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IS CALL AUCTION EFFICIENT FOR BETTER PRICE DISCOVERY?

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Abstract

The National Stock Exchange of India (NSE) implemented call auction trading mechanism on18 October 2010 in its opening session for better opening price discovery. Excess volatility is observed at the opening due to uncertainty surrounding the fundamental value following the overnight non-trading hours. Therefore, the objective of call auction during a pre-open session is to minimize the market price fluctuations which subsequently leading to better price-discovery. GARCH (1, 1) model, after accounting for the impact of overnight information, noise and previous day's closing market, found that the unconditional volatility at the opening, in 16 out 26 stocks, is reduced following the introduction of pre-open call auction session. In absence of spread in call auction market Lee (2008), the lower volatility could be attributed to higher depth in terms of more outstanding orders at the best bid and ask price, given the strong endogeneity amongst spread, depth and volatility. Consequently it is the depth in call market which could lower the price volatility for better price discovery.

Keywords: GARCH (1 1), market depth, pre-open call auction, pricing efficiency, price discovery, volatility

1. INTRODUCTION

Following global trends in designing the security market, the National Stock Exchange of India (NSE) introduced call auction trading mechanism to open day's trading, while relying on the order-driven continuous trading system for rest of the day's trading. The objective of introducing this new trading protocol is to enhance the process of price discovery by minimizing fluctuations in the market price of stocks that push prices away from their fundamental values. A call auction differs from continuous trading. In a continuous order driven market, a trade is made whenever a bid and offer match or cross each other and public limit orders set quotes and trade is made whenever a public market order arrives. The market order is executed at the best price set by a previously placed limit order. In a call auction, buy and sell orders are accumulated for each stock for simultaneous execution in a multilateral, batched trade at a single price at a predetermined time. By consolidating liquidity at specific times, a call auction is intended to reduce execution costs for individual participants and to sharpen the accuracy of price discovery for the broad market. Further, at the resulting price of the call auction market, the total traded quantity is maximized and the gap between demand and supply is ideally zero. Also the price so determined is better than the best bid (i.e. the highest buying price) and best ask price (i.e. lowest selling price).

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Economides and Schwartz's (1995) theoretical model maintains that, as trading is followed by price discovery in a call auction, it provides for the latter an efficient mechanism to aggregate varied information. However, Schwartz (2000) maintains that, in a continuous market, trades may occur at false prices due to simultaneous incidences of price discovery and trading. Therefore, the curtailment of unwarranted volatility is expected in call auctions if indeed price discovery process is expedited. Studying a call auction in a closing market, Hillion and Suominen (2004) found that the potential for closing price manipulation by market participants was successfully decreased, consequently resulting in lower inter-day volatility.

The price discovery process ensures incorporation of information relating to the stocks into their prices through the trading mechanism of the market. However, due to the 18 hours of non-trading period prior to the opening, price discovery is commonly noisy and less efficient (Amihud and Mendelson, 1991). As a result of which, price can deviate from its fundamental value, creating a difference between the price and value of the stock due to imperfect price adjustments and noise, Black (1986). However, the changes to the price of the stock due to the information relating to its fundamental factors is termed as fundamental volatility, which is not mean reverting as it reflects the value of the stock. On the other hand price changes in the stock due to factors other than its fundamentals, such as bid-ask spread, liquidity needs and traders' reaction to information is called transitory volatility which will revert to its mean level being temporary and noisy in nature. The call auction method of trading is expected to reduce volatility, caused due to these transitory factors, which is mean reverting. Comparing the informational efficiency of the call auction market and continuous market, Theissen (2000) found that opening prices in the call market are closer to the true value of the asset due to under reaction to new information and lower bid-ask spread than the opening price in the continuous market. It is consistent with the practice of many exchanges to start trading with call auction.

Furthermore, price discovery occurs at the pre-opening call as participants gain knowledge on the value of the stock from the indicative prices. Analysing the price discovery process during the pre-opening of the Paris Bourse, which opens through an automated call, Biais *et al.* (1999) found that the first part of the market is characterised by noisy indicative prices. This gives way to a second part of the market wherein indicative prices signal information, which shows that learning on the value of the stock has taken place. The institutional set up and trading rules related to the call auction market at the opening allowing dissemination of indicative prices and volumes during the order placement period motivates to study the impact of the call auction on price volatility and consequently the process of price discovery. The need to study the call auction of the NSE is further attributed to the findings of Thomas (2010), who argues that a continuous market upon opening takes more than half an hour for opening volatility to settle down. So opening stock price is expected to deviate from its true value.

In addition, the importance of studying the efficiency of call market is due to the fact that, across markets and geographies, it differs in terms of its design and trading mechanism. Further, NSE reintroduced the call auction method after a gap of 15 years following its suspension on 6 June 1999 which was for a period of 5 minutes. Following this suspension, Camilleri and Green (2004) found no evidence of increased volatility but rather volatility decreased. In its new form, the call auction market spans for a period of 15 minutes. The remainder of this paper is organised as follows: Section 2 outlines the relevant literature and motivation for the study. Section 3 presents the institutional set-up of a call auction market. Section 4 documents the study's data and methodology. Section 5 discusses how a call auction market impacts opening price volatility. Section 6 summarises the findings and concludes of the study.

2. LITERATURE REVIEW

The opening of a market has enormous significance for traders and regulators. An opening trading assimilates information gathered overnight and facilitates important information aggregation and price discovery functions. Much of the literature on opening mechanisms has focussed exclusively

on issues of the price discovery. Biais *et al.* (1999), in their study on the Paris Bourse, support the learning hypothesis over the noise hypothesis during a pre-opening session. They found strong evidence of active learning on the value of the stock from the indicative prices during the pre-opening session that led to better price discovery. Economides and Schwartz (1995) propose a call auction upon opening as the ideal solution to the problem of assimilating diverse information from traders so as to achieve informational efficiency of prices and thereby minimizing adverse selection problems, such as when certain traders have superior information over others. Domowitz and Madhavan (2001) go so far as to state that, the benefits of an opening auction are, in theory, most valuable for thinly traded assets where public information is poor and hence adverse selection is a serious problem.

The results of Cao *et al.* (2000) reveal that the fast price adjustment of Nasdaq stocks can be attributed to the informational role of the pre-opening session. Nasdaq's pre-opening operates as a significant coordination vehicle to absorb price shock and facilitate price discovery. This notion is supported by Greene and Watts (1996), who, examining the difference between the New York Stock Exchange's(NYSE) and Nasdaq's reactions to overnight earning announcements, found that the Nasdaq's opening mechanism impounded more non-trading-hours information into prices. Specialists facilitate price discovery using a stabilized auction mechanism upon opening that utilises public orders Madhavan and Panchapagesan (2000). Furthermore, Barclay *et al.* (2008) report that, during times of extreme market stress (e.g., quadruple witching days), the NYSE's opening call performs better than the Nasdaq's opening call, while the new opening procedures implemented by the Nasdaq in 2004 improved price efficiency.

In a comparison prospective, Ellul *et al.* (2005) observed that the call market method's price discovery is more efficient than the dealer market of the London Stock Exchange (LSE), yet traders tend to prefer trading on the dealer market even in the presence of uncertainty. Chang *et al.* (1999) compared the price discovery process of an actual call market to simulated continuous auction trading on the Taiwan Stock Exchange and found that volatility under the call market method is, on average, one-half of that under the continuous auction method. In addition, they found that price discovery is more efficient in a call market than in a continuous auction market for Taiwan-listed stocks when the price impacts of large order imbalances were similar between the two trading methods.

The study by Theissen (2000) indicates that call and continuous auction markets are much more efficient than dealer markets in terms of price efficiency, whereas a call market tends to under react to new information. Call auctions upon closing also improve market quality, resulting in lower transaction costs for traders and better price discovery, Pagano and Schwartz (2003); Smith (2006). The theoretical work of Hillion and Souminen (2004) further supports the successful reduction of price manipulation upon market closing by call auction trading. However, conflicting results have been reported by Muscarella and Piwowar (2001) and Pagano and Schwartz (2003). Using a sample of stocks listed on the Paris Bourse, Muscarella and Piwowar (2001) report that price discovery in the call market method is inferior to the continuous auction method. Furthermore, Caillaud and Mezzetti (2004) point out that there may be a limit to information aggregation in call auctions when participants in such markets conceal information from other traders by not trading with the hope of greater profit in a successive market set-up. Theoretically investigating the performance of different market structures, Madhavan (1992) evidenced the efficient information aggregation of call auctions, especially when higher information asymmetry in the market made dealers reluctant to trade in the opposite side of the trade.

Given the fact that most studies of western markets have focused on different environments from diverse perspectives, this study focuses exclusively on the call auction method in a single trading environment to identify the volatility impact of the call auction trading on price volatility and adopted by the NSE in an emerging market context. The main objective of this paper is to assess the impact of the introduction of call auctions in the pre-open session of the NSE on price volatility and its effect on price discovery. Decreased volatility subsequent to the introduction of call auction will

improve the process of price discovery (Comerton, 1999). Conversely, no substantial changes to volatility or even increased volatility will result in the inefficient discovery of prices in the process following the introduction of a call auction (Angel and Wu, 2001; Pouget, 2004).

An examination of the ability of the NSE's pre-opening session to facilitate price discovery and assimilation of overnight information into opening prices will provide insight into the functioning of pre-opening sessions. Moreover, analysing the overnight return generation process, the study tires to find out the contribution of trading mechanism to the discovery of opening prices .A price discovery process should result in the efficient pricing of assets in the market. Conversely, inefficient price discovery creates volatility, as asset prices deviate from their values, which is unwarranted to the objective of market structure. Moreover, in an economy, financial market through innovative trading mechanism contributes to the allocation of resources at efficient price. Our objective is to find out the impact of the call auction trading mechanism on the opening price volatility and price discovery of 50 stocks, the constituents of Nifty, the bellwether index of NSE.

3. MARKET STRUCTURE

Initially NSE was set up with a continuous order-driven electronic trading system. In a continuous market, a trade occurs whenever a buy order and sell order match each other at a particular price. Thus, opening price is the price at which first trade is executed. Conversely, in a call auction market, orders are gathered for execution at pre-determined times when the market is called for. Then all buy and sell orders are aggregated into a downward sloping demand function and upward sloping supply function respectively, resulting in determination of market opening price and quantity traded at that price. The orders that trade and the price and quantity at which they trade are set by multilateral matching rather than by the sequence of bilateral matching used to determine trades in a continuous market. Each time an order is entered, modified, or cancelled during the pre-opening period, the resultant indicative market- clearing price from the current order book is announced electronically along with the associated indicative trading volume along with the five best unmatched buy and sell orders.

Spanning 15 minutes from 9:00am to 9:15am, the call auction period is comprised of the following three sub-periods.

- Order entry period (9:00am–9:08am): During this period, order addition/modification and cancellation can be done. In order to prevent manipulation, random stoppage of order cancellation happens between the seventh and eighth minute. The information on indicative price, matchable quantity at the indicative price, and indicative index are disseminated to the investors by the exchange. A uniform price band of 20% is applicable to all permissible securities and only market orders and limit orders are permitted during this period. Both order types will be considered for the computation of opening prices. No iceberg orders are allowed (i.e., orders shall be disclosed in full quantity). Furthermore, during this period, indicative opening price(s) will be calculated for each stock at regular intervals and disseminated. Indicative cumulative buy and sell quantities for stocks will also be displayed, and subsequently indicative index will be calculated based on the indicative prices.
- Order-matching and confirmation period (9:08am–9:12am): No order addition/modification or cancellation can be done during this period. Order matching, trade confirmation, and open price determination are performed by the exchange. It should be noted that limit orders get priority over market orders at the time of execution of trade on time price priority. The orders are executed in the following sequence during the matching period.
    - Eligible limit orders will be matched with eligible limit orders.
    - Residual eligible limit orders will be matched with market orders.
    - Residual market orders will be matched with market orders.

All orders entered in the system will match at the same price (i.e., the market opening price).

- Buffer period (9.12 am – 9.15 am): This period facilitates the transition between pre-open and continuous trading sessions.

The following process is followed in computing the opening price of the stock during the pre-open call auction session:

Opening price = Price at which maximum quantity is traded
If multiple prices exists then

⇩

Opening price = Price at which there is minimum order imbalance
If multiple prices exists then

⇩

Opening price = Price closest to the previous closing price

A continuous trading session will commence immediately after call auction session.

The call auction serves to create a fairer market, especially for small and non-professional investors, as all trades are executed at the same price. Since, all the trades happened at the same time, it eliminates the possibility of front-running customer orders in the same security.

Although the price seems noisy due to the inbuilt feature of modification and cancellation of orders at the beginning and actual trading followed by price discovery in the call auction trading mechanism, in their study on Paris Bourse, Biais *et al.* (1999) found that price discovery becomes stronger as call market approaches to closing, supporting the learning hypothesis against the noise hypothesis. The call auction mechanism at the preopen session of NSE provides the learning about the stock through the indicative price and indicative volume disseminated during order placement period. Therefore, better price discovery is expected in the call auction market.

4. DATA AND METHODOLOGY

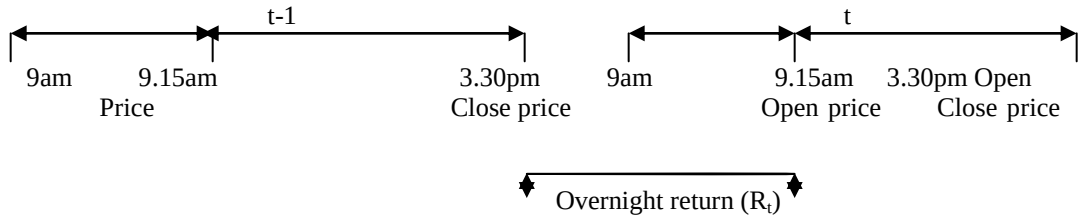

Figure 1: Timeline of trading in NSE

The sample period under investigation included 442 observations of pre- and post-call auction periods from 1 January 2009to 16 July 2012. Time series data of the previous day's(t-1) closing price and the today's (t) opening and closing prices of 48 constituent stocks of Nifty, the bellwether stock index of NSE consisting of 50 stocks, were collected from www.nseindia.com, the official website of the National Stock Exchange of India. Two stocks Sterlite and Sesagoa were omitted from the study due to their merger. For the purposes of the study, we have calculated the following two return series through equation (1) and (2).Returns are calculated as a continuously compounding process as follows:

Overnight return (R_t) = Log (Opening price)$_t$ - Log (Closing price)$_{t-1}$ ……..…… (1)
Intraday return (r_t) = Log (Closing price)$_t$ - Log (Opening price)$_t$ ……..…… (2)

4.1. Distributional properties of stock returns

The descriptive statistics used to assess the distributional properties of overnight returns of 48 stocks are reported in Table1. It is evident that, there is no significant difference between the pre- and post-call auction period variance of overnight returns for 10 stocks. However, changes in the skewness and kurtosis of the overnight return data among the 48stocks are evident. Furthermore, at 1% and 5%

level of significance, the null hypothesis of equal variance is rejected for 38 stocks by Levene's statistics and their respective *p* values reported in the last two columns, which show significant differences of variance between the pre- and post-call auction periods. In what follows, the cause of the change in variance in the overnight returns of the sample stocks will be examined.

Table 1: Descriptive statistics of pre- and post-call auction overnight returns and Levene's statistics showing the significance of the change in variance between the pre and post call auction period

Stock	Pre Call Auction				Post Call Auction				Levene Stat.	Probability
	Mean	Std. Dev.	Skewness	Kurtosis	Mean	Std. Dev.	Skewness	Kurtosis		
ACC	0.001	0.010	1.267	18.774	-0.001	0.008	-1.314	8.924	5.238	0.022**
AMBUJACEM	0.002	0.016	3.937	42.223	-0.001	0.009	-1.108	7.779	12.896	0.000***
AXISBANK	0.002	0.016	-0.395	17.100	0.001	0.011	-0.367	5.957	8.417	0.004***
BAJAJ-AUTO	0.002	0.015	-2.046	22.561	0.002	0.008	-0.260	7.781	34.058	0.000***
BHARTIARTL	0.002	0.017	2.301	38.882	0.001	0.009	-0.731	5.705	9.067	0.003***
BHEL	0.002	0.012	5.645	70.969	0.002	0.009	-0.509	9.105	0.248	0.619
BPCL	0.003	0.014	3.122	34.837	0.001	0.009	0.246	5.776	5.987	0.015***
CAIRN	0.003	0.013	1.679	18.654	0.002	0.009	-0.302	4.645	7.811	0.005***
CIPLA	0.002	0.010	3.563	37.020	0.002	0.007	-0.445	6.079	0.170	0.68
DLF	0.001	0.022	-1.465	38.745	0.000	0.011	-0.578	4.799	8.620	0.003***
DRREDDY	0.002	0.010	-0.388	8.131	0.001	0.008	-2.298	20.981	17.702	0.000***
GAIL	0.002	0.014	-4.560	63.267	0.002	0.008	0.170	5.831	11.808	0.001***
HCLTECH	0.000	0.020	0.271	13.279	0.000	0.011	-0.470	8.997	34.746	0.000***
HDFC	0.001	0.013	-1.469	25.785	0.001	0.009	-0.013	7.164	7.571	0.006***
HDFCBANK	0.000	0.014	-4.847	73.070	0.002	0.009	1.784	14.570	8.939	0.003***
HEROMOTOCO	0.001	0.010	1.803	18.945	0.000	0.009	0.276	8.002	0.303	0.582
HINDALCO	0.003	0.015	-0.253	7.407	0.001	0.012	0.375	5.563	6.930	0.009***
HINDUNILVR	0.002	0.010	1.947	32.730	0.001	0.006	0.494	7.282	12.729	0.000***
ICICIBANK	0.001	0.020	-1.440	37.297	0.001	0.010	0.399	6.867	14.797	0.000***
IDFC	0.002	0.017	-3.042	34.981	0.002	0.010	-0.090	4.384	2.588	0.108
INFY	0.000	0.010	-0.498	13.679	-0.001	0.012	-2.853	22.855	2.057	0.152
ITC	0.001	0.010	-2.335	25.519	0.001	0.006	0.301	7.030	19.334	0.000***
JINDALSTEL	0.002	0.015	0.406	15.790	0.001	0.011	0.607	7.177	3.561	0.06
JPASSOCIATE	0.003	0.021	-0.837	32.016	0.002	0.012	-0.727	6.216	9.175	0.003***
KOTAKBANK	0.004	0.017	1.554	22.563	0.000	0.008	-0.158	6.026	28.948	0.000***
LT	0.003	0.013	3.294	38.103	0.001	0.008	-0.374	5.483	11.121	0.001***
M&M	0.002	0.016	2.419	43.679	0.001	0.009	-0.480	6.199	15.424	0.000***
MARUTI	0.001	0.014	-0.710	20.760	0.000	0.009	-0.456	6.570	9.614	0.002***
NTPC	0.002	0.009	-2.385	26.274	0.001	0.007	0.569	6.338	3.087	0.079
ONGC	0.000	0.015	-0.585	10.614	0.002	0.009	1.509	10.987	18.978	0.000***
PNB	-0.004	0.020	-1.365	18.669	0.001	0.008	-0.707	5.561	91.636	0.000***
POWERGRID	0.005	0.015	-0.285	23.298	-0.001	0.007	-1.291	10.844	38.707	0.000***
RANBAXY	0.003	0.013	-0.158	22.767	0.002	0.010	-0.127	23.856	11.408	0.001***
RCOM	0.004	0.017	2.635	29.201	0.002	0.012	-0.596	7.194	3.968	0.047**
RELCAP	0.005	0.017	1.875	23.636	0.001	0.011	0.088	6.078	16.210	0.000***
RELIANCE	0.002	0.012	1.505	15.917	0.001	0.008	-0.346	7.714	8.802	0.003***
RELINFRA	0.003	0.014	-0.262	8.139	0.002	0.011	-0.163	6.630	6.605	0.010***
RPOWER	0.004	0.015	2.427	20.950	0.001	0.010	-0.358	5.894	6.104	0.014***
SAIL	0.004	0.015	2.341	22.812	0.002	0.009	-0.018	4.688	14.209	0.000***
SBIN	0.003	0.013	3.555	29.560	0.001	0.008	-0.001	5.146	7.107	0.008***
SIEMENS	0.000	0.010	5.946	83.917	0.002	0.018	3.205	34.229	30.799	0.000***
SUNPHARMA	0.002	0.013	0.723	47.226	0.001	0.009	-0.431	5.775	0.001	0.971
SUZLON	0.004	0.021	-1.689	19.445	0.003	0.012	-0.024	4.968	18.019	0.000***
TATAMOTORS	0.002	0.019	-1.121	35.527	0.001	0.012	-0.230	7.462	4.568	0.033**
TATAPOWER	0.001	0.011	-0.935	10.810	0.001	0.010	-0.371	9.788	0.008	0.931
TATASTEEL	0.002	0.020	-1.598	34.166	0.001	0.009	-0.193	6.511	31.134	0.000***
TCS	0.001	0.016	2.108	41.322	0.001	0.010	-0.162	9.222	7.618	0.006***
WIPRO	0.002	0.012	0.431	16.157	-0.002	0.009	-0.968	6.972	0.594	0.441

Note: ** and *** indicate 5% and 1% level of significance, respectively

The existing literature shows that excess kurtosis and skewness are evidence of possible heteroskedasticity, Akgiray *et al.* (1991); Hall *et al.* (1989) and Harvey & Siddique, (1999). Furthermore, evidence suggests price changes in a stock market exhibit heteroskedasticity Mandelbrot (1963), Fama (1965) and Bollerslev *et al.* (1992). The ARCH LM test proposed by Engle (1982) supports the descriptive statics that the return series are heteroskedastic at 5% level of

significance for lag 1, 5 and 12 in 26 out of 48 stocks. These findings help in choosing the appropriate GARCH (1, 1) model in the next section for further analysis of only these eligible 26 stocks for further analysis. Further, the overnight and intraday time series return data through equation (1) and (2) for all individual stocks are tested for stationarity with the null hypothesis of unit root in the data under Augmented Dickey-Fuller test. The null hypothesis is rejected at 5% level of significance and the results are available on request.

4.2. Model-building

An opening price is the outcome of the joint interaction of previous day's closing price, overnight information, noise in the form of liquidity needs and market friction, and finally, the trading mechanism itself at the opening of the market. In the mean equation (3), the coefficient *b* reflects the impact of the previous day's closing. If the coefficient *b* is significantly negative, the usual price deviation at the previous day's closing reverts to the mean at the opening, thereby indicating the efficiency of a call market upon opening wherein traders find the market suitable for trade. The second important factor that affects opening prices is overnight information, which may be related to fundamental factors of the stock causing the permanent component of the price change. The other part of the price change which is temporary in nature is caused by transitory factors such as traders' desires for liquidity, misinterpretation of information, and market friction. Price changes due to these transitory factors are not permanent, and consequently revert to the mean level in the next trades. The call auction is expected to reduce the transitory volatility in the opening price of the stocks.

Our particular interest in the present study lies in the third important factor that contributes to opening prices i.e. the call auction trading mechanism upon opening and its price discovery process. It is anticipated that price changes due to transitory factors will revert to its mean and that the assimilation of information relating to fundamental factors into stock prices will result in lower volatility. Taking smooth information assimilation happens following an overnight non-trading period, this study aimed to discern the call auction method's volatility impact on the opening of a market. In equation (3), overnight returns R_t are modelled as a function of the previous day's intraday return $\boldsymbol{r_{t-1}}$, with the error term ε_t representing the overnight innovation, and $\boldsymbol{\psi_{t-1}}$ representing the overnight information set.

$$R_t = a + br_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,

$\varepsilon_t/\psi_{t-1} = z_t\sqrt{ht}$

Equation (3) states that, in the absence of overnight news, the opening returns of the day will be equal to the intraday returns of the previous day (i.e., *b=1*). In other words, today's opening price will be equal to the previous day's closing price, which is one of the criteria for determining opening prices in which orders are matched at the previous day's closing price subject to the fact that only market orders are collected on both buy and sell sides during the pre-open call auction period. Conversely, if there is news related to the previous day's unusual price variation upon closing, *b* will be less than 1. If the coefficient *b* is negatively significant, the return will be mean reverting upon opening, signifying the efficiency of the call market. The opening price so determined should be such that all news is assimilated into the price, making it less volatile to the point that a transaction price should approach the value of a stock. This study attempts to identify what happens to the average unconditional volatility of stocks open for trade through a call auction market at opening session of NSE.

By and large, the summary of various stock return statistics presented in table 1 is best described as presenting an unconditional leptokurtic distribution and volatility clustering with time-varying volatility which can be best estimated in a conditional framework by GARCH (1, 1) model, as it is the most parsimonious model (Bollerslev *et al.*, 1992).

The GARCH (1, 1) model is described through equation (4) and (5) as follows:

$$h_t = \omega + \alpha\varepsilon^2_{t-1} + \beta h_{t-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$h_t = \omega + \alpha\varepsilon^2_{t-1} + \beta h_{t-1} + \gamma D_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

In equation (5), D is the dummy variable, which was labelled with a 1 for post-call observations and a 0 for pre-call observations. This is a shifting dummy that impacts average value in the conditional volatility equation (5) i.e. ω. The coefficient γ represents the incremental average impact of a call auction on conditional volatility. Thus, the post average value of ω= Pre $\omega+\gamma$. The γ should be significantly negative in order for a call auction market to have a lower conditional volatility i.e. h_t and positive effect on price discovery upon the market opening. Furthermore, $(\alpha+\beta)$ represents the persistence of volatility in terms of news unabsorbed by the market impacting volatility in the future. Thus, 1- $(\alpha+\beta)$ indicates the extent of news that has been assimilated into prices. Finally, to study the impact of the call auction trading mechanism on volatility, we calculated unconditional volatility during both the pre- and post-auction periods. If a call auction market is able to ensure better discovery of prices through assimilation of information and mean reversion of temporary volatility, the post-unconditional volatility should be less than the pre-unconditional volatility calculated through equation (6) and (7) respectively. In fact, the persistence of volatility due to transitory factors represented by $(\alpha+\beta)$ reverts to the level of conditional volatility.

Post-unconditional volatility = Pre $\omega+\gamma/1-(\alpha+\beta)$ ……..…… (6)
Pre-unconditional volatility = $\omega/1-(\alpha+\beta)$ ……..…… (7)

5. EMPIRICAL RESULT

Table 2: Estimates of the GARCH (1, 1) mean equation (3)

Stock	*a*	p value	*b*	p value
JPASSOC	0.001	0.000	-0.007	0.502
RANBAXY	0.002	0.000	0.061	0.000***
RCOM	0.002	0.000	-0.021	0.0001***
RELCAP	0.002	0.000	0.021	0.027**
RELINFRA	0.002	0.000	-0.016	0.108
RPOWER	0.002	0.000	-0.019	0.0436**
SAIL	0.003	0.000	0.025	0.080
SIEMENS	0.001	0.289	-0.052	0.0025***
SUZLON	0.003	0.000	0.036	0.0008***
ACC	0.000	0.368	-0.007	0.566
AMBUJACEM	0.000	0.930	0.008	0.530
AXISBANK	0.001	0.000	0.021	0.157
BAJAJ-AUTO	0.002	0.000	0.027	0.099
BHARTIARTL	0.001	0.050	-0.001	0.939
BHEL	0.002	0.000	0.035	0.0061***
BPCL	0.002	0.000	0.006	0.745
CIPLA	0.002	0.000	0.017	0.230
CAIRN	0.002	0.000	0.032	0.0167***
DLF	0.001	0.035	-0.018	0.160
DRREDDY	0.001	0.000	-0.011	0.453
GAIL	0.002	0.000	-0.031	0.0437**
HCLTECH	0.000	0.727	0.024	0.0007***
HDFC	0.001	0.008	-0.014	0.420
HDFCBANK	0.001	0.001	-0.013	0.555
HEROMOTOCO	0.001	0.034	-0.009	0.450
HINDALCO	0.001	0.001	0.026	0.069
HINDUNILVR	0.001	0.004	-0.059	0.0002***
ICICIBANK	0.001	0.019	0.013	0.452
IDFC	0.002	0.000	0.033	0.0219**
INFY	0.000	0.696	-0.013	0.407
ITC	0.001	0.001	-0.009	0.452

JINDALSTEL	0.001	0.002	0.016	0.317
KOTAKBANK	0.001	0.013	0.011	0.407
LT	0.002	0.000	-0.003	0.765
M&M	0.001	0.002	-0.002	0.925
MARUTI	0.000	0.736	0.002	0.885
NTPC	0.001	0.000	-0.031	0.0361**
ONGC	0.002	0.000	-0.003	0.852
PNB	0.001	0.145	0.001	0.963
POWERGRID	0.000	0.851	-0.052	0.0017***
RELIANCE	0.002	0.000	0.049	0.000***
SBIN	0.001	0.000	-0.068	0.093
SUNPHARMA	0.001	0.000	-0.024	0.148
TATAMOTORS	0.001	0.004	0.017	0.281
TATAPOWER	0.000	0.316	0.001	0.973
TATASTEEL	0.001	0.003	0.027	0.093
TCS	0.001	0.002	-0.001	0.937
WIPRO	0.001	0.038	-0.034	0.0268**

Note: ** and *** represent significance at 5% and 1% level of significance

Brooks and Moulton (2004) found that unusual price changes in prior-day's closings are reversed in the opening price. If a continuous market is more efficient in terms information assimilation and price discovery than a call market, price reversals should be absent upon opening. Out of 26 stocks in table 3, the coefficient *b* was found to be negatively significant in case of eight stocks (in bold letter) only implying price reversal at the opening. However, the absence of reversal was evidenced in 24 stocks. This suggested the efficiency of a continuous auction market, as well as the unwillingness of traders to trade in acall auction upon opening due to the inefficient handling of information in this market. Furthermore, the positive and significant value of the coefficient *b* indicated trading momentum continues from the previous day's closing to today's opening (Brooks and Moulton, 2004).

In further investigating the efficiency of call markets, we estimated the variance equation (5) of the GARCH (1, 1) model while examining the coefficient of the dummy variable γ for a negative significance.

Table 3: GARCH (1, 1) estimation of equation (5)

Stock	Ω	Prob.	*A*	Prob.	β	Prob.	α+ β	γ	Prob.
ACC Ltd.	0.007	0.000	0.271	0.000	0.596	0.000	0.867	-0.008	0.0044***
AXISBANK	0.002	0.000	0.187	0.000	0.630	0.000	0.817	-0.001	0.000***
BHEL	0.007	0.007	0.093	0.000	0.901	0.000	0.994	0.006	0.0001***
CIPLA	0.003	0.000	0.163	0.000	0.586	0.000	0.749	-0.001	0.000***
DLF	0.008	0.008	0.025	0.000	0.970	0.000	0.995	0.001	0.080
DRREDDY	0.001	0.000	0.282	0.000	-0.023	0.772	0.259	-0.007	0.000***
HDFC	0.006	0.000	0.046	0.000	0.774	0.000	0.820	-0.001	0.000***
HEROMOTOCO	0.005	0.008	0.081	0.000	0.912	0.000	0.993	0.007	0.140
HINDALCO	0.009	0.000	0.061	0.000	0.919	0.000	0.980	-0.006	0.0008***
HINDUNILVR	0.001	0.000	0.179	0.000	0.537	0.000	0.715	-0.005	0.000***
INFY	-0.003	0.000	-0.004	0.000	1.001	0.000	0.997	0.002	0.000***
JPASSOCIATE	0.001	0.031	0.370	0.000	0.741	0.000	1.111	-0.005	0.435
KOTAKBANK	0.004	0.000	0.164	0.000	0.765	0.000	0.929	-0.009	0.000***
LT	0.009	0.000	0.321	0.000	0.575	0.000	0.895	-0.005	0.0002***
ONGC	0.009	0.000	0.074	0.000	0.903	0.000	0.977	-0.008	0.0007***
PNB	0.005	0.000	0.099	0.000	0.860	0.000	0.958	-0.007	0.000***
POWERGRID	0.008	0.000	0.029	0.000	0.955	0.000	0.984	-0.007	0.0046***
RELCAP	0.004	0.000	0.267	0.000	0.723	0.000	0.990	-0.006	0.0124***
RELINFRA	0.004	0.000	0.031	0.000	0.950	0.000	0.980	0.008	0.093

RPOWER	0.003	0.000	0.615	0.000	0.243	0.000	0.859	-0.019	0.0044***
SAIL	0.006	0.000	0.103	0.000	0.855	0.000	0.958	-0.009	0.000***
SBIN	0.007	0.000	0.233	0.000	0.803	0.000	1.035	-0.006	0.460
SIEMENS	0.001	0.000	0.277	0.000	0.438	0.000	0.715	-0.009	0.000***
SUNPHARMA	0.002	0.000	0.116	0.000	0.820	0.000	0.936	0.006	0.0388**
TATAMOTORS	0.008	0.004	0.061	0.000	0.937	0.000	0.998	0.004	0.065
TATAPOWER	0.009	0.104	0.048	0.000	0.947	0.000	0.995	0.001	0.0035***

Note: ** and *** represent significance at 5% and 1% level of significance, respectively

It is evident from Table 3 that the coefficient γ is negatively significant in 16 stocks (in bold letter), which suggests that call auction markets contribute to the reduction of opening price volatility. This study focused on unconditional volatility to investigate the impact of the call auction trading mechanism. Unconditional volatility refers to the long-term average volatility to which temporary variations in price changes return back. If unconditional volatility increases following a call auction, this is due to call auction the trading method, as the transitory factors of volatility are reflected in the persistent coefficient $\alpha+\beta$. The greater the value of $\alpha+\beta$, the greater the persistence of volatility contributing to a day's opening conditional volatility. Conversely, the lesser the persistence of volatility, the more is information assimilation, leading to less conditional opening volatility. Volatility caused by noise due to transitory factors will move a price away from its fundamental value and then revert to the mean (i.e. unconditional volatility) in the next trade on the stock, or, the next session of the market, is reflected in the persistence of volatility. As information related to fundamental factors gets assimilated into the stock prices, it leads to a lower value of $\alpha+\beta$, this causes no change in volatility, as price changes due to fundamental factors are not mean reverting. The results of the impact of a call auction on long-term volatility (i.e., unconditional volatility) are presented in table 4. The average unconditional volatility of the 16 stocks (in bold letter) can be seen as coming down by 47% in the post call auction period in comparison to pre call auction period, which suggests that call auction markets provide an efficient process for discovering the opening prices.

Table 4: Estimation of pre- and post-unconditional variances of overnight returns through equation (6) and (7)

Stock	Unconditional Variance		
	Pre call auction period	Post call auction period	% Change
ACC Ltd.	0.000117906	7.75E-05	-0.343
AXISBANK	0.000230372	0.000120645	-0.476
BHEL	0.000131562	0.000302254	1.297
CIPLA	0.000104751	4.86E-05	-0.536
DLF	9.30E-05	0.000171078	0.839
DRREDDY	0.000114836	5.10E-05	-0.556
HDFC	0.000153075	6.93E-05	-0.547
HEROMOTOCO	0.000184475	0.000253394	0.374
HINDALCO	0.000273993	0.000116285	-0.576
HINDUNILVR	9.52E-05	3.72E-05	-0.609
INFY	-6.53E-05	0.00027977	-5.285
JPASSOCIATE	-4.60E-05	-3.02E-05	-0.342
KOTAKBANK	0.000358388	7.76E-05	-0.783
LT	0.000151907	8.84E-05	-0.418
ONGC	0.000209573	0.000127319	-0.392
PNB	0.000252629	0.000239227	-0.053
POWERGRID	7.44E-05	3.93E-05	-0.472
RELCAP	0.001488372	0.000955039	-0.358
RELINFRA	0.000114654	0.000144239	0.258
RPOWER	0.000412778	0.000321443	-0.221
SAIL	0.000279222	9.89E-05	-0.646
SBIN	-6.71E-05	-5.42E-05	-0.192

SIEMENS	0.000323113	0.000141033	-0.564
SUNPHARMA	9.59E-05	0.00012659	0.320
TATAMOTORS	0.000771381	0.001310229	0.699
TATAPOWER	7.64E-05	0.000245291	2.209

Increased volatility, however, could be attributed to lack of depth in the stock in call markets during their openings, as increased depth leads to lower volatility and vice-versa. As an indicator of liquidity, depth refers to unmatched buying and selling orders that exist at the best bid and ask price. Given the strong endogeneity among spread, depth, and volatility, Lee (2008) if a stock lacks depth, only small-sized orders will benefit, whilst larger-sized market orders will be forced to absorb limit orders for liquidity at higher ask prices and lower bid prices, leading to a rise in stock price fluctuation. This situation will lead to quoted prices that deviate from value or equilibrium prices, which will eventually cause higher stock price volatility (Porter and Weaver, 1997). Since spread is not an issue for a pre-open call auction at NSE, as orders are executed at a single price, the apparent volatility is liquidity-driven (Ahn *et al.*, 2001).

6. CONCLUSION

This study analysed the call auction method of opening the market at the NSE, which facilitates the crucial role of information aggregation following the overnight non-trading period. Studying overnight returns, it was found that returns are not mean reverting in a call market due to better price discovery at the closing, suggesting that a continuous market to be more efficient than a call market. The momentum of trade from closing market to opening market, however, suggests that overnight portfolio investors do not find a call market suitable in terms of reversing excess fluctuation among prices upon a closing. However, extending the study to investigate the nature variance of the return process, it is found that call market is able to reduce the unconditional volatility ensuring the efficient opening price of the stock in line with its value, thereby confirming a good market to trade with. Furthermore, given the endogeneity among the spread, depth and volatility of stocks, increased stock volatility can be attributed to a lack of depth as trade happens at a single price in call auction.

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