, and in which impatient traders seek liquidity from a market maker. The findings are consistent with the models in which the trade horizon matters, as traders can choose whether to supply or demand liquidity depending on whether they are informed (as in Kaniel and Liu, 2006), or uninformed (as in Foucault et al. (2005), and Rosu (2009)), as well as on the degree of their impatience. We do not treat this evidence to refute the information story, but rather to state that in this particular case the liquidity effects are much stronger.

Finally, we show that the choice of the algorithm to calculate the RP has a significant effect on the trading pattern at the close, especially during the volatile days, when everybody prefers to trade in the deep CA regardless of the algorithm used. We show that equating the RP with the CA price attracts more volume to the CA and makes the RP less dependent on the past.

Even though a CA has been introduced in a large number of financial markets around the world, the literature on the subject is not very large, and mostly focuses on the CA rather than the preceding continuous phase. Hillion and Souminen (2004) demonstrate that the introduction of a CA in Paris Bourse reduced price manipulation at the end of the continuous phase, reducing transitory volatility. Pagano and Schwartz (2003) study the same event and show that price discovery improves and the volatility of the closing price declines for illiquid stocks. They show that the quality of the market in the last half hour of the continuous phase does not seem to deteriorate after CA, but provide little insight on the microstructure. Aitken et al. (2005) study the introduction of a CA into the Australian Stock Exchange and, using half-hourly data, find mixed results. Their findings are further complicated

[2] In 2004 the NASDAQ introduced a crossing mechanism that overlaps with the last 10 min of the continuous trading. A similar mechanism was in effect in Tel Aviv before July 2007. This mechanism does not determine the price.

by the fact that the exchange uses an inefficient algorithm, as shown by Comerton-Forde and Rydge (2006). Ellul et al. (2005) analyze the CA in London, where it is introduced as an alternative trading venue to a dealer market, thus cannot be used to study the effect on the LOB.

NASDAQ introduced a closing cross in 2004 that overlaps with the final minutes of continuous trading. This feature allows agents to choose their preferred trading venue since they can submit orders to both at the same time. Smith (2005) shows that NASDAQ volume allocation across venues depends on the Reference Price on that day. In a recent paper Pagano et al. (2008) show that NASDAQ opening and closing crosses significantly reduce volatility at the open and at the close, and that lower volatility improved price discovery for NASDAQ stocks.

The paper is organized as follows: Section 1 focuses on the most relevant literature and presents testable hypotheses in light of the existing theories; Section 2 describes the general features of Borsa Italiana and Euronext as well as our sample. Section 3 discusses the empirical results and Section 4 concludes the paper.

2. Empirical hypotheses

In this section we rely on existing theories to discuss the effects of the introduction of a CA on the quality of the continuous auction market at the end of the trading day and make empirical predictions.

2.1. Summary of theoretical papers

The standard model of Admati and Pfleiderer (1988) (AP) draws on Kyle (1985) where informed and uniformed traders alike always demand liquidity (extremely impatient) from a competitive market maker, who sets the market clearing price to reflect the conditional expected value of the asset based on the aggregate order flow. The innovation of the AP paper is that informed and uninformed traders can choose the timing of their trades throughout the day, which leads to an endogenous emergence of active trading sessions, when all traders prefer to congregate to minimize their price impact (the Kyle's λ). This predicts the appearance of endogenous spikes in trading volumes during the day, but does not predict when these spikes should occur. Empirically, such spikes are well documented at the opening and towards the close of the continuous trading phase in a market without a closing auction (e.g., McInish and Wood, 1992).[3]

AP allow for some flexibility, but still focus on the adverse selection costs imposed by informed traders on liquidity suppliers. While their traders seem patient, as they are allowed to choose the timing of their trading throughout the day, at the same time they are precluded by assumption from providing liquidity and earning the spread. This makes the model less applicable to the study of order driven equity markets where traders can choose whether to demand or supply liquidity, depending on how impatient they are to trade.[4] Thus considerations of time must be important in this decision and the equilibrium price must reflect the strategic interaction of liquidity suppliers with liquidity demanders and consequently their degree of impatience.

Kaniel and Liu (2006) go one step further: they use the Glosten and Milgrom (1985) framework, but allow the informed traders to choose between market and limit orders depending on the longevity of their private information (which determines their patience in this context). Traders with long-lived private information choose to submit limit orders (as long as they have time to trade on it), as market orders reveal this information too quickly. Consequently, the trading horizon of the patient informed traders is negatively correlated with their aggressiveness. Kaniel and Liu (2006) model is still quote driven, and does not embed the strategic choice of liquidity provision, but it does introduce the time horizon as an important feature of the trading environment.

Foucault et al. (2005)[5] assume away the information asymmetry and focus instead on strategic liquidity traders. They model the interaction between patient traders (long-term players, such as pension

[3] In their paper on "sunshine trading" Admati and Pfleiderer (1991) suggest that when traders can move to a new trading venue that gathers more liquidity, there should be less price impact per unit of aggregate volume.

[4] This feature may be the main reason for the adoption of the limit order book format in equity markets worldwide.

[5] One could also derive similar predictions from the model by Rosu (2009).

funds), who serve as liquidity suppliers, and impatient traders (arbitrageurs, day traders, index funds, hedge funds) who demand liquidity.[6] An incoming trader can be either patient or impatient, but has to trade regardless of price. He has to make a decision on the type of order to submit, and this decision depends on his degree of impatience, the proportion of impatient traders in the population, the tick size, and the arrival rate of traders. The resulting equilibrium in a dynamic limit order book is characterized by high spreads and high volatility in a market with even a small majority of impatient traders, and by low spreads and low volatility in a market with even a small majority of patient ones. Thus a change in patience of a small percentage of traders can have a profound effect on spread, volatility, and microstructure noise in prices.

The three papers surveyed above were chosen due to their relevance for the introduction of the CA on the continuous phase, as well as their mutual complementarity: they focus on three different aspects of the process and offer a range of alternative hypotheses. Two additional relevant papers must be mentioned. Foucault (1999) focuses on the effects of volatility on traders' order submission strategies and shows that when volatility decreases, the risk that agents run of being picked off at stale prices decreases and hence they submit more aggressive limit orders. Hillion and Souminen (2004) construct an agency-based model of price manipulation in which brokers execute their clients' orders and then manipulate the closing price to alter the clients' perception of their performance. Their model predicts that the introduction of a CA affects the ability to manipulate the closing price[7] and reduces volatility.

2.2. Empirical predictions

In what follows we use the above models to derive predictions on the effect of the CA introduction on the end of the continuous trading phase. For readers' convenience we summarize the predictions in Table 2.

2.2.1. Predictions on market quality

A CA introduces another opportunity to trade after the close of the continuous trading phase. According to the model of Admati and Pfleiderer (1988) two scenarios are possible: the first is that the CA attract only a small share of volume leaving the main trading session at the end of the continuous phase. We focus on the second scenario that is more consistent with the extant evidence as well as with the evidence we present, that a significant proportion of volume shifts from the end of the continuous phase to the CA.

Many investors, mutual funds for example, have strong incentives to trade at the closing price. Both passively and actively managed mutual funds are subject to unexpected inflows and outflows of capital on a daily basis, which force funds to trade for liquidity (i.e. non-informational) reasons. Since the settlement with the departing/new owners is based on the RP, mutual funds prefer to execute most of these non-discretionary trades at the RP as well, so as not to bear the settlement risk. This is especially true for index funds, which are evaluated solely on their tracking errors. All institutional investors who settle with their clients, or are evaluated by them at the RP, must act in a similar way. Before the introduction of the CA, such funds traded late in the day, thus making the market thicker and attracting other traders to that period as well (consistent with AP predictions). In Paris this effect is profound as the RP was equated to the CA price, thus the volume shift to the CA is expected to be more pronounced in Paris relative to Milan. While the RP algorithm did not change in Milan, the CA volume was included in the computation of the last 10% of the daily volume, thus encouraging index funds to shift much of their trading to the CA as well. According to Admati and Pfleiderer (1988) the rest of the market should follow, making the CA the new high-volume period, replacing the end of the continuous phase. In Milan, this effect should be the most pronounced on days with large price changes, as the difference between the CA price and the RP price increases.

[6] Keim and Madhavan (1995) describe various order submission strategies utilized by various trader types.

[7] Investors may profit from large positions in derivatives, brokers may alter customers' inference of their performance and fund managers may affect their ranking relative to competitors.

Table 2
Empirical predictions on the effects of the introduction of a CA on the continuous auction market This Table reports the empirical predictions offered by the existing theory about the effects of the introduction of a CA on the continuous auction market. More precisely, the reference models are listed in the first column, and the variables of interest are reported in the second row. The latter are indicators of market quality and of order aggressiveness. Notice that for the first three models, namely, Admati and Pfleiderer (1998, 1991) and Kaniel and Liu (2006), that are à la Kyle, predictions for the spread are in terms of price impact (Kyle's λ). Notice also that the indicator of volatility refers to the variance of the theoretical equilibrium prices; the spread is the difference between the best ask and the best bid equilibrium prices; price discovery is the inverse of the equilibrium price variance conditional on all the available information, and finally order aggressiveness refers to the classification reported in Section 3.6.2, with N for neutral limit orders at or within the BBO, NA for non-aggressive orders posted beyond the spread, and A for aggressive orders that are market orders or marketable limit orders. Red arrows indicate predictions that are rejected.

Paper	Intuition	Predictions					
		Spread	Volatility	Price discovery	Limit order aggressiveness		
					NA	N	A
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 Rosu (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 Souminen (2004)	Price manipulation decreases	↓	↓	↑	–	–	–
Foucault (1999) and Buti and Rindi (2009)	When volatility decreases, picking-off risk decreases and traders post more aggressive LO	↓	↓	↑	↓	↑	↑
Results							
Milan		↓	↓	↑	↓	↑	?
Paris		↓	↓	↑	–	–	–

The shift in volume from the end of the continuous trading phase to the CA has direct implications for the liquidity of the former. Admati and Pfleiderer (1988) make clear empirical predictions on market quality during the high and low-volume periods of the trading day: during the high-volume periods the bid-ask spread is lower, volatility is higher and prices are more informative than in the low-volume periods.[8] Hence, if the trading volume shifts from the last minutes of the continuous phase to the CA, then we expect an increase in the bid-ask spread and a reduction in volatility at the end of the continuous trading phase.

The fact that the introduction of a CA offers another opportunity to trade after the end of the continuous phase is largely lost in the Admati and Pfleiderer model: the patience of traders cannot play a role in their order submission strategies. In the context of Kaniel and Liu (2006), the introduction of a CA awards another trading opportunity to informed traders with longer lived information, making them more patient. This encourages them to submit more limit and fewer market orders at the end of the continuous auction, causing a reduction in spread and volatility.

A similar prediction emerges from the liquidity-based model of Foucault et al. (2005) (as well as Rosu, 2009): following the introduction of the CA liquidity demanders receive another chance to trade and many (e.g. mutual funds) become less impatient to trade before the close. As a consequence, they

[8] While the applicability of Admati and Pfleiderer's model to the high volume period at the opening is questioned by Foster and Vishwanathan (1994), their criticism does not apply to the closing phase.

submit fewer market orders, and may even supply liquidity instead, which reduces spreads and volatility. These predictions follow from the change in the equilibrium submission strategies of uninformed, rather than informed traders as in Kaniel and Liu (2006).

Two additional effects are at work following the introduction of the CA. First, as shown by Hillion and Souminen (2004), the introduction of a CA can reduce price manipulation and volatility. Second, Foucault (1999) shows that whenever volatility decreases, the picking-off risk of limit orders decreases, reducing the cost of providing liquidity. As a consequence, limit orders are more aggressively priced and the bid-ask spread declines further.[9]

The above discussion leads to the following hypotheses:

HI.1. The introduction of a CA moves significant trading volume from the last minutes of the continuous phase to the CA.

HI.2. The reallocation of volume is more pronounced in Paris than in Milan. This is due to the fact that the Reference Price is determined at the CA only in Paris, which brings more non-discretionary traders to the CA. This feature leads to another prediction as well:

HI.3. On days with large price changes towards the end of the day, more volume shifts to the CA in Milan. This effect should not be pronounced in Paris.

The intuition is as follows: when the RP is determined using the weighted average of the last 10% volume (as in Milan), on days with a large price change towards the end of the day the RP is very different from the price at the end of the day. This prompts traders to postpone their trades towards the CA to trade at a more representative price. As in Paris the RP is determined at the CA, no such effect is predicted for the CAC40 stocks.

HII.1. The introduction of a CA leads to an increase in spreads at the very end of the continuous trading phase, and the effect intensifies with the amount of volume reallocation to the CA (Admati and Pfleiderer, 1988, 1991).

HII.2. The introduction of a CA leads to a decline in spreads at the end of the continuous trading phase (Foucault et al., 2005; Kaniel and Liu, 2006; Foucault, 1999; Rosu, 2009).

Finally, we have a common prediction on volatility:

HIII. The introduction of a CA decreases volatility at the end of the continuous trading phase.

2.2.2. Predictions on price discovery

If significant volume shifts to the CA, then Admati and Pfleiderer predict that informed traders move to the CA and hence the efficiency of the price discovery mechanism at the end of the continuous phase deteriorates; at the CA, however, prices become more informative.

Kaniel and Liu (2006) also suggest that the introduction of a CA reduces price informativeness at the end of the continuous phase, but for a different reason. The introduction of another trading opportunity allows the informed traders with long-lived private information to reveal less of it at the end of the continuous phase by submitting limit instead of market orders. Consequently, the price becomes less revealing at the end of the continuous trading.

Models based on the endogenous submission strategies of uninformed investors (Foucault, 1999; Foucault et al., 2005; Rosu, 2009) offer an opposite prediction. The intuition is simple: lower liquidity demand by impatient traders induces lower price changes and lower volatility, which in turn decreases microstructure noise. The introduction of a CA reduces impatience, making prices more informative (less noisy). These predictions lead to the following hypotheses:

[9] Similar predictions derive from Buti and Rindi (2009) in the context of a LOB model with an endogenous market depth and various orders and trader types.

HIV.1. The introduction of a closing auction worsens price discovery right before the close (Admati and Pfleiderer, 1988, 1991; Kaniel and Liu, 2006).

HIV.2. The introduction of a closing auction improves price discovery right before the close (Foucault et al., 2005; Foucault, 1999; Rosu, 2009).

2.2.3. Predictions on order aggressiveness

Order aggressiveness can manifest itself in two ways: price (limit order or market order) and order size. We can make predictions regarding the order size only by assuming that the composition of traders at the end of the continuous phase remains the same after the CA introduction. This may not be the case, thus some caution must be warranted.

Admati and Pfleiderer (1998, 1991) models predict that the price response to volume is higher during the less liquid times of the day (Kyle's λ decreases with the volume of trading). This implies that liquidity demanders should reduce their trade sizes, ceteris paribus. Given that market makers are the only liquidity suppliers in their model, it cannot make predictions about the order choice: only market orders are allowed. The size of market orders depends on Kyle's λ: according to their prediction it increases at the end of the continuous trading phase, predicting a decline in the order size.

Kaniel and Liu (2006) show that informed traders become liquidity providers due to CA introduction, hence the proportion of market orders should decline and the proportion of limit orders increase. Given lower spreads and larger liquidity supply, the size of market orders should increase.

Foucault et al. (2005) make similar predictions, even though the effect comes from the uninformed traders. Fewer market orders are submitted, and limit orders are more aggressive. Their model does not specifically allow for that, but it would be reasonable to predict that improved liquidity would induce larger market orders, as a substitute for order splitting. Foucault (1999) and Buti and Rindi (2009) argue that the reduction in volatility makes limit orders less costly, thus the limit order become more aggressive. The resulting reduction in the cost of liquidity should increase the attractiveness of submitting market orders and making them larger. The overall effect on the proportion of market orders is ambiguous.

This leads us to the following hypotheses:

HV.1. The introduction of a CA reduces the trade size at the end of the continuous trading phase, assuming that the composition of traders does not change (Admati and Pfleiderer, 1988).

HV.2. The introduction of a CA increases the trade size at the end of the continuous trading phase, assuming that the composition of traders does not change (Foucault et al., 2005; Kaniel and Liu, 2006; Foucault, 1999; Buti and Rindi, 2009).

HVI.1. The introduction of a CA reduces the proportion of market orders, and increases the proportion of price improving limit orders (Foucault et al., 2005; Kaniel and Liu, 2006).

HVI.2. The introduction of a CA increases the proportion of market orders, and increases the proportion of price improving limit orders (Foucault, 1999; Buti and Rindi, 2009).

3. The data and the samples

3.1. Borsa Italiana

We focus on the Blue Chip stocks with a market capitalization in excess of 800 million Euros traded on the MTA electronic market. Our sample consists of the 30 largest and most liquid stocks, which form the MIB30 index, and the following 25 stocks that form the MIDEX index. All the stocks that belong to our sample are traded under the rules described below.

Prior to December 2001 the trading day started with the Opening Auction (OA),[10] followed by the Continuous trading phase (9:30 am–5:30 pm) organized as an electronic limit order book. On December 3, 2001, Borsa Italiana introduced the CA mechanism replacing the last 5 min of the continuous session. The rules governing the closing auction are similar to the opening auction: the Pre-auction phase (5:25–5:35 pm) is followed by the Validation and the Closing phase (5:35–5:40 pm) during which the theoretical closing auction price is determined and orders are executed. The Pre-auction phase of the opening and closing auctions has a random close over the last minute between the Pre-auction and the Validation phase.

The Reference Price in Milan remained a weighted average price of the last 10% volume traded during the end of the daily session, excluding crossed orders. For the pre-CA period, the Closing Price is the price of the last contract executed; in the post-CA periods the Closing Price is the closing auction price.

Our analyses are based on several data sets made available to us by Borsa Italiana that include transactions prices with time stamps and sizes, as well as the daily Reference and Closing Prices as calculated by BIt. In addition, we obtained all the orders entered for each stock throughout the sample period, including time stamps, signs, prices, quantities, and broad category identifiers of the originating party. Finally, we obtained the first five levels of the limit order book including time stamps, prices, and quantities.

We divide our sample into the following periods[11]:

Pre-periods for trading data we use the January 29 through March 22, 2001 sample, for a total of 40 trading days. We have chosen not to use the period immediately before the introduction of the CA so as to avoid the contamination of the financial markets by the September 11 event; these repercussions seem to have died out only by the beginning of 2002. Due to order data availability, we only use the period August 1–September 10, 2001, for a total of 28 trading days.

Post-period immediately after the introduction of the closing auction; it lasts from January 28 to March 22, 2002, for a total of 40 trading days, for which we observe both orders and trades.

Post–post-period roughly one year after the introduction of the CA; it starts on January 13 and ends on March 5, 2003, for a total of 38 trading days; both orders and trades are available for this period as well.

In addition to the comparison across the two groups of stocks, we test our predictions on the CAC40 stocks traded on Paris Bourse for the period May–June 1998, i.e. before and after the introduction of the CA on Paris Bourse. The CAC40 is the main index of the French market, comparable to the MIB30 of BIt. Although each exchange sets its own rules and requirements, the CAC40 and the MIB30 stocks are comparable in terms of index inclusion criteria, as well as trading environment. It is worth noting that the Paris Bourse added the CA after the regular trading hours, while BIt substituted it for the last 5 min of continuous trading. The most significant difference, however, is that the Paris Bourse uses the CA price as the Reference Price, while BIt continued using the weighted average price for the last 10% of volume during the sample period.

4. Results

We first present summary statistics and non-parametric tests. Table 3 presents the allocation of the trading volume over the course of the day during the three sample periods. Distinctions have been made between the Opening Auction, the Continuous Phase, and the closing auction, where relevant. It is shown that initially 2.8% of the daily volume shifts to the CA in MIB30 stocks and somewhat more in MIDEX. The CA attracts relatively more trading volume from the CAC40 stocks than from the stocks in the MIB30 index. One year after the CA introduction both the MIB30 and the MIDEX stocks exhibit a further increase in the CA volume. Interestingly, the use of the Opening Auction initially increases for both the MIB30 and the CAC40 stocks, which is consistent with the gradual learning hypothesis: when

[10] Pre-auction phase (8:00 am–9:15 am) when traders submitted their offers, a Validation phase (9:15 am–9:20 am) which set the opening auction price, and an Opening phase (9:20 am–9:30 am), which executed transactions at that price.

[11] The expiration days of derivative contracts were excluded from the analysis.

Table 3
Volume allocation over the course of the trading day. Computations reported in this Table are performed as follows: firstly, for each stock, for each trading phase (opening, closing and continuous), and for each sample period, (Pre-, Post- and Post–post-period for both the MIB30 and MIDEX stocks, and Pre- and Post-period for the CAC40 stocks), average trading volume is computed; secondly, the ratio between the average volume for each phase and trading period to the average volume for the whole trading day for the same trading period is computed; finally, the statistic obtained for each stock is averaged across the MIB30, MIDEX, and CAC40 stocks.

Segment:		MIB 30			MIDEX			CAC 40		
Period:		Pre	Post	Post–post	Pre	Post	Post–post		Pre	Post
Phase	Time							Time		
% Volume at the Opening	9.20–9.30 am	1.1	1.5*	1.2**	2.0	1.4	1.7	10.00 am, 10.01 am	3.43	3.9
	9.30 am–5.00 pm	83.6	85.3*	85.6*	81.9	84.7*	85.4	10.00 am, 4.30 pm	78.4	78.2
% Volume during the Day	5.00–5.25 pm	10.6	10.4	9.2*	9.8	10.8	10.6	4.30 pm, 4.55 pm	12.2	10.1**
	5.25–5.30 pm	4.7			6.7			4.55 pm, 5.00 pm	5.97	4.1*
% Volume at the CA	5.25–5.40 pm		2.8	4.0[a, **]		3.2	4.4[a, *]	5.00 pm, 5.10 pm		3.72[b, **,c, **]

Significance is relative to the Pre-period, except for the% volume at the CA.
** 1% Significance.
* 5% Significance.
[a] Post vs. Post–post.
[b] CAC40 vs. MIB30.
[c] CAC40 vs. MIDEX.

traders are still novices at using the CA, they may submit orders that are not executed, and so part of the unexecuted volume spills over to the Opening Auction. When traders get used to the closing auction, fewer orders are left unexecuted.

In all our hypotheses we must control for the period-specific market conditions. We first conjecture that the microstructure effects of the CA introduction are localized around the close of the market; thus we normalize all the variables of interest by their comparable average values calculated over one hour between 11 am and 12-noon during the same day. First, we calculate the average value of the relevant variables for the stock during the time frame of interest, and then divide it by the same variable average for that stock calculated over the 11–12 interval within the same sample period. Finally, we calculate the cross-section average. Such normalized values are used throughout the paper, unless indicated otherwise.

Using this normalization, we show that the main impact of the introduction of the CA is indeed concentrated at the very end of the trading session, namely during the last 10 min of trading. Table 4 presents the normalized values of volume, volatility, trade size, and bid-ask spread across the sample periods. These values are calculated over 5-min intervals taken in the morning, early afternoon, half-an-hour before the close, and 10 min before the close. The differences in the daily values across the sample periods are not significant, except for those calculated during the last 10 min before the close. This confirms our conjecture and prompts us to focus on the last 10 min before the close of the market, for all sample periods.

4.1. Volume

Before proceeding to test the other hypotheses, we must show that the volume from the last few minutes in the continuous trading phase indeed shifts to the CA.

Fig. 1 presents the trading volume minute by minute during the last 10 min of the continuous phase, normalized by the average trading volume in the 11–12 interval. Table 5 reports more detailed results for the last minute before the close of the Continuous Phase. Prior to the CA introduction, trading towards the end of the day is very active, but is fairly constant between 5:20 pm and 5:29 pm. The

Table 4
Comparisons of normalized variables of interest at various times during the day across the three sample periods. Computations are for differences in normalized values of Volume, Volatility, Bid-Ask Spread and Average Trade Size. Results (e.g., Volume) are obtained as follows: firstly, for each stock average volume is computed for every time interval reported below; secondly, daily values are averaged over each of the three sample periods (two for the CAC40 stocks) and this statistic is normalized to the average volume computed for the interval 11 am–12 pm of the same sample period; finally, differences between the Pre-Period and both the Post-period and the Post–post-period (PP) are computed. Average Trade Size is the ratio between volume and the number of observations; Quoted Bid-Ask Spread (BA) is computed as: $\frac{\text{Ask}-\text{Bid}}{(\text{Ask}+\text{Bid})/2}$; Volatility is computed as $100 * \sum_{t=1}^{T}[\ln(\frac{p_t}{p_{t-1}})]^2/T$, where p_t is the spread midpoint.

Segment	Pre period	10.00–10:05 am	10.20–10:25 am	2.00–2:05 pm	2.20–2:25 pm	5:05–5:10 pm	5:20–5.25 pm	5:25–5.30 pm
	Post and Post–post					5.00–5:05 pm	5.15–5.20 pm	5.20–5.25 pm
	CAC40					4:35–4:40 pm	4:50–4:55 pm	4:55–5:00 pm
							Last 10 min in all markets	
MIB 30	*Volume*							
	Post–Pre	0.010	0.016*	−0.002	−0.007	−0.014	−0.051*	−0.180**
	PP–Pre	0.013	0.021	0.002	−0.000	−0.015*	−0.068**	−0.158*
	Volatility							
			0.078	−0.113*	−0.128*	−0.293*	−0.542**	−2.340**
	Post–Pre	0.090	0.020	−0.048	−0.139*	−0.347**	−0.668**	−2.820**
	PP–Pre	−0.116						
	BA Spread							
	Post–Pre	−0.016	−0.011	−0.008	0.013	−0.020	−0.050**	−0.136**
	PP–Pre	−0.038	−0.007	−0.020	0.004	−0.046	−0.052**	−0.132**
	Trade Size							
	Post–Pre	−0.021	0.031	−0.085	−0.085	−0.200**	−0.242**	−0.236**
	PP–Pre	0.028	0.114	−0.113	−0.166**	−0.260**	−0.317**	−0.232*
MIDEX	*Volume*							
	Post–Pre	−0.014	−0.004	−0.025	−0.026**	0.084	0.016	−0.297**
	PP–Pre	0.005	0.016	0.020	0.005	−0.048	−0.025	−0.282**
	Volatility							
	Post–Pre	−0.194	−0.426	−0.144	−0.177*	−0.193	−0.322*	−2.819**
	PP–Pre	−0.636**	−0.691	−0.040	−0.118	0.202	−0.390*	−3.423**
	BA Spread							
	Post–Pre	−0.063	−0.086*	0.062*	0.018	0.040	−0.027	−0.213**
	PP–Pre	−0.487	−0.335	0.002	0.016	−0.023	−0.064	−0.238**
	Trade Size							
	Post–Pre	−0.045	0.044	−0.036	−0.110	−0.992	0.091	−0.008
	PP–Pre	−0.067	0.016	−0.066	0.087	−1.035	−0.097	0.088
CAC40	*Volume*							
	Post–Pre	−0.067	0.007	−0.002	0.003	−0.002	−0.002	−0.242
	Volatility							
	Post–Pre	0.010	−0.527**	0.036	−0.002	−0.220*	−0.498**	−0.531
	BA Spread							
	Post–Pre	−0.081	−0.155**	−0.005	−0.015	−0.066*	−0.157**	−0.304**
	Trade Size							
	Post–Pre	−1.248*	0.042	0.035	−0.091	0.073	−0.515**	−1.515

** 1% Significance.
* 5% Significance.

last minute at the end of the day exhibits over 20% of the midday hourly volume for the MIB30 and the CAC40 stocks and 40% for the MIDEX stocks, which is almost a 200% increase over the previous minutes. As this was the last chance to trade for that day, traders seem to utilize this option extensively. After the CA, the normalized volume during the last 5 min (5:20–5:25 pm) stays relatively constant and close to previous levels, even in the last minute, which indicates a significant decline for the last minute. Results in Table 5 confirm that the observed patterns are statistically significant.

The results clearly indicate that, consistent with *HI.1*, much of the volume from the last minute shifts to the CA, which becomes the "high-volume" period in the context of Admati and Pfleiderer.

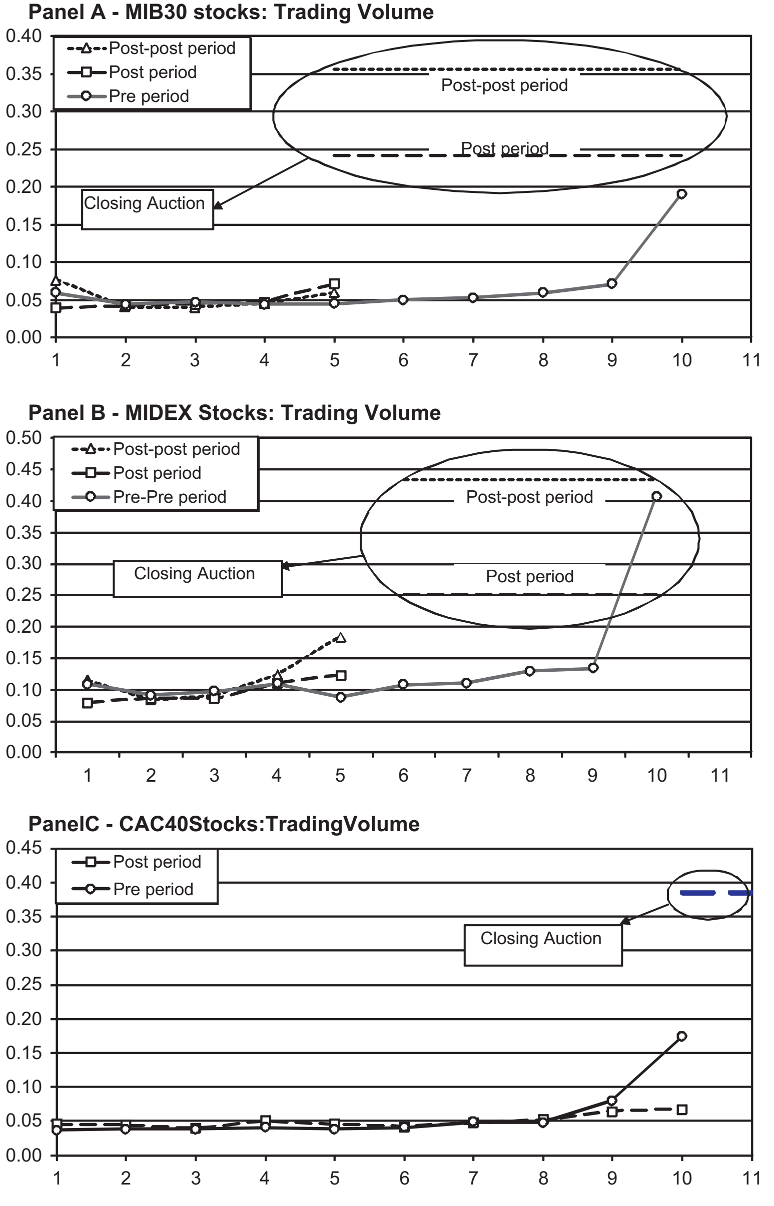

Fig. 1. Trading Volume over the last 10 min of the continuous trading phase for the three sample periods (Pre-, Post-, and Post–post), scaled by the Trading Volume in the same stock during the 11 am–12 pm interval averaged over the period. Normalized values are obtained as follows: firstly, for each stock, average volume is computed for the last minute of the continuous trading phase; secondly, daily values are averaged over each of the three sample periods (two for the CAC40 stocks) and this statistic is normalized to the average volume computed for the interval 11 am–12 pm of the same sample period. Notice that for CAC40 stocks, the closing auction was added up to the close of the continuous phase; for Borsa Italiana's stocks, the closing auction replaced 5 min of the continuous phase and added up to another 10 min.

Notice also (Table 3) that, the reallocation of volume seems more pronounced in Paris than in Milan in the Post-period, consistent with *HI.2*. Thus, we can proceed with testing the other hypothesis.

Table 5
Quoted Bid-Ask Spread, Volume, Average Trade Size, and Volatility during the last minute before the close of the Continuous Phase, normalized by the average spread during the interval 11 am–12 pm . Normalized values (e.g., Volume) are obtained as follows: firstly, for each stock average volume is computed for the last minute of the continuous trading phase; secondly, daily values are averaged over each of the three sample periods (two for the CAC40 stocks) and this statistic is normalized to the average volume computed for the interval 11 am–12 pm of the same sample period. Average Trade Size is the ratio between volume and the number of observations; Quoted Bid-Ask Spread is computed as: $\frac{\text{Ask}-\text{Bid}}{(\text{Ask}+\text{Bid})/2}$; Volatility is computed as $100 * \sum_{t=1}^{T}\left(\log\frac{p_t}{p_{t-1}}\right)^2/T$, where p_t is the spread midpoint. *P*-values are reported.

Variable	Period	MIB30		MIDEX		CAC40	
		Value	*p*-value	Value	*p*-value	Value	*p*-value
Volume	Pre	0.190		0.406		0.174	
	Post	0.071	0.000	0.123	0.000	0.067	0.000
	Post–post	0.060	0.000	0.179	0.003		
Bid-Ask Spread	Pre	1.589	–	1.728	–	1.471	–
	Post	1.177	0.000	1.497	0.031	0.996	0.000
	Post–post	1.138	0.000	1.448	0.003	–	–
Volatility	Pre	11.854		11.934		4.057	
	Post	2.968	0.004	3.044	0.000	1.963	0.028
	Post–post	1.946	0.001	1.722	0.000		
Average Trade Size	Pre	1.807		1.526		1.413	
	Post	1.522	0.002	1.525	0.993	1.655	0.245
	Post–post	1.408	0.000	1.372	0.126		

As previously mentioned, the choice of the optimal Reference Price algorithm is an important issue in market design, since this price serves for settlement of various contracts and is used to compute the investment performance for most institutional investors. Overall, much uncertainty remains regarding the optimal way to choose the RP, which explains the variety of choices among the world's leading stock exchanges, as presented in Table 1.

As mentioned above, Paris Bourse sets RP equal to the CA price, while Borsa Italiana uses the weighted average price based on the last 10% of the daily volume. The concern behind the latter choice is that if the CA does not attract enough volume, the RP can be manipulated. However, this decision reduces the attractiveness of the CA for non-discretionary liquidity traders who must execute at the RP. We saw that the Paris CA attracts a higher percentage of the daily volume than the CA in Milan, which we attribute to this difference. We provide indirect evidence below.

We focus on days with significant price moves towards the end of the day and study the allocation of volume between the end of the continuous phase and the CA. On these days the RP in Milan, which is the volume weighted average price of the last 10% of the traded volume, deviates more from the fundamentals and is less informative that the CA price.[12] The non-discretionary liquidity traders must trade at the RP, but a significant proportion of traders are sensitive to the deviation of the RP from the fundamental value. These traders should shift their trading to the CA on such days, increasing the relative volume during the CA. This should bring more volume from the non-discretionary traders as well, as the RP is now more dependent on the CA price (volume weighted). Consequently we should observe an increase in the relative volume during the CA on the days with significant price movements before the close. At the same time we do not expect to observe this effect in the Paris Bourse, since the CA price is the RP, and so there is no reason to shift volume.

We estimate the following regression:

$$V_{ca,t} = a + cR^{+}_{bca,t} + dR^{-}_{bca,t} + z\text{ZVolume}_t + e$$

where $V_{ca,t}$ is the trading volume at the CA on day t, normalized by the same stock average trading volume between 11 am and 12 noon over the relevant period; $R^{+}_{bca,t}$ ($R^{-}_{bca,t}$) is the return over the period

[12] Here we refer to the fundamental value at the very last moment of the trading session, rather than over a period of time. Traders may differ in terms of their preferences for prices reflecting one or the other. We are grateful to the referee for pointing this out.

Table 6
This table reports results for the following cross-sectional regression for each sub-sample: $V_{ca,t} = a + cR^{+}_{bca,t} + dR^{-}_{bca,t} + z\text{ZVolume}_t + e$, where $V_{ca,t}$ is the trading volume at the closing auction on day t, normalized by the same stock average trading volume between 11 am and 12 pm over the relevant period; $R^{+(-)}_{bca,t}$ is the return over the interval 5.20 pm and 5:25 pm on the same day, when it is positive (negative), and zero otherwise; ZVolume_t is the standardized daily trading volume on the specific day t between the opening and 3:00 pm (daily volume less the average volume and divided by the standard deviation over the entire period).

Market segment	Post-period					Post–post-period				
	a (STERR)	c (STERR)	d (STERR)	z (STERR)	Adj R^2	a (STERR)	c (STERR)	d (STERR)	z (STERR)	Adj R^2
MIB30	0.219 (0.007)	8.379 (2.475)	10.130 (3.280)	0.056 (0.006)	0.077	0.283 (0.013)	4.155 (1.844)	5.101 (2.062)	0.096 (0.015)	0.034
MIDEX	0.267 (0.015)	−0.324 (0.771)	−1.486 (0.953)	0.092 (0.013)	0.055	0.338 (0.026)	5.044 (1.124)	2.239 (0.962)	0.116 (0.023)	0.059
CAC40	0.287 (0.016)	−0.350 (0.350)	0.412 (0.534)	0.047 (0.008)	0.051					

5.00–5:25 pm on the same day, when it is positive (negative), and zero otherwise; and ZVolume_t is the Z score of the trading volume on the specific day t between the opening and 3.00 pm (calculated over the entire sample period), which controls for the early trading activity during the day. *HI.3* postulates that **c** and **d** are positive in Milan, as a larger absolute price change induces higher proportion of volume shifting to the CA. We do not expect this relationship to hold in Paris.

Table 6 shows that for the MIB30 stocks **c** and **d** are indeed large, positive and highly significant in both periods (as well as not very different), while for MIDEX they are positive and significant only in the Post–post-period. The effect is quite sizeable: a 1% higher absolute return prior to close translates into a 5–10% increase in the relative trading volume during the closing auction. The comparison with the CAC40 results is illuminating: Table 6 shows that in Paris Bourse there is no connection between the pre-close return and the proportion of trading at the CA, as predicted. At the same time, in all three sub-samples we find that higher volume during the day translates into a higher relative trading volume during the CA.

These findings are consistent with *HI.3* and indicate that the choice of the algorithm to calculate the RP has a significant effect on the trading pattern at the close. This suggests that institutions care about the RP, and that equating the RP with the CA price may be very useful precisely when it counts, i.e. during volatile days, when under some algorithms the RP may significantly deviate from the fundamental value. We must caution that our findings are based on the more liquid stocks in both markets, thus conclusions may not apply to less liquid stocks.

4.2. Quoted bid-ask spread

Fig. 2 presents the changes in the Quoted Bid-Ask Spread before and after the introduction of the CA. During the last 10 min of continuous trading prior to the CA, the spread is only marginally higher than the midday spread for the MIB30 stocks; but during the last minute it is 60% higher than the midday spread. This finding contradicts *HII.1* based on Admati and Pfleiderer (1988) that during the high-volume period the spread should be lower than the spread in the low-volume periods. Once the CA is introduced, the spread in the last 4 min before the end of the continuous phase remains of the same magnitude as the midday spread, but the corresponding jump in the last minute is only 15% of the midday spread, much lower than the 60% during the Pre-period.

Panel B shows the same pattern in MIDEX, except that all the respective spread levels are much higher than in MIB30, as one would expect in stocks with lower liquidity. This is consistent with the findings of Pagano and Schwartz (2003) for less liquid stocks on the Paris Bourse. Panel C shows that the CAC40 stocks exhibit a similar pattern: the introduction of the CA significantly reduces the spread in the last minute of trading, to a level equal to the midday spread. The difference is that in the Post-period the spread during the previous 9 min is 20% below the midday spread. This is consistent with the evidence that more traders trade at the CA in Paris, arguably due to the differences in the RP algorithm.

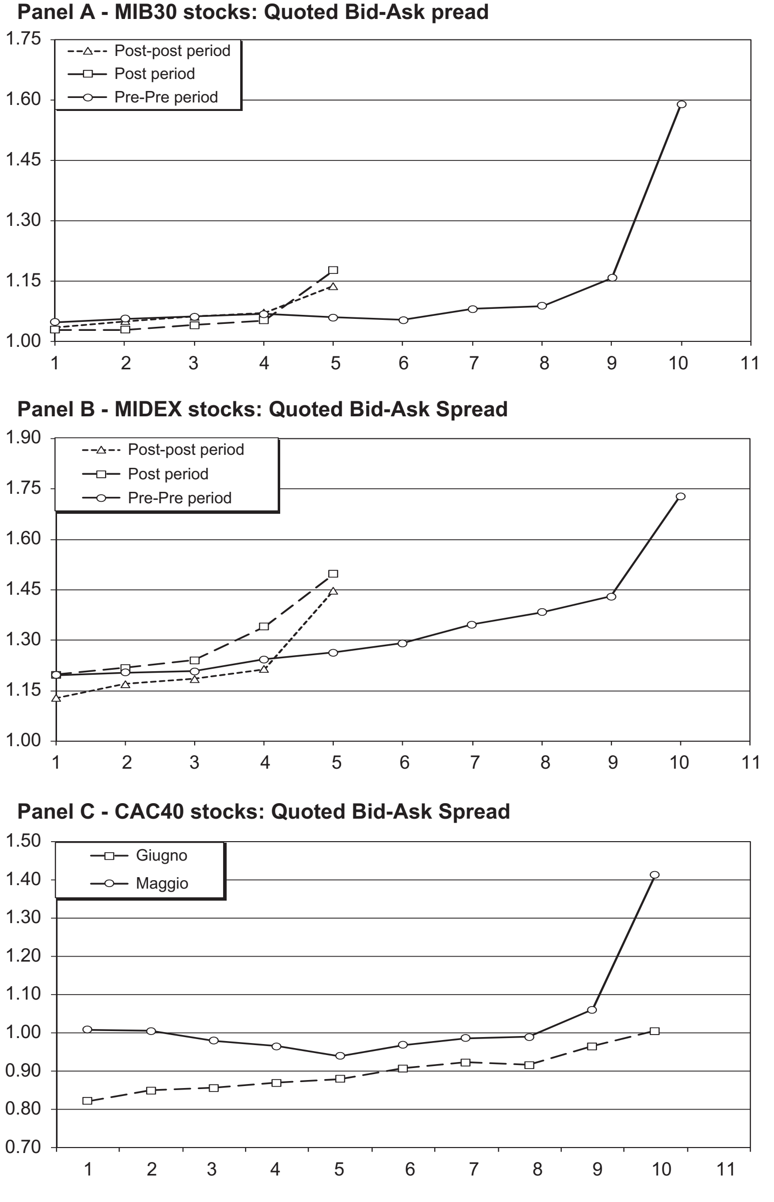

Fig. 2. Quoted Bid-Ask Spread over the last 10 min of continuous trading for the three sample periods (Pre-, Post-, and Post–post), scaled by the Bid-Ask Spread in the same stock during the 11 am–12 pm interval averaged over the period. Normalized values are obtained as follows: firstly, for each the stock Bid-Ask Spread is computed for the last minute of the continuous trading phase; secondly, daily values are averaged over each of the three sample periods (two for the CAC40 stocks) and this statistic is normalized to the average Quoted Bid-Ask Spread computed for the interval 11 am–12 pm of the same sample period. Notice that for CAC40 stocks, the closing auction was added up to the close of the continuous phase; for Borsa Italiana's stocks, the closing auction replaced 5 min of the continuous phase and added up to another 10 min.

Table 5 shows that for the French and the Italian stocks the quoted spread during the last minute after the CA introduction is significantly lower both economically and statistically than the spread in the last minute before the CA. We can reject *HII.1*, but cannot reject the alternative *HII.2* that follows from Foucault (1999), Kaniel and Liu (2006), Foucault et al. (2005), and Rosu (2009).

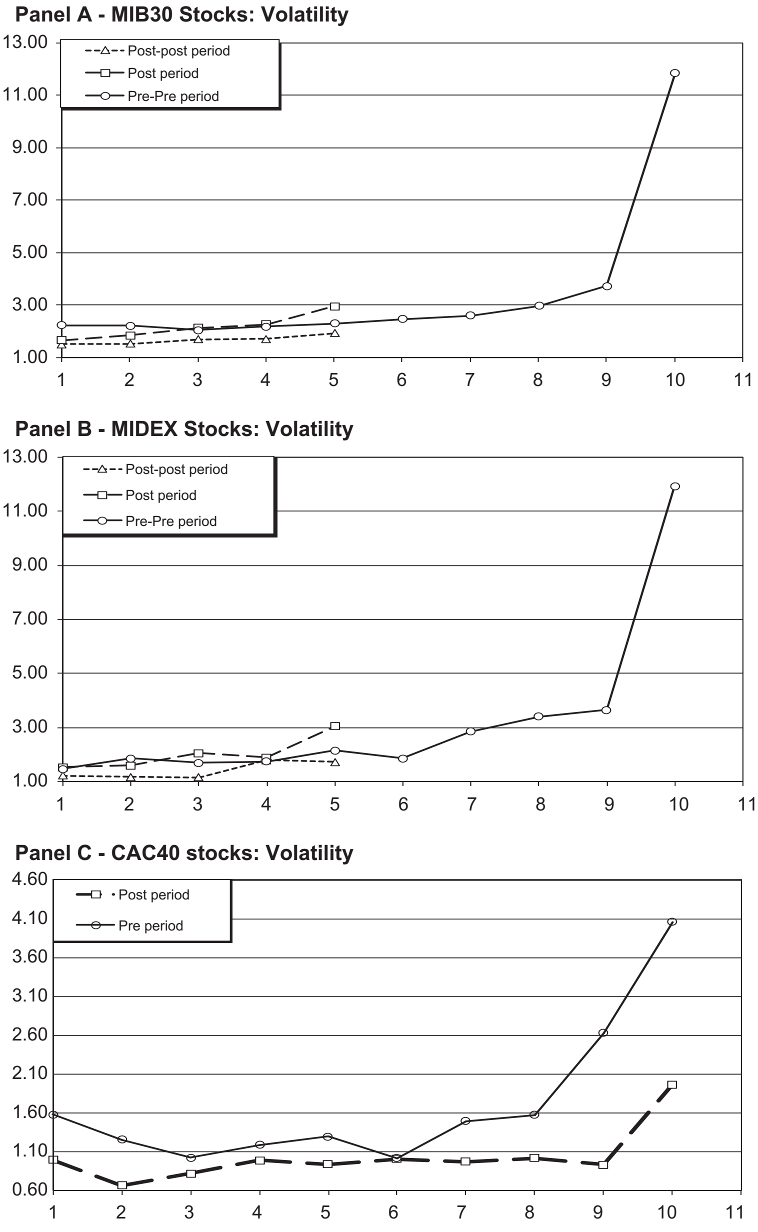

Fig. 3. Volatility over the last 10 min of continuous trading for three periods (Pre-, Post-, and Post–post), scaled by Volatility in the same stock during the 11 am–12 pm interval averaged over the period. Normalized values are obtained as follows: firstly, for each stock volatility is computed for the last minute of the continuous trading phase; secondly, daily values are averaged over each of the three sample periods (two for the CAC40 stocks) and this statistic is normalized to the average Volatility computed for the interval 11 am–12 pm of the same sample period. Notice that for CAC40 stocks, the closing auction was added to the close of the continuous phase; for Borsa Italiana's stocks, the closing auction replaced 5 min of the continuous phase and added up to another 10 min.

4.3. Volatility

We do not expect the introduction of the CA to change the fundamental volatility stemming from the arrival of news about the firms' prospects. Any period-specific variation in volatility should be significantly reduced by our normalization procedure (relative to 11 am–12 noon). Consequently, we attribute the changes in volatility mostly to the microstructure-level effects, e.g. bid-ask spread bounce and temporary price pressure from liquidity demanders, as well as to possible manipulation.

Following Hillion and Souminen (2004), we use the realized return variance. Volatility before the CA shows a similar pattern to that of the quoted spread (Fig. 3). During the 5:20–5:29 pm period, volatility is about three times higher than during the midday period. It reaches the staggering 12 times the midday level during the last minute of trading for MIB30 and MIDEX. Again, in periods of high volume, volatility is significantly higher than in periods of low volume, which is consistent with the predictions of Admati and Pfleiderer (1988). Following the CA introduction, volatility does not change much, except in the last minute, where the effect is dramatic: relative to midday, volatility declines by 70% relative to the Pre-period level and becomes comparable to the volatility during the previous minutes. These estimates are surprisingly consistent across the two groups of Italian stocks.

Panel C of Fig. 3 presents the findings for the CAC40 stocks. The relative levels are much lower in both the Pre and the Post-periods, but during the last-minute volatility declines by 50% following the CA introduction. This suggests that the reduction in volatility is not due to the Exchange's specific features, but to the CA introduction. The findings of Pagano et al. (2008) corroborate this conclusion: they also show that the introduction of the open and closing cross on NASDAQ significantly reduced the volatility of the first few minutes after the open and the last minutes before the close.

Table 5 shows that the reported reductions in volatility in the last minute are statistically significant, as consistent with *HIII*.

4.4. Price discovery

The next test aims to determine whether the introduction of the CA makes transaction prices right before the end of the continuous phase more or less noisy. Assuming that the opening auction facilitates price discovery at the same level before and after the CA introduction, we can test these predictions by computing the serial correlation between the Open-to-Close and the Close-to-Open returns. More negative significant correlation would indicate a larger amount of noise.

Table 7
The correlation between the Open-to-Close and Close-to-Open returns for the MIB30 MIDEX and CAC40 stocks. Returns are computed using the last price of the continuous auction (first row), and the average of the last 10 transaction prices of the continuous auction (second row) for all sample periods. Correlations are computed for each stock and then averaged within the relevant index. In the parentheses we report the number of stocks with significant (at the 10% level) negative and positive correlations in each period.

Index		Average correlation (stocks with significant negative/positive correlation)			*p*-values	
		Pre-period	Post-period	Post–post-period	Pre vs. Post	Pre vs. post–post
MIB30	Last Price in Continuous Phase	−0.190 (14/0)	−0.004 (3/0)	−0.067 (1/1)	0.000	0.001
	Average of the Last 10 Prices in Continuous Phase	−0.179 (15/15)	−0.005 (3/0)	−0.07 (2/1)	0.000	0.004
	Number of stocks	30	32	30		
MIDEX	Last Price in Continuous Phase	−0.138 (8/0)	0.006 (6/6)	−0.088 (7/2)	0.025	0.459
	Average of the Last 10 Prices in Continuous Phase	−0.106 (8/1)	0.005 (3/5)	−0.07.7 (7/4)	0.078	0.664
	Number of stocks	24	21	20		
CAC40	Last Price in Continuous Phase	−0.08 (8/2)	0.164 (0/13)	–	0.000	–
	Average of the Last 10 Prices in Continuous Phase	−0.069 (7/2)	0.181 (0/12)	–	0.000	–
	Number of stocks	41	41			

We compute the Open-to-Close return for day t, $r_{OC,t}$, and the Close-to-Open of day t to the next day, $r_{CO,t+1}$. To ensure robustness, we compute these returns using two definitions of the closing price: the price of the last trade and the average price of the last 10 trades in the continuous phase. We then compute the serial correlation between these returns for every stock and every sample period and average the results within the relevant index. In addition, we report the proportion of stocks with significant negative and significant positive correlation coefficients, respectively. Table 7 presents the results.

About 50% of the MIB30 stocks exhibit a significant (at the 10% level) negative correlation between the returns in the Pre-period, and the average correlation is −0.18 to −0.19 for both definitions of the closing price. In case of the last price, there are no stocks with significant positive correlations, whereas in the average of the last 10 prices, there are also quite a few stocks with positive and significant correlations. After the CA introduction the correlation increases to −0.005 and one year later goes somewhat back to −0.07. In both cases the drop is significant, indicating that the level of noise in the before-closing prices declined significantly due to CA introduction. The number of stocks with significant negative correlations declines significantly, which strengthens the result. We conclude that the end of the day price is less noisy following the CA introduction. This is consistent with *HIV.2*, but contradicts *HIV.1*, that is based on Admati and Pfleiderer' prediction.

MIDEX stocks exhibit a very similar pattern in the last price, but a much weaker one in the last 10 prices. Given that these stocks are much less liquid, the 10 price average may require going back to much earlier hours of trading, which makes the comparison less relevant.

We also observe a very similar effect in CAC40 stocks, except that it starts with a correlation of only −0.08 and becomes very large and positive in the post-CA period. Bessembinder and Hertzel (1993) also find positive and significant correlation between the Close-to-Open and Open-to-Close returns in Paris Bourse.

The observed changes are economically and statistically significant, indicating that the amount of noise in prices declines significantly as predicted by *HIV.2*.

4.5. Parametric tests

Below we perform parametric tests on the impact of the introduction of the CA on spread and volatility, conditioning on the proportion of the daily volume allocated to the CA. This is another test of the above hypotheses, conditional on the daily trading volume reallocation. We calculate for every stock over the three sample periods: the average Quoted Bid-Ask Spread over the last minute of continuous trading (S_{last}), and the average Quoted Bid-Ask Spread over the 11–12 trading hour (S_{11-12}). Both variables are averaged over the entire period. The ratio of the two, denoted by $S_{\text{rel}} = S_{\text{last}}/S_{11-12}$, is the first dependent variable. Similarly, we calculate the normalized volatility using the realized variance approach, as before. The resulting normalized measure is denoted by Vlt_{rel}. The normalization removes the need to include stock-specific variables in the regression.

The main explanatory variable is average volume traded at the CA, normalized by the average volume over the 11–12 time interval, averaged over the respective sample period, and denoted by CAVol. The variable DUM_p takes the value of 1 in the Post-period, while DUM_{pp} takes the value of 1 in the Post–post-period. We run the following cross-sectional regressions separately for each sub-sample of stocks over the three periods:

$$S_{\text{rel}} = a_0 + a_1\text{DUM}_p + a_2\text{DUM}_{pp} + b_1\text{DUM}_p * \text{CAVol} + b_2\text{DUM}_{pp} * \text{CAVol} + e$$

$$\text{Vlt}_{\text{rel}} = \alpha_0 + \alpha_1\text{DUM}_p + \alpha_2\text{DUM}_{pp} + \beta_1\text{DUM}_p * \text{CAVol} + \beta_2\text{DUM}_{pp} * \text{CAVol} + \varepsilon$$

Consistent with the above evidence we expect the spread and the volatility to decline, i.e. a_1, a_2 and α_1, α_2 should be negative. Furthermore, to investigate the relation between the volume at the close and the change in market quality, i.e., the significance of b_1, b_2, β_1, and β_2, the regression includes the interactive term of the CA volume. The results are presented in Table 8, Panel A.

Consistent with the non-parametric results, there is strong evidence that both the relative spread and the relative volatility decline: a_1, a_2, α_1, and α_2 are negative and significant in all samples. At the same time neither b_1 and b_2, nor β_1 and β_2 are significant for MIB30 and MIDEX; thus there is no

Table 8
Panel A reports results for the following cross-sectional regressions for each sub-sample of stock over the three sample periods (pooled):

$$S_{\mathrm{rel}} = a_0 + a_1 \mathrm{DUM_p} + a_2 \mathrm{DUM_{pp}} + b_1 \mathrm{DUM_p} * \mathrm{CAVol} + b_2 \mathrm{DUM_{pp}} * \mathrm{CAVol} + e$$

$$\mathrm{Vlt_{rel}} = \alpha_0 + \alpha_1 \mathrm{DUM_p} + \alpha_2 \mathrm{DUM_{pp}} + \beta_1 \mathrm{DUM_p} * \mathrm{CAVol} + \beta_2 \mathrm{DUM_{pp}} * \mathrm{CAVol} + \varepsilon$$

where S_{rel} is the ratio $S_{\mathrm{last}}/S_{11-12}$ and S_{last} is the average Bid-Ask Spread over the last minute of continuous trading normalized to the average Bid-Ask Spread over the interval 11 am–12 pm denoted by S_{11-12} (both averaged over the entire period). Similarly, $\mathrm{Vlt_{rel}}$ is the ratio $\mathrm{Vlt_{last}}/\mathrm{Vlt}_{11-12}$, with $\mathrm{Vlt_{last}}$ equal to the average Volatility over the last minute of the continuous trading normalized to the average Volatility over the interval 11 am–12 pm denoted by Vlt_{11-12} (both averaged over the entire period). CAVol is the average percentage (of the 11 am–12 pm interval) of the daily volume traded at the CA, and DUM_p is a dummy variable that takes value 1 in the Post-period and 0 otherwise, whereas DUM_{pp} takes value 1 in the Post–post-period and 0 otherwise. Standard errors are in parentheses. Panel B reports results for the following regressions for each sub-sample of stock using the panel data:

$$S_{\mathrm{rel},t} = a_0 + a_1 \mathrm{DUM_p} + a_2 \mathrm{DUM_{pp}} + b_1 \mathrm{DUM_p} * \mathrm{CAVol}_t + b_2 \mathrm{DUM_{pp}} * \mathrm{CAVol}_t + e$$

$$\mathrm{Vlt}_{\mathrm{rel},t} = \alpha_0 + \alpha_1 \mathrm{DUM_p} + \alpha_2 \mathrm{DUM_{pp}} + \beta_1 \mathrm{DUM_p} * \mathrm{CAVol}_t + \beta_2 \mathrm{DUM_{pp}} * \mathrm{CAVol}_t + \varepsilon$$

where $S_{\mathrm{rel},t}$ is the ratio $S_{\mathrm{last},t}/S_{11-12}$ and $S_{\mathrm{last},t}$ is the average daily Bid-Ask Spread over the last minute of continuous trading normalized to the average Bid-Ask Spread over the interval 11 am–12, denoted by S_{11-12}, the latter being averaged over the sample period. Similarly, $\mathrm{Vlt}_{\mathrm{rel},t}$ is the ratio $\mathrm{Vlt}_{\mathrm{last},t}/\mathrm{Vlt}_{11-12}$, with $\mathrm{Vlt_{last}}$ equal to the average daily Volatility over the last minute of continuous trading normalized to the average Volatility over the interval 11 am–12 pm, denoted by Vlt_{11-12}. CAVol_t is the average daily volume (% of the 11.00 am–12.00 pm interval) traded at the CA, and DUM_p is a dummy variable that takes value 1 in the Post-period and 0 otherwise, whereas DUM_{pp} takes value 1 in the Post–post-period and 0 otherwise. Standard errors are in parentheses.

Market segment	a_0	a_1	a_2	b_1	b_2	Adj R^2	α_0	α_1	α_2	β_1	β_2	Adj R^2
Panel A												
MIB30	1.589	−0.473	−0.510	0.255	0.165	0.535	7.4645	−4.656	−5.576	0.658	0.160	0.566
	(0.034)	(0.113)	(0.105)	(0.422)	(0.262)		(0.393)	(1.219)	(1.139)	(4.543)	(2.821)	
MIDEX	1.728	−0.271	−0.428	0.161	0.341	0.098	11.934	−9.087	−10.260	0.782	0.109	0.324
	(0.068)	(0.190)	(0.142)	(0.653)	(0.223)		(1.257)	(3.510)	(2.617)	(12.048)	(4.117)	
CAC40	1.471	−0.469		−0.021	–	0.421	4.057	−4.541		−8.275	–	0.058
	(0.043)	(0.132)		(0.394)			(0.657)	(2.007)		(−6.015)	–	
Panel B												
MIB30	1.584	−0.397	−0.432	−0.033	−0.048	0.051	11.812	−9.026	−9.879	0.767	0.122	0.002
	(0.021)	(0.041)	(0.039)	(0.098)	(0.054)		(1.872)	(3.681)	(3.498)	(8.731)	(4.789)	
MIDEX	1.727	−0.189	−0.310	−0.099	0.002	0.012	12.412	−9.581	−10.878	0.000	0.000	0.008
	(0.030)	(0.060)	(0.066)	(0.113)	(0.087)		(1.345)	(2.622)	(2.878)	(0.000)	(0.000)	
CAC40	1.478	−0.412		−0.223	–	0.061	3.400	−1.637		−0.750	–	0.022
	(0.030)	(0.059)		(0.114)	–		(0.201)	(0.397)		(0.765)	–	

evidence of a correlation between the use of the CA and the liquidity measures. These coefficients are negative, yet not significant for the CAC40 stocks. These findings are not consistent with the predictions of Admati and Pfleiderer, who argue that the decline in volume should reduce the volatility and increase the bid–ask spread.

An alternative specification of the same hypotheses looks at the panel data, rather than averaging over time for each stock. To reduce day-specific outliers, the daily values of a variable are still normalized by the average of the 11–12 period values of the same variable over the entire period. The resulting equations are:

$$S_{\mathrm{rel},t} = a_0 + a_1\mathrm{DUM}_p + a_2\mathrm{DUM}_{pp} + b_1\mathrm{DUM}_p * \mathrm{CAVol}_t + b_2\mathrm{DUM}_{pp} * \mathrm{CAVol}_t + e$$

$$\mathrm{Vlt}_{\mathrm{rel},t} = \alpha_0 + \alpha_1\mathrm{DUM}_p + \alpha_2\mathrm{DUM}_{pp} + \beta_1\mathrm{DUM}_p * \mathrm{CAVol}_t + \beta_2\mathrm{DUM}_p p * \mathrm{CAVol}_t + \varepsilon$$

The results are presented in Table 8, Panel B. The coefficients for the period dummies are the same as in Panel A, providing strong support for the first two hypotheses. The data still shows no significant relation between the degree of use of the CA and the liquidity measures, with the exception of CAC40, where the higher proportion of trading at the CA does reduce the bid-ask spread. It is worth noting that the explanatory power of the above estimation models is low, but is much higher for the larger and very liquid stocks, such as MIB30 and CAC40, than for the less liquid stocks. Large institutions, which are much more liquidity-oriented, presumably prefer these larger and more liquid stocks.

In conclusion, the evidence suggests that the introduction of the Call Auction by itself has a profound impact on the very end of the continuous trading phase. The most striking effects are the dramatic reduction in the bid-ask spread and volatility, which significantly reduce the cost of immediacy. At the same time there is practically no effect on market characteristics five or more minutes prior to the close.[13] Moreover, the average volume and average trade size significantly increase at the CA, which attracts institutional traders submitting larger orders than those submitted during the continuous phase. Contrary to the prediction of Admati and Pfleiderer (1988), the spread does not increase with the higher percentage of volume moving to the CA. Overall, these findings are not consistent with the predictions of Admati and Pfleiderer (1988), but do provide support to Foucault (1999), Kaniel and Liu (2006), Foucault et al. (2005), Rosu (2009), and Buti and Rindi (2009).

4.6. Order aggressiveness and trade size

We start from trade size, which is another dimension of trader's aggressiveness, which depends on the perceived available liquidity in the market. Higher perceived liquidity allows traders to submit larger market orders. More aggressive competition on the supply side necessitates a submission of larger limit order to ensure time priority. Recall that our predictions for trade size are conditional on the persistent composition of traders.

4.6.1. Trade size

Fig. 4 presents the average trade size in the last 10 min of trading. Panel A shows that in the Pre-period, the average trade size for the MIB30 stocks was about 50% higher than during the midday period, increasing even further in the last 2 min. After the introduction of the CA, the last-minute trade size (continuous trading) declines significantly relative to the Pre-period. We also observe that during the CA in the Post-period, the average trade size is the same as that registered during the last minute of the Pre-period. One year later the average trade size becomes significantly higher, perhaps indicating that traders have a greater confidence in their ability to execute large trades in the CA. For MIDEX and CAC40 stocks we do not observe a comparable increase: as a matter of fact, the Post–post-period shows an overall decline in the average trade size compared to the other periods. It may well be that pre-arranged trades of large size dominate trading in these stocks during the continuous phase.

[13] This may explain why Pagano and Schwartz (2003) do not find significant microstructure-level effects averaged over the last 30 min of trading on Paris Bourse following the CA introduction. The time resolution of their study is not fine enough.

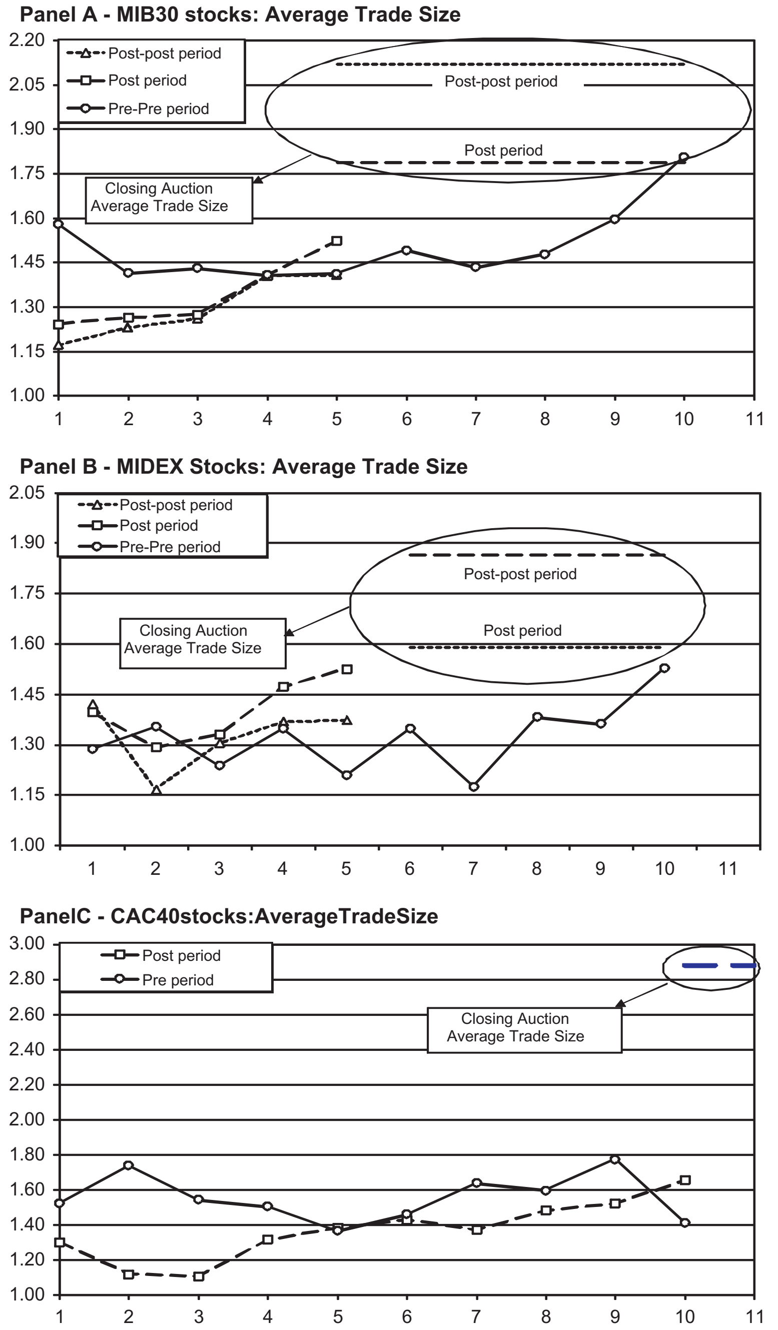

Fig. 4. The Average Trade Size over the last 10 min of continuous trading for the three sample periods (Pre-, Post-, and Post–post), scaled by the Average Trade Size in the same stock during the 11 am–12 pm interval averaged over the period. Notice that for CAC40 stocks, the closing auction was added to the close of the continuous phase; for Borsa Italiana's stocks, the closing auction replaced 5 min of the continuous phase and added up to another 10 min.

Table 9
This table presents a classification of orders by their degree of aggressiveness during the continuous phase and during the call auction. The continuous phase order classification is consistent with Bias, Hillion, and Spatt (1995). Note that these are orders submitted over the last five of the continuous trading. On BIt a market order cannot "walk up" the order book unless specified by a special code (ECO); therefore a market order submitted without such code is executed up to the amount of shares available at the best price on the opposite side of the book, while the residual quantity is converted into a limit order (at the same best price) on their own side of the book. While a market order with the ECO code always increases the spread, without this code it may also reduce the spread.

Classification	During the continuous phase	During the call auction
"Aggressive orders"	Market Orders and Marketable limit orders (i.e., Limit Orders that are submitted at prices equal to or greater than the best price on the opposite side of the order book.). The MO orders increase the spread; the LO may increase or reduce it	Market Buy (Sell) Orders, or Marketable Buy (Sell) Limit Orders submitted at prices that are greater (less) than the average ask (bid) prices computed over the last 5 min of continuous trading
"Neutral orders"	Limit Orders that are submitted at or within the prevailing bid ask spread at the time of the order submission. These orders may reduce the spread	Limit Orders that are submitted between the average ask and bid prices computed over the last 5 min of continuous trading
"Non-aggressive orders"	Limit Orders that are submitted at prices below the current best price on the same side. These orders do not affect the spread	Limit Buy (Sell) Orders that are submitted at prices that are greater (less) than the average ask (bid) prices computed over the last 5 min of the continuous trading

Table 5 presents the comparisons of the means across the three periods and shows that only the results for MIB30 are statistically significant, thus consistent with *HV.1*. Presumably, changes in the composition of traders have an effect as well.

4.6.2. Price aggressiveness

Borsa Italiana made available order submission data, which permits us to study the effect of the CA introduction on order-submission strategies during the last minutes of continuous trading. Unfortunately, this data are only available since August 1, 2001; therefore for the Pre-period we use the sample August 1–September 10, 2001. The Post and Post–post samples are the same. We do not have a comparable data set for CAC40 stocks.

To define order aggressiveness we use a coarser partition than Bias, Hillion, and Spatt (1995) and classify orders into three categories: Aggressive, Neutral, and Non-aggressive. Table 9 summarizes the criteria. Basically, Aggressive orders are market and marketable limits, Neutral orders are the limit order at or within the spread, and Non-aggressive orders are placed behind the best prices. During the continuous trading phase this classification is based on the location of the order price relative to the state of the book. During the CA it is based on the order price relative to prices at the end of the continuous trading phase.

Table 10 presents the results on order aggressiveness during the last 5 min of the continuous trading phase. We partition the orders into Large, Medium, and Small, since the order-submission strategy may be quite different for orders of varying sizes. These partitions are stock-specific: the top 25% of order sizes for each stock are considered Large, the bottom 25% are considered Small, while the rest are Medium. Since we cannot control for order splitting, we take the distribution of orders as exogenous.

Panel A reports the results for the MIB30 stocks. Following the introduction of the CA, Non-aggressive orders (NA) decrease from 49% in the Pre-period, to 34% in the Post-period and 37% in the Post–post-period. Neutral orders (N) increase from 19% in the Pre-period, to 30% and 28% in the Post- and Post–post-periods, respectively. This result is consistent with the theoretical predictions obtained from the models of LOB as summarized by *HVI.1* and *HV1.2*. The reduction in Non-aggressive orders and the increase in Neutral orders are strongest for the Large sizes. Small orders do not exhibit similar changes across the three sample periods. This suggests that the introduction of the CA mainly affects large institutional traders with high liquidity demands. Another interesting feature is that the size of the largest Non-aggressive orders declines dramatically. This suggests that submitting these orders

Table 10
This table presents the results on Order Aggressiveness during the last 5 min of the continuous session. Panel A and Panel B report data on average order size for the MIB30 and the MIDEX stocks; Panel C reports data on total order value and number of shares for both MIB30 and MIDEX Panels A and B classify orders both by type, according to the partition presented in Table 9, and by size; orders are partitioned into large, medium, and small: the largest 25% of orders, for each stock, is considered large, the bottom 25% is considered small, while the rest are medium. Both Panel A and Panel B report results for the average order size (in Euro amounts) and the percentage number of orders over the two periods Post and Post–post respectively. The percentage is computed over the total number of orders by row.

Order size	Time periods	Order type					
		Non aggressive		Neutral		Aggressive	
		Avg order size Euro	% tot	Avg order size Euro	% tot	Avg order size Euro	% tot
Panel A – MIB30							
Total							
	Pre	**131,181**	48.7%	**14,062**	18.8%	**22,468**	32.5%
	p-value pre vs. post	0.000	0.000	0.066	0.000	0.000	0.359
	p-value pre vs. Post–post	0.000	0.000	0.083	0.000	0.000	0.147
	Post (P)	**20,333**	34.3%	**16,149**	29.9%	**16,398**	35.9%
	p-value post vs. Post–post	0.000	0.173	0.229	0.228	0.628	0.371
	Post–post (Pp)	**14,161**	36.8%	**20,466**	28.4%	**15,893**	34.8%
Large							
	Pre	**438,408**	67.6%	**35,311**	11.7%	**57,643**	20.7%
	p-value pre vs. post	0.000	0.000	0.014	0.000	0.046	0.018
	p-value pre vs. Post–post	0.000	0.000	0.046	0.000	0.048	0.001
	Post (P)	**64,594**	35.7%	**45,280**	33.1%	**48,989**	31.2%
	p-value post vs. Post–post	0.000	0.139	0.173	0.973	0.865	0.590
	Post–post (Pp)	**40,642**	33.4%	**64,596**	32.3%	**48,563**	34.2%
Medium							
	Pre	**37,894**	45.8%	**9431**	21.2%	**14,578**	33.0%
	p-value pre vs. post	0.000	0.000	0.148	0.002	0.000	0.244
	p-value pre vs. Post–post	0.000	0.000	0.000	0.040	0.000	0.034
	Post (P)	**6874**	33.1%	**8690**	31.3%	**7142**	35.6%
	p-value post vs. Post–post	0.628	0.005	0.000	0.086	0.004	0.215
	Post–post (Pp)	**7044**	37.7%	**7015**	29.4%	**6264**	32.9%
Small							
	Pre	**2280**	35.4%	**1707**	21.5%	**2567**	43.2%
	p-value pre vs. post	0.000	0.002	0.000	0.200	0.000	0.011
	p-value pre vs. Post–post	0.000	0.039	0.000	0.007	0.000	0.001
	Post (P)	**732**	35.1%	**703**	23.9%	**953**	40.9%
	p-value post vs. Post–post	0.002	0.132	0.475	0.239	0.286	0.245
	Post–post (Pp)	**878**	38.4%	**736**	22.7%	**902**	38.9%
Panel B – MIDEX							
Total							
	Pre	**18,287**	45.6%	**6624**	19.7%	**10,259**	34.7%
	p-value pre vs. post	0.000	0.000	0.868	0.030	0.009	0.701
	p-value pre vs. Post–post	0.000	0.000	0.116	0.952	0.000	0.000
	Post (P)	**11,190**	35.4%	**6860**	26.7%	**8000**	37.9%
	p-value post vs. Post–post	0.000	0.001	0.065	0.260	0.000	0.001
	Post–post (Pp)	**6475**	35.2%	**4799**	31.1%	**5121**	33.8%
Large							
	Pre	**52,396**	47.0%	**17,421**	16.1%	**23,310**	36.9%
	p-value pre vs. post	0.000	0.002	0.935	0.003	0.267	0.156
	p-value pre vs. Post–post	0.000	0.000	0.176	0.070	0.000	0.000
	Post (P)	**31,665**	40.3%	**17,074**	23.6%	**20,620**	36.1%
	p-value post vs. Post–post	0.000	0.000	0.119	0.808	0.000	0.012
	Post–post (Pp)	**16,119**	36.5%	**12,059**	28.7%	**12,240**	34.8%

(*continued on next page*)

Table 10 (*continued*)

Order size	Time periods	Order type					
		Non aggressive		Neutral		Aggressive	
		Avg order size Euro	% tot	Avg order size Euro	% tot	Avg order size Euro	% tot
Medium							
	Pre	**6095**	47.0%	**2819**	20.0%	**5877**	32.9%
	p-value pre vs. post	0.000	0.000	0.741	0.056	0.003	0.763
	p-value pre vs. Post–post	0.000	0.000	0.123	0.850	0.000	0.000
	Post (P)	**3608**	34.7%	**2919**	28.2%	**4235**	37.1%
	p-value post vs. Post–post	0.000	0.051	0.017	0.466	0.000	0.000
	Post–post (Pp)	**2328**	35.4%	**2384**	33.1%	**2759**	31.5%
Small							
	Pre	**984**	41.8%	**751**	22.9%	**1200**	35.3%
	p-value pre vs. post	0.627	0.000	0.773	0.298	0.006	0.653
	p-value pre vs. Post–post	0.001	0.000	0.258	0.056	0.001	0.000
	Post (P)	**1227**	31.6%	**722**	27.5%	**790**	41.0%
	p-value post vs. Post–post	0.243	0.013	0.260	0.028	0.252	0.008
	Post–post (Pp)	**644**	33.5%	**645**	30.3%	**685**	36.2%

Panel C – MIB30 and MIDEX

	Time periods	Order type					
		Non aggressive		Neutral		Aggressive	
		Order value Euro m	Number of orders	Order value Euro m	Number of orders	Order value Euro m	Number of orders
MIB30							
	Pre	**7589.7 m**	**57,857**	**314.8 m**	**22,385**	**867.1 m**	**38,591**
	p-value pre vs. post	0.000	0.000	0.003	0.000	0.008	0.534
	p-value pre vs. Post–post	0.000	0.000	0.057	0.000	0.001	0.188
	Post (P)	**690.0 m**	**33,937**	**477.5 m**	**29,568**	**582.2 m**	**35,502**
	p-value post vs. Post–post	0.235	0.158	0.224	0.362	0.306	0.454
	Post–post (Pp)	**508.5 m**	**35,906**	**568.0 m**	**27,754**	**540.1 m**	**33,981**
MIDEX							
	Pre	**122.6 m**	**6705**	**19.2 m**	**2902**	**52.3 m**	**5100**
	p-value pre vs. post	0.000	0.000	0.059	0.354	0.006	0.012
	p-value pre vs. Post–post	0.000	0.000	0.099	0.912	0.000	0.000
	Post (P)	**51.3 m**	**4588**	**23.7 m**	**3460**	**39.3 m**	**4914**
	p-value post vs. Post–post	0.000	0.000	0.084	0.258	0.000	0.000
	Post–post (Pp)	**21.2 m**	**3273**	**13.9 m**	**2889**	**16.1 m**	**3141**

before the close of the continuous stage is no longer profitable, presumably due to increased competition from the Neutral orders.

In some cases, the proportion of Aggressive orders increases somewhat, which is consistent with *HVI.2*, suggesting that the state of the book is a factor affecting agents' order-submission strategies. At the same time overall the evidence is mixed as the percentage of total aggressive orders does not change significantly. Hence we cannot differentiate between the two hypotheses.

The results obtained for the MIB30 stocks are reproduced for the MIDEX stocks. Panel B shows that Non-aggressive orders decrease and Neutral orders increase over the sample periods; the pattern of Aggressive orders is ultimately decreasing for the MIDEX stocks. Larger orders again show the largest change. Hence, our results indicate a complex effect on the overall order aggressiveness.

The analysis of order-submission strategies during the CA is presented in Table 11. Results are not directly comparable to those of Table 10 because the definitions of order aggressiveness during the CA are different. However, we can compare the order size, as well as the evolution over time. Overall, the results from Table 11 show that over time the traders' confidence in the CA increased and traders

Table 11
Order Aggressiveness during the closing auction. Panel A reports the results for the MIB30 stocks and Panel B for the MIDEX stocks. Orders are classified by type (NAO, NO, and AO) and by size (small, medium, and large); they report results for the average order size (in Euro amounts) and the percentage number of orders over the two periods Post and Post–post. The percentage is computed over the total number of orders by row.

Order size	Time periods	Order type					
		Non aggressive		Neutral		Aggressive	
		Avg trade size (ATS) Euro	% tot	Avg trade size (ATS) Euro	% tot	Avg trade size (ATS) Euro	% tot
Panel A – MIB30							
Total							
	Post	40,041	65.5%	6731	6.6%	21,842	27.9%
	p-value post vs. Post–post	0.000	0.999	0.000	0.092	0.000	0.000
	Post–post	21,164	42.5%	9046	5.2%	50,078	52.4%
Large							
	Post	85,064	80.4%	18,450	4.2%	54,068	15.5%
	p-value post vs. Post–post	0.000	0.152	0.002	0.000	0.000	0.000
	Post–post	40,041	50.7%	28,413	6.4%	135,842	42.9%
Medium							
	Post	40,276	60.7%	4327	6.6%	16,266	32.7%
	p-value post vs. Post–post	0.000	0.042	0.117	0.565	0.000	0.000
	Post–post	20,930	37.9%	3392	4.6%	29,450	57.5%
Small							
	Post	2872	59.9%	561	9.0%	2343	31.1%
	p-value post vs. Post–post	0.742	0.000	0.246	0.330	0.000	0.000
	Post–post	2829	43.0%	470	5.0%	3811	52.0%
Panel B – MIDEX							
Total							
	Post	37,690	63.0%	10,311	13.5%	16,093	23.5%
	p-value post vs. Post–post	0.000	0.000	0.000	0.021	0.000	0.000
	Post–post	11,657	53.0%	3283	11.1%	8395	35.9%
Large							
	Post	71,662	76.1%	22,473	9.6%	31,426	14.3%
	p-value post vs. Post–post	0.000	0.000	0.000	0.063	0.000	0.000
	Post–post	21,334	66.0%	7,522	8.1%	17,649	26.0%
Medium							
	Post	40,722	61.9%	8,222	12.8%	14,008	25.3%
	p-value post vs. Post–post	0.000	0.000	0.000	0.323	0.000	0.000
	Post–post	12,087	50.8%	2458	12.0%	6515	37.1%
Small							
	Post	5894	51.8%	2030	18.6%	4195	29.6%
	p-value post vs. Post–post	0.000	0.001	0.000	0.001	0.000	0.000
	Post–post	1427	44.3%	451	12.5%	1341	43.2%

became more aggressive. This result, which holds for both stock samples, is especially evident in the most liquid MIB30 stocks. Furthermore, the aggressiveness of orders increased principally for large orders: during the Post-period large aggressive orders made up 16% of the total large orders submitted at the close, while during the Post–post-period this percentage increased to 43%. The average size of the MIB30 Aggressive orders during the CA is larger than the size of similar orders at the end of the continuous phase. The difference increases dramatically in the Post–post-period, indicating that traders feel confident enough about the depth of the CA to submit large Aggressive orders. The MIDEX results are only slightly different. While in the Post-period the Aggressive order size is also larger at the CA than before it, the size of orders actually declines in the Post–post-period and the difference shrinks. The size of Aggressive orders remains larger at the CA.

Overall Tables 10 and 11 suggest that the aggregate results presented earlier in the paper are indeed driven by the impact of the CA introduction on order-submission strategies.

To summarize, the results confirm the empirical implications of the theoretical models in Foucault (1999), Kaniel and Liu (2006), and Foucault et al. (2005). The reductions in traders' impatience and in volatility induce suppliers to offer liquidity at better prices and result in lower bid-ask spreads.

5. Conclusions

In December 2001 Borsa Italiana, an order-driven market, introduced a Closing Call Auction at the end of the continuous auction market. The objective of this innovation in market design was to increase the quality of the market at the end of the trading day. The Italian experiment was not isolated: practically all the main European exchanges introduced a Closing Call Auction (e.g. Deutsche Börse, Paris Bourse, and the London Stock Exchange) and, more recently, the NASDAQ market introduced a closing-batch mechanism at the end of the trading day.

In the call auction, consolidation of order flows may reduce the price impact of a trade. Furthermore, the enhancement of information revelation could improve the price discovery process and, by reducing intraday volatility, result in increased price stability. Finally, comparing the two systems, one should consider the relative benefits that some traders could obtain by moving from the discriminatory pricing rule of the continuous auction to the uniform pricing rule, which governs the batch system. The success of this change in market architecture depends on how effectively traders develop new strategies to deal with this new trading opportunity.

Using data from both the Italian and the French stock markets, we show that the effects of the introduction of the call auction are concentrated in the very last minutes of the continuous phase. We observe a significant reduction in quoted spread, volatility, trading volume and average trade size.

We also find strong support for the empirical implications of the existing theoretical models that focus on the impatience of traders prior to close (Kaniel and Liu (2006), Foucault (1999) and Foucault et al. (2005)), but not much support for the predictions of Admati and Pfleiderer (1988). This does not invalidate the latter model, but suggests that impatience and its effects in this case are more powerful than the information asymmetry ones. The introduction of the closing auction makes liquidity demanders less impatient and induces liquidity suppliers to offer liquidity at narrower bid-ask prices. The reduction in market orders and in the bid-ask bounce reduces volatility; this makes limit order submitters even more willing to supply liquidity. It follows that in terms of the agents' order-submission strategies, the proportion of Non-aggressive orders decreases, and the share of the orders submitted at or inside the BBO increases.

Using a data set on the agents' order submissions, we test the empirical implications on order aggressiveness. The results obtained for the different groups of stocks of the Borsa Italiana strongly confirm these predictions.

We also find evidence that the volume at the CA is much more sensitive to the intraday price movements in Milan than in Paris. We attribute this fact to the bias introduced by the BIt computation of the Reference Price. This suggests that by equating the Reference Price to the closing auction Price, as is done on Paris Bourse, BIt may increase the volume of trading at the closing auction, and make the closing price more efficient.

Acknowledgments

We would like to thank Borsa Italiana and Paris Bourse, particularly Luca Filippa, for providing the data, for comments and support. We would also like to thank an anonymous referee, A. Admati, T. Foucault, M. Ghezzi, D.Goldreich, O. Kadan, R. Kaniel, M. Pagano, I. Tkatch, S. Viswanathan (the Editor), A. Wohl as well as participants at the Bank of Canada conference on "Microstructure of Foreign Exchange and Equity Markets" (November 2006) and at Bocconi University workshop for their comments and help. Massimo Matraia, Davide Melone, Yehuda Porath, and Stefano Rivellini provided valuable research assistance. Rindi would like to acknowledge the financial support from Bocconi University ("Ricerca di Base" Project). Kandel would like to thank the Krueger Center for Finance Research at the Hebrew University for financial support.

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