Intraday Volatility and the Closing Auction at Borsa Istanbul

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Abstract

The effect of the implementation of a closing call auction on market efficiency and volatility is examined at Borsa Istanbul (BIST) stock exchange in Turkey. Borsa Istanbul is distinctive that it employs two consecutive trading sessions during the day, and similar to other emerging markets trading patterns there are significantly influenced by global developments. Using 30-, 15, and 5-minute intervals, we document the accentuated volatility after the market open in the morning and afternoon sessions, and before the market close. Accentuated intra-day volatility is indicative of a lack of market efficiency, and points to the difficulty traders and market makers have in interpreting information and clearing accumulated trading orders. We show that the implementation of a closing call decreases volatility accentuation just prior to the market close, and hence increases market efficiency. During heightened volatility price discovery process is hampered, and thus taking accentuated volatility patterns into account helps control unnecessary risk exposure and would help with the performance of investment portfolios. Risk management and hedging strategies should consider this information by adjusting their trading patterns during these higher volatility periods.

JEL classification: G14; D40

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1. Introduction

Global trade and international investments have seen continual growth over the last decades owing to a reduction of frictions on capital flows across borders, a higher level of integration across markets, and the ease with which information can be accessed around the world. Investors have increased their allocations of funds to international markets, especially to emerging country financial markets.

In this global framework, intraday trading activity in developed and emerging country equity markets have become more susceptible to international news and events, and volatilities have increased. Recent studies such as Jawadi, et al. (2015) find evidence of volatility spillover from the U.S. to European markets and vice versa at different times during the trading day supporting the contagion hypothesis between the U.S. and European stock markets. Nishimura, et al. (2015) study return/volatility spillover from China to Japan with high frequency data and report that China's large impact on Japanese stocks has become stronger in recent years, as the Chinese economy has gained importance. A detailed study by Ozenbas, et al. (2002) investigates and compares intra-day volatility patterns across several European and US equities markets.

Overly accentuated volatility in stock markets is not a desirable characteristic because it may indicate periods of inefficiency, difficulties in price discovery, and potential disadvantages to some market participants. Consequently, exchange regulators and policy makers try to develop ways to reduce accentuated volatility in stock markets. One such mechanism is implementing opening, closing and/or intra-day call auction systems. According to Schwartz and Davis (2010), a call auction batches orders together for simultaneous execution in a multilateral trade, at a single price, at a single point in time. In other words, a call auction accumulates the buy and sell orders prior to a set point in time, and then determines a fair execution price that maximizes the number of shares traded based on these orders. For example, before the market opens in the morning, the accumulated orders are used to determine the opening auction price. Similarly, after the continuous market closes in the evening, unexecuted orders and orders that were specifically sent to the call auction are accumulated to determine the closing call auction price. The auction mechanism is supposed to alleviate the frantic trading behavior right after the market open and right before the market close. Thus, the volatility smile (the observed accentuated volatility pattern at the market open and close) which is a common characteristic of many stock exchanges is expected to diminish with the help of these auction systems.

This issue is particularly important for emerging markets, such as Borsa Istanbul. The large and open Turkish economy is a good representative of an emerging economy, where a significant portion of participants are non-domestic and international news and economic events have a significant impact. For example, when economic news are announced in the U.S. on a typical weekday morning, the time zone difference corresponds roughly to the closing time of Borsa Istanbul. Given the increased globalization of recent years and the difficulty of full and correct interpretation of international news, we expect significant increase over time in intraday volatility in the Turkish Stock exchange, particularly around closing time. Indeed, due to these and other concerns, Borsa Istanbul implemented on March 2, 2012 a closing call auction that takes place soon after the closing of continuous trading.

In this paper, we investigate the impact of the global information flow on the intraday stock market price behavior of Borsa Istanbul. Borsa Istanbul is an interesting case since it employs two consecutive trading sessions during the day; the most current trading hours are an initial session between 9.35am and 12.30pm and a second session between 2.15pm and 5.30pm. Therefore, it has two market openings and two closings per day. Additionally, Turkey has become a larger and more important developing market over the last decade and similar to all emerging markets the trading patterns there are significantly influenced by global developments. In this study, we examine several different issues. First, using up-to-date intraday data, we address the intraday volatility pattern at Borsa Istanbul. Second, we document the dynamic evolution of the pattern over an extended period of time and determine whether volatility has increased with time. Third, we examine whether the implementation of a closing auction by the exchange has been successful in reducing intraday volatility. We investigate these issues by measuring volatility using a variety of alternative techniques. We document volatility throughout the trading day focusing on the opening and closing 1-hour periods, as well as the mid-session periods. Since the Turkish stock exchange has a mid-day break, we measure intraday volatility both during the morning and the afternoon sessions, and around the midday closing and reopening periods.

We find that there is a volatility smirk for the morning session. The accentuated volatility when the market opens in the morning subsides during the morning session without any increase before the midday close; hence the smirk. We find a volatility smile in the afternoon session. The accentuated volatility when the market reopens subsides during mid-trading period and then

increases again before the market closes for the day. This finding is consistent with academic literature that shows that the volatility at the close is mainly driven by the traders scrambling to complete their orders before an extended period of non-trading such as Ozenbas et. al. (2010). Since there is no extended period of non-trading there is also no volatility accentuation at the market close during the mid-day break at Borsa Istanbul. We also document that intraday volatility has increased substantially over time due to the increase of the consequential impact of international news and events. Finally, we find that the closing call auction system has had a positive impact on the reduction of intraday volatility. A comparison of intraday volatility before and after the implementation of the closing call indicates a clear reduction in volatility accentuation before the market close. These conclusions are statistically significant and robust to several volatility measurements.

The rest of the paper is organized as follows. Section 2 provides an overview of related literature review, and describes the trading procedures and the implementation of the closing call by Borsa Istanbul in 2012. Section 3 presents the data and empirical framework. Section 4 presents the discussion and interpretation of the empirical results. Conclusion follows.

2. Literature Review

Intraday volatility accentuation has been investigated extensively, especially for developed country stock markets. Short-term volatility patterns provide information about the efficiency of equity markets. Accentuated opening volatility indicates the difficulty market participants have in translating information accumulated overnight into trading prices. On the other hand, accentuated volatility before the closing indicates the difficulty traders face when trying to complete their trades before an extended period of non-trading.

Stoll (2000) shows that noisy trading leads to arbitrary price fluctuations. These fluctuations increase short-term volatility and lead to illiquidity, inefficiency, and ultimately the discouragement of investors from participating in financial markets. Schwartz and Francioni (2004) analyze the microstructure of international stock exchanges and intraday volatility patterns. Kissell (2014) compares the performance of different intraday volatility models applied to the US stock exchanges. Studies such as Madhavan, et al. (1997), Ozenbas (2006), and Nguyen and Phengpis (2009) find a U-shaped curve in volatility during the day. Ozenbas, et al. (2010) and Hussain (2009) examine the quality of price discovery and find that large

capitalization stocks lead smaller-cap stocks to their new equilibrium values in the U.S. and U.K. stock markets.

The opening and closing procedures play an extremely critical role in facilitating price discovery. For example, many exchanges including Nasdaq, New York Stock Exchange, London Stock Exchange and the Deutsche Börse use opening and closing call auctions to generate liquidity and to execute orders at one price. In addition to Borsa Istanbul, other developing markets such as the Bombay Stock Exchange also recently implemented auctions to close trading. London Stock Exchange, further, recently announced plans to implement intra-day call auctions to control volatility and assist price discovery and liquidity. Using call auctions is advocated by studies such as Barclay, et al. (2008), Chang, et al. (2008), and Schwartz and Davis (2010) where the authors document that the market quality of continuous trade increases because of the call auction systems.[1]

While developed country equity markets have been investigated extensively for intraday price movements and volatility patterns, there has been relatively limited research on emerging country equity markets in general. Choe and Shin (1993) and Tian and Guo (2007) study Korean Stock Exchange and Shanghai Stock Exchange, respectively, and find L shaped volatility patterns both for the morning trading session and for the afternoon trading session. Tissaoui (2012) presents evidence of a seasonal U-shaped pattern in return volatility at the Tunisian Stock Market.

The Turkish 'Borsa Istanbul' (BIST) became active in 1986. Bildik (2001) and Inci (2012) have surveyed the intraday return and volatility behavior at the Istanbul Stock Exchange using different sample periods. Kucukkocaoglu (1997) discusses auction systems at stock exchanges in his descriptive study. Kadıoglu, et al. (2015) examine the closing call auction system at Borsa Istanbul focusing on the system's impact on price manipulation and stock price returns. Our paper is different from previous work; we examine the impact of the call auction system on intraday volatility accentuation, especially near the market close.

Borsa Istanbul has a midday trading break. The trading hours have changed evolved over

[1] It should be noted that the call auction system has also received criticism. Hillion and Suominen (2004) develop a theoretical model for the Paris Bourse to examine the relationship between closing price manipulation and the impact of call auction at close. Furthermore, according to Camilleri and Green (2009), potential order imbalances may lead to even lower liquidity during the call auction. The call auction trading mechanism may spill over to regular trading hours, which may reduce liquidity and price efficiency. Without a doubt the call auction procedures need to be designed carefully to avoid any manipulation or other adverse effects. Overall, however, the call auction system is currently utilized in the majority of the developed country stock exchanges.

the three decades. The morning session starts at 9.50am and concludes at 12.30pm for the break. The afternoon session starts at 2.20pm and concludes at 5.30pm. There are two blind pre-opening auctions in the morning and in the afternoon. The first opening auction is from 9.30am to 9.50am (order collection is from 9.30am to 9.45am and price determination is from 9.45am to 9.50am). The second opening auction is from 2pm to 2.20pm (order collection is from 2pm to 2.10pm and price determination is from 2.10pm to 2.20pm).

There are approximately 300 stocks traded at the BIST; however, the focus of this study is the 100 most actively traded stocks at the exchange. Thus, the volatility patterns are not related to liquidity frictions. For robustness, we also examine the 30 largest stocks. Using 30-minute, 15-minute, and 5-minute trading intervals separately, we use various intraday volatility measures to explore accentuated volatility and the impact of the closing call auction system.

2.1. Trading hours and opening procedures at the BIST

There are various trading instruments at the Borsa Istanbul Stock Exchange (BIST), such as ordinary shares (most of the intra-day volume), ETFs, preference shares, right issues, and ADRs. The stock exchange regulator is the Capital Markets Board of Turkey (CMB). There is no foreign ownership restriction, and foreign ownership has been between 60-70% of the float over the last decade. Trading at the BIST operates on an order driven system with two blind opening auctions preceding each of the two sessions during the day. The exchange has instituted a call auction system in 2001 to open the market in the morning. The closing call auction and the corresponding price determination were implemented in March 2, 2012.

The changes in trading hours since the inception of the BIST is as follows:

10am to 12pm and 2pm to 4pm	[1 January 1986 – 13 August 2001]
9.30 am to 12pm and 2pm to 4.30pm	[13 August 2001 – 2 February 2007]
10am to 12pm and 2pm to 4.30pm	[2 February 2007 – 7 September 2007]
9.45am to 12pm and 2pm to 5pm	[7 September 2007 – 13 October 2008]
9.50am to 12.30pm and 2pm to 5pm	[13 October 2008 – 19 October 2009]
9.50am to 12.30pm and 2pm to 5.30pm	[19 October 2009 – 13 November 2009]
9.50am to 12.30pm and 2.20pm to 5.30pm	[13 November 2009 – 5 April 2013]
9.45am to 12.30pm and 2.20pm to 5.30pm	[5 April 2013 – 10 June 2013]

9.35am to 12.30pm and 2.15pm to 5.30pm [10 June 2013 – Current]

There are two opening auctions: before the market opens in the morning and before the market opens in the afternoon. The current opening auction session is from 9.15am to 9.35am (the call phase from 9.15am to 9.30am is used for order collection, and the price determination phase from 9.30am to 9.35am is used for producing a consensus share price). The first quotation by the market maker is collected between 9.30am and 9.34am and the first quotation is provided by the electronic system at 9.34am. The afternoon opening auction session is from 2pm to 2.15pm (the call phase is from 2pm to 2.10pm for order collection, and the price determination phase is from 2.10pm to 2.15pm.).

2.2. Closing Call Auction System

The closing call auction has been introduced by Borsa Istanbul on March 2, 2012. The purpose is to determine a single price at which the highest number of trades can be matched by combining, in a single call auction, the unmatched orders from the main trading session and the new orders received prior to the auction. All trades are executed at the single price to achieve the highest trading volume. The closing auction has four phases:

(1) Order transfer phase (3 minutes, 17:30 – 17:33): All unmatched orders excluding quotation orders are transferred to be included in the closing session.

(2) Order collection phase (3 minutes, 17:33 – 17:36): New bid and ask orders are also entered into the trading system for price determination. Market-on-Close bid and ask orders with quantity but without price are also entered into the trading system.

(3) Price determination and closing session transactions phase (2 minutes, 17:36–17:38): The closing price is determined. The orders from the continuous auction phase, the limit price orders from the order collection phase, and market on close (MoC) orders are executed at this price.

(4) Trades at the closing price/single price phase (2 minutes, 17:38 – 17:40): During this 2-minute phase, orders may be entered only for the securities traded in the closing session. New bid and ask orders entered in the trading system at the closing price are traded in accordance with the priority rules if matched with a pending order of the same price.

3. Data

The sample period is from January 5, 1998 through December 31, 2014 and includes tick by tick price data during the day for every trading day.[2] The 100 most liquid of the approximately 300 stocks of the stock exchange are used for the investigation. 30-minute, 15-minute, and 5-minute trading period volatilities of the stock price movements are computed.

We follow two alternatives to generate volatility measurements. In the first alternative, we focus on the trading segment (30-, 15-, or 5-minute) itself. We use the price changes at the beginning of the trading period and at the end of the trading period to calculate four variables: the regular return (ret), the log return (log), the absolute value of the price difference (abs), and the normalized absolute price difference (nabs) ('abs' divided by the end price of the trading period). Each variable of the same trading period of every day are collected altogether. Volatility of the measurement is then computed for that trading period segment. In addition to these four variables, we also calculate the differences between the maximum and minimum prices during that trading period (maxmin), and the normalized max-min differences (nmaxmin) ('maxmin' divided by the average of the beginning price and the end price of the interval). Then we compute the standard deviations of these variables for the trading period segment. The six volatility measures from this first alternative are commonly used in this area of the literature. We call this set of measurements as periodic (5-, 15-, 30-minute) return volatility measurements.

The second alternative set of volatility measures focuses on the tick-by-tick price movements within the trading segment (30-, 15-, or 5-minute). We compute the tick-by-tick price returns (ret), the log returns of the tick prices (log), the absolute values of the tick price differences (abs), and the normalized absolute price differences (nabs) ('abs' divided by the final price) within the trading segment. We then collect each variable of the same trading period for each day and compute its volatility measurement. We call this second set of measurements as tick return volatility measurements.

Previous studies have reported an evolving ecology of the stock markets over time. We

[2] Research involving intraday frequency data tend to use shorter sample periods due to the high volume of the data. For example, Belhaj, et al. (2015) use an intraday data sample from October 2011 through September 2012 even though their daily frequency portion of their paper uses a sample from January 2008 through June 2012. Similarly, Tissaoui (2012) uses intraday data covering the period October 2008 to June 2009. Bildik (2001) examines intraday return behavior at the Istanbul Stock Exchange using a very limited sample period from 1996 through 1998. In this paper, the sample period is much longer than previous studies on the Turkish stock exchange. The proprietary data are not readily available and were provided by Borsa Istanbul. The extensive data period covers most of the policy changes in the microstructure of the Turkish Stock Exchange. Therefore, the results, conclusions, and comparisons represent Turkish and similar emerging country stock markets.

split the entire sample period into two parts to examine the dynamic evolution of the volatility patterns: the early sample from January 5, 1998 to July 1, 2006 and the recent sample from July 1, 2006 to December 31, 2014. We also split the entire sampling period into three parts for robustness: the early sub-sample from January 5, 1998 through May 1, 2003; the middle sub-sample from May 1, 2003 through September 1, 2009; and the recent sub-sample from September 1, 2009 to December 31, 2014. We investigate these early and recent sub-sample periods for pattern changes over the decades.

We explore the presence of accentuated volatility during the opening of the stock market in the morning, during the closing of the stock market before the lunch break, during opening of the stock market after the lunch break, and during the closing of the stock market at the end of the trading day. The differences in the volatilities of different intraday time periods are presented with point estimates, statistical tests, and graphical plots.

We investigate the closing call auction system in March, 2012. We explore whether the implementation was necessary due to an overall elevation of volatility over time. We then try to find out the impact of the closing call auction by presenting intraday volatility patterns before and after the implementation of the closing auction. We focus especially on volatility in the last few minutes before the close of the market for the day. We conjecture accentuated volatility before March 2012 implementation of the closing call auction system. We also conjecture subsiding volatility after March 2012. We find clear evidence supporting our conjectures.

4. Results and Discussion

We first document the general characteristics of intraday volatility patterns at Borsa Istanbul. Different volatility measurements using the 5-minute time intervals are presented in Table 1. For both the morning and afternoon sessions, volatilities are for the opening 20-minutes, the middle of the session, and the last 20 minutes before the market closes. A quick inspection of our 1998-2014 sample reveals that highest volatilities are during the 5-minutes when the stock market opens in the morning. The second highest volatility is seen the market reopens in the afternoon. The third highest volatility is around when the market closes, but this last observation is not supported by all the volatility measures.

We repeat the analysis with different intervals to determine whether the initial conclusions are supported. In Panel A of Table 2, we use 30-minute intervals and examine the

opening and closing of the market. Panel B of Table 2 reports volatilities computed for 15-minute intervals. Both panels support the initial pattern in Table 1. During the morning session, volatility is very high when the market opens in the morning; and eventually subsides for the rest of the first session. The pattern looks like a 'smirk', or an L-shape. The afternoon session also starts with accentuated volatility, diminishes by the middle of the session, but kicks up as the market close nears. By some volatility measures, the afternoon volatility pattern resembles a 'smirk'; but by other volatility measures, the pattern looks like a 'smile', or U-shape.

Visual representation of the conclusions in Table 1 and Table 2 are in Figure 1. Figure 1(a) is based on 5-minute return volatilities. We can clearly observe the 'smirk' pattern in volatility in the morning. The afternoon pattern is not entirely clear. Some volatility measures indicate a 'smile', while others indicate a similar 'smirk' like that of the morning session. Figure 1(b) is based on 15-minute intervals, and Figure 1(c) is based on 30-minute intervals, and the patterns are very similar to those of the 5-minute intervals.

The volatility measures in the first two tables are based on the defined intervals. For example, absolute value of the price difference is computed using the beginning and the end of the period prices. As an alternative to this set of volatility measurements, we compute variables based on tick-by-tick price movements during the pre-specified interval. We report this alternative set of intraday volatility measurements in Table 3. Panel A is based on tick-by-tick returns during 5-minute intervals. Panel B tick returns are based on 30-minute intervals, and Panel C tick results are based on 15-minute intervals. The alternative intraday volatility measures in Table 3 also confirm the accentuated volatility pattern during the opening of the market in the morning and in the afternoon. There is also stronger evidence of accentuated volatility before the close of the market. All four tick-by-tick volatility measures point to volatility 'smile' pattern in the afternoon session. These conclusions from Table 3 are confirmed in Figure 2. The morning session is characterized by an intraday volatility 'smirk', while the afternoon session by an intraday volatility 'smile' based on either 5-minute or 15-minute intervals.[3]

It has been reported in previous studies that intraday volatility evolves over time. Reduction of trade barriers across borders and increasing relevance of international news and events have made emerging equity markets more susceptible to non-domestic developments, and

[3] The intraday volatility graph for 30-minute intervals is very similar to 5-and 15-minute graphs and therefore not included for brevity.

thus, more volatile. To investigate the evolution of intraday volatility at Borsa Istanbul, we split our 1998-2014 sample into two sub-samples: Early and Recent; and also into three sub-samples: Early, Middle, and Recent. For brevity, we report a subset of the volatility measures in Table 4. The volatilities for the first two columns are based on the trading interval. The last column is based on tick-by-tick values during the interval. Panel A reports the results for 5-minute intervals, while the other two panels report the results for 30-minute and 15-minute intervals, respectively. We consistently observe an increasing volatility pattern from the early sub-samples to the recent sub-samples in every panel.

We now focus on the implementation of the closing call auction system by Borsa Istanbul on March 2, 2012 and its impact on the rising intraday volatility over time. For our analysis in this section, we examine a 5-year sub-sample around the closing call auction; namely, from May 1, 2009 to December 31, 2014. We compare the volatility patterns of the sub-samples before (May 1, 2009 to March 2, 2012) and after (March 2, 2012 to December 31, 2014) the closing call auction. Our main interest is finding out whether the closing call auction has led to a decrease in intraday volatility right before the market closes, and whether this decrease is statistically significant. We conjecture that the existence of a closing call auction system should alleviate the intense pressure to trade before the market closes for the day because the closing call auction provides another opportunity. Additionally, some market participants may decide to skip the period leading to the market close and choose to trade only during the closing call, taking advantage of its superior price discovery based on matching the highest number of buys and sells possible. Ultimately volatility before the closing of the market should decline with the introduction of the closing call auction.

Table 5 presents the intraday volatility measurements before and after the closing call auction system using 5-minute interval returns. The results reveal the same L-shaped intraday volatility pattern during the morning session both before and after the closing call auction system. The magnitudes of intraday volatility measures are comparable before and after the closing call auction system. On the other hand, the afternoon session exhibits very different patterns before and after the closing call auction system. The pattern before the implementation of the auction system is a clear volatility ‘smile’ with accentuated volatility before the close of the market. After the auction system, intraday volatility diminishes such that the pattern changes from a ‘smile’ to an L-shaped ‘smirk’, just like the morning session. Table 6 investigates the

same issue, but utilizing volatilities based on tick prices. The results are consistent with those in Table 5. The afternoon session exhibits a significant difference after the closing call auction system is enacted, especially before the market closes for the day.

The conclusions in Table 5 and Table 6 are also confirmed in Figure 3. Based on 5-minute intervals, the volatility measures are plotted in Figure 3(a) before the closing call auction of March 2012, and in Figure 3(b) after the closing call auction. Comparison of the two figures reveals the definitive impact of the closing auction system in reducing accentuated volatility near the close of the market for the day. Figure 4 is based on tick-by-tick return volatilities. Before and after plots of Figure 4 are consistent with those of Figure 3. We observe the calming effect of the closing call auction in the afternoon, even extending into the morning session.

The evidence thus far indicates that implementation of a closing call reduces intraday volatility around the market close. There is also evidence of an overall decline in volatility levels in the afternoon session. There is mixed evidence about the impact of a closing call on intraday volatility during the morning session. In order to better understand the impact of a closing call compared to mid-session volatility we compute volatility ratios. This way we are able to examine the relative effect of the closing call throughout the trading day. If the ratio of the closing volatility to the average mid-session volatility declines (i.e. if the volatility ratio declines), it would further provide evidence of the effectiveness of the closing auction system. Therefore, we calculate the closing period-to-mid-afternoon volatility ratio for each of our volatility measures. We also calculate the closing period-to-mid-morning volatility ratios. We use 5-minute (Panel A) and 15-minute (Panel B) period returns and tick-by-tick returns to compute and report volatility ratios in Table 7. Naturally, most volatility ratios in the table are larger than one, reflecting the accentuation of volatility before the market closes for the day. We also see that the volatility ratios decline consistently after the implementation of the closing call auction system. While the ratio continues to be above one for some volatility rations, it is less than one for others. This is further confirmation of the effectiveness of the closing call auction in reducing volatility accentuation prior to the market close. Figure 5 is based on the 5-minute period returns reported on the second part of Panel A in Table 7. For each measure, the first two volatility ratios use mid-morning volatilities, while the last two volatility ratios use mid-afternoon volatilities as the denominator. Each case depicts the decline of the volatility ratio after the implementation of the closing call auction.

We investigate the closing minutes of the stock market more carefully in Table 8. We report the point estimates of the closing interval volatilities before and after the implementation of the closing call auction system. The point estimates are consistently lower for the sub-sample after the closing call auction according to 5-minute, 30-minute, and 15-minute intervals. Every volatility measure, whether based on tick price returns, or based on interval returns provide similar evidence, except for a couple of exceptions.

The point estimates in Table 8 are informative; however, the conclusions must be statistically confirmed. In Table 9, we report the statistical significance of the differences in end-of-the-day volatilities before and after the closing call auction of March 2012. For each volatility measure, we conduct a test of equality of volatilities before and after the closing auction date. As the last column of the table demonstrated, almost all the statistical tests confirm at 1% significance level that intraday volatility has decreased statistically after the implementation of the closing call auction. For robustness, we also split the May 2009 to December 2014 data into three subsamples. We compared the closing period volatilities of the earliest subsample with the most recent subsample. Results reported in Table 10 confirm that the reduction of intraday volatility after the implementation of the closing call auction is statistically significant mostly at 1% level.

For further robustness checks, we investigate the subset of 30 largest and most actively traded stocks. We focus on the differences between end-of-day volatilities before and after the implementation of the closing call auction. As in Table 9 and Table 10, we split the May 2009 - December 2014 sample into two and then into three sub-samples (and compare the volatilities from the first and the third sub-sample). The F-test statistics in both Panel A and Panel B of Table 11 clearly demonstrate the decline in volatility after the implementation of the closing call auction.

5. Conclusion

A closing call auction can be an important tool for reducing intraday volatility and enhancing market efficiency and price discovery, especially in emerging country equity markets. In this paper, we examine an important emerging country stock market: Borsa Istanbul of Turkey. Borsa Istanbul is distinctive that it employs two consecutive trading sessions during the day, and as a large and significant emerging market, the trading patterns there are significantly influenced by

global developments. Using the longest time series data to date analyzing this market, we verify that intraday volatility in the Turkish stock exchange exhibits a 'smirk' in the morning session and a 'smile' in the afternoon session. This finding is consistent with academic literature that shows that the volatility at the close is mainly driven by the traders rushing to complete their orders before an extended period of non-trading. Since there is no extended period of non-trading there is also no volatility accentuation at the market close during the mid-day break at Borsa Istanbul, hence the 'smirk'.

We examine the evolution of the smile over the 1998-2014 period, and verify that the 'smile' has become more pronounced in the second half of the sample period. The reduction of trade restrictions along with economic policies supporting full integration with global economy has increased the impact of global news and events on Borsa Istanbul. This is manifest in higher levels of accentuated volatility, especially during the afternoon trading session when there is more overlap with developed country markets due to time zone differences. We document that this trend has mobilized the exchange to take precautions by adopting the closing call auction system in March 2012. Opening and closing call auctions, while widely used in developed country markets such as NASDAQ, NYSE, London Stock Exchange, and Deutsche Börse, are relatively less common tools for developing country markets where there is typically much less liquidity. Bombay Stock Exchange is another developing country market that recently implemented call auctions. Using a detailed examination of the 5-year period around the implementation of the call auction, we show that intraday volatility near the end of the trading day has statistically declined following the implementation of the closing call at Borsa Istanbul.

The presence of a closing call auction system reduces volatility accentuation and increases market efficiency. Confidence of market participants are boosted. Domestic and international capital flows into the equity market increase in such an environment. The findings in the paper are important for risk management policies. Strategies looking for reduced volatility and increased efficiency thrive with the closing call auction system, while counter strategies become less profitable. Closing auction system and the related policies adopted at Borsa Istanbul, Turkey can be a guide for other emerging stock exchanges for the promotion of an attractive and efficient investment environment. There are some initiatives in developed country equity markets, such as the London Stock Exchange, for intraday call auction sessions. The results of this paper on the effectiveness of a closing call auction system are encouraging for

these initiatives as well.

References

Barclay, M.J., Hendershott, T., and Jones, C.M. (2008). Order Consolidation, Price Efficiency, and Extreme Liquidity Shocks. The Journal of Financial and Quantitative Analysis, 43, 93-121.

Belhaj, F., Abaoub, E., and Mahjoubi, M.N. (2015). Number of Transactions, Trade Size and the Volume-Volatility Relationship: An Interday and Intraday Analysis on the Tunisian Stock Market. International Business Research, 8, 135-152.

Bildik, R. (2001). Intra-day seasonalities on stock returns: Evidence from the Turkish stock market. Emerging Markets Review, 2, 387-417.

Camilleri, S.J., and Green, C.J. (2009). The impact of the suspension of opening and closing call auctions: evidence from the National Stock Exchange of India. International Journal of Banking, Accounting and Finance, 1, 257–284.

Chang, R., Rhee, G., Stone, G. and Tang, N. (2008). How does the Call Market method affect price efficiency? Evidence from the Singapore Stock Market. Journal of Banking and Finance, 32, 2205–2219.

Choe, H., and Shin, H.K. (1993). An Analysis of Interday and Intraday Return Volatility Evidence from the Korea Stock Exchange. Pacific-Basin Finance Journal, 1, 175-188.

Hillion, P., and Suominen, M. (2004). The Manipulation of Closing Prices. Journal of Financial Markets, 7, 351-375.

Hussain, S.M. (2009). Intraday Dynamics of International Equity Markets. Hanken School of Economics Ph.D. Thesis.

Inci, A.C. (2012). Accentuated Intraday Volatility in Emerging Markets: The Turkish Stock Exchange. Journal of International Finance Studies, 12, 37-52.

Jawadi, F., Louhichi, W., and Cheffou, A.I. (2015). Intraday bidirectional volatility spillover across international stock markets: does the global financial crisis matter? Applied Economics, 47, 3633-3650.

Kadıoglu, E., Kuçukkocaoglu, G., and Kılıç, S. (2015). Closing price manipulation in Borsa Istanbul and the impact of call auction sessions. Borsa Istanbul Review, 15, 213-221.

Kissell, R. (2014). The Science of Algorithmic Trading and Portfolio Management. Academic Press, Waltham, MA.

Kucukkocaoglu, G. (2008). Intra-Day Stock Returns and Close-End Price Manipulation In the Istanbul Stock Exchange. Frontiers in Finance and Economics, 5, 46-84.

Kucukkocaoglu, G. (1997). Single Price Auction System for the Istanbul Stock Exchange. ISE Review, 8, 65-79.

Madhavan, A., Richardson, M., and Roomans, M. (1997). Why do security prices change? A transaction-level analysis of NYSE stocks. Review of Financial Studies, 10, 1035-1064.

Nguyen, V., and Phengpis, C. (2009). An analysis of the opening mechanisms of Exchange Traded Fund markets. The Quarterly Review of Economics and Finance, 49, 562-577.

Nishimura, Y., Tsutsui, Y., and Hirayama, K. (2015). Intraday return and volatility spillover mechanism from Chinese to Japanese stock market. Journal of the Japanese and International Economies, 35, 23-42.

Ozenbas, D. (2006). Pattern of Short-Term Volatility Accentuation within the Trading Day: An Investigation of the US and European Equity Markets. International Business & Economics Research Journal, 5, 11-24.

Ozenbas, D., Pagano, M.S., and Schwartz, R.A. (2010). Accentuated Intraday Stock Price Volatility: What is the Cause? The Journal of Portfolio Management, 36, 45-55.

Ozenbas, D., Schwartz, R.A., and Wood, R.A. (2002). Volatility in US and European Equity Markets: An Assessment of Market Quality. International Finance, 5, 437-461.

Hillion, P., and Suominen, M. (2004). The manipulation of closing prices. Journal of Financial Markets, 7, 351–375.

Schwartz, R.A., and Davis, P.L. (2010). Call Auction Markets. Encyclopedia of Quantitative Finance, Wiley, Hoboken NJ.

Schwartz, R.A., and Francioni, R. (2004). Equity Markets in Action. Wiley, Hoboken NJ.

Stoll, H. (2000). Friction. The Journal of Finance, 55, 1479–1515.

Tian, G., and Guo, M. (2007). Interday and Intraday Volatility: additional evidence from the Shanghai Stock Exchange. Review of Quantitative Finance and Accounting, 28, 287-306.

Tissaoui, K. (2012). The Intraday Pattern of Trading Activity, Return Volatility and Liquidity: Evidence from the Emerging Tunisian Stock Exchange. International Journal of Economics and Finance, 4, 156-176.

Table 1. 5-minute Intraday Volatilities

The sample period is from January 5, 1998 through December 31, 2014. Each variable in the table represents a different standard deviation measurement: absprcdif is of absolute values of the final and beginning price differences for the period; retlog is of the log returns in basis points; ret is of the returns expressed in basis points; mad is of the absolute value of end of period and beginning of period price difference normalized by the final price in basis points; maxmin is of the difference between maximum and minimum values of the trading period; and normmaxmin is of the difference between maximum and minimum values of the trading period divided by the average of the final and beginning prices of the trading period in basis points.

5-Minute Intervals	N	absprcdif	retlog	ret	mad	maxmin	normmaxmin
All	75,364	65.98	34.93	34.90	28.48	75.18	31.74
1st 5 min.	4,198	133.15	85.81	85.50	68.75	138.05	71.53
2nd 5 min	4,198	71.58	42.26	42.58	33.56	79.73	36.58
3rd 5 min.	4,195	68.93	36.52	36.50	28.62	76.01	30.18
4th 5 min.	4,198	62.15	34.41	34.41	25.52	69.08	28.22
Mid-morning 5 min.	4,204	43.24	21.97	21.95	16.38	53.68	20.55
4th to last 5 min. bef. break	4,204	38.98	21.48	21.44	16.51	49.95	20.57
3rd to last 5 min. bef. break	4,204	36.43	20.28	20.26	15.09	47.19	19.32
2nd to last 5 min.bef.break	4,204	35.95	20.69	20.67	15.46	47.52	19.71
Last 5 min. before break	4,204	38.29	22.23	22.23	16.57	50.37	20.41
1st 5 min. after break	4,181	84.50	45.91	45.75	38.10	89.44	40.78
2nd 5 min after break	4,179	59.16	29.81	29.81	23.28	69.12	27.41
3rd 5 min. after break	4,181	53.13	29.63	29.60	22.50	61.93	25.96
4th 5 min. after break	4,184	60.05	28.30	28.30	21.72	66.97	25.78
Mid-afternoon 5 min.	4,186	54.68	24.56	24.56	18.64	65.50	22.09
4th to last 5 min. bef. close	4,183	56.75	25.00	24.99	18.02	66.57	21.01
3rd to last 5 min. bef. close	4,185	54.53	24.97	24.95	18.09	64.99	21.33
2nd to last 5 min.bef. close	4,091	51.83	24.22	24.22	16.97	63.12	21.20
Last 5 min. before close	4,185	61.71	27.75	27.78	19.90	74.36	23.84

Table 2. 30-minute and 15-minute Intraday Return Volatilities

Panel A is for 30-minute trading intervals. Panel B is for 15-minute trading intervals. The intraday sample is from January 5, 1998 through December 31, 2014. The volatility measurements are the same as those in Table 1.

Panel A. 30-Minute Intervals	N	absprcdif	retlog	ret	mad	maxmin	normmaxmin
All the returns	41,594	127.53	66.97	66.88	51.73	158.52	63.72
1st 30 min.	4,204	165.70	112.14	112.07	85.87	204.47	102.09
2nd 30 min	4,203	118.29	61.94	61.74	46.53	143.93	57.21
Mid-morning 30 min.	3,840	98.06	56.67	56.40	42.90	121.97	51.68
2nd to last 30 min. bef. break	4,209	97.58	53.29	53.03	42.14	116.69	51.30
Last 30 min. before break	4,205	86.73	48.13	48.02	36.53	110.56	46.69
1st 30 min. after break	4,185	156.94	81.99	81.93	61.81	182.87	75.41
2nd 30 min. after break	4,187	106.31	55.10	55.07	41.72	132.75	53.20
Mid-afternoon 30 min.	4,188	124.93	56.14	56.09	41.62	153.24	50.95
2nd to last 30 min. bef. close	4,186	120.56	56.29	56.34	40.79	151.13	50.40
Last 30 min. before close	4,187	146.30	61.78	61.78	43.50	176.96	50.55
Panel B. 15-Minute Intervals	N	absprcdif	retlog	ret	mad	maxmin	normmaxmin
All	75,498	93.41	48.90	48.85	38.27	113.28	45.84
1st 15 min.	4,200	149.66	101.02	100.92	78.20	175.86	90.42
2nd 15 min	4,201	99.51	55.93	55.95	40.64	118.98	47.64
3rd 15 min.	4,202	85.71	48.24	48.14	35.85	100.89	42.66
4th 15 min.	4,201	79.74	39.74	39.73	29.31	97.17	36.41
Mid-morning 15 min.	4,206	72.40	39.27	39.11	30.30	89.79	36.00
4th to last 15 min. bef. break	4,207	67.22	39.54	39.25	32.13	82.11	37.85
3rd to last 15 min. bef. break	4,206	68.34	36.70	36.60	28.55	83.13	35.13
2nd to last 15 min. bef. break	4,204	67.04	36.07	35.95	28.10	83.99	34.96
Last 15 min. before break	4,205	58.45	34.54	34.52	26.03	75.27	32.30
1st 15 min. after break	4,182	123.58	67.66	67.52	53.05	140.69	62.12
2nd 15 min after break	4,185	102.19	47.39	47.45	35.61	117.17	43.65
3rd 15 min. after break	4,186	81.31	42.29	42.26	32.30	97.81	38.80
4th 15 min. after break	4,185	74.76	38.26	38.23	29.08	93.02	35.95
Mid-afternoon 15 min.	4,187	87.20	39.94	39.91	29.75	106.86	36.80
4th to last 15 min. bef. close	4,186	89.93	40.55	40.54	29.38	109.94	35.67
3rd to last 15 min. bef. close	4,184	81.86	40.72	40.77	30.36	103.58	36.50
2nd to last 15 min. bef. close	4,185	102.58	44.30	44.30	31.36	122.60	36.10
Last 15 min. before close	4,186	97.61	42.56	42.56	29.94	117.90	35.67

Table 3. Tick Return Intraday Volatilities

The sample is from January 5, 1998 through December 31, 2014. Standard deviation measurements are: absprcdif - absolute values of the tick price differences during the period; retlog - log returns of tick-by-tick price movements in basis points; ret - the tick-by-tick price returns in basis points; mad - absolute value of tick-by-tick price differences normalized by the end tick price in basis points.

Panel A. 5-Minute Intervals	N	absprcdif	retlog	ret	mad
All Returns	2,142,602	17.36	8.86	8.86	7.29
1st 5 min.	121,037	24.42	15.18	15.17	13.02
2nd 5 min	120,277	17.31	8.81	8.81	7.03
3rd 5 min.	118,789	17.01	8.30	8.30	6.69
4th 5 min.	120,880	16.64	8.36	8.36	6.61
Mid-morning 5 min.	118,018	14.80	7.13	7.13	5.87
4th to last 5 min. bef. break	116,727	14.64	7.00	7.00	5.80
3rd to last 5 min. bef. break	116,893	14.41	6.89	6.89	5.70
2nd to last 5 min.bef.break	117,334	14.58	6.89	6.89	5.68
Last 5 min. before break	118,653	15.29	7.27	7.27	5.93
1st 5 min. after break	119,734	20.95	11.25	11.26	9.28
2nd 5 min after break	116,646	16.45	8.20	8.20	6.70
3rd 5 min. after break	119,349	15.88	8.09	8.09	6.52
4th 5 min. after break	120,539	15.56	8.01	8.01	6.47
Mid-afternoon 5 min.	117,897	15.41	7.28	7.28	5.97
4th to last 5 min. bef. close	120,831	16.54	8.04	8.04	6.40
3rd to last 5 min. bef. close	120,002	16.97	8.42	8.42	6.63
2nd to last 5 min.bef. close	119,037	17.42	9.07	9.07	7.07
Last 5 min. before close	119,959	20.93	11.00	11.00	8.38
Panel B. 30-Minute Intervals	N	absprcdif	retlog	ret	mad
All the returns	7,041,063	16.03	7.91	7.91	6.49
1st 30 min.	718,998	18.41	9.77	9.77	8.12
2nd 30 min	717,327	15.49	7.58	7.58	6.16
Mid-morning 30 min.	641,954	15.08	7.57	7.57	6.19
2nd to last 30 min. before break	701,880	14.66	7.11	7.11	5.90
Last 30 min. before break	701,583	14.75	6.99	6.99	5.77
1st 30 min. after break	713,191	16.82	8.60	8.60	7.04
2nd 30 min. after break	709,535	15.09	7.39	7.39	6.06
Mid-afternoon 30 min.	707,181	15.26	7.35	7.35	6.04
2nd to last 30 min. before close	710,953	15.84	7.46	7.46	6.07
Last 30 min. before close	718,461	17.65	8.73	8.73	6.91
Panel C. 15-Minute Intervals	N	absprcdif	retlog	ret	mad
All Returns	6,402,389	16.09	7.93	7.93	6.51
1st 15 min.	359,201	20.09	11.24	11.23	9.49
2nd 15 min	360,332	16.46	8.05	8.05	6.41
3rd 15 min.	360,817	15.67	7.79	7.79	6.31
4th 15 min.	356,928	15.31	7.35	7.35	5.99
Mid-morning 15 min.	353,719	14.84	7.22	7.22	5.95
4th to last 15 min. bef. break	352,543	14.67	7.24	7.24	6.00
3rd to last 15 min. bef. break	349,688	14.64	6.98	6.98	5.79
2nd to last 15 min. bef. break	349,434	14.74	6.96	6.96	5.77
Last 15 min. before break	352,511	14.77	7.02	7.02	5.78
1st 15 min. after break	354,679	18.01	9.31	9.32	7.66
2nd 15 min after break	359,004	15.49	7.82	7.82	6.35
3rd 15 min. after break	356,141	15.22	7.48	7.48	6.12
4th 15 min. after break	353,833	14.96	7.30	7.30	6.00
Mid-afternoon 15 min.	353,428	15.23	7.33	7.33	6.02
4th to last 15 min. bef. close	355,095	15.85	7.44	7.44	6.06
3rd to last 15 min. bef. close	356,218	15.83	7.48	7.48	6.08
2nd to last 15 min. bef. close	360,271	16.49	7.82	7.82	6.26

Last 15 min. before close	358,547	18.63	9.56	9.56	7.44

Table 4. Evolving Intraday Volatility

Left half of the table uses period returns to compute standard deviations: absprcdif (absolute values of the final and beginning price differences for the period) and maxmin (difference between maximum and minimum values of the trading period). Right half of the table uses tick data to compute standard deviation: absprcdifT - absolute values of the tick price differences during the period. Panel A is based on 5-minute periods, Panel B is based on 15-minute periods, and Panel C is based on 30-minute periods. The sample period is from January 5, 1998 through December 31, 2014, Early half sample is from January 5, 1998 to July 1, 2006 and Recent half sample is from July 1, 2006 to December 31. Finally the entire sample is split into three parts and First (January 5, 1998 through May 1, 2003), Second (May 1, 2003 through September 1, 2009), and Third (September 1, 2009 to December 31, 2014).

Panel A. 5mR	N	absprcdif	maxmin	5mT	N	absprcdifT
Entire Sample	75,364	65.98	75.18	Entire Sample	2,142,602	17.36
Early	37,597	52.35	58.73	Early	1,017,951	12.64
Recent	37,767	73.13	76.99	Recent	1,124,651	19.92
First	23,650	41.25	49.07	First	608,979	12.65
Second	28,477	68.42	72.41	Second	839,858	15.57
Third	23,469	75.01	77.75	Third	700,424	21.14
Panel B. 30mR	N	absprcdif	maxmin	30mT	N	absprcdifT
Entire Sample	41,594	127.53	158.52	Entire Sample	7,041,063	16.03
Early	20,911	89.49	113.50	Early	3,362,985	11.25
Recent	20,683	147.83	160.22	Recent	3,678,078	18.63
First	13,159	75.15	98.03	First	2,010,407	11.52
Second	15,836	120.53	141.71	Second	2,776,818	13.73
Third	12,729	157.63	169.56	Third	2,275,807	20.10
Panel C. 15mR	N	absprcdif	maxmin	15mT	N	absprcdifT
Entire Sample	75,498	93.41	113.28	Entire Sample	6,402,389	16.09
Early	37,620	67.16	81.30	Early	3,030,336	11.33
Recent	37,878	106.99	114.25	Recent	3,372,053	18.65
First	23,671	56.68	71.20	First	1,811,378	11.58
Second	28,493	90.41	101.77	Second	2,502,499	13.84
Third	23,568	112.08	120.09	Third	2,108,308	20.04

Table 5. Closing Call Auction – Volatility Before and After

The table presents the volatility analysis around the implementation of the Closing Call Auction on March 2, 2012. The subsample from May 1, 2009 through December 31, 2014 around the closing call auction is split into two parts: Before the start of the closing auction from May 1, 2009 to March 2, 2012 and After the start of the closing auction from March 2, 2009 to December 31, 2004. 5-minute period beginning and final prices are used for volatility measurements as in Table 1.

Before Auction Policy	N	absprcdif	retlog	ret	mad	maxmin	normmaxmin
1st 5 min.	715	104.36	30.71	30.68	20.21	97.58	19.33
2nd 5 min	715	83.58	23.76	23.74	16.29	79.20	15.51
3rd 5 min.	714	83.31	23.80	23.79	15.95	76.10	14.96
4th 5 min.	714	70.03	20.16	20.16	13.49	66.98	13.23
Mid-morning 5 min.	715	49.81	13.80	13.80	9.21	55.08	10.44
4th to last 5 min. before break	713	48.37	13.38	13.38	9.11	55.78	10.50
3rd to last 5 min. before break	713	45.40	12.58	12.58	8.48	53.36	9.94
2nd to last 5 min. before break	713	42.60	11.90	11.90	8.03	51.96	9.59
Last 5 min. before break	713	45.61	12.26	12.27	8.10	54.62	10.04
1st 5 min. after break	708	86.80	22.46	22.43	15.94	81.17	15.08
2nd 5 min after break	708	71.96	19.01	18.98	13.63	71.36	13.54
3rd 5 min. after break	708	62.03	17.26	17.26	11.31	62.18	11.33
4th 5 min. after break	708	99.94	21.58	21.76	17.47	99.89	17.81
Mid-afternoon 5 min.	708	63.16	17.89	17.88	12.87	66.60	14.17
4th to last 5 min. before close	708	67.73	18.93	18.92	13.01	65.77	12.86
3rd to last 5 min. before close	708	70.97	20.06	20.04	14.20	70.59	14.15
2nd to last 5 min. before close	708	65.50	18.37	18.35	12.55	64.91	12.69
Last 5 min. before close	708	85.94	22.36	22.40	16.10	79.69	15.30
After Auction Policy	N	absprcdif	retlog	ret	mad	maxmin	normmaxmin
1st 5 min.	685	118.29	24.53	24.52	16.26	123.04	16.52
2nd 5 min	685	89.51	17.65	17.63	11.98	89.30	11.79
3rd 5 min.	685	84.40	17.22	17.22	11.33	79.97	10.71
4th 5 min.	686	75.39	14.91	14.91	9.98	71.35	9.38
Mid-morning 5 min.	687	59.07	11.04	11.04	7.98	60.37	8.00
4th to last 5 min. before break	687	43.75	8.73	8.73	6.05	47.29	6.34
3rd to last 5 min. before break	687	40.40	8.28	8.28	5.60	42.06	5.68
2nd to last 5 min. before break	687	42.93	8.53	8.53	5.95	43.92	5.98
Last 5 min. before break	686	44.39	8.72	8.72	6.03	45.82	5.99
1st 5 min. after break	681	92.04	17.75	17.72	12.74	91.62	12.45
2nd 5 min after break	681	76.59	14.98	14.97	10.19	74.09	9.64
3rd 5 min. after break	681	66.91	12.98	12.98	9.07	66.79	8.90
4th 5 min. after break	681	64.31	12.48	12.48	8.68	61.53	8.29
Mid-afternoon 5 min.	683	63.22	11.93	11.94	8.61	64.93	8.74
4th to last 5 min. before close	683	74.97	14.30	14.30	9.91	74.48	9.57
3rd to last 5 min. before close	683	70.87	13.71	13.71	9.50	68.53	8.88
2nd to last 5 min. before close	589	68.39	13.26	13.27	9.05	66.89	8.75
Last 5 min. before close	683	57.59	12.00	12.00	7.82	60.43	7.89

Table 6. Closing Call Auction Implementation – Tick Return Volatilities

The table presents the volatility analysis around the implementation of the Closing Call Auction on March 2, 2012. The subsample from May 1, 2009 through December 31, 2014 around the closing call auction date is split into two parts: Before the start of the closing call auction from May 1, 2009 to March 2, 2012 and After the start of the closing call auction from March 2, 2009 to December 31, 2004. Tick-by-tick price returns are used for volatility measurements for the 5-minute trading periods as in Table 3.

Before Closing Auction	N	absprcdif	retlog	ret	mad
1st 5 min.	21,503	28.53	7.36	7.36	5.28
2nd 5 min	21,504	23.87	6.12	6.12	4.42
3rd 5 min.	21,484	23.68	6.06	6.06	4.38
4th 5 min.	21,482	23.73	6.03	6.03	4.38
Mid-morning 5 min.	21,401	21.67	5.16	5.16	3.95
4th to last 5 min. before break	21,236	21.47	5.03	5.03	3.93
3rd to last 5 min. before break	21,212	21.57	4.99	4.99	3.90
2nd to last 5 min. before break	21,231	21.51	5.01	5.01	3.88
Last 5 min. before break	21,301	22.19	5.30	5.30	4.04
1st 5 min. after break	21,261	26.90	6.79	6.79	5.01
2nd 5 min after break	21,274	23.26	5.76	5.76	4.28
3rd 5 min. after break	21,240	22.86	5.56	5.56	4.16
4th 5 min. after break	21,253	22.85	5.57	5.57	4.20
Mid-afternoon 5 min.	21,199	22.24	5.38	5.38	4.13
4th to last 5 min. before close	21,297	23.31	5.85	5.85	4.25
3rd to last 5 min. before close	21,300	24.09	6.16	6.16	4.44
2nd to last 5 min. before close	21,277	24.30	6.33	6.33	4.49
Last 5 min. before close	21,298	29.88	7.91	7.91	5.60
After Closing Auction	N	absprcdif	retlog	ret	mad
1st 5 min.	20,736	22.60	4.23	4.23	3.06
2nd 5 min	20,724	17.70	3.40	3.40	2.39
3rd 5 min.	20,711	16.40	3.18	3.18	2.24
4th 5 min.	20,712	16.12	3.09	3.09	2.18
Mid-morning 5 min.	20,569	14.37	2.64	2.64	1.95
4th to last 5 min. before break	20,437	14.15	2.56	2.56	1.92
3rd to last 5 min. before break	20,429	13.23	2.45	2.45	1.82
2nd to last 5 min. before break	20,440	13.65	2.50	2.50	1.86
Last 5 min. before break	20,464	14.71	2.74	2.74	1.98
1st 5 min. after break	20,579	17.52	3.26	3.26	2.38
2nd 5 min after break	20,592	16.02	2.98	2.98	2.14
3rd 5 min. after break	20,588	15.67	2.95	2.95	2.13
4th 5 min. after break	20,579	14.96	2.87	2.87	2.04
Mid-afternoon 5 min.	20,438	14.74	2.74	2.74	1.99
4th to last 5 min. before close	20,505	17.58	3.39	3.39	2.38
3rd to last 5 min. before close	18,902	17.81	3.45	3.45	2.40
2nd to last 5 min. before close	17,685	18.35	3.43	3.43	2.38
Last 5 min. before close	18,017	18.88	3.74	3.74	2.53

Table 7. Volatility Ratios Before and After Closing Call Auction

Volatility ratios use the closing period volatility in the numerator and either mid-morning or mid-afternoon volatility in the denominator. 5-minute (Panel A) and 15-minute (Panel B) period returns and tick-by-tick returns are used for volatility measurements. The volatility ratios before and after the implementation of the closing Call Auction Mechanism (CAM) are reported. The standard deviation measures are the same as those in Table 1 and in Table 3.

Panel A. 5-minute periods

	Tick-by-Tick Returns					Period Returns			
	Mid-morning		Mid-Afternoon			Mid-morning		Mid-Afternoon	
	Before CAM	After CAM	Before CAM	After CAM		Before CAM	After CAM	Before CAM	After CAM
absprcdif	1.38	1.31	1.34	1.28	absprcdif	1.73	1.36	0.97	0.91
retlog	1.53	1.42	1.47	1.36	retlog	1.62	1.25	1.09	1.01
ret	1.53	1.42	1.47	1.36	ret	1.62	1.25	1.09	1.01
mad	1.42	1.30	1.36	1.27	mad	1.75	1.25	0.98	0.91
					maxmin	1.45	1.20	1.00	0.93
					normmaxmin	1.47	1.08	0.99	0.90

Panel B. 15-minute periods

	Tick-by-Tick Returns					Period Returns			
	Mid-morning		Mid-Afternoon			Mid-morning		Mid-Afternoon	
	Before CAM	After CAM	Before CAM	After CAM		Before CAM	After CAM	Before CAM	After CAM
absprcdif	1.23	1.20	1.28	1.23	absprcdif	1.45	1.26	1.30	0.95
retlog	1.32	1.28	1.34	1.28	retlog	1.49	1.25	1.31	1.05
ret	1.32	1.28	1.34	1.28	ret	1.49	1.25	1.31	1.04
mad	1.24	1.21	1.25	1.20	mad	1.51	1.23	1.32	0.95
					maxmin	1.37	1.19	1.26	0.96
					normmaxmin	1.43	1.16	1.24	0.92

Table 8. End-of-Day Volatilities Before and After Closing Call Auction

Closing time volatilities are reported before and after the implementation of the closing call auction system. The point estimates of the volatility measures are reported. The volatility measures are the same as those in Table 1 and in Table 3.

Closing Time Volatilities					
absprcdif	Before	After	**retlog**	Before	After
5mRet	85.94	57.59	5mRet	22.36	12.00
15mRet	124.76	111.33	15mRet	35.08	22.73
30mRet	175.07	200.87	30mRet	49.80	39.01
5mTick	29.88	18.88	5mTick	7.91	3.74
15mTick	26.43	18.37	15mTick	6.85	3.54
30mTick	25.18	17.84	30mTick	6.39	3.43
ret	Before	After	**mad**	Before	After
5mRet	22.40	12.00	5mRet	16.10	7.82
15mRet	35.08	22.73	15mRet	23.92	15.04
30mRet	49.70	38.99	30mRet	34.12	26.98
5mTick	7.91	3.74	5mTick	5.60	2.53
15mTick	6.85	3.54	15mTick	4.91	2.44
30mTick	6.39	3.43	30mTick	4.64	2.39
maxmin	Before	After	**normmaxmin**	Before	After
5mRet	79.69	60.43	5mRet	15.30	7.89
15mRet	120.66	118.31	15mRet	24.30	15.49
30mRet	177.69	196.74	30mRet	36.15	25.82

Table 9. Statistical Tests of End-of-Day Volatilities Before and After Closing Call Auction Implementation

The statistical significance of the differences in end-of-the-day volatilities before and after the closing call auction of March 2012 are reported. For each volatility measure, F-test of equality of volatilities before and after the closing auction date is reported. The last column reports the p-values, while the next to last column reports the F-test statistics. The May 2009 to December 2014 data is split into two sub-samples in the table.

Before Half vs. After Half		Numerator DoF	Denom. DoF	F Value	Pr > |F|
5m Period Volatilities	absprcdif	707	682	2.23	0.00
	retlog	707	682	3.47	0.00
	ret	707	682	3.48	0.00
	mad	707	682	4.24	0.00
	maxmin	707	682	1.74	0.00
	normmaxmin	707	682	3.76	0.00
5m Tick Volatilities	absprcdif	21,297	18,016	2.5	0.00
	retlog	21,297	18,016	4.47	0.00
	ret	21,297	18,016	4.47	0.00
	mad	21,297	18,016	4.9	0.00
15m Period Volatilities	absprcdif	707	682	1.26	0.00
	retlog	707	682	2.38	0.00
	ret	707	682	2.38	0.00
	mad	707	682	2.53	0.00
	maxmin	707	682	1.04	0.60
	normmaxmin	707	682	2.46	0.00
15m Tick Volatilities	absprcdif	63,759	54,564	2.07	0.00
	retlog	63,759	54,564	3.74	0.00
	ret	63,759	54,564	3.74	0.00
	mad	63,759	54,564	4.05	0.00
30m Period Volatilities	absprcdif	470	103	1.5	0.01
	retlog	470	103	2.03	0.00
	ret	470	103	2.04	0.00
	mad	470	103	1.71	0.00
	maxmin	470	103	2.21	0.00
	normmaxmin	470	103	2.59	0.00
30m Tick Volatilities	absprcdif	127,401	115,981	1.99	0.00
	retlog	127,401	115,981	3.46	0.00
	ret	127,401	115,981	3.46	0.00
	mad	127,401	115,981	3.75	0.00

Table 10. Statistical Tests of End-of-Day Volatilities around Closing Auction Implementation

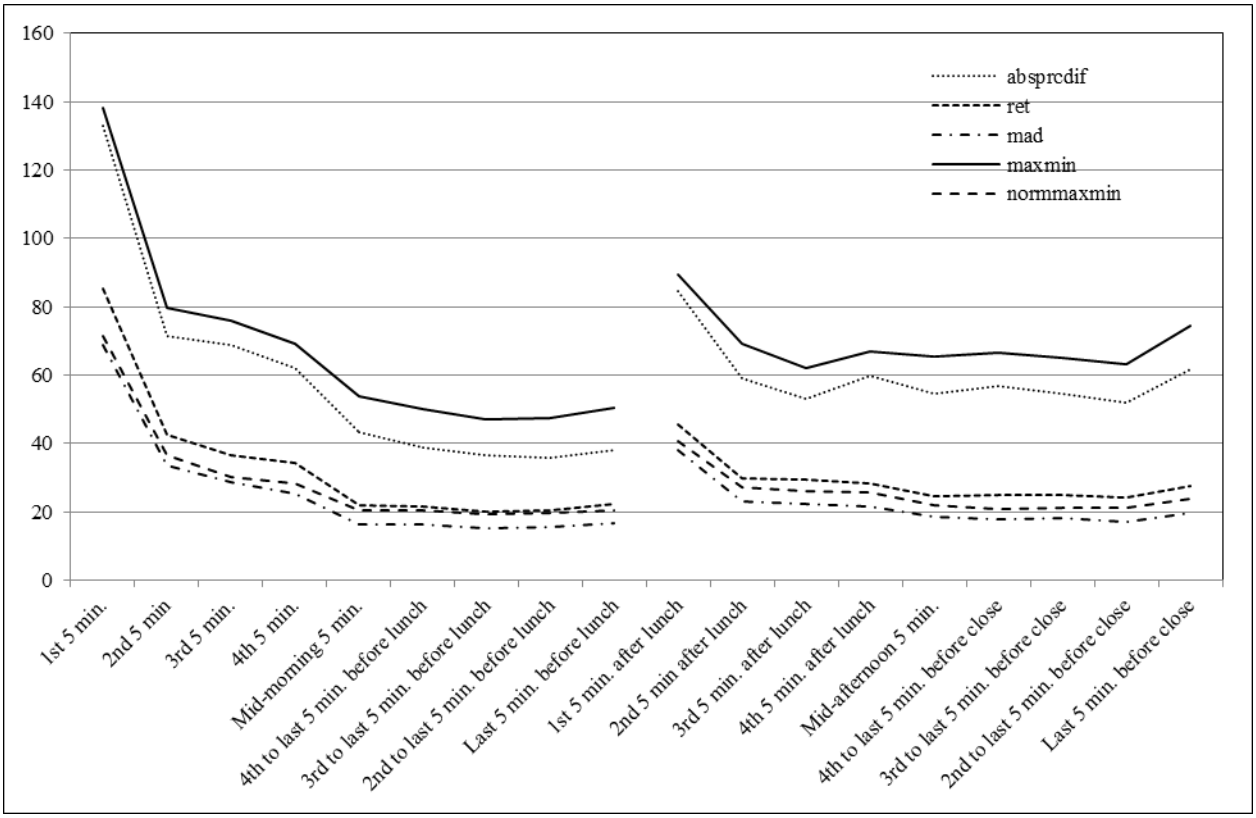
The statistical significance of the differences in end-of-the-day volatilities before and after the closing call auction of March 2012 are reported. For each volatility measure, F-test of equality of volatilities before and after the closing auction date is reported. The last column reports the p-values, while the next to last column reports the F-test statistics. The May 2009 to December 2014 data is split into three sub-samples in the table. And the earliest and most recent sub-samples are compared.

First 1/3rd Before vs. Third 1/3 After		Numerator DoF	Denom. DoF	F Value	Pr > |F|
5m Period Volatilities	absprcdif	467	467	1.61	0.00
	retlog	467	467	2.97	0.00
	ret	467	467	2.97	0.00
	mad	467	467	3.34	0.00
	maxmin	467	467	1.6	0.00
	normmaxmin	467	467	3.27	0.00
5m Tick Volatilities	absprcdif	14,074	14,049	3.09	0.00
	retlog	14,074	14,049	6.14	0.00
	ret	14,074	14,049	6.14	0.00
	mad	14,074	14,049	6.67	0.00
15m Period Volatilities	absprcdif	467	467	1.03	0.71
	retlog	467	467	2.05	0.00
	ret	467	467	2.05	0.00
	mad	467	467	2.27	0.00
	maxmin	467	467	1.17	0.09
	normmaxmin	467	467	2.01	0.00
15m Tick Volatilities	absprcdif	42,143	42,123	2.51	0.00
	retlog	42,143	42,123	4.98	0.00
	ret	42,143	42,123	4.98	0.00
	mad	42,143	42,123	5.32	0.00
30m Period Volatilities	absprcdif	470	467	1.27	0.01
	retlog	470	467	1.28	0.01
	ret	470	467	1.28	0.01
	mad	470	467	1.21	0.04
	maxmin	470	467	1.52	0.00
	normmaxmin	470	467	1.39	0.00
30m Tick Volatilities	absprcdif	84,203	84,220	2.35	0.00
	retlog	84,203	84,220	4.54	0.00
	ret	84,203	84,220	4.55	0.00
	mad	84,203	84,220	4.86	0.00

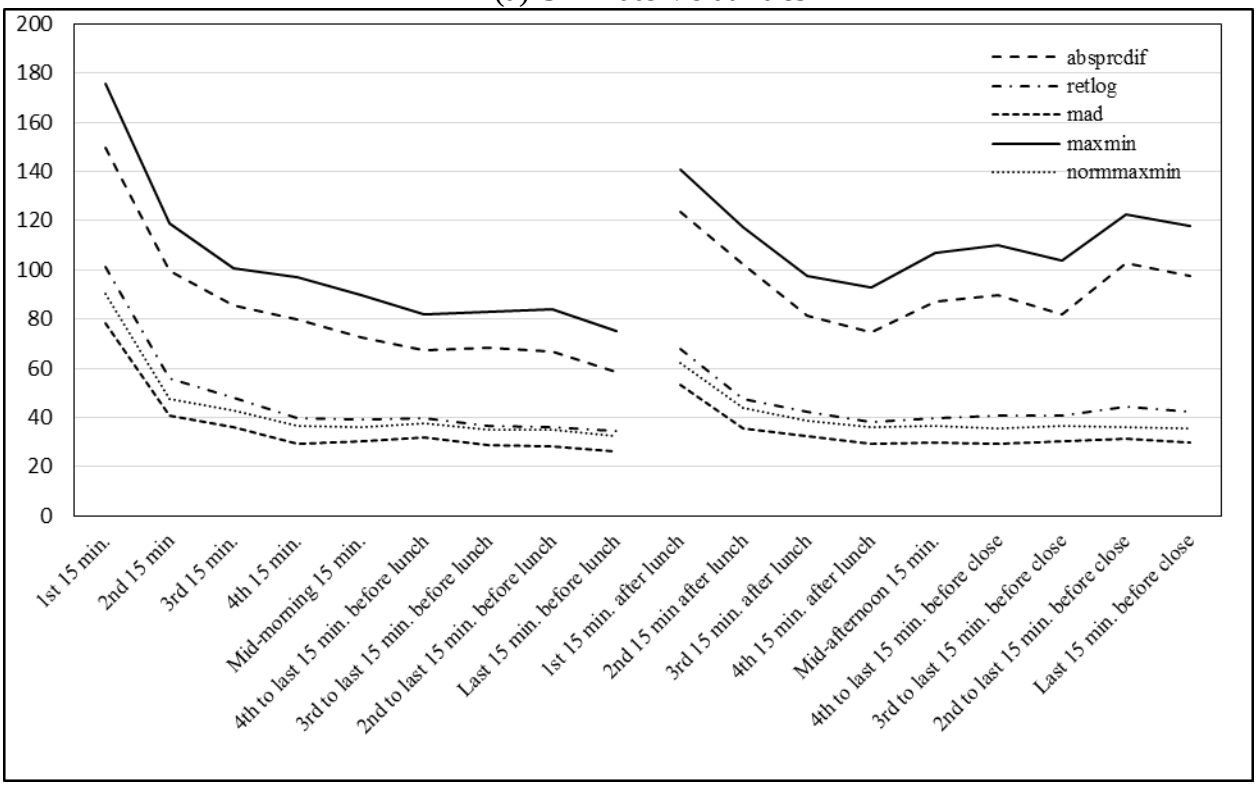
Table 11. Statistical Tests of End-of-Day Volatilities around Closing Auction Implementation for Top 30 Stocks

The statistical differences between end-of-day volatilities before and after the implementation of the closing call auction system are reported for 30 largest and most actively traded stocks at Borsa Istanbul. As in Table 9 and Table 10, the May 2009 - December 2014 sample is split into two sub-samples on the left part of the table and then into three sub-samples on the right part of the table (the first and the third sub-samples are compared). The F-test statistics and the corresponding p-values are reported.

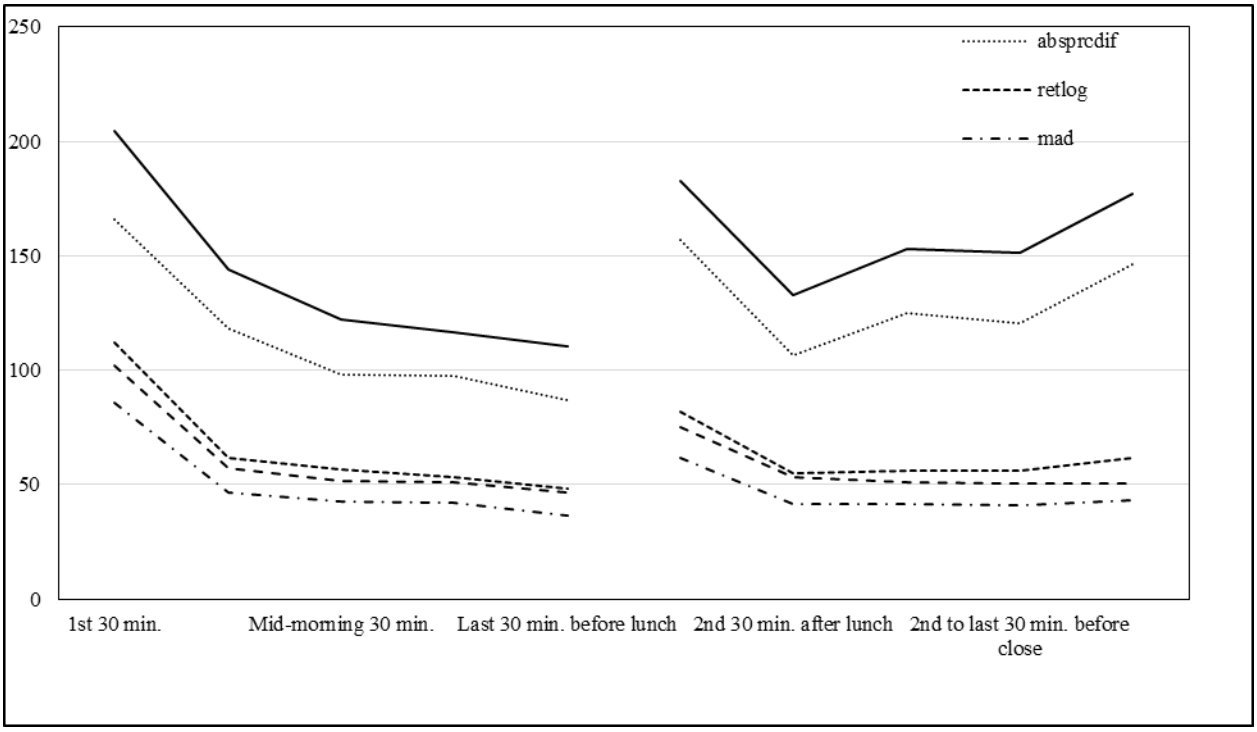
		Panel A. Early Half vs. Recent Half				Panel B. First 1/3rd vs. Third 1/3			
		Num.DoF	Den.DoF	F Val	Pr > |F|	Num.DoF	Den.DoF	F Val	Pr > |F|
5m Period	absprcdif	707	682	2.14	0.00	467	467	1.63	0.00
	retlog	707	682	3.55	0.00	467	467	3.06	0.00
	ret	707	682	3.56	0.00	467	467	3.07	0.00
	mad	707	682	3.99	0.00	467	467	3.19	0.00
	maxmin	707	682	1.68	0.00	467	467	1.74	0.00
	normmaxmin	707	682	3.44	0.00	467	467	3.32	0.00
5m Tick	absprcdif	21,820	17,921	2.65	0.00	14,599	14,025	3.35	0.00
	retlog	21,820	17,921	4.41	0.00	14,599	14,025	6.04	0.00
	ret	21,820	17,921	4.41	0.00	14,599	14,025	6.04	0.00
	mad	21,820	17,921	4.89	0.00	14,599	14,025	6.77	0.00
15m Period	absprcdif	707	682	1.27	0.00	467	467	1.06	0.52
	retlog	707	682	2.34	0.00	467	467	1.98	0.00
	ret	707	682	2.34	0.00	467	467	1.98	0.00
	mad	707	682	2.44	0.00	467	467	2.15	0.00
	maxmin	707	682	1.05	0.51	467	467	1.11	0.26
	normmaxmin	707	682	2.37	0.00	467	467	1.92	0.00
15m Tick	absprcdif	64,788	54,024	2.22	0.00	43,294	41,856	2.73	0.00
	retlog	64,788	54,024	3.74	0.00	43,294	41,856	4.93	0.00
	ret	64,788	54,024	3.74	0.00	43,294	41,856	4.93	0.00
	mad	64,788	54,024	4.1	0.00	43,294	41,856	5.4	0.00
30m Period	absprcdif	682	707	1.33	0.00	467	467	1.71	0.00
	retlog	707	682	1.58	0.00	467	467	1.3	0.00
	ret	707	682	1.57	0.00	467	467	1.29	0.01
	mad	707	682	1.51	0.00	467	467	1.26	0.01
	maxmin	682	707	1.24	0.00	467	467	1.7	0.00
	normmaxmin	707	682	1.86	0.00	467	467	1.33	0.00
30m Tick	absprcdif	127,780	114,085	2.16	0.00	85,181	83,212	2.57	0.00
	retlog	127,780	114,085	3.49	0.00	85,181	83,212	4.56	0.00
	ret	127,780	114,085	3.49	0.00	85,181	83,212	4.56	0.00
	mad	127,780	114,085	3.82	0.00	85,181	83,212	4.96	0.00



(a) 5-minute Volatilities

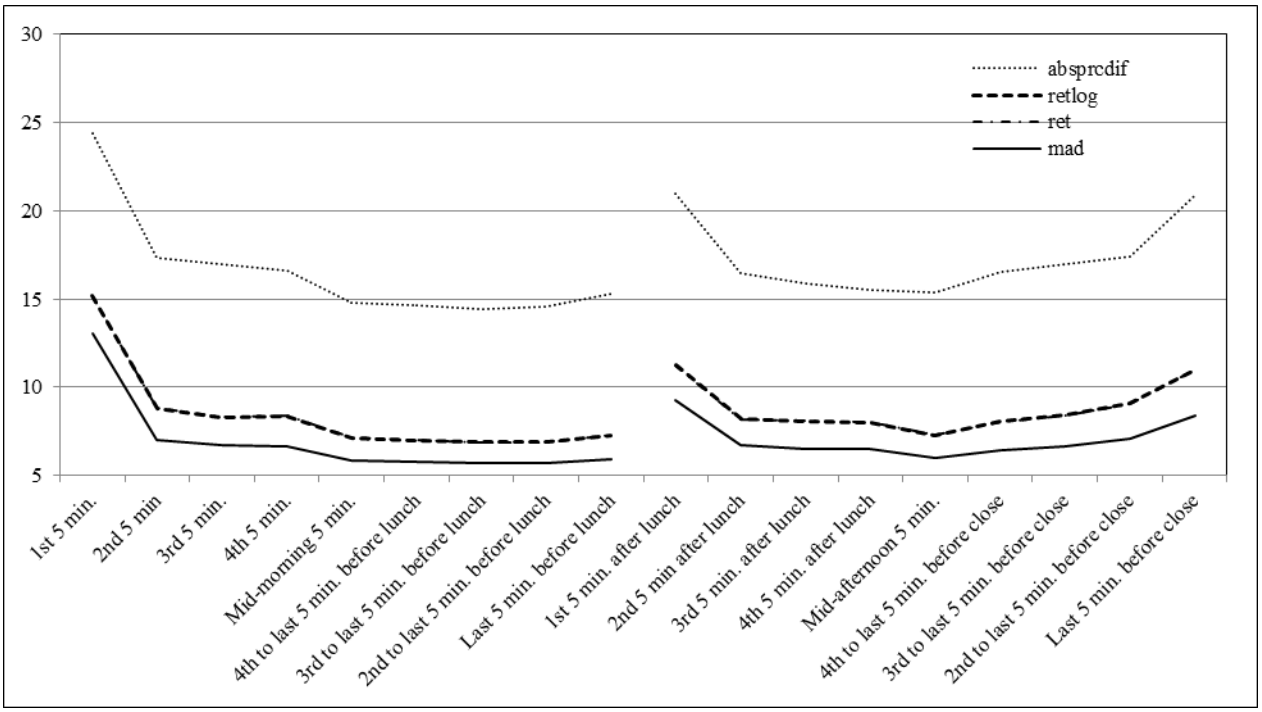


(b) 15-minute Volatilities

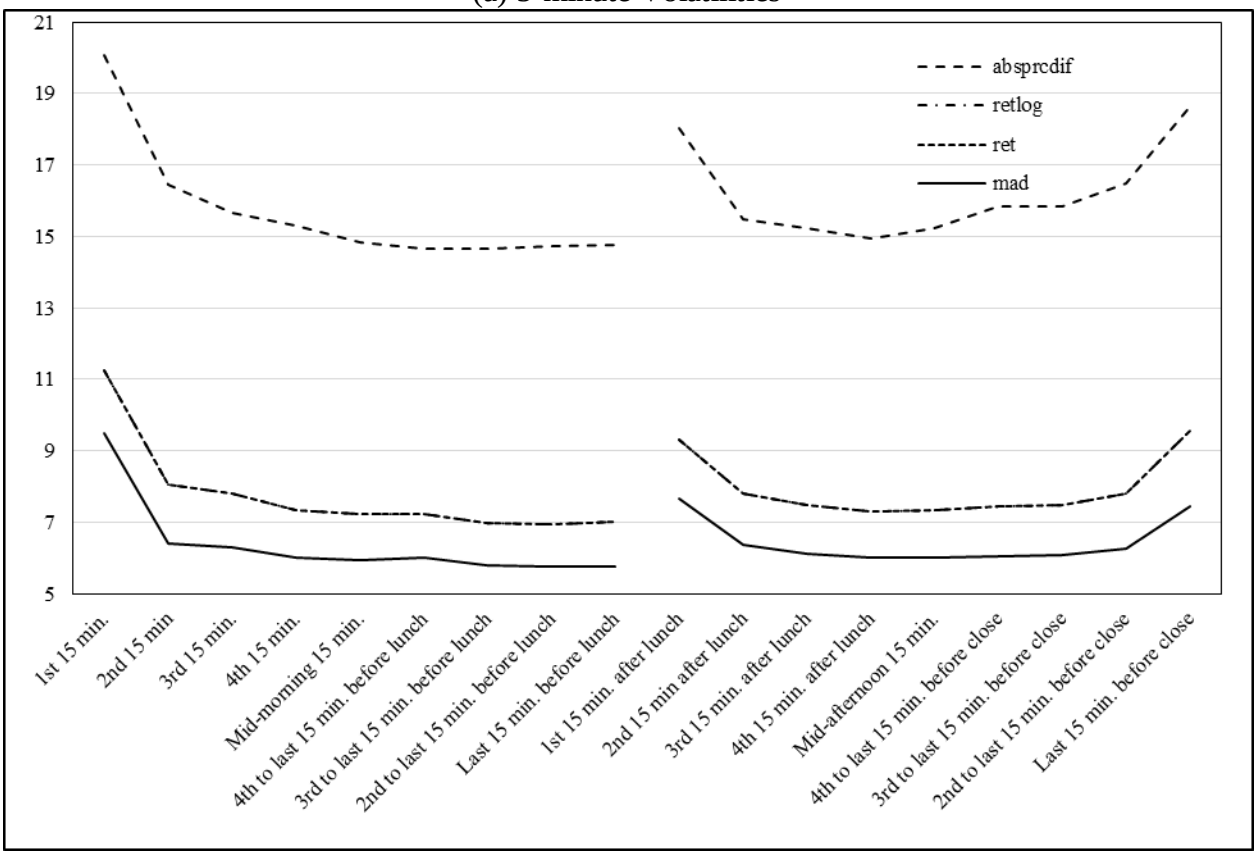


(c) 30-minute Volatilities

Figure 1. 5-, 15-, 30-minute Trading Period Segment Return Volatility

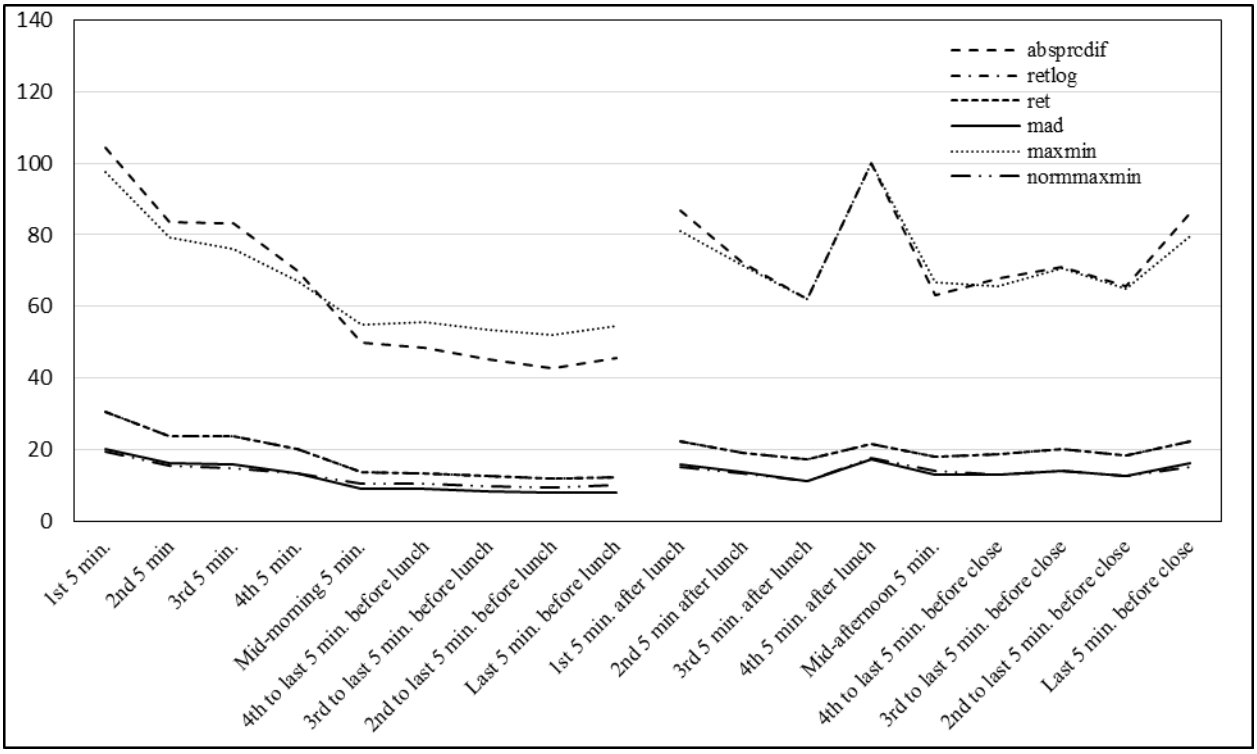


(a) 5-minute Volatilities

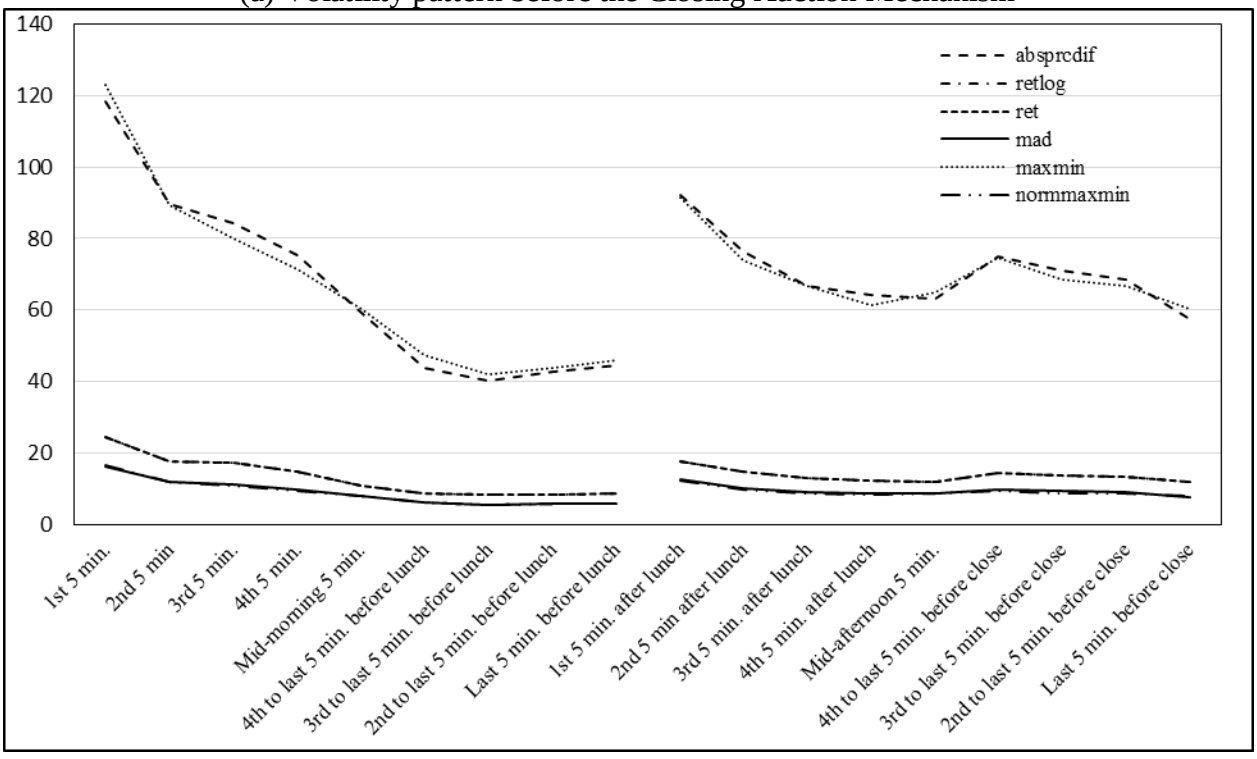


(b) 15-minute Volatilities

Figure 2. Tick Return Volatilities

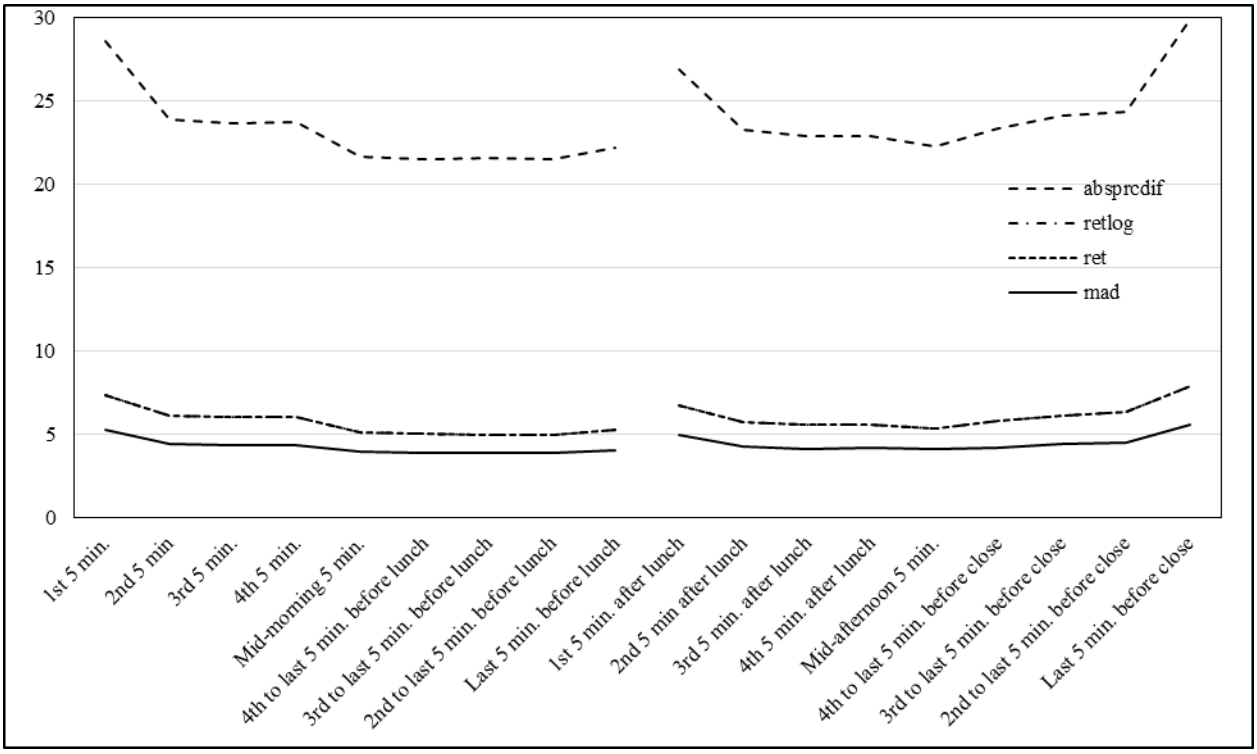


(a) Volatility pattern before the Closing Auction Mechanism

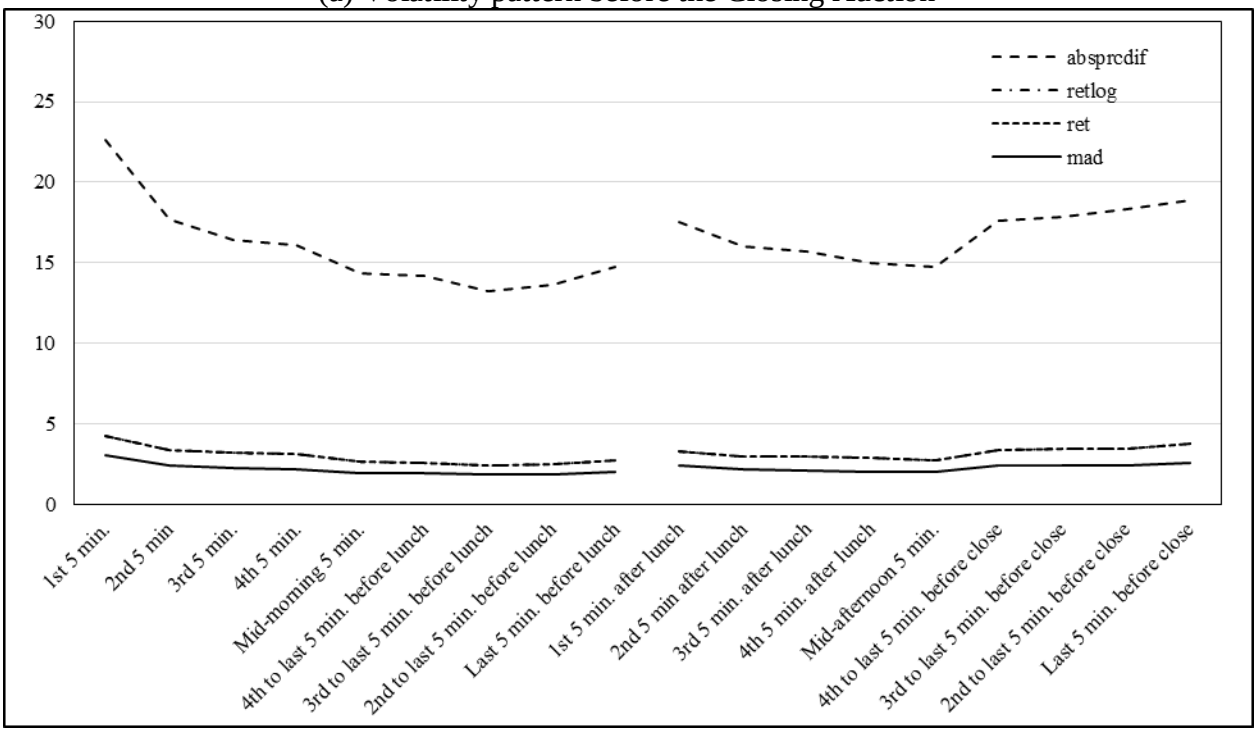


(b) Volatility pattern after the Closing Auction Mechanism

Figure 3. 5-minute Period Volatilities around Closing Call Auction



(a) Volatility pattern before the Closing Auction



(b) Volatility pattern after the Closing Auction

Figure 4. 5-minute Tick-by-Tick Volatilities around Closing Auction

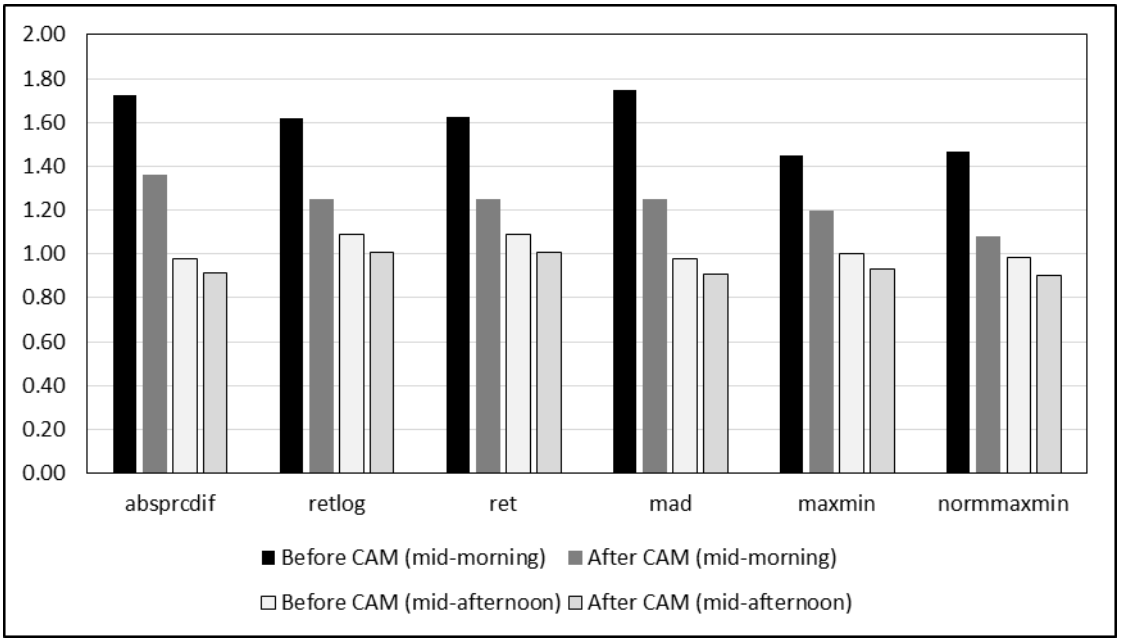


Figure 5. Volatility Ratios from 5-minute Period Returns before and after the implementation of the Closing Auction Mechanism (CAM)