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

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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. Possibly due to faulty design or due to "thick market externalities", the impact of the introduction of call has not been found uniformly beneficial. This paper examines the recent re-introduction of opening call auction at the National Stock Exchange of India. This was advocated based on the supportive evidence of the positive effect of call auction at the time of high market 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 call market. The volatility and volume still takes about 30 minutes to stabilize and the auction attracts very little volume. The negative intraday return correlations suggest excessive price movement at the call auction. However, the synchronicity of price discovery, on the lines of Pagano and Schwartz (2003), indicates some improvement in the market quality. Possibly, the no all-round improvement of price discovery could be attributed to the extremely short duration of the 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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1 Introduction

World-wide, the use of call auctions for opening and closing the market trading is indeed common and has been increasing[1]. Call auction as an alternative to the continuous order-matching mechanism for opening the trading has been advocated on theoretical and empirical grounds by various researchers. It has been argued that call markets can aggregate information over time and hence facilitate price discovery even when continuous markets may fail. For instance, Madhavan (1992) showed that continuous markets can fail when the information asymmetry is very high. In such cases, call markets can still discover prices more effectively by pooling orders over time and executing them at a uniform price. 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. Economides and Schwartz (1995) and Schwartz and Wood (2001) argued for the use of call markets on derivative expiration dates. 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 during opening call auction is found to be highly significant in some of the 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.

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. There are several comparative studies on the trading costs and price discovery between the call and continuous markets. These comparative studies covers context such as within a market, across markets, and across time when call market has been replaced with continuous market. Within a market, several papers analysed the market opening (Stoll and Whaley 1990, Biais et al. 1999, Cao et al. 2000, Domowitz et al. 2001, Madhavan and Panchapagesan 2000, Kehr et al. 2001, Davies 2003, Barclay and Hendershott 2003). Some have attempted to compare the characteristics of trading and price discovery when both call auctions and an alternative trading mechanism are available for trade. Some of the key researches on the impact of the replacement of call market with continuous market or vice versa are Amihud et al. (1997), Muscarella and Piwowar (2001) and Kalay et al. (2002), among others.

This paper, examines 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 auction in 1999. A study of this episode by Camilleri and Green (2009) found that the suspension did not worsen the market quality. They also report that the less liquid stocks used to trade infrequently in call auctions. Pagano and Schwartz (2003) analysed the effect of the introduction of the closing call on Euronext Paris in 1996

[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 NYSE. Kehr et al. (2001) report that opening call accounts for 12.1% of daily volume at Frankfurt Stock Exchange.

for the less liquid category B stocks and in 1998 for the more active Category A stocks. They concluded that the introduction of closing call lowered the execution costs and improved price discovery. Aitken et al. (2005) analysed the impact of the introduction of closing call in Australian Stock Exchange in 1997. They found that while the closing call attracted about 2.5% of daily trading activity, most of it came at the expense of the last two hours of trading volume. Comerton-Forde et al. (2007b) and Chang et al. (2008) found that the introduction of call market at opening and close of trading at Singapore Exchange improved the market quality, with the latter study reporting that the beneficial effect was more on the liquid stocks. Comerton-Forde et al. (2007a) analysing the impact of the introduction of opening call in Hong Kong concluded that with less than 1% volume, the opening call decreased the quality of the market in terms of return volatility and liquidity. The negative effect of the introduction of opening call was found to be more on less liquid stocks.

In the Indian context, Thomas (2010) builds a case for the use of call auctions for market opening and closing, of illiquid securities such as bonds, on extreme news events and as a replacement of 'circuit breakers'[3]. She analyses the intraday volatility and spread of a few stocks as an illustration and argues that it takes as long as half-an-hour for the opening volatility to settle down in Indian stock market. Based on this, she goes on to argue that introducing a call auction may hasten the assimilation of information faster.

The motivation for this paper comes from the fact that empirically the effect of introduction of opening and closing call has not been found to be always unambiguously beneficial despite theoretical arguments and increasing acceptance of call auctions for opening and closing the markets. It has also been argued that all call markets are not alike and hence call market design and trading rules can have significant effect on its outcomes (Comerton-Forde et al. 2007a). The popular press and the trading community feels that given the low level of volume transacted through the opening call, in India its effect on the price discovery is not significant. Nonetheless, a more systematic enquiry is warranted.

Our major results are as follows. On analysing the intraday return volatility, volume and serial correlation of returns, we find that the introduction of call auction for opening the market has merely shifted the intraday volatility and volume pattern without changing the time taken by the Indian market to settle down from the higher volume and volatility experienced in the opening hours. Following the event-study methodology of Pagano and Schwartz (2003), however, we find that the market quality, in terms of increased synchronicity of stock prices, has improved after the introduction of call auctions. We also find that higher synchronicity is observed in closing prices after the introduction of call auctions 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 by it during the call auction

[3]NSE employs a 3-stage market-wide circuit breaker system wherein there is a trading halt when there is a movement in any of the major index (either the BSE Sensex or the Nifty) to the extent of 10%, 15% and 20%. The duration of halt varies from 30 minutes to the remainder of the day depending on the extent of 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

and the subsequent continuous trading. Section 3 provides a brief review of the theoretical and empirical research related to the use of call auction mechanism for market opening and close. Section 4 details the methodology and data used in this study. Section 5 reports the results of our analysis and section 6 concludes.

2 National Stock Exchange of India: Institutional Details

The Indian capital market ranked tenth in the world by the total traded value and seventh in the world by market capitalization in 2010 (ISMR 2011). The NSE, recognized as a stock exchange in 1993, catalysed radical microstructure reforms in the Indian market and became the market leader in India. By 2010-11 NSE had a market share of 76.36% in the cash market segment and 100% in the individual futures and options segment (ISMR 2011).

The average trading volume of its cash market segment has increased from $192.3 billion (Rs. 8,390 billion) in 1999-2000 to $801.2 billion (Rs. 35,774 billion) in 2010-11. The market capitalization of all stocks listed at NSE has increased $234 billion in 1999-2000 to $1501 billion in 2010-11 (NSE 2011). Around 1450 companies were listed on the NSE as of March 2011.

It offers a fully automated screen-based order-driven trading system, which operates on a price-time priority, known as the National Exchange for Automated Trading (NEAT). NSE is the world's first stock exchange to use satellite communication to enable 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.

3 Research on Call Market

3.1 Theoretical Models and Arguments for Call Market Mechanism

The performance of quote-driven, periodic order-driven and continuous order-driven markets, in the presence of information asymmetry is modelled by Madhavan (1992) . He concluded that a certain amount of non-information trading is required to achieve equilibrium in a continuous quote-driven (dealer) market. On the other hand, auction markets, he showed, are more robust to the problem of information asymmetry even though it (call market) may suffer from the loss of continuity. The main advantage of the order-driven system is that the traders and not the dealer(s) have to make the first move. In the presence of severe information asymmetry, Madhavan (1992), showed that the dealer would be unable to open a market without expecting a loss.

Several other arguments are also advanced in favour of call market. A call market can consolidate order flow (or temporally aggregates orders), can lower execution and market impact costs, can eliminate the risk of front-running and information disclosure when directly accessed, and can 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, close and also once during the trading hours. Schwartz and Wood (2001) advocated the use of an electronic call market also for discovering the settlement price on the expiry of derivative contracts.

The ability of call market mechanism to temporally aggregate orders and thus handle market failure in the face of severe information asymmetry, however, does not imply that the prices discovered in call auctions would be, in general, pareto-efficient. Modelling the behaviour of traders in a call (batch) market; Ho et al. (1985) showed that the prices in a call market would differ from pareto-efficient values. Strategic behaviour by the traders means that the transacted 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'* (Ho et al. 1985). They also showed that in a call market the prices would fluctuate randomly around pareto-efficient price and argued that due to the ability to observe the order flow the dealer performs a useful function in price discovery process.

Using a single 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 found to be able to set a more efficient opening price than the public in an auction. They also validated the ability of the dealers with the trade level data of NYSE. 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, pg. 18). However, Madhavan and Panchapagesan (2000) report that the batch mechanism (call) is used only 20% of the times for the least liquid stocks and it is used more often in the case of liquid stocks. The supposed theoretical benefits of call markets is 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 lower execution costs (Admati and Pfleiderer 1988) and face lower risk of being picked by informed traders, then call auctions may indeed 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.

3.2 Empirical Research on Call Markets

Experimentally, it is found that batch markets suffer less from adverse selection problems (Schnitzlein 1996) and the prices in experimental call markets are less volatile than continuous (Chang et al. 1999). Theissen (2000) found that prices in auction markets, whether continuous or batch, are more efficient than in the dealer markets.

Price discovery in call market has been the focal point of many strands of empirical market microstructure research. The discussion of the empirical research here is limited to the impact of the introduction of opening and closing call, given the focus of the paper.

The opening prices have long been found to be more volatile (Amihud and Mendelson 1987) and there has been extensive research on how markets discover opening prices (Stoll and Whaley 1990, Biais et al. 1999, Cao et al. 2000, Domowitz et al. 2001, Madhavan and Panchapagesan 2000, Kehr et al. 2001, Davies 2003, Barclay and Hendershott 2003). There is an extensive accumulation of public and private information during the open hours of an exchange and this accumulated information induces high volatility and volume at the commencement of trading.

Ko et al. (1995) found that the introduction of an additional clearing at the afternoon closing makes price discovery more efficient than before from the viewpoint of stock price volatility. Pagano and Schwartz (2003) analysed the effect of the introduction of closing call on Euronext Paris in 1996 for the less liquid category B stocks and in 1998 for the more active Category A stocks. They concluded that the introduction of the closing call lowered the execution costs and improved price discovery. They used event study approach (pre and post introduction of closing call) based on market model with systematic risk estimated following Cohen et al. (1983a;b) and concluded that the synchronicity of returns did increase after the introduction of closing call on Paris Bourse. They also examined the 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 volume and spread during the last hour of the continuous trading for category B (less liquid) stocks. As mentioned earlier, Aitken et al. (2005) analysed the impact of the introduction of closing call in Australian Stock Exchange in 1997. They used intraday half-hourly and opening/closing call volume and spread and found that while the closing call attracted volume, it was at the expense of volume in the previous two hours of the continuous market. Unlike Pagano and Schwartz (2003), they found that the spread went up in the last half-an-hour of the continuous trading (but not in the last two hours associated with decreased volume) post introduction of the closing call.

Ellul et al. (2005) analysed high-frequency trade data in the context of introduction of opening call at London Stock Exchange (LSE) in 1997 and a closing call in 2000. The LSE had allowed parallel running of the order-driven and quote-driven (dealer) market. This meant that the opening and closing trade could be in the dealer market or in the call market. They found that even though call market suffers from a high failure rate, the prices discovered in call market are closer 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 open and close to "thick market externalities". Using an endogenous switching regression model with explanatory variables reflecting the state of the order book, state of entire market and controls, they concluded 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 introduction of call at LSE. She used market model R-squared (Pagano and Schwartz 2003), average relative return dispersion (RRD) coefficient (Amihud et al. 1997), and MEC coefficients (Hasbrouck and Schwartz 1988) as the measures of market quality[4]. She found that all the measures indicated improvement in market quality and the improvement was more at the open than at the close. Contrary to some of the findings noted in this paper

[4]MEC coefficient as used by Hasbrouck and Schwartz (1988) refers to the ratio of implied volatility to observed volatility.

elsewhere, she found that the stocks of firms with the lowest pre-call liquidity experienced the greatest increase in market quality.

Chang et al. (2008) studied the impact of introduction of the call market to open and close the market at Singapore Exchange in 2000. They used market-adjusted return volatility (squared residual of market model). They also used correlation between trading day returns and overnight returns as a measure of trading noise and two-day volume-weighted prices as the benchmark for pricing errors. They concluded that introduction of call at opening and closing reduced volatility and pricing errors even when call was not used by some of the stocks for opening and closing trade. They also found that the gains were much less for less liquid stocks. According to Singapore Exchange protocol, if no crossing buy and sell orders are placed during the pre-open or pre-close call routine, no call trade takes place. In such an event, the continuous market takes over the trades immediately at opening and ends the trade at closing. Comerton-Forde et al. (2007b) also looked at the same event but used methodology followed by Pagano and Schwartz (2003) besides analysing intraday spread and volume dynamics post the "event". They found that while the frequency of call trades is not very high at the Singapore Exchange, the call volumes are high when traded. Using Pagano and Schwartz (2003) methodology, they concluded 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 introduction of call market to open the market by Hong Kong Exchange and Clearing Ltd. in 2002. They used Pagano and Schwartz methodology to address the price efficiency around the event of introduction of call auction and also examined the price volatility, relative volume in call market and bid-ask spread. Volatility is measured by- (a) ratio of the variance of open-to-open returns to variance of close-to-close returns, and (b) absolute percentage change between the first price and volume-weighted price in the first half-an-hour. They found that opening call auctions at Hong Kong accounted for less than 1% of the daily volume, opening price volatility is higher post the opening call, and the market quality has deteriorated post the introduction. They attributed the failure of opening call in attracting volume to its faulty design. Particularly, they pointed out that the pre-open price discovery period was unusually short (overall 30 minutes) and there were order restrictions. The Hong Kong market opened at 10 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 was 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, algorithm was applied by the exchange to complete the call auction. The exchange used the time between 9:58 and 10 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.

In summary, the empirical research on the impact of the introduction of call auctions by the exchanges world-wide has been broadly supportive of the notion that call method at the open and close can improve market quality and price discovery. Besides the stocks directly benefitting 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). 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).

3.3 NSE Call Auction

NSE reintroduced[5] call auction to open trading in 50 of its large capitalization stock underlying its prime index, S&P CNX Nifty (Nifty) on 18 October 2010. The pre-open 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; a silent period immediately following the order matching period till 9:15 am, at which the normal market opens. The order collection period is meant for order entry, modification, and cancellation. Only limit orders and market orders[6] can be placed during this period. Transparency is ensured during the pre-open session through the dissemination of market depth, indicative equilibrium price, scrip-wise total buy and sell quantity, indicative Nifty value[7], 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, orders are matched at a single price[8], at which the maximum volume could be executed. In case of a tie between two prices, the price closest to the previous days 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-stamp with limit orders retaining the limit price, and market orders priced at the discovered equilibrium price. Where no equilibrium price is discovered in the pre-open session, all market orders are priced at the closing price of the previous day (adjusted for corporate actions, if any)[9]. Trade details are disseminated to the members before the start of the normal market.

3.4 Motivation to Study the Impact of the Introduction of Opening Call

NSE used to have call auctions at open and close till 1999. The impact of the suspension by NSE 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 reversals and liquidity. They used market model for computing CARs (Cumulative Abnormal Returns), and related CARs to Volatility, Efficiency and Liquidity (VEL) measures. They found that the suspension improved the VEL measures.

[5]SEBI Circular No. CIR/MRD/DP/21/2010 dated 15 July 2010. ISMR (2011) (pp 73-74). 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

[6]Iceberg orders, disclosed quantity orders, Immediate or Cancel orders and order valid only for Preopen session were not allowed to be placed during the order collection period.

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

[8]The equilibrium price is reported as open price of the day, and if no orders are matched in the preopen the price of the first trade in the normal market shall be the opening price.

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

However, they did not find any cross-sectional relationship between CARs and the changes in the VEL measures.

The motivation behind the reintroduction of call auction in the Indian market appears to be the world-wide experience with call auctions. Thomas (2010) advocated call auction in India by pointing out that it took almost half-an-hour for the volatility and volume to settle down in India. If call market could allow for faster information assimilation at the open, it could arguably improve the market quality. Despite the several advantages of call market at the open and close, it has been recognized that the call may or may not work as effectively, possibly due to faulty design or "thick market externalities". The NSE pre-open session by design is an extremely short one, one of the reasons cited by Comerton-Forde et al. (2007a) for the low volume in opening call in Hong Kong market. Therefore, the impact of the reintroduction of call at open by NSE needs to be examined empirically.

4 Methodology and Data

The impact of the introduction of the call auction on market efficiency is examined by studying the intraday pattern of volume, volatility and return correlation. An opening phase of the market characterized by large share of volume, low volatility and no intraday return correlation would suggest an efficient market. The study compares these aspects of the market before and after the introduction of the call auction. We also examine any change in the synchronicity of prices based on the market model used by Pagano and Schwartz (2003). Any improvement is synchronicity after the introduction of the auction would indicate improvement in market efficiency.

The volume, volatility and return correlations are examined using data of the 50 Nifty constituents stocks as on 18 October 2010[10], from 15 July 2010 to 30 June 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) 18 October 2010 to 31 December 2010 (referred as 'Postcall-1') (b) 1 January 2011 to 31 March 2011 (referred as 'Postcall-2') and (c) 1 April 2011 to 30 June 2011 (referred as 'Postcall-3'). The three sub-periods cover 52, 62 and 62 trading days respectively[11].

The intraday returns are measured at 5-minutes' interval. The intraday volatility estimates are based on absolute returns and averaged across stocks. The intraday volume, measured using 5-minutes interval, are initially standardized to account for 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 analysed based on '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 29 January 2010 to 7 July 2011 (180

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

[11]We have excluded trading data for 5 November 2011 (Diwali Muhurrat Trading) when 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.

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 market model is based on the Nifty index returns. Nifty, constituted 50 stocks spread over 24 sectors, is the most widely used large cap stock index. As on 31 March 2011, the aggregate market capitalization of its constituent stocks was Rs. 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 of the Nifty suggest that it is an efficient indicator 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).

5 Impact of the Introduction of Opening Call

5.1 Intraday Volume, Volatility and Return Correlation

As pointed out elsewhere, one of the arguments advanced in favour of the introducing call auction was based on the observation 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 call auction can, in theory, aggregate information at the opening and reduce 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 call auction at opening had any impact on intraday volume and volatility dynamics, we plot the intraday volatility and volume during the first trading hour in Figure 1 and 2 respectively. The figures plot 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 call auction attracts very little volume in the Indian market. All the three sub-periods post the introduction have seen insignificant volumes ($\sim$ 0.1% of daily volume) with no visible improvement over time. Table 1 reports the descriptive statistics of intraday volume before and after the introduction of call auction at the opening. 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 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 introduction of call auction, it still takes 25-30 minutes for the volatility and volume to

[12]We have excluded 6 February 2010 (Saturday) when NSE had a special session of two hours from 11 AM, to upgrade the system, from the analysis.

settle down from the opening of the normal market and not from the opening of the call auction. This suggest that the call auction does not help to stabilize the opening phase of the market quicker. Figure 3 and 4 plot the intraday volatility and volume throughout the trading hours before and after the introduction of call auction for opening the market. Prior to the introduction of the call auction, the volatility is higher in the first three 5-minutes intervals and follows a reverse-J shape pattern, a feature of Indian Stock market reported earlier (for instance, Agarwalla (2010)). Intraday volumes follow a U-shape 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 and normal market open', and subsequent 5-minutes returns. If call auction prices are robust, the return correlation should not be significantly different from zero. Low volume in the opening call can, however, result in returns being negatively correlated if the prices move too much in 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 call at opening, we also estimate the return correlations at opening and subsequent 5-minutes intervals for the period prior to the introduction of 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 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 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 there is no improvement in 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 call auctions. The high volatility experienced in the Indian market only gets delayed by the 15 minutes duration of the call market.

5.2 Impact on Market Quality

Besides investigating the intraday volatility and volume dynamics for any impact of the introduction of call auctions, we also investigate its impact on market quality in terms of improved 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 call auctions at opening) and estimate market model for 10 return intervals. Our choice of 10 return intervals as opposed to 12 return intervals ranging from 1-10 days, 15 days and 20 days by Pagano-Schwartz is conditioned by another market microstructure change in India where the normal market timings was extended by 55 minutes to start at 9:00 am instead of 9:55 am on 4th January 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 close-to-close, open-to-open and close-to-open returns. Unlike Pagano-Schwartz, interestingly we find that averages R-square are not significantly different across return intervals for close-to-close returns indicating relatively less synchronicity problem for the 50 most liquid Indian stocks as far as closing prices are concerned. In case of 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 R-square estimates have increased after the introduction of call auctions for opening the market indicating higher synchronicity of prices. This is true for all return intervals and for 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 the NSE Nifty index is that opening prices of all the stocks from the call auctions determine the index open. Earlier, the lag in trading in some of these 50 stocks would have resulted in some non-synchronicity with respect to 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 close-to-close returns to infer any market quality improvement due to higher synchronicity as the increase in open-to-open return R-squares could be due to forced synchronicity induced by the simultaneous call auctions. We find that close-to-close return market model average R-squares also show significant improvement particularly for longer return intervals indicating that the increased synchronicity across stock prices is not merely because of simultaneous price discovery of these stocks and the index.

Following Pagano-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)-

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

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 first-pass regressions, $Dummy_{jE}$ is a dummy variable that is equal to 1 if first-pass beta is estimated using 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.

[13]The results in Table 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 not reported.

For stocks which lag the market, the slope $b_{j,2}$ is expected to be negative. In our sample, these estimates are negative for close-to-close and open-to-open returns but positive for close-to-open returns. In the second pass regressions, these beta estimates are expected to increase if the introduction of opening call reduces the market frictions as argued by Pagano-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 call auctions. The increase is maximum in the case of open-to-open returns and is statistically significant. In case of close-to-close returns, the increase is not statistically significant. Only the close-to-open return betas exhibit decrease. These results indicate that the introduction of call auctions has possibly reduced frictions in the market.

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 (Equation 1 and 2) are reported in Table 4. If market quality improves with the introduction of opening call, it is expected that R-squares for 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 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-Schwartz, for example, found that the t_j's in the context of 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-Schwartz. After the introduction of 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 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 50 to be synchronized, we also explore whether the forced simultaneity of

auctions is not the only reason for improvement in the market quality. We estimate market model equations for all 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 Table 3 and 4. As is evident from the tables, the increase in market quality measured using open-to-open returns, based on prices taken after one-minute of the start of trading in 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 methodology extensively used is assessing market quality in terms of price synchronicity of stocks suggests improved market quality after the introduction of call auctions in India for market opening.

5.3 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 but puzzling 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 remains unaffected by the introduction of call auctions and is merely delayed due to the delayed normal (continuous) market opening. While these effects suggest largely neutral impact of call auctions, the serial return correlation observed between the close-to-call and call-to-continuous returns at opening indicate 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 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 very 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-Schwartz event study methodology, may not be the only important criterion for assessing efficient price discovery of highly liquid stocks.

As far as 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. Figure 5 and 6 show the average trade size at various 5-minutes intraday intervals. It is clear that the average trade size is relatively low in India and the high initial volume is more due to the increased frequency rather than trade size. With 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.

6 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 supposed 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 will be able to attract high volume and result in better price discovery. Call auctions were introduced in the Indian stock market for opening on 18th October 2010. We analyse the impact of 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 auctions attract insignificant volume (b) the intraday volume and volatility dynamics remain unaffected by the call auction except for, the delay induced by 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 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 of 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 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-Schwartz may not necessarily be very relevant for highly traded liquid stocks of our sample unlike that of their sample from Euronext Paris.

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Table 1: Volume Share during Intraday Intervals

The table presents average of the volume percentage (of daily volume) at various intervals during the day before and after the introduction of call auction. Period 'Before' covers 66 trading days from 15 July 2010 to 17 October 2010 and period 'Postcall-1' to 'Postcall-3' covers 52 trading days from 18 October 2010 to 31 December 2010, 62 trading days from 1 January 2011 to 31 March 2011 and 62 trading days from 1 April 2011 to 30 June 2011 respectively. 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; a silent period immediately following the order matching period till 9:15 am, when the normal market opens.

Time		Pre-	Post-introduction		
Before	After	introduction	Period1	Period2	Period3
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 introduction of Pre-open Auction)

The table presents correlation of returns at various intervals for 50 stocks which were constituent of Nifty Index during the first hour of trading before and after the introduction of Pre-open auction (18 October 2010). Panel A reports the return correlation over 66 trading days from 15 July 2010 to 17 October 2010. Panel B, C and D covers 52 trading days from 18 October 2010 to 31 December 2010 ('Postcall-1'), 62 trading days from 1 January 2011 to 31 March 2011 ('Postcall-2') and 62 trading days from 1 April 2011 to 30 June 2011 ('Postcall-3'). PCLOSE indicates the previous trading days 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 indicates significance at 10% level. PCLOSE implies closing price on the previous trading day.

PANEL A: N = 3300; Period: 15 July 2010 - 16 October 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	0.02	-0.004	-0.005	-0.02	**-0.029**				
9:30-9:35	0.01	-0.029	**0.03**	-0.003	**-0.049**	0.007	-0.023			
9:35-9:40	0	0.005	-0.012	0.02	**-0.05**	**-0.049**	-0.004	0.018		
9:40-9:45	-0.019	0.019	-0.007	0.01	0	-0.002	**0.038**	0.026	0.026	
9:45-9:50	-0.02	-0.023	0	0.002	-0.005	**0.031**	0.023	**-0.04**	**-0.043**	**-0.059**

PANEL B: N = 2600; Period: 18 October 2010 - 31 December 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	0.02	-0.01	-0.001	-0.006	-0.021			
9:35-9:40	-0.004	-0.002	0.02	-0.012	**0.122**	**0.072**		
9:40-9:45	-0.015	0.02	-0.007	**-0.066**	**-0.131**	-0.029	**-0.13**	
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: 1 January 2011 - 31 March 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	0.02	-0.021	-0.02	**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: 1 April 2011 - 30 June 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	**-0.12**	0.017						
9:20-9:25	-0.02	**0.035**	0.019					
9:25-9:30	**-0.091**	**-0.04**	**0.068**	-0.001				
9:30-9:35	**-0.078**	**0.05**	**0.072**	0.019	**0.067**			
9:35-9:40	0.005	**-0.035**	-0.009	**-0.07**	**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 the averages of the adjusted R^2 statistics (Panel A) and of the b_1(Panel B) from 500 conventional market model regressions ($R_j = \alpha + b_1 R_m + \epsilon_j$), ran for each of the 50 stocks which were constituents of the Nifty Index using 1-day, 2-days ... 10-days returns. Returns are calculated using non-overlapping close to close prices, open to open prices, close to open prices and open to open prices measured at the end of first trading minute. ***, ** and * indicates significance at 1%, 5% and 10% level 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 introduction of Pre-open Call Auction

This table reports the parameter estimates of market quality estimated from second pass regression. $R2CONSTANT$ and $R2SLOPE$ parameters 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^2 statistic 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 first-pass regressions, $DummyRsq_{jE}$ is a dummy variable for the slope that is equal to 1 if the first-pass adjusted R^2 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^2 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. $R2CONSTANT$ equals r_j and $r_j + _j$ and $R2SLOPE$ equals ($s_j and t_j$) for period before and after introduction of call auction respectively. Returns are calculated using non-overlapping close to close prices, open to open prices, close to open prices and open to open prices measured at the end of 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 first-pass regressions, $Dummy_{jE}$ is a dummy variable that is equal to 1 if first-pass beta is estimated using 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. $BETA-SLOPE$ equals $b_(j,2)$ and $(b_(j,2)+c_(j,2))$ for period before and after introduction of call auction respectively.

$AvgVar1$ and $AvgVar2$ are averages of 1- and 2-day return variance. The first-pass regressions were estimated over a 180 days period before and after the introduction of pre-open call auction. ***, ** and * indicates 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 average 5-minutes return volatility (absolute returns) during the first trading hour before and after the introduction of call (18 October 2010). The different sub-periods are as follows: (a) 'Precall' covers 66 trading days from 15 July 2010 to 17 October 2010; (b) 'Postcall-1' covers 52 trading days from 18 October 2010 to 31 December 2010; (c) 'Postcall-2' covers 62 trading days from 1 January 2011 to 31 March 2011; (d) 'Postcall-3' covers 62 trading days from 1 April 2011 to 30 June 2011 respectively. Volatility at 'Interval No. 0' indicates overnight return volatility. Volatility of the first 5-minutes interval after the introduction of call ('Interval No 4') is computed using the opening price of the continuous market (9:15 open)

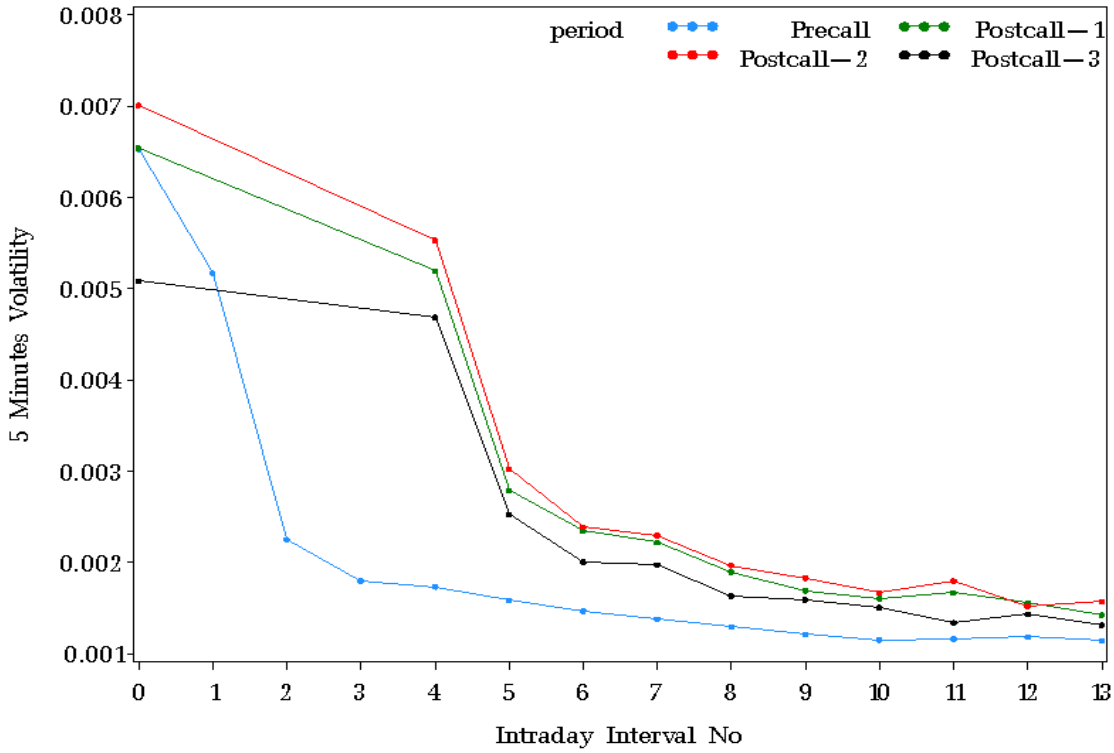

Figure 2: Standardized volume before and after the introduction of call auction (first trading hour)

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

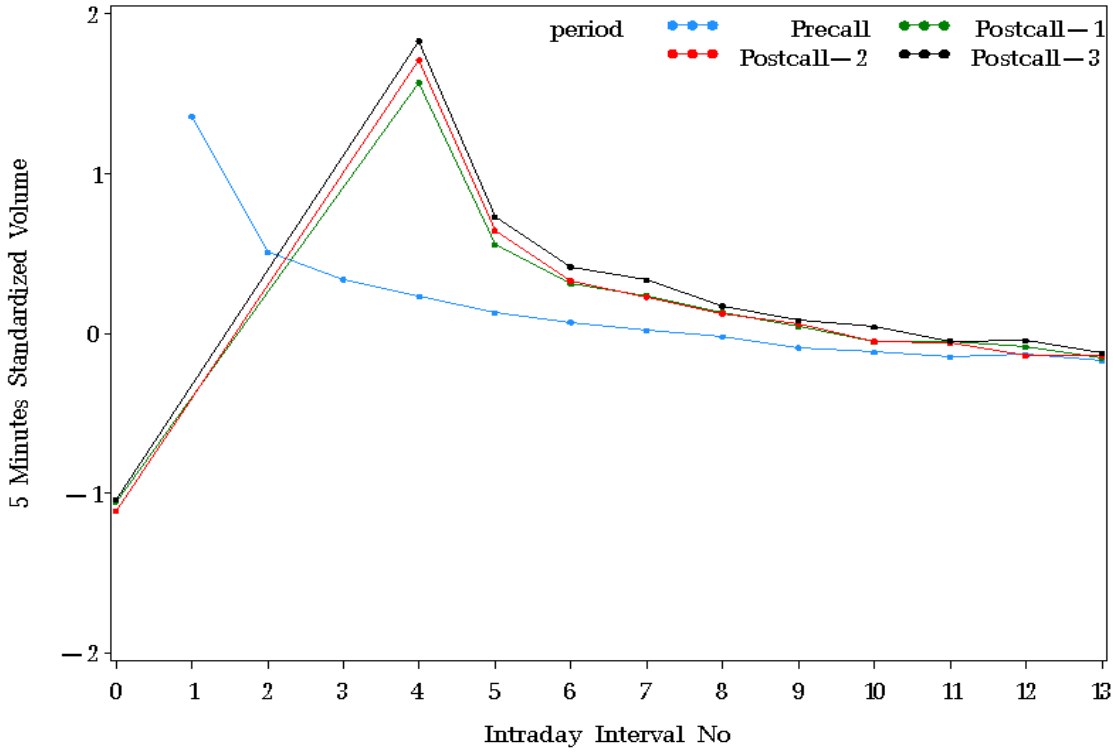

Figure 3: Intraday return volatility before and after the introduction of call auction

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

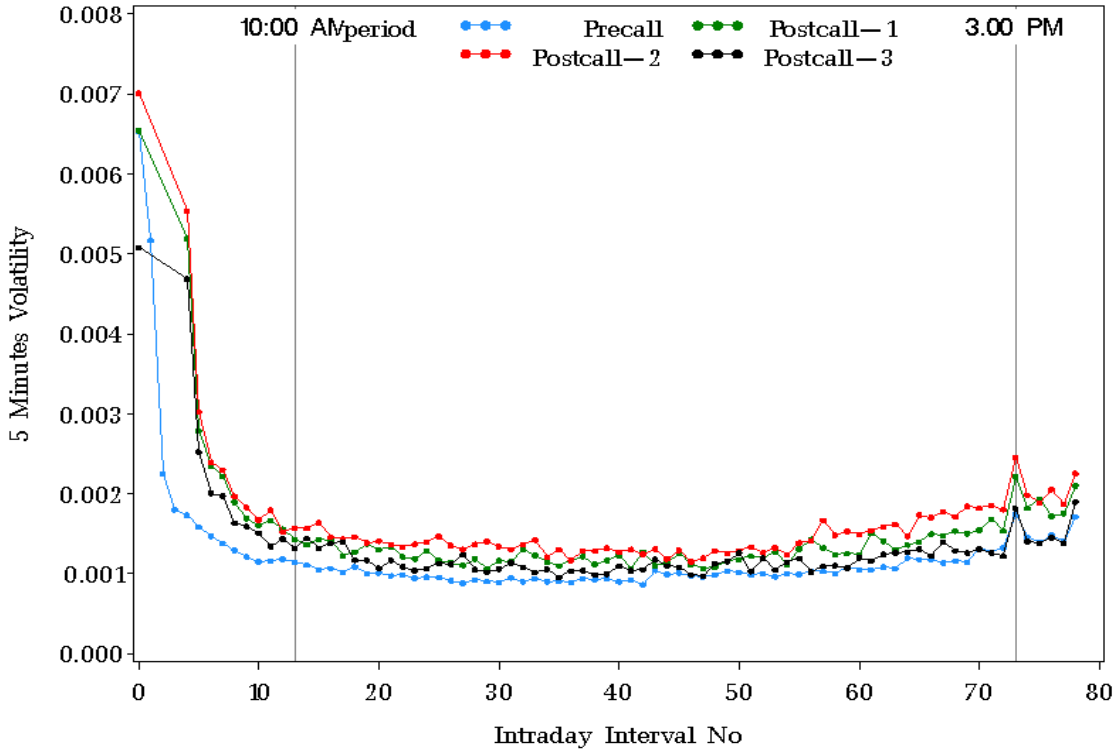

Figure 4: Intraday standardized volume before and after the introduction of call auction

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

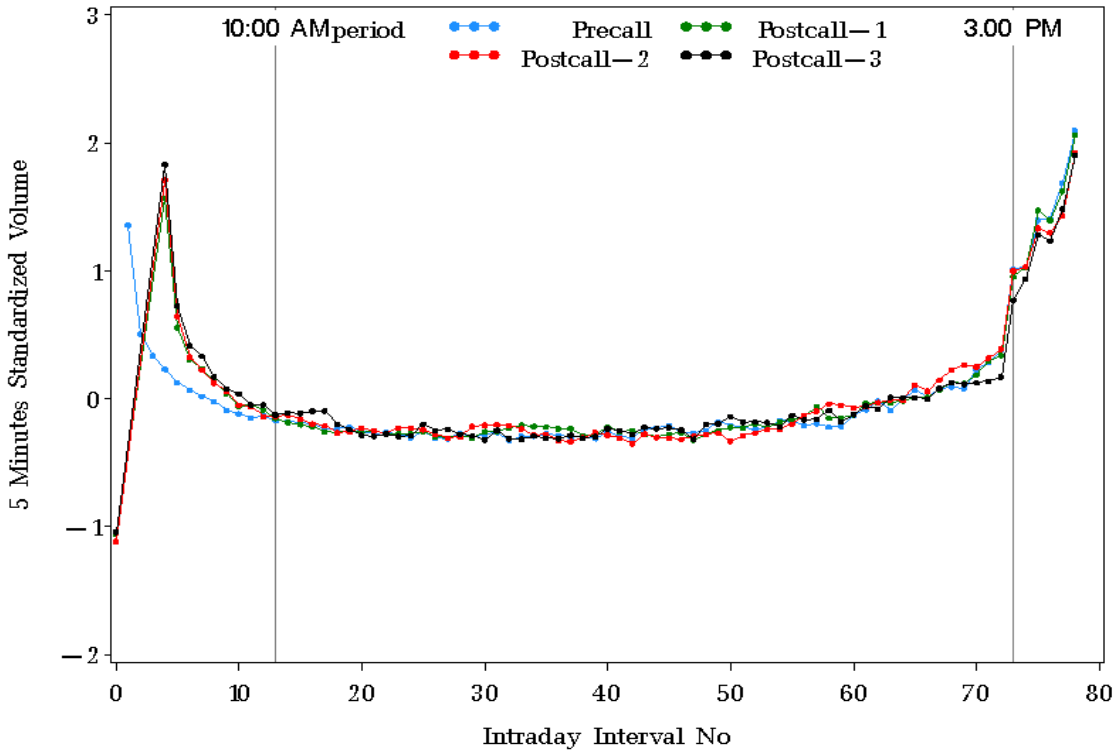

Figure 5: Intraday Average Trade Size (in Rs) before and after introduction of Pre-open Auction

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

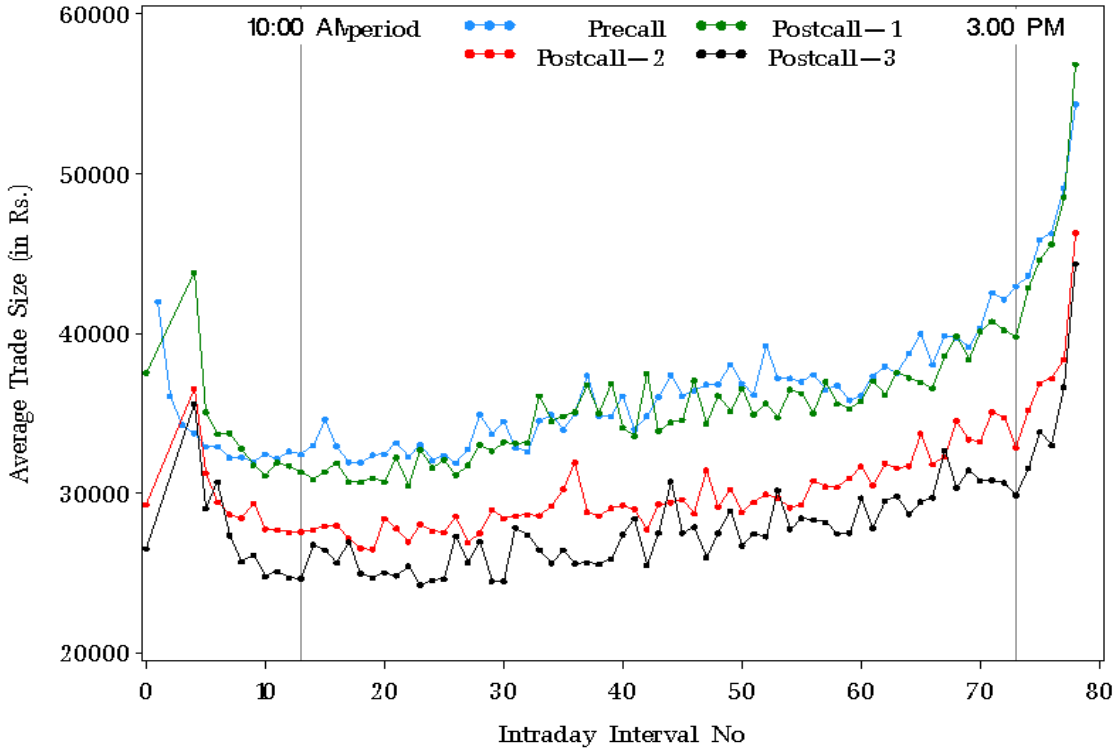

Figure 6: Intraday Average Trade Size (in Rs.) before and after introduction of Pre-open Auction

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