Impact of the Introduction of Call Auction on Price Discovery: Evidence from the Indian Stock Market Using High-Frequency Data

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May 30, 2013

Abstract

Call markets are claimed to aggregate information and facilitate price discovery where continuous markets may fail. Its advantage, however, comes at the cost of immediacy. The impact of the introduction of call auction has not been found uniformly beneficial, possibly due to poor design or due to "thick market externalities". This paper examines the recent re-introduction of opening call auction at the National Stock Exchange of India. The reintroduction was advocated based on the evidence of positive effect of call auction on market quality in periods associated with high volatility or information asymmetry. The results suggest that the intraday pattern of volume and volatility in the continuous market remains unchanged even after the introduction of the call. The volatility and volume still take about 30 minutes to stabilize and the auction attracts very little volume. There is excessive price movement in the call auction as suggested by the negative intraday return correlations. However, the synchronicity of price discovery, on the lines of Pagano and Schwartz (2003), indicates some improvement in the market quality. Possibly, the lack of all-round improvement in price discovery could be attributed to the extremely short duration of the call auction. The paper contributes to the understanding of the impact of opening call auction on market quality.

Keywords: Call Auction, Market Opening, Market Efficiency, Intraday Behaviour, Emerging Markets

JEL classifications: G12, G14, G15

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We gratefully acknowledge the financial support from the Indian Institute of Management Ahmedabad for this research. The authors thank Ravi Agarwal and Abhilash B. Chowdary for the research support. All errors are our own.

1 Introduction

Call auction as an alternative to continuous order-matching for trading in the financial markets has been advocated by many researchers. It has been argued that call markets can aggregate information over time by pooling orders and thus facilitate price discovery even where continuous markets may fail due to high information asymmetry (for instance, Madhavan 1992). A call market is claimed to lower execution and market impact costs, eliminate the risk of front-running and information disclosure when directly accessed, and lower price manipulations. Based on these arguments, Economides and Schwartz (1995) advocated the use of an electronic call market, integrated within a continuously trading system, for market opening, closing and also once during the trading hours. Schwartz and Wood (2001) also advocated the use of an electronic call market for discovering the settlement price on the expiry of derivative contracts.

The use of call auctions is common in financial markets world-wide for opening and closing trades. Motivated by the high volatility and volume experienced during these market phases its use has been increasing[1]. At the market open, high volatility and volume are induced by the substantial accumulation of public and private information. Buttressing the argument that call auctions are ideal to aggregate diverse information across traders in order to minimize adverse selection at the opening (Domowitz et al. 2001), the volume is found to be highly significant during opening call auction in some markets.[2] The high volume at the opening call can also be interpreted as the evidence of trading by the uninformed liquidity traders at the opening call in line with the theoretical market microstructure models (Admati and Pfleiderer 1988). Since uninformed liquidity traders choose to trade when the transactions costs are low, high volume at the opening call may indicate lower transaction cost of trading.

[1]For example, Singapore introduced call auction at open in 2000, Hong Kong in 2002, London introduced call auction at close in 2000.

[2]Madhavan and Panchapagesan (2000) report that opening call auction accounts for 9.7% of daily trade at the NYSE. Kehr et al. (2001) report that opening call accounts for 12.1% of daily volume at the Frankfurt Stock Exchange.

The advantage of call auction in pooling orders, however, comes at the cost of immediacy and can lead to market failure where value-sensitive information arrives between the two passes of call auctions. Also the prices discovered in the call market may not be generally efficient. Ho et al. (1985) showed that the prices in a call market, in general, are not equal to Walrasian Prices unless- (a) there is 'symmetry in the distribution of individual buy/sell orders', and (b) 'investors' expectation about market clearing prices are accurate'. Using a price auction model, where a single strategic trader sets the opening price based on the information observed in the limit order book, Madhavan and Panchapagesan (2000), showed that the dealer is able to set a more efficient opening price than the public in an auction. They also validated this ability of the dealers with the trade level data of NYSE. Further, the theoretical benefits of call markets are countered by, the possibility of order flow imbalances (Ho et al. 1985, Angel and Wu 1995), the transparency of orders deterring traders from submitting orders, and the conditional provision of liquidity due to the opportunity to cancel orders (Angel and Wu 1995). Thus, any failure to attract sufficient liquidity, possibly from uninformed traders, can substantially erode the well-cited advantages of call auctions. On the other hand, if uninformed liquidity traders choose to clump together to trade, driven by the lower execution costs (Admati and Pfleiderer 1988) and lower risk from the informed traders, then call auctions may provide some of the advantages cited earlier. In short, the advantage of call market mechanism could be subject to thick market externalities (Diamond 1982), wherein each trader's willingness to trade is contingent on others. These arguments suggest that the beneficial outcomes of a call auction are crucially dependent on the market conditions.

Researchers have investigated the effect of the introduction and suspension of opening and closing call auctions on market quality and price discovery and have compared the call auction markets to continuous markets.

Pagano and Schwartz (2003) found that the introduction of closing call at Euronext Paris lowered execution costs and improved price discovery. They used an event study based on market model with systematic risk estimated following Cohen et al. (1983a;b) and found an increase in return synchronicity following the introduction of the call. They also

examined intraday volume, return volatility and spread (at hourly interval) but did not find any significant change during most of the day, except a decrease in the volume and spread during the last trading hour of the continuous market for the less liquid stocks. Aitken et al. (2005) analysed the impact of the introduction of closing call in Australian Stock Exchange in 1997 and found that while the closing call attracted volume, it was at the expense of the volume in the previous two hours of the continuous market. Unlike Pagano and Schwartz (2003), they found that the spread increased in the last half-an-hour of the continuous trading after the introduction.

Ellul et al. (2005) analysed the opening call introduction in 1997 and the closing call introduction in 2000 at the London Stock Exchange (LSE). They found that even though the call market suffered from a high failure rate, the prices discovered in call market were close to volume weighted prices in the neighbourhood (used as a benchmark). They attributed the higher failure rate of the call market relative to the dealer market at the open and close to "thick market externalities". They found that "call's trading costs increase significantly when (a) asymmetric information is high, (b) trading is expected to be **slow**, (c) order flow is unbalanced, and (d) uncertainty is high". Chelley-Steeley (2009) also studied the call introduction at the LSE. She used market model R-squared (as used by Pagano and Schwartz 2003), average relative return dispersion (RRD) coefficient (Amihud et al. 1997), and ratio of implied volatility to observed volatility (MEC Coefficient) as the measures of market quality.[3] She found that all the measures indicated improvement in market quality and the improvement was more at the open than at the close. She also found that stocks with the lowest pre-call liquidity experienced the greatest increase in market quality contrary to many other research findings.

Chang et al. (2008) studied the introduction of call auctions to open and close trading at the Singapore Exchange in 2000.[4] They concluded that the introduction of the call at the opening and closing reduced market-adjusted return volatility and pricing errors. They

[3]MEC coefficient as used by Hasbrouck and Schwartz (1988) refers to the ratio of implied volatility to observed volatility. There is evidence that the dealers would be able to a set a more efficient opening price than the public in an auction market (for example, Madhavan and Panchapagesan 2000).

[4]They used market-adjusted return volatility. They also used the correlation between trading day returns and overnight returns as a measure of the trading noise and two-day volume-weighted prices as the benchmark for pricing errors.

found that the gains in pricing efficiency were much less for the less liquid stocks. Comerton-Forde et al. (2007b) also examined the same event with the methodology followed by Pagano and Schwartz (2003) and found that the market quality went up after the introduction of call markets for opening and close. Comerton-Forde et al. (2007a) analysed the impact of the introduction of call market to open trading at the Hong Kong Exchange and Clearing Ltd. in 2002. They found that the opening call auctions accounted for less than 1% of the daily volume, the opening price volatility was higher with the opening call, and the market quality (price synchronicity) deteriorated after the call introduction. They attributed the failure of the opening call in attracting volume to its poor design, particularly to the unusually short pre-open price discovery period (overall 30 minutes) and to the order restrictions.[5]

In summary, the empirical research on the impact of the introduction of call auctions by exchanges world-wide has been broadly supportive of the notion that call auction at the open and close can improve market quality and price discovery. Besides the stocks directly benefiting from call auctions, there has been some evidence of positive spillover effect of call auctions on the overall market quality (Pagano and Schwartz 2003, Chang et al. 2008). Arguments have been made that call market openings can be most useful for the smaller or less liquid stocks with higher adverse selection due to the poor public information around them (Domowitz et al. 2001, pp.18). In the cases where the call has not been found to be as successful, such as Hong Kong, the elements of call auction design have been argued to be a possible reason for the failure (Ellul et al. 2005, Comerton-Forde et al. 2007a).

In this paper, we examine the impact of the re-introduction of opening call auction by the National Stock Exchange (NSE) of India on October 18, 2010. The NSE had suspended opening and closing call auctions in 1999. The impact of the suspension has been studied by Camilleri and Green (2009) using the RRD coefficient and the serial correlation of returns as measures of pricing efficiency besides examining intraday volatility, overnight return

[5]The Hong Kong market opened at 10:00 AM. The pre-open started from 9:30 and at-auction limit orders were allowed to be entered, amended and cancelled till 9:45. Short selling was prohibited in the call auction. During this phase, indicative auction price, best bid-asks, aggregate and equilibrium volume were displayed. After 9:45 and till 9:50, only at-auction orders could be entered with restrictions that the orders cannot be amended or cancelled. During 9:50 and 9:58 AM, algorithm was applied by the exchange to complete the call auction. The exchange used the time between 9:58 and 10:00 AM as the blocking period to break between the call auction and the continuous market and during which the call auction trade information was communicated to the market.

reversals and liquidity. They used market model for computing cumulative abnormal returns (CARs), and related CARs to Volatility, Efficiency and Liquidity (VEL) measures. They found that the suspension improved the VEL measures. However, they did not find any cross-sectional relation between CARs and the changes in the VEL measures. In all, they found that the suspension did not worsen the market quality. They also reported that the less liquid stocks used to trade infrequently in call auctions. The reintroduction of call at the open by NSE appears to be motivated by the somewhat supportive experience with call auctions world-wide and the high volatility experienced/ observed at the open in the Indian market. For instance, Thomas (2010) advocated the use of call auctions for market opening and closing, for illiquid securities such as bonds, on extreme news events and as a replacement of 'circuit breakers' in India.[6]. Her support for call auction was mostly based on the evidence that that it takes as long as half-an-hour for the opening volatility to settle down in the Indian stock market. She argued that the introduction of a call auction could hasten the information assimilation. This paper is motivated by the fact that empirically the effect of the introduction of opening and closing call has not been always beneficial, despite the supportive theoretical arguments and the increasing acceptance of call auctions for opening and closing the markets. It has also been argued that call market design and trading rules can have significant impact on its outcomes (Comerton-Forde et al. 2007a). The NSE pre-open session by design is extremely short, one of the reasons cited by Comerton-Forde et al. (2007a) for the low volume in opening call in the Hong Kong market. Therefore, the impact of the reintroduction of call at open by NSE needs to be examined empirically.

Our key results are as follows. It appears that the introduction of the call auction did not help to quickly stabilize the opening phase of the market. On analysing the intraday return volatility, volume and serial correlation of returns, we find that the introduction of the call has not reduced the time taken by the Indian market to settle down from the

[6]NSE employs a 3-stage market-wide circuit breaker system where a trading halt is imposed when any of the major index (either the BSE Sensex or the Nifty) moves to the extent of 10%, 15% and 20%. The duration of the halt varies from 30 minutes to the remainder of the day depending on the extent of the market movement and the time of the day when the circuit was breached. For more details, see http://www.nseindia.com/products/content/equities/equities/circuit_breakers.htm

higher volume and volatility levels experienced in the opening hours. Instead, it has merely shifted the pre-existing intraday volatility and volume pattern at the open period to the post-call normal market. However, we do find that the market quality, measured in terms of the increased synchronicity of the stock prices with the market, has improved after the introduction of the auction. We also find higher synchronicity in the closing prices after the introduction of the call auction even though there has been no change in the way market is closed. This is puzzling because we find that- (a) the call auctions do not attract any significant volume, (b) there is no change in volatility and volume dynamics after the introduction of call auctions, and (c) worse, there is evidence of price reversal at normal continuous market opening after the completion of call auctions.

The remaining part of the paper is structured as follows. Section 2 describes the institutional details of NSE and the trading protocol followed during the call auction and the subsequent continuous trading. Section 3 details the methodology and data used in this study. Section 4 reports the results of our analysis and section 5 concludes.

2 Call auction at the National Stock Exchange of India (NSE)

The NSE, established in 1993, catalysed many microstructure reforms in the Indian market and became the most active exchange in India. By 2010-11 NSE had a volume share of nearly three-fourth in the cash segment and nearly 100% in the individual futures and options segment (ISMR 2011). The 2010-11 average trading volume of its cash market segment was about $800 billion (₹ 35,774 billion) and the market capitalization of the listed stocks (nearly 1450 companies) around $1,500 billion (NSE 2011). Its fully automated and screen-based trading system, known as NEAT, is order-driven and operates on a strict price-time priority. NSE is the world's first stock exchange to use satellite communication for trading across a country. The NEAT has an uptime record of 99.999% and all the trades entered into the system are executed with a uniform response time in the range of milliseconds (ISMR 2011). The market is highly transparent as NSE provides detailed online real-time trading information.

NSE reintroduced[7] call auction to open trading in 50 large capitalization stocks underlying its prime index, S&P CNX Nifty (Nifty) on October 18, 2010. The pre-open call session starts at 9:00 am and ends at 9:15 am. It has three phases - an order collection period (9:00 am to a random time point between 9:07 am and 9:08 am); an order matching period immediately following the order collection period till 9:12 am; and a silent period immediately following the order matching period till 9:15 am. At 9:15 am, the normal market opens. The order collection period in the call auction phase is meant for order entry, modification, and cancellation. Only limit orders and market orders can be placed during this period. Iceberg orders, disclosed quantity orders, immediate or cancel orders and order valid only for the pre-open session are not allowed to be placed during the order collection period. Transparency is ensured during the pre-open session through the dissemination of information on market depth, indicative equilibrium price, scrip-wise total buy and sell quantity, indicative Nifty value[8], and percentage change in indicative clearing price (from previous close price) on a real-time basis. Cancellation or modification of orders are not allowed during the order matching period.

For each stock, the orders are matched at a single price where the maximum volume could be executed. In a tie between two prices, the price closest to the previous day's closing price (adjusted for corporate actions, if any) is taken as the clearing price. Order matching is done in the following sequence: (i) eligible limit orders against eligible limit orders (ii) residual eligible limit orders against market orders; and (iii) residual market orders against residual market orders. If only market orders exist in the buy and the sell side, the market orders are matched at the last traded price, and all unmatched orders are shifted to the order book of the normal market at the last traded price following time priority. All outstanding orders are moved to the normal market, retaining their original time-stamps with limit orders retaining the limit price, and market orders being priced at the discovered equilibrium price. When no equilibrium price is discovered in the pre-open

[7]SEBI Circular No. CIR/MRD/DP/21/2010 dated July 15, 2010. NSE Presentation dated October 14, 2010 which can be downloaded from http://www.nseindia.com/live_market/dynaContent/live_watch/pre_open_market/PreOpen-October2010.pdf

[8]Trading halts will be triggered if the index value breaches threshold limits, which will be applicable for the normal market session.

session, all market orders are priced at the closing price of the previous day (adjusted for corporate actions, if any)[9]. The discovered equilibrium price is reported as the open price of the day, and if no orders are matched in the pre-open, the price of the first trade in the normal market is considered as the opening price. The call auction trade details are disseminated to members before the start of the normal market.

3 Methodology and Data

We study the impact of the re-introduction of the opening call auction on market quality at NSE. The impact is examined by comparing the pattern of intraday trade volume, volatility, and return correlations before and after the introduction of the call auction. The opening phase of a market characterized by a large share of the volume, low volatility and no intraday return correlation would suggest an efficient market. We also examine changes, if any, in the synchronicity of stock returns with that of the market. The synchronicity change is measured by the R-square of the single factor market model regressions before and after introduction of the opening call, as used by Pagano and Schwartz (2003). Any increase in synchronicity after the introduction of the auction would suggest an improvement in market efficiency.

The volume, volatility and return correlations are examined using data of the 50 constituent stocks of Nifty as on October 18, 2010[10]. The study covers the period from July 15, 2010 to June 30, 2011. The period before the introduction of call auction (referred as 'Precall') covers 66 trading days. The period after the introduction of the call auction is split into three sub periods to understand any evolution of the call auction market over the 9-months period. The sub-periods are as follows: (a) October 18, 2010 to December 31, 2010 ('Postcall-1') (b) January 1, 2011 to March 31, 2011 ('Postcall-2') and (c) April

[9]SEBI Circular No. CIR/MRD/DP/32/2010 dated September 17, 2010.

[10]One stock, SUZLON was replaced with GRASIM in the Nifty on 25 March 2011. However, we have not considered this change. The pre-open session for GRASIM continued even after it was replaced.

1, 2011 to June 30, 2011 ('Postcall-3'). The three sub-periods cover 52, 62 and 62 trading days respectively[11].

The intraday returns are measured using prices at 5-minutes' interval. The intraday volatility is measured as the average absolute return across stock-days for each interval. The intraday volume, measured using 5-minutes interval, are initially standardized to account for the variation across intraday intervals and then averaged across stock-days. At the 5-minutes' interval, there are 78 intraday periods during a trading day.

Market efficiency in terms of synchronicity is measured with 'close-to-close', 'open-to-open' and 'close-to-open' returns at 10 different intervals (1-day, 2-days, ... 10-days). The period of analysis covers 360 trading days from January 29, 2010 to July 7, 2011 (180 trading days before and after the event)[12]. The 'open-to-open' and 'close-to-open' returns of individual stocks are estimated separately with two prices: (1) reported opening price from the call auction, if available, otherwise the first traded price from the normal market (2) the first traded price in the normal market. The Nifty returns are estimated based on the reported Nifty opening, which corresponds to the opening of the normal continuous market, disseminated at 9:15 am.

The single factor market model is based on the Nifty index returns. Nifty, which constituted 50 stocks spread over 24 sectors, is the most widely used large cap stock index. As on March 31, 2011, the aggregate market capitalization of the Nifty constituent stocks was ₹ 17,554 billion (NSE 2011). Nifty accounted for 63% of the free float market capitalization of NSE on December 31, 2010 (ISMR 2010). The average impact cost of trading in Nifty constituents was 0.06% for September 2010 (ISMR 2010). These characteristics suggest that Nifty is an efficient barometer of the Indian stock market.

The intraday data are obtained from the NSE and the daily data from the Prowess database of Centre for Monitoring Indian Economy (CMIE).

[11] We have excluded the trading data of November 5, 2011 (Diwali Muhurrat Trading) when the market was open for only 45 minutes in the evening (6:15 pm to 7:00 pm). Diwali is a major festival of the Hindus in India.

[12] The trade data of February 6, 2010 (Saturday), when NSE had a special session of two hours from 11:00 am to upgrade the system is excluded from the analysis.

4 Impact of the Introduction of Opening Call Auction

4.1 Intraday Volume, Volatility and Return Correlation

As pointed out elsewhere, one reason to introduce the call auction was that it took almost half-an-hour for the volatility and volume to settle down in the Indian market. It was contended that the introduction of the call auction can aggregate information at the opening and reduce the adverse selection costs (Thomas 2010). If it were to happen, then the volume in the opening call should be high and the volatility should settle down relatively faster. To test whether the introduction of the call auction at opening had any impact on the intraday volume and volatility dynamics, we plot the intraday volatility and volume during the first trading hour in Figures 1 and 2 respectively. The figures show the dynamics prior to the introduction of the call auction and during the three sub-periods after its introduction.

It is evident from the figures that that the call auction attracts very little volume in the Indian market. All the three sub-periods post the introduction of the call auction have seen insignificant volumes ($\sim$ 0.1% of daily volume) with no visible improvement over time. Table 1 reports the descriptive statistics of the intraday volume before and after the introduction of the call auction. With the 15-minutes' delayed opening of the normal market, after the introduction of the call auction, the intraday volume dynamics just appears to be pushed by 15 minutes. Given the inability of the call to attract volume, it is no surprise that the intraday volatility dynamics also has been pushed by 15 minutes. With opening volatility being exhibited in the call market as well as in the normal market open prices it still takes around 30 minutes to stabilize. It is clear from the figures that both the volume and volatility used to take 25-30 minutes after opening of the market to settle down. After the introduction of the call auction, it still takes 25-30 minutes for the volatility and volume to settle down from the opening of the normal market. This suggests that the call auction does not help to stabilize the opening phase of the market quicker. Figures 3 and 4 give the intraday volatility and volume throughout the trading hours before and after the introduction of the call auction. Prior to the introduction of the call auction, the volatility is higher in the first three 5-minutes' intervals and follows a reverse-J pattern, a

feature of the Indian Stock market reported earlier (for instance, Agarwalla 2010). Intraday volumes follow a U-pattern and are higher in the first six 5-minutes intervals and in the last six 5-minutes intervals.

The quality of price discovery in the call auction is examined through return correlations between the overnight return and the subsequent returns. For this, we estimate overnight returns, returns from 'call market close to normal market open', and subsequent 5-minutes returns. If the call auction prices are robust, the return correlation should not be significantly different from zero. Low volume in the opening call can, however, results in returns being negatively correlated if the prices move too much in the call market. Returns can also be positively correlated if the prices do not change enough in the call market. To control for similar possibilities prior to the introduction of the call, we also estimate the return correlations at opening and subsequent 5-minutes intervals for the period prior to the introduction of the call market. The return correlations are reported in Table 2 in different panels for four different sub-periods (panel A for the quarter before the introduction of the call and panel B, C and D for three successive quarters after introduction). As can be seen from the Table, the return correlations indicate that there is excessive price movement at the opening leading to negative return correlation between opening returns and the first 5-minutes returns. This is observed in the period prior to the introduction of the call auction and has continued even after the introduction. What is surprising is that the negative correlation has risen to as high as -0.28 later (in the third quarter after the introduction of call, see panel D) in the sample period. Further, the overnight returns after the introduction of the call auction, computed using the price discovered at the pre-open session, is negatively correlated with the subsequent three 5-minutes intervals (significant in Postcall-1 and Postcall-3 period) indicating excessive price movement at the pre-open session.

On the basis of the evidence, we find that there is no improvement in the volume attracted by the call auction in all the three sub-periods after its introduction. The high volume and volatility in the first 25-30 minutes of the continuous market remain unchanged

after the introduction of the call auction. The high volatility experienced at the opening of the Indian market only gets delayed by the 15 minutes duration of the call market.

4.2 Impact on Return Synchronicity

Besides investigating the intraday volatility and volume dynamics for any impact of the introduction of the call auction, we also investigate its impact on the market quality in terms of synchronicity of price discovery. Following Pagano and Schwartz (2003), we split our sample period into pre- and post-event periods (the event being the introduction of the call auction at opening) and estimate market model for 10 return intervals. Our choice of the 10 return intervals as opposed to 12 return intervals ranging from 1-10 days, 15 days and 20 days by Pagano and Schwartz is due to another market microstructure change in India where the normal market timing was extended by 55 minutes to start at 9:00 am instead of 9:55 am on January 4, 2010. A longer time period taken to accommodate 15- and 20-days returns would have confounded the results with that of the impact of the change in the market timings.

The synchronicity of the price discovery is judged by the market model's ability to explain the stock return variation, judged by the R-square of the market model regressions (referred as first-pass regressions). Table 3 reports the average R-squares and betas for the 50 stocks in the sample for the 10 different intervals before and after the event (in all 1000 regressions: 50 stocks by 10 return intervals and by two periods)[13]. The results are presented for the close-to-close, open-to-open and close-to-open returns. Unlike Pagano and Schwartz, interestingly we find that the average R-squares are not significantly different across return intervals for close-to-close returns indicating relatively less non-synchronicity for the 50 most liquid Indian stocks, as far as the closing prices are concerned. In case of the open-to-open returns, the average R-square tends to increase with increase in the return interval. Particularly, one-day open-to-open average R-square is much lower in the pre-event period as compared to longer return intervals. As can be seen in Table 3, the average

[13]The results in Tables 3 and 4 correspond only to returns estimated using the reported opening price of the individual stocks. The results based on the first price of the normal continuous market are almost similar to the reported results and hence not reported.

R-square estimates have increased after the introduction of call auctions for opening the market indicating the higher synchronicity of prices. This is true for all the return intervals and for the open-to-open, close-to-close as well as close-to-open returns.

One of the reasons for the higher synchronicity in the opening prices after the introduction of the call auctions for the 50 high capitalization stocks underlying Nifty is that all their opening prices from the call auction determine the index open. Earlier, a lag in the trading of some of these 50 stocks would have resulted in some non-synchronicity with the index. This is evident from the dramatic improvement in the average R-square for one-day close-to-open returns, which have gone up from 0.06 to 0.37! It is, perhaps, more meaningful to focus on the close-to-close returns to infer any market quality improvement due to the higher synchronicity as the increase in the open-to-open return R-squares could be due to the forced synchronicity induced by the simultaneous call auctions. We find that the close-to-close return market model average R-squares also show significant improvement, particularly for the longer return intervals, indicating that the increased synchronicity across stock prices is not merely due to the simultaneous price discovery of these stocks and the index.

Following Pagano and Schwartz, we further estimate the following second-pass stock-specific regressions using the first-pass market model beta estimates obtained from 500 regressions (50 stocks for 10 time intervals)-

$$b_{j,LE} = a_{j,2} + b_{j,2} \ln(1 + L^{-1}) + c_{j,2}(Dummy_{jE}. \ln(1 + L^{-1}) + e_{jLE} \tag{1}$$

where $b_{j,LE}$ is the first-pass beta estimate for security j based on $L-$day stock returns for the time period E ; where $E = A$ (after) or B (before) the event; L is the return interval used in the first-pass regressions, $Dummy_{jE}$ is a dummy variable that is equal to 1 if the first-pass beta is estimated with the post-event data ($E = A$) and 0 otherwise; and e_{jLE} is a stochastic disturbance term. $a_{j,2}$, $b_{j,2}$ and $c_{j,2}$ are second-pass parameter estimates.

For the stocks which lag the market, the slope $b_{j,2}$ is expected to be negative. In our sample, these estimates are negative for the close-to-close and open-to-open returns but positive for the close-to-open returns. In the second pass regressions, these beta estimates are expected to increase if the introduction of the opening call reduces the market frictions as argued by Pagano and Schwartz. As expected, we find that the average beta estimates (BETA-SLOPE) as reported in third-row of Table 4 are higher after the introduction of the call auction. The increase is maximum for the open-to-open returns and is statistically significant. In case of the close-to-close returns, the increase is not statistically significant. Only the close-to-open return betas exhibit a decrease. These results indicate that the introduction of the call auction has possibly reduced market frictions.

As the market model R-squares are expected to be depressed for shorter return intervals and they are expected to increase with longer return intervals, we estimate second pass stock-specific regressions on R-squares estimated from the first-pass regressions (reported in Table 3):

$$AdjRsq_{jLE} = r_j + s_j \ln(1+L^{-1}) + t_j\Big(DummyRsq_{jE}.\ln(1+L^{-1})\Big) + u_j(DummyC_{jE}) + v_{jLE} \tag{2}$$

where $AdjRsq_{jLE}$ is the adjusted R-square statistic from the market model regression for security j based on L day stock returns for the time period E, where $E = A$ (after) or B (before) the event; L is the return interval used in first-pass regressions, $DummyRsq_{jE}$ is a dummy variable for the slope that is equal to 1 if the first-pass adjusted R-square statistic is estimated using the post-event data ($E = A$) and 0 otherwise; $DummyC_{jE}$ is a dummy variable for the intercept that is equal to 1 if the first-pass adjusted R-square statistic is estimated using the post-event data ($E = A$) and 0 otherwise; and v_{jLE} is a stochastic disturbance term. r_j, s_j, t_j and u_j are second-pass parameter estimates.

The results of the second pass regressions (Equations 1 and 2) are reported in Table 4. If market quality improves with the introduction of the opening call, it is expected that

R-square of the short-term return intervals will increase towards their asymptotic levels and the coefficient r_j plus u_j (R2CONSTANT in Table 4) will improve after the event. The coefficient s_j is expected to be negative as R-square of market is expected to increase with return interval. Our results are along the expected lines as far as the sign of s_j is concerned for the open-to-open and close-to-open returns. A priori, it is difficult to expect that the sign of t_j, the improved R-square associated with higher market quality may or may not be proportional to longer return intervals. Pagano and Schwartz, for example, found that the t_j's in the context of the closing call introduction at Euronext Paris were negative.

The coefficients of the second pass regressions of R-squares in our context are in the direction of the findings of Pagano and Schwartz. After the introduction of the opening call auctions, the asymptotic R-squares given by R2CONSTANT in Table 4 are significantly higher post-event irrespective of whether open-to-open, close-to-close or close-to-open returns are analysed. The change in R2SLOPE is positive for the open-to-open and close-to-open returns and negative for close-to-close returns.

Since the opening of the market through call auctions forces trades across constituent stocks of Nifty to be synchronized, we also explore whether the forced simultaneity of auctions is not the only reason for the improvement in market quality. We estimate market model equations for all the 10 return intervals by using the prices of stocks and index one-minute after the start of trading in the continuous market in both the periods (prior to and after introduction of call auctions). These are also reported in Tables 3 and 4. As is evident from the tables, the increase in market quality measured using the open-to-open returns, based on prices taken after one-minute of the start of trading in the continuous session, are much less than reported open-to-open prices. Nonetheless, the asymptotic R-square estimates indicate significant improvement in synchronicity after the introduction of call auctions. Overall, the evidence from the market model based event study, extensively used is assessing market quality in terms of price synchronicity of stocks, suggests improved market quality after the introduction of the call auction in India for market opening.

4.3 Discussion of the Results

Our analysis of the intraday volume and volatility dynamics and the assessment of the impact on the market quality before and after the introduction of call auctions at opening provide some interesting evidence. Contrary to the arguments in support of the introduction of call auctions for opening the market, we find that the volumes attracted by call auctions in India are abysmally low. Not only the volumes are low, the price discovery in the call auction does not seem to affect the subsequent intraday volatility and volume dynamics. The intraday volatility and volume dynamics remain unaffected by the introduction of call auctions and they are merely delayed due to the delayed normal (continuous) market opening. While these effects suggest a largely neutral impact of the call auctions, the serial return correlation observed between the close-to-call and call-to-continuous returns at opening indicates price reversal from the call auction to the normal continuous market.

Despite not attracting significant volume and the worrisome sign of price reversal following the call, we find puzzling evidence in support of improved market quality in terms of price synchronicity. We not only find evidence on improved synchronicity at the opening but also at the closing. The improved synchronicity at opening is by design as both the index and its underlying stocks are based on simultaneously discovered prices after the introduction of the call auction. Earlier, some of these stocks would have lagged behind. No such effect can explain the improved synchronicity at the closing, however. One possible explanation for the observed improvement is due to opening through call auctions but it begs an explanation as to how improved synchronicity at opening can affect the closing. Another possibility is that the improved synchronicity may be due to uncontrolled market conditions (liquidity or any other factors which exhibit commonality). Methodologically, our sample is that of the most liquid stocks in the Indian market for which the call auction have been introduced and the index is composed of these constituents. This explains the high observed R-squares as opposed to the ones reported by Pagano and Schwartz (2003). We could not have used any other index as it would have lagged the high capitalization index used in the sample. The relatively high R-squares and the observed anomalous high frequency results (low volume in call, no change in intraday volatility and volume, price

reversal after call etc.) indicate that possibly the higher synchronicity, the focal point in Pagano and Schwartz event study methodology, may not be the only important criterion for assessing efficient price discovery of highly liquid stocks.

As far as the failure to attract volume is concerned, one possible reason could be that the traders, particularly the uninformed liquidity traders, do not expect large volume from similar traders on the opposite side in the call market. In that case, there is an in-built disincentive for any large liquidity trader to reveal the "order-size" in the auction market. Once revealed, and if the trade is not executed in the auction market, the trader runs the risk of exposing his order. This risk is high because iceberg orders are not allowed in the auction market. To investigate whether the initial high volume in the Indian market is caused by large number of trades or by large trade sizes, we examine the average trade size through the day. Figures 5 and 6 show the average trade size at various 5-minutes intraday intervals. It is clear that the average trade size is low in India and the high initial volume is more due to the increased frequency rather than the trade size. With a large fraction of volume coming from day traders (Agarwalla 2010) and the low trade size, revealing large trades in call auction may be sub-optimal as compared to executing trade in "slice-and-dice" mode by large traders.

5 Conclusions

Call auctions at the opening have been advocated by a large number of researchers and experts on the ground of their ability to temporally aggregate the orders when the information asymmetry is high. The auctions are expected to reduce the problem of price discrimination for the traders thereby making trading less costly for uninformed liquidity traders. Consequently, it is expected that a call auction would be able to attract high volume and would result in a better price discovery. Call auctions were introduced in the Indian stock market for opening on October 18, 2010. We analyse the impact of the introduction of call auctions for 50 stocks, which are the constituents of the large cap NSE Nifty index by using the data of 180 trading days prior to and after the event. On analysing

the high-frequency data of returns and volume, we find that (a) the call auction attract insignificant volume (b) the intraday volume and volatility dynamics remain unaffected by the call auction except for, the delay induced by the call auctions, and (c) there is a tendency for price reversal in the continuous normal market from the price discovered in the call auction. These findings together do not provide any evidence for the positive impact of the call auctions at the opening.

Interestingly, however, we do find that the market quality in terms of price synchronicity improves after the introduction of call auction at opening. Not only synchronicity improves at opening, which is expected, but also surprisingly at the closing. This is puzzling as the introduction of call auction at opening should have no effect on the price discovery through the day and that too for the most liquid stocks. Either this is due to some uncontrolled market-wide factor which may have coincided the event, or it is due to the positive effect of call auctions being transmitted to the closing prices. No such transmission is, however, posited in the literature. As far as the effect of the introduction of call auction on price discovery is concerned, we are inclined to give greater weight to the evidence from high-frequency data. The improved price synchronicity, which is the focal point in market quality assessment by Pagano and Schwartz, may not necessarily be very relevant for highly traded liquid stocks of our sample unlike that of their sample from Euronext Paris.

References

Admati, A. R. and Pfleiderer, P. (1988). A theory of intraday patterns: volume and price variability. *Review of Financial Studies*, 1(1):3–40.

Agarwalla, S. K. (2010). *Intraday activity patterns and market microstructure effects in Indian capital markets: An empirical investigation using high frequency data*. PhD thesis, Indian Institute of Management Ahmedabad.

Aitken, M., Comerton-Forde, C., and Frino, A. (2005). Closing call auctions and liquidity. *Accounting & Finance*, 45(4):501–518.

Amihud, Y., Mendelson, H., and Lauterbach, B. (1997). Market microstructure and securities values: Evidence from the Tel Aviv Stock Exchange. *Journal of Financial Economics*, 45(3):365–390.

Angel, J. J. and Wu, S. Z. (1995). Dealer markets, derivative expirations, and a call. *Derivatives Quarterly*, 2:38–45.

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(3):257 – 284.

Chang, R. P., Rhee, S. G., Stone, G. R., and Tang, N. (2008). How does the call market method affect price efficiency? Evidence from the Singapore stock market. *Journal of Banking & Finance*, 32(10):2205 – 2219.

Chelley-Steeley, P. (2009). Price synchronicity: The closing call auction and the London stock market. *Journal of International Financial Markets, Institutions and Money*, 19(5):777 – 791.

Cohen, K. J., Hawawini, G. A., Maier, S. F., Schwartz, R. A., and Whitcomb, D. K. (1983a). Estimating and adjusting for the intervalling-effect bias in beta. *Management Science*, 29(1):135 – 148.

Cohen, K. J., Hawawini, G. A., Maier, S. F., Schwartz, R. A., and Whitcomb, D. K. (1983b). Friction in the trading process and the estimation of systematic risk. *Journal of Financial Economics*, 12(2):263 – 278.

Comerton-Forde, C., Rydge, J., and Burridge, H. (2007a). Not all call auctions are created equal: evidence from Hong Kong. *Review of Quantitative Finance and Accounting*, 29(4):395 – 413.

Comerton-Forde, C., Ting Lau, S., and McInish, T. (2007b). Opening and closing behavior following the introduction of call auctions in Singapore. *Pacific-Basin Finance Journal*, 15(1):18 – 35.

Diamond, P. A. (1982). Aggregate demand management in search equilibrium. *Journal of Political Economy*, 90(5):pp. 881–894.

Domowitz, I., Glen, J., and Madhavan, A. (2001). Liquidity, volatility and equity trading costs across countries and over time. *International Finance*, 4(2):221–55.

Economides, N. and Schwartz, R. A. (1995). Electronic call market trading. *Journal of Portfolio Management*, 21:10–18.

Ellul, A., Shin, H. S., and Tonks, I. (2005). Opening and closing the market: Evidence from the London stock exchange. *Journal of Financial and Quantitative Analysis*, 40(4):779.

Hasbrouck, J. and Schwartz, R. A. (1988). Liquidity and execution costs in equity markets. *Journal of Portfolio Management*, 14:10–16.

Ho, T. S. Y., Schwartz, R. A., and Whitcomb, D. K. (1985). The trading decision and market clearing under transaction price uncertainty. *The Journal of Finance*, 40(1):pp. 21–42.

ISMR (2010). *Indian Securities Market - A Review 2010*, volume XIII. National Stock Exchange of India Limited.

ISMR (2011). *Indian Securities Market - A Review 2011*, volume XIV. National Stock Exchange of India Limited.

Kehr, C. H., Krahnen, J. P., and Theissen, E. (2001). The anatomy of a call market. *Journal of Financial Intermediation*, 10(3):249 – 270.

Madhavan, A. (1992). Trading mechanisms in securities markets. *Journal of Finance*, 47(2):607 – 641.

Madhavan, A. and Panchapagesan, V. (2000). Price discovery in auction markets: A look inside the black box. *Review of Financial Studies*, 13(3):627 – 658.

NSE (2011). *NSE Fact Book - 2011*. National Stock Exchange of India Limited.

Pagano, M. S. and Schwartz, R. A. (2003). A closing call's impact on market quality at Euronext Paris. *Journal of Financial Economics*, 68(3):439 – 484.

Schwartz, R. A. and Wood, R. A. (2001). Calling the open: Price discovery evidence from Nasdaq. *Working Paper, The Nasdaq Stock Market, Inc. Economic Research*.

Thomas, S. (2010). Call auctions: A solution to some difficulties in indian finance. *Finance Working Papers, Indira Gandhi Institute of Development Research*.

Table 1: Volume share during intraday intervals

The table presents the average of the volume recorded at various intervals as a percentage of daily volume before and after the introduction of the call auction. The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. The pre-open session was from 9:00 am to 9:15 am which consist of three phases - an order collection period (9:00 am to a random time between 9:07 am and 9:08 am); an order matching period immediately following the order collection period till 9:12 am; and a silent period immediately following the order matching period till 9:15 am, when the normal market opens.

Time		Precall	Postcall-1	Postcall-2	Postcall-3
From	To				
9:07	9:07	-	0.10	0.07	0.08
9:00	9:15	6.38	-	-	-
9:15	9:30	4.30	6.79	6.95	7.65
9:30	10:00	7.02	7.99	8.01	8.37
10:00	10:30	6.12	6.22	6.59	6.86
10:30	11:00	5.64	5.84	6.12	5.72
11:00	11:30	5.47	5.71	6.01	5.85
11:30	12:00	5.52	6.17	6.04	5.62
12:00	12:30	5.51	5.99	5.72	5.76
12:30	13:00	5.86	5.74	5.78	6.04
13:00	13:30	6.14	6.23	5.94	6.53
13:30	14:00	6.23	6.85	7.17	6.77
14:00	14:30	7.52	7.72	7.95	7.69
14:30	15:00	9.23	9.27	9.77	8.93
15:00	Close	19.08	19.37	17.88	18.13

Table 2: Correlation between 5-minutes' intraday returns (before and after the introduction of the call auction)

The table presents the correlation of the intraday returns of the 50 constituent stocks of Nifty at various intervals during the first hour of trading before and after the introduction of the call auction (October 18, 2010). Panel A reports the return correlation over 66 trading days from July 15, 2010 to October 17, 2010. Panels B, C and D covers 52 trading days from October 18, 2010 to December 31, 2010 ('Postcall-1'), 62 trading days from January 1, 2011 to March 31, 2011 ('Postcall-2') and 62 trading days from April 1, 2011 to June 30, 2011 ('Postcall-3'), respectively. 'Pclose' indicates the previous trading day's closing price. Pre-open price is the price established in the call-auction session which concludes at 9:07 / 9:08 am. Figures in bold indicate the significance at 10% level.

PANEL A: N = 3300; Period: July 15, 2010 - October 17, 2010 (Precall)

	Pclose-9:00	9:00-9:05	9:05-9:10	9:10-9:15	9:15-9:20	9:20-9:25	9:25-9:30	9:30-9:35	9:35-9:40	9:40-9:45
9:00-9:05	**-0.109**									
9:05-9:10	**0.041**	0.016								
9:10-9:15	-0.001	-0.019	**-0.034**							
9:15-9:20	**-0.034**	0.016	-0.015	-0.013						
9:20-9:25	-0.009	-0.024	**0.038**	**-0.087**	0.022					
9:25-9:30	-0.001	0.020	-0.004	-0.005	-0.020	**-0.029**				
9:30-9:35	0.010	-0.029	**0.030**	-0.003	**-0.049**	0.007	-0.023			
9:35-9:40	0.000	0.005	-0.012	0.020	**-0.050**	**-0.049**	-0.004	0.018		
9:40-9:45	-0.019	0.019	-0.007	0.010	0.000	-0.002	**0.038**	0.026	0.026	
9:45-9:50	-0.020	-0.023	0.000	0.002	-0.005	**0.031**	0.023	**-0.040**	**-0.043**	**-0.059**

PANEL B: N = 2600; Period: October 18, 2010 - December 31, 2010 (Postcall-1)

	Pclose-9:07	9:07-9:15	9:15-9:20	9:20-9:25	9:25-9:30	9:30-9:35	9:35-9:40	9:40-9:45
Preopen-9:15	**-0.124**							
9:15-9:20	**-0.052**	**0.063**						
9:20-9:25	**-0.087**	0.006	0.032					
9:25-9:30	0.015	**-0.044**	**0.065**	-0.013				
9:30-9:35	0.020	-0.010	-0.001	-0.006	-0.021			
9:35-9:40	-0.004	-0.002	0.020	-0.012	**0.122**	**0.072**		
9:40-9:45	-0.015	0.020	-0.007	**-0.066**	**-0.131**	-0.029	**-0.130**	
9:45-9:50	0.001	-0.036	**-0.056**	**-0.101**	**-0.052**	-0.019	**-0.136**	**0.091**

PANEL C: N = 3100; Period: January 1, 2011 - March 31, 2011 (Postcall-2)

	Pclose-9:07	9:07-9:15	9:15-9:20	9:20-9:25	9:25-9:30	9:30-9:35	9:35-9:40	9:40-9:45
Preopen-9:15	**-0.108**							
9:15-9:20	-0.007	0.007						
9:20-9:25	-0.016	0.014	0.006					
9:25-9:30	0.005	0.002	**0.033**	**-0.033**				
9:30-9:35	0.008	0.009	**0.054**	**-0.033**	**-0.052**			
9:35-9:40	0.005	-0.009	0.014	0.024	-0.013	-0.024		
9:40-9:45	**-0.031**	-0.021	0.020	-0.021	-0.020	**0.078**	**-0.041**	
9:45-9:50	-0.028	-0.008	**-0.068**	**0.055**	**0.049**	0.001	**-0.047**	-0.002

PANEL D: N = 3100; Period: April 1, 2011 - June 30, 2011 (Postcall-3)

	Pclose-9:07	9:07-9:15	9:15-9:20	9:20-9:25	9:25-9:30	9:30-9:35	9:35-9:40	9:40-9:45
Preopen-9:15	**-0.282**							
9:15-9:20	**-0.120**	0.017						
9:20-9:25	-0.020	**0.035**	0.019					
9:25-9:30	**-0.091**	**-0.040**	**0.068**	-0.001				
9:30-9:35	**-0.078**	**0.050**	**0.072**	0.019	**0.067**			
9:35-9:40	0.005	**-0.035**	-0.009	**-0.070**	**0.063**	**-0.073**		
9:40-9:45	**-0.119**	0.006	**0.075**	**0.035**	**-0.034**	**0.063**	**-0.076**	
9:45-9:50	**-0.068**	0.003	0.007	**-0.081**	-0.022	0.019	-0.001	**0.045**

Table 3: Average adjusted R-squares for the first-pass (market model) regressions for different intervals

The table presents averages of the adjusted R-squares (Panel A) and average betas (Panel B) from the 500 market model regressions ($R_j = \alpha + b_1 R_m + \epsilon_j$), for each of the 50 stocks which were constituents of Nifty using 1-day, 2-days ... 10-days returns. Returns are calculated using non-overlapping close-to-close, open-to-open (reported), open-to-open (at end of 1st trading minute) and close-to-open prices measured at the end of the first trading minute. Diff. is the difference between the figures in the 'Pre' and 'Post' columns. ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

Return interval	Close-to-close				Open-to-open (reported)				Open-to-open (end of 1st trading minute)				Close-to-open (reported)			
	Pre	Post	Diff.	t-stat.	Pre	Post	Diff.	t-stat.	Pre	Post	Diff.	t-stat.	Pre	Post	Diff.	t-stat.
Panel A: Average Adjusted R-Squares																
1 day	0.31	0.34	0.03	1.91 *	0.12	0.32	0.20	10.47 ***	0.34	0.34	0.00	-0.11	0.06	0.37	0.32	13.27 ***
2 days	0.31	0.36	0.04	2.06 **	0.20	0.37	0.17	7.16 ***	0.30	0.36	0.06	2.60 **	0.22	0.36	0.14	7.00 ***
3 days	0.30	0.43	0.13	5.45 ***	0.15	0.34	0.19	7.56 ***	0.28	0.34	0.06	2.33 **	0.32	0.33	0.01	0.58
4 days	0.25	0.39	0.14	5.74 ***	0.23	0.41	0.18	6.53 ***	0.30	0.39	0.09	3.65 ***	0.28	0.37	0.09	3.82 ***
5 days	0.26	0.41	0.15	5.50 ***	0.24	0.44	0.19	6.38 ***	0.30	0.44	0.14	4.62 ***	0.31	0.38	0.07	2.14 **
6 days	0.35	0.42	0.08	2.57 **	0.24	0.37	0.13	3.65 ***	0.31	0.39	0.08	2.17 **	0.40	0.38	-0.02	-0.76
7 days	0.30	0.42	0.12	3.77 ***	0.28	0.38	0.10	3.24 ***	0.30	0.39	0.10	3.30 ***	0.33	0.39	0.06	1.91 *
8 days	0.31	0.42	0.11	3.83 ***	0.32	0.42	0.10	2.85 ***	0.36	0.42	0.06	1.88 *	0.26	0.43	0.18	5.67 ***
9 days	0.28	0.44	0.16	5.53 ***	0.26	0.45	0.19	6.75 ***	0.30	0.44	0.15	5.64 ***	0.39	0.45	0.06	2.14 **
10 days	0.25	0.40	0.15	4.63 ***	0.31	0.45	0.14	3.88 ***	0.33	0.44	0.12	3.50 ***	0.34	0.38	0.03	1.04
Panel B: Average Betas																
1 day	0.96	0.98	0.02	0.50	0.73	0.99	0.26	5.97 ***	1.01	1.01	0.00	-0.01	2.53	0.95	-1.58	-8.85 ***
2 days	0.94	1.02	0.08	1.64	0.91	0.97	0.06	1.04	0.98	0.99	0.01	0.22	0.96	0.97	0.01	0.25
3 days	0.97	1.05	0.08	1.38	0.76	0.98	0.22	3.40 ***	0.94	0.98	0.04	0.64	1.08	0.99	-0.08	-1.43
4 days	0.97	1.01	0.03	0.51	1.10	1.00	-0.09	-1.23	1.00	1.02	0.03	0.40	0.98	1.01	0.03	0.47
5 days	0.93	0.99	0.06	0.83	0.92	1.02	0.10	1.30	0.97	1.02	0.04	0.63	1.14	1.00	-0.14	-1.99 *
6 days	1.00	1.04	0.04	0.51	0.98	1.01	0.03	0.33	0.97	1.02	0.04	0.53	1.05	1.03	-0.02	-0.32
7 days	0.96	0.99	0.03	0.41	0.89	0.97	0.08	1.13	0.94	0.97	0.03	0.31	1.12	0.97	-0.15	-1.70 *
8 days	0.98	0.97	-0.01	-0.18	1.09	0.95	-0.14	-1.69 *	1.00	0.98	-0.02	-0.23	0.94	0.94	0.00	-0.04
9 days	0.97	1.09	0.12	1.66	0.94	1.08	0.15	2.20 **	0.89	1.09	0.20	2.18 **	1.07	1.09	0.02	0.40
10 days	0.92	1.04	0.12	1.39	0.94	1.09	0.14	1.57	0.93	1.09	0.16	1.59	1.05	1.11	0.06	0.72

Table 4: Market efficiency measures before and after the introduction of the call auction

This table reports the estimates of market quality measured using the second pass regressions. *R2CONSTANT* and *R2SLOPE* are estimates from the following second-pass regression: $AdjRsq_{jLE} = r_j + s_j \ln(1 + L^{-1}) + t_j(DummyRsq_{jE}.\ln(1 + L^{-1})) + u_j(DummyC_{jE}) + v_{jLE}$, where $AdjRsq_{jLE}$ is the adjusted R-square from the market model regression for security j based on L day stock returns for the time period E, $E = A$ (after) or B (before) the event; L is the return interval used in the first-pass regressions, $DummyRsq_{jE}$ is a dummy variable for the slope equal to 1 if the first-pass adjusted R-square is estimated using the post-event data ($E = A$) and 0 otherwise; $DummyC_{jE}$ is a dummy variable for the intercept equal to 1 if the first-pass adjusted R-square is estimated using the post-event data ($E = A$) and 0 otherwise; and v_{jLE} is a disturbance term. r_j, s_j, t_j and u_j are second-pass parameter estimates. *R2CONSTANT* equals r_j and $r_j + u_j$ and *R2SLOPE* equals s_j and $s_j + t_j$ for the period before and after the introduction of the call auction respectively. Returns are calculated using non-overlapping close-to-close, open-to-open (reported), open-to-open (at end of 1st trading minute) and close-to-open prices measured at the end of the first trading minute.

BETA-SLOPE is estimated from the following second pass regression: $b_{j,LE} = a_{j,2} + b_{j,2} \ln(1 + L^{-1}) + c_{j,2}(Dummy_{jE}.\ln(1 + L^{-1}) + e_{jLE}$, where $b_{j,LE}$ is the first-pass beta estimate for security j based on $L-$day stock returns for the time period E ; where $E = A$ (after) or B (before) the event; L is the return interval used in the first-pass regressions, $Dummy_{jE}$ is a dummy variable equal to 1 if first-pass beta is estimated using post-event data ($E = A$) and 0 otherwise; and e_{jLE} is a disturbance term. $a_{j,2}$, $b_{j,2}$ and $c_{j,2}$ are second-pass parameter estimates. *BETA-SLOPE* equals $b_{j,2}$ and $b_{j,2} + c_{j,2}$ for the period before and after the introduction of the call auction respectively.

Avg-Var1 and *Avg-Var2* are averages of 1- and 2-day return variances. The first-pass regressions are estimated over a 180 days period before and after the introduction of the call auction. Diff. is the difference between the figures in the 'Pre' and 'Post' columns. ***, ** and * indicate significance at 1%, 5% and 10% level respectively.

Variable	**Close-to-close**			**Open-to-open (reported)**			**Open-to-open (end of 1st trading minute)**			**Close-to-open (reported)**		
	Pre	**Post**	**Diff.**	**Pre**	**Post**	**Diff.**	**Pre**	**Post**	**Diff.**	**Pre**	**Post**	**Diff.**
R2CONSTANT	0.280	0.436	0.156	0.308	0.442	0.135	0.306	0.436	0.130	0.402	0.402	-0.001
t-stat.	20.281 ***	31.597 ***	8.016 ***	22.109 ***	31.161 ***	6.837 ***	21.604 ***	30.677 ***	6.481 ***	28.434 ***	28.279 ***	-0.045
R2SLOPE	0.046	-0.144	-0.190	-0.300	-0.200	0.100	0.023	-0.165	-0.188	-0.472	-0.076	0.396
t-stat.	0.995	-3.099 ***	-2.894 ***	-6.419 ***	-4.263 ***	1.519	0.489	-3.458 ***	-2.793 ***	-9.927 ***	-1.597	5.890 ***
BETA-SLOPE	-0.100	0.034	0.134	-0.406	-0.073	0.333	-0.021	0.064	0.085	1.626	0.329	-1.296
t-stat.	-1.034	0.349	1.356	-4.008 ***	-0.723	3.222 ***	-0.207	0.622	0.812	13.310 ***	2.697 ***	-10.408 ***
Avg-Var1	0.0003	0.0004	0.0001	0.0005	0.0004	-0.0001	0.0004	0.0004	0.0000	0.0001	0.0001	-0.0001
t-stat.	16.52 ***	14.89 ***	3.55 ***	15.90 ***	16.34 ***	-2.86 ***	7.23 ***	16.07 ***	-0.07	11.27 ***	18.50 ***	-5.20 ***
Avg-Var2	0.0007	0.0009	0.0002	0.0008	0.0008	0.0000	0.0008	0.0008	0.0001	0.0005	0.0004	0.0000
t-stat.	16.12 ***	12.65 ***	3.34 ***	14.61 ***	16.73 ***	0.85	7.26 ***	16.53 ***	0.65	16.99 ***	17.36 ***	-0.32

Figure 1: Return volatility before and after the introduction of call auction (first trading hour)

The figure shows the average 5-minutes' return volatility (absolute returns) during the first trading hour before and after the introduction of the call (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. Volatility at 'Interval 0' indicates the overnight return volatility. Volatility of the first 5-minute interval after the introduction of the call ('Interval No 4') is computed using the opening price of the continuous market (9:15 open)

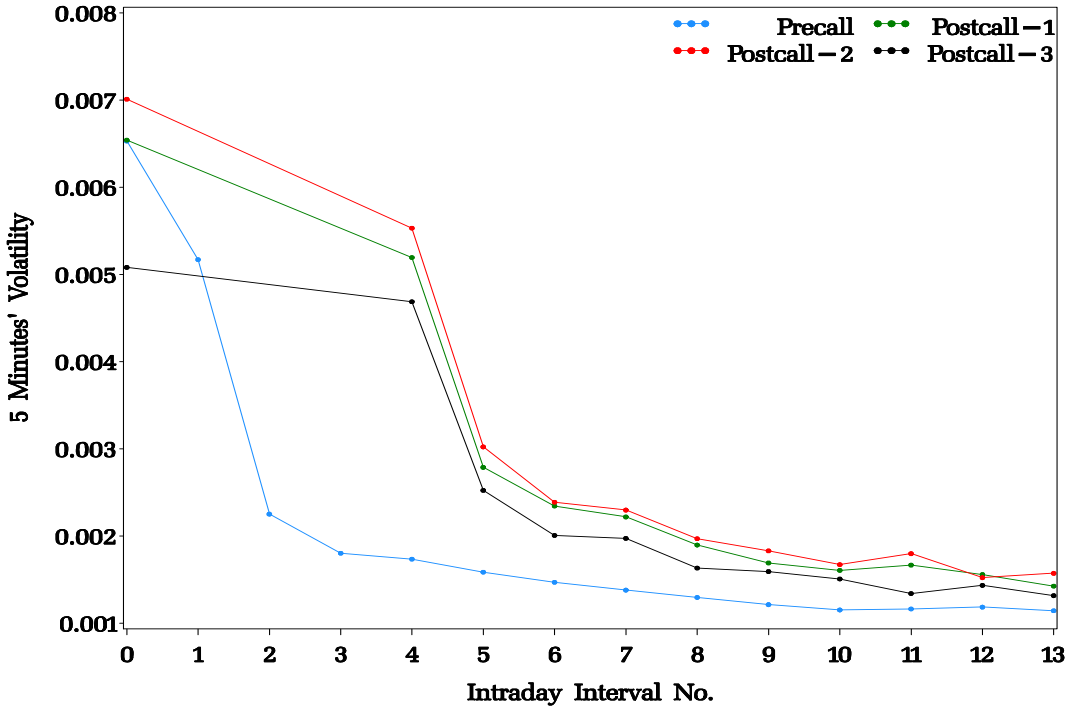

Figure 2: Standardized volume before and after the introduction of call auction (first trading hour)

The figure shows the average 5-minutes' standardized volume (across intervals within a stock-day) during the first trading hour before and after the introduction of the call auction (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. The volume at interval '0' indicates the volume at the pre-open session.

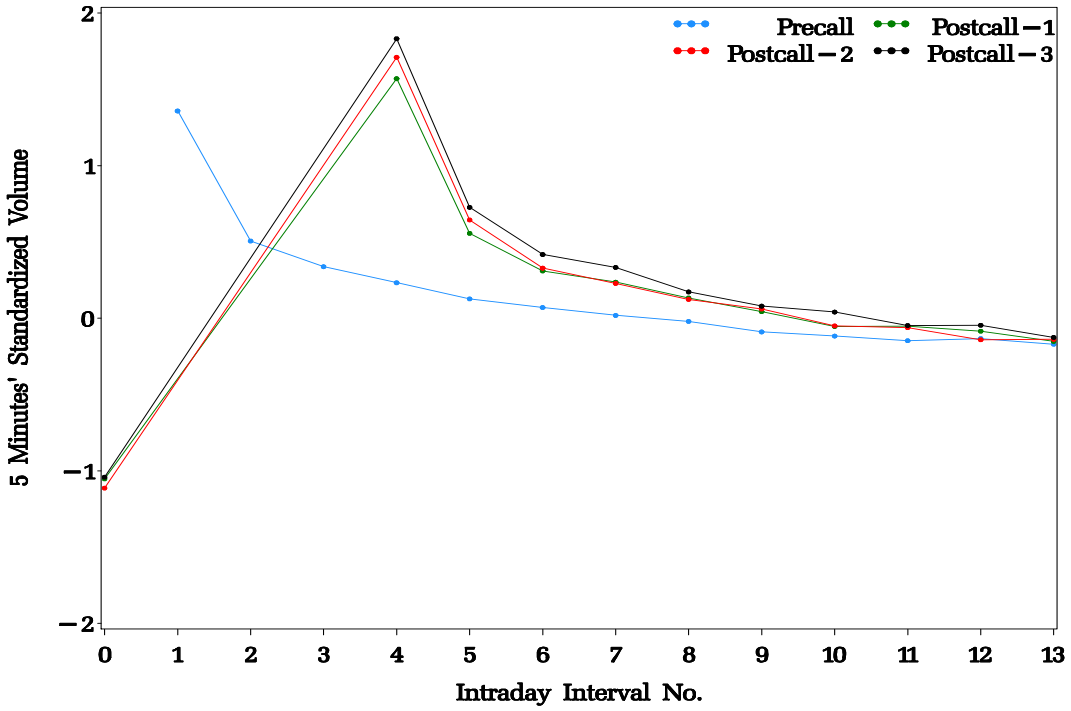

Figure 3: Intraday return volatility before and after the introduction of call auction

The figure shows the average 5-minutes' return volatility (absolute returns) before and after the introduction of the call (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. Volatility at 'Interval 0' indicates the overnight return volatility. Volatility of the first 5-minute interval after the introduction of the call ('Interval No 4') is computed using the opening price of the continuous market (9:15 open)

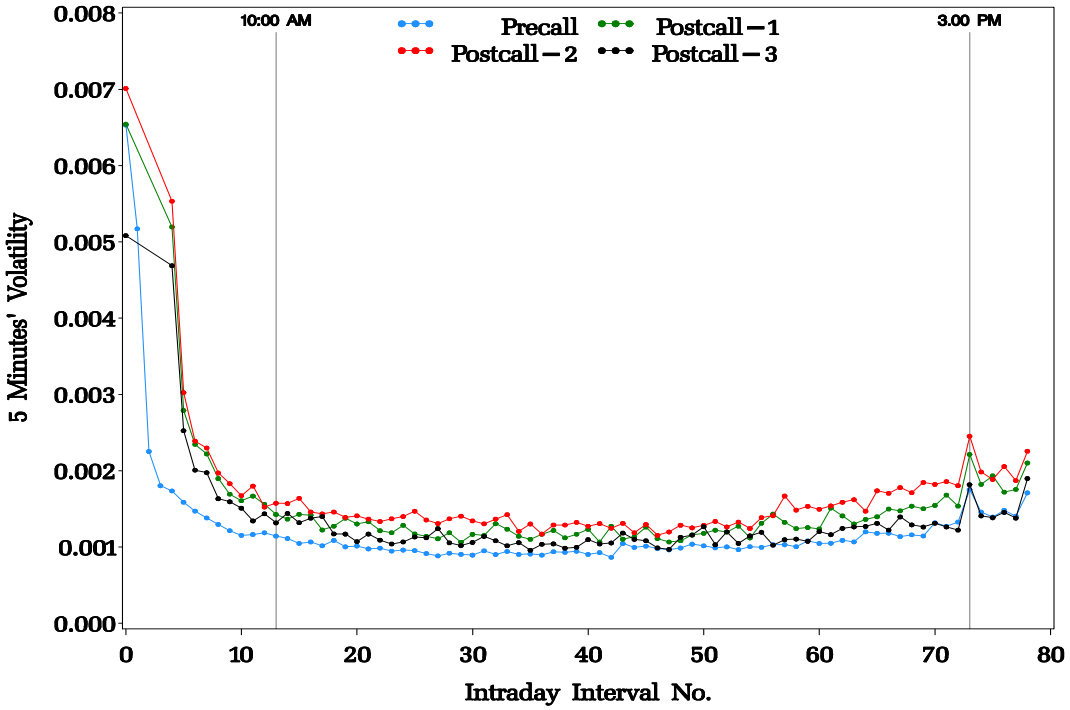

Figure 4: Intraday standardized volume before and after the introduction of call auction

The figure shows the average 5-minutes' standardized volume (across intervals within a stock-day) before and after the introduction of the call auction (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. The volume at interval '0' indicates the volume at the pre-open session.

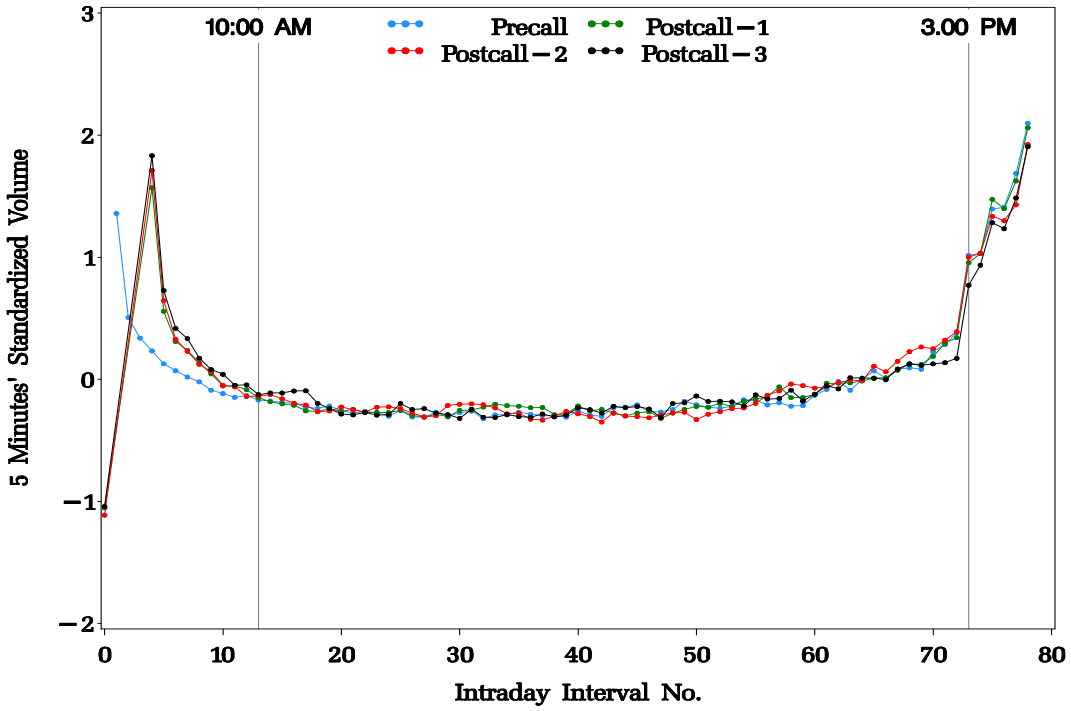

Figure 5: Intraday average trade size (in ₹) before and after introduction of pre-open auction

The figure shows the average trade size (in ₹) during the various 5-minutes intervals before and after the introduction of the call auction (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. The average trade size during interval '0' indicates the trade size during the pre-open session.

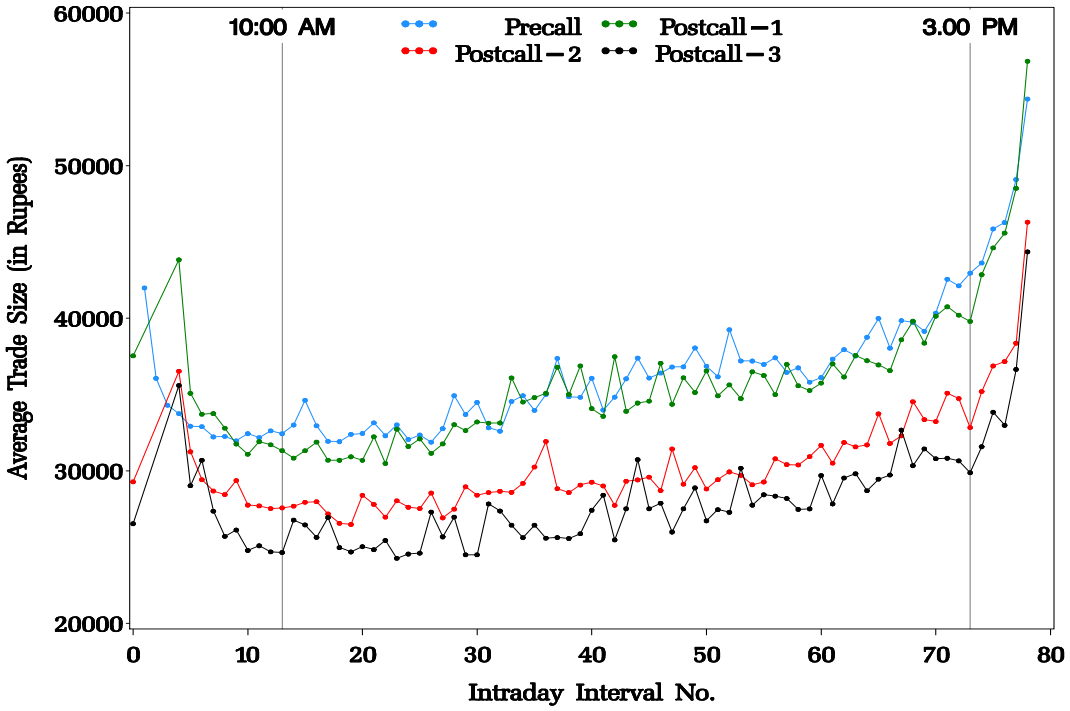

Figure 6: Intraday average trade size (in ₹) before and after the introduction of the pre-open auction

The figure shows the average trade size (in ₹) during the various 5-minutes intervals during the first trading hour before and after the introduction of the call auction (October 18, 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from July 15, 2010 to October 17, 2010; (b) 'Postcall-1' covers 52 trading days from October 18, 2010 to December 31, 2010; (c) 'Postcall-2' covers 62 trading days from January 1, 2011 to March 31, 2011; and (d) 'Postcall-3' covers 62 trading days from April 1, 2011 to June 30, 2011. The average trade size during interval '0' indicates the trade size during the pre-open session.