Lead-Lag Relationship between Equities and Stock Index Futures Market and It's Variation around Information Release: Empirical Evidence from India

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ABSTRACT

By using intraday data from April to September 2004, an effort has been made to investigate the possible lead-lag relationship, both in terms of return and volatility, among the NIFTY spot index and index futures market in India and also to explore the possible changes (if any) in such relationship around the release of different types of information. Our results suggests that though there is a strong contemporaneous and bi-directional relationship among the returns in the spot and futures market, the spot market has been found to play comparatively stronger leading role in disseminating information available to the market, and therefore said to be more efficient. Apart from this, there is also interdependence (in both direction) and therefore more or less symmetric spillovers among the stock return volatility in the spot and futures market. The results relating to the informational effect on the lead-lag relationship exhibit that though the leading role of the futures market wouldn't strengthen even for major market-wide information releases, the role of the futures market in the matter of price discovery tends to weakens and sometime disappear after the release of major firm-specific announcements.

JEL Classification: G10; G14.

Key Words: Lead-Lag Relationship, Volatility Spillover, Informational Efficiency.

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I. INTRODUCTION

It is very well known that the Indian capital market has witnessed a major transformation and structural change from the past one decade as a result of ongoing financial sector reforms. Gupta (2002) has rightly pointed out that improving market efficiency, enhancing transparency, checking unfair trade practices and bringing the Indian capital market up to a certain international standard are some of the major objectives of these reforms. Due to such reforming process, one of the important step taken in the secondary market is the introduction of derivative products in two major Indian stock exchanges (viz. NSE and BSE) with a view to provide tools for risk management to investors and also to improve the *informational efficiency* [1] of the cash market.

Many emerging and transition economies had started introducing derivative contracts since 1865 when the commodity futures were first introduced on the Chicago Board of Trade. The Indian capital markets have experienced the launching of derivative products on June 9, 2000 in BSE and on June 12, 2000 in NSE by the introduction of index futures. Just after one year, index options were also introduced to facilitate the investors in managing their risks. Later stock options and stock futures on underlying stocks were also launched in July 2001 and Nov. 2001 respectively.

In India, derivatives were mainly introduced with view to curb the increasing volatility of the asset prices in financial markets and to introduce sophisticated risk management tools leading to higher returns by reducing risk and transaction costs as compared to individual financial assets. Though the onset of derivative trading has significantly altered the movement of stock prices in Indian spot market, it is yet to be proved whether the derivative products has served the purpose as claimed by the Indian regulators. In an efficient capital market where all available information is fully and instantaneously utilized to determine the market price of securities, prices in the futures and spot market should move simultaneously without any delay. However, due to market frictions such as transaction cost, capital market microstructure effects etc., significant lead-lag relationship between the two markets has been observed.

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[1] According to Fama (1970), a market is said to be informationally efficient if the prices always reflect all the information available to the market. Depending on availability of information, Fama suggested three types of market efficiency- Weak form, Semi-strong form and Strong form efficiency. This proposition to market efficiency is termed as Efficient Market Hypothesis (EMH).

Therefore the present study is being contemplated with the following specific objectives:

i) Investigating the lead-lag relationship between the spot and futures market in India, both in terms of return and volatility; and

ii) Analyzing the possible explanations behind the variation in the above relationship over time. In this regard, the important propositions / hypothesis attempted to be tested are:

a) Futures market leads (if at all) the spot market not because of infrequent trading of component stocks;

b) The leading role of futures market will be greater around macroeconomic information release; and

c) The leading role of futures market weakens around the firm-specific announcements.

As far as developed markets, such as USA, UK, Japan etc., are concerned, a number of important and in-depth studies have been carried out to examine the lead-lag relationship between the spot and derivative, viz. futures market and also to provide the possible explanations behind such relation and its changes over time. But, as far as our knowledge is concerned, there is no relevant study either examining the lead-lag relationship between the derivative market and the underlying spot market in India by using high-frequency, i.e., intraday price data, or examining the variation in such relationship around the release of different types of information. Therefore, the present study seeks to contribute to the existing knowledge base and literature by not only examining the *actual* [2] lead-lag relationship among the Indian spot and futures market in terms of return, but also in terms of volatility. Apart from this, an effort has also been made to provide some impact, on the above relation, of (i) infrequent trading of component stock in cash market, (ii) the release of market wide information and also (iii) the exposure of firm-specific announcements.

The remainder of this study is organized as follows. Section II presents a brief review of existing literature relevant with this study. The details of data used along with some preliminary analysis are presented in Section III. Section IV gives a comprehensive description of the methods and the tests applied in this study. The analysis of major empirical findings is shown in Section V. Section VI concludes.

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[2] In Indian context, the lead-lag relationship has been examined by using daily data [Thenmozhi (2002), Anand Babu (2003)], while in the presence of informational efficiency, one market can lead the other only for a few minutes, not for a whole day. So, the actual or significant lead-lag relationship can be measured only by using intra-day data. Daily data can’t capture the true relationship.

II. REVIEW OF LITERATURE

There is an extensive amount of literature examining the impact of derivative trading on the return as well as on the volatility of underlying spot market, giving special emphasis on the lead-lag relationship between the spot and the derivatives, viz., futures and options market all over the world.

In a world of complete market and no transaction costs, any new security can be synthesized from existing securities. Consequently, the introduction of derivatives, such as options should have no effect on underlying assets. According to Grossman (1988), the existence of transaction costs and incomplete markets suggests the possibility that futures or options can have an impact on spot market volatility. Nathan Associates (1969) makes clear that diversion of speculative interest to the option market may reduce stock trading and therefore may cause reduction in liquidity which might increase the stock's return variance. However, studies by Bansal et al. (1989), Skinner (1989), Damodoran et al. (1991) find significant increase in stock trading volume after the onset of derivative trading. Cox (1976) argues that futures trading can alter the available information and thus spot market volatility for two reasons. First, futures attract additional traders to a market. Second, as transaction costs in the futures market are lower than those in the spot market, new information may be transmitted to the futures market more quickly. Now, the question is how the rate of information flow relates to spot price volatility. This issue is addressed by Ross (1989). He assumes that there exist economies that is devoid of arbitrage and proceeds to provide a condition under which the no-arbitrage situation will be sustained. Ross's condition ($\sigma_p = \sigma_s$) for no arbitrage implies that the variance of price change will be equal to the rate (or variance) of information flow. The implication of this condition is that the volatility of asset price will increase as the rate of information flow increases. Thus, if derivative trading increases the flow of information, then in the absence of arbitrage opportunity, the volatility of the spot price must change. However, Researchers like Skinner (1989), Black (1975), Fedinia & Grammatikos (1992) offers some reasons to support that there is a reduction in the variance of stock returns following option introduction. As noted by Skinner (1989), exchange officials have indicated that usually high or rising variance is a criterion for selecting the stocks on which to lists options. Now, if the variance is supposed to be mean-reverting, one can expect it to revert to its mean some time after option introduction. This may result in a reduction in the return variance of underlying stocks. Black (1975) argued that financial leverage provided by stock options can lower transaction costs, thereby attracting otherwise unprofitable informed trades. He also noted that options could also attract informed trades by enabling more efficient trading on negative information than is possible in the stock market. Fedenia and Grammatikos (1992) suggests that bid-ask spread in the stock markets tends to narrow after the options listings, thereby reducing the bid-ask bounce in stock prices and hence the variance of stock returns.

The empirical literature supporting the hypothesis that derivative trading might affect the underlying stock return variance include Chin (1991), Antoniou (1995), Choudhry (1997), Pericil (1997), Bollen (1998), Abhayankar (1998), Gulen (2000), Mckenzie (2001), Gupta (2002), Thenmozhi (2002), Shenbagaraman (2002) and Hetamsaria (2003). Most of them had examined the impact of derivative trading, mainly of futures and /or options trading, on the volatility of the underlying spot market. Alternatively, their main emphasis was on measuring the volatility level of underlying spot market and derivative market separately to reach some conclusion on whether derivative trading stabilize or de-stabilize the spot market. Except someone, all of them suggested that derivative market stabilizes the spot market by reducing its volatility or at least by keeping it unchanged.

Now, as far as the temporal relationship among the spot and futures (options) market is concerned, several studies, attempted to examine the lead-lag relationship between the spot and the futures market both in terms of return and / or volatility includes Ng. (1987); Kawaller, Koch, and Koch (1987); Harris (1989); Stoll & Whaley (1990); Chin, Chan and Karolyi (1991); Chan (1992); Abhyankar (1995); Shyy (1996); Iihara (1996); Pizzi (1998); De Jong (1998); Chatrath (1998); Min (1999); Tse (1999); Frino (2000); Thenmozhi (2002); Anand babu (2003); Simpson (2004) etc. Almost all of these studies have concluded that there is a significant lead-lag relationship among the spot and the futures market, and also have tried to provide the possible explanation behind this.

Most of the studies have suggested that the leading role of the futures market varies from five to forty minutes, while the spot market rarely leads the futures market beyond one minute.

While explaining the causes behind such relation, Kawaller et al. (1987) attribute the stronger leading role of the futures market to the infrequent trading of component stocks. Though, at the same time, Stoll & Whaley (1990), Chan (1992) etc. proved the existence of such relation even in case of highly traded stocks or after adjusting for infrequent trading of component stocks.

Chin (1991) has examined the intraday relationship among price changes and volatility of price changes in the stock index and stock index futures markets. Unlike the fact that the index futures markets served as the primary market for price discovery, as found in the previous studies, they have found the stronger interdependence in both the directions in the volatility of price changes between the cash and the futures markets than that observed in case of price changes only. Their evidence supported that the price innovations originate in one market, e.g. cash (futures) market, can predict the future volatility in the other, such as futures (cash), market. In other words, both cash and futures markets serve important role in discovering the price.

Chan (1992) have investigated the intraday lead-lag relationship between MM cash index and MM and S&P futures index returns under different situations. Their results confirmed the leading role of the futures market even against all the component stocks. They have also empirically proved the leading role (to a greater degree) of the futures market for the release of any market-wide information.

Abhyankar (1995) have found the possibilities of the cash and the futures market playing the leading role, even in different intensities, under different situations, such as for change in transaction cost, in periods of good, moderate and bad news, for high and low trading volume in the underlying equity market etc. But as far as the conditional volatility is concerned, they could not found any clear pattern of one market leading the other neither during the periods of good or bad news nor for varying levels of market activity.

By using a specially designed correlation measure that takes into account the fact that high frequency data are often observed at irregular intervals, De Jong (1998) have confirmed that even in the presence of significant contemporaneous correlation among the spot, futures and the options market, the futures price changes lead both the changes in the cash index and index option by five to ten minutes. But, among the cash and the options market, the relations are largely symmetrical and neither market consistently leads the other.

Chatrath (1998) have examined the intraday behavior of the spot and futures market following the release of information and also investigate the role of such information in the volatility spillover among the two markets. Their results have supported that one market leading to greater volatility in the other is partly driven by information and therefore the leading role played by the futures market may be the result of new information efficiently reflected in the futures market.

Min (1999) has investigated the possible lead-lag relationships in returns and volatilities between cash and futures markets. Their results have suggested that unlike the lead-lag relationship in the returns of spot and futures markets, there is significant but time dependent bidirectional causality between the markets, as far as the volatility interaction among the markets is concerned.

Frino (2000) have examined the temporal relationship among the spot and the futures market around the release of different types of information. They have found that the lead of the futures market strengthens significantly around the release of macroeconomic information, while, the leading role of the futures market weakens around stock-specific information release. Therefore, according to them the disintegration in the relationship between the two markets is mainly driven by noise associated with trading activity around the release of different types of information.

Simpson (2004) suggest that informed traders should trade in the futures market around the release of macroeconomic announcements; while, the leading role of futures market weakens through the discovery of stock specific information [Grunbicher, Longstaff and Schwartz (1994)].

By looking at the Indian market, Thenmozhi (2002); Anand babu (2003) etc. have found that the futures market in India has more power in disseminating information and therefore has been found to play the leading role (for one or two days) in the matter of price discovery.

III. DATA AND PRELIMINARY ANALYSIS

Data

In order to examine the lead-lag relationship between the underlying spot market and the futures market, the basic data used in this study consist of intraday price histories for the nearby contract of nifty index futures, nifty cash index and also the prices of some specific component stocks, recorded in each second but picked up with a frequency of one minute, during April 2004 to September 2004.

In order to carry out the study at the stock / script level, five underlying NIFTY stocks, viz. HINDPETRO, INFOSYSTCH, MARUTI, RELIANCE and TISCO, having very high trading frequency in the cash market have been taken into consideration. Each day trading hour has been partitioned into one minute intervals. The first price observation for the last second (i.e. 59 Second) of each interval (i.e. of each minute) has been picked up from the cash index market data. While, the first trading price, recorded in each minute, whatever be the second, in the index futures market and for underlying stocks have been sorted out. Such an inconsistent practice has been considered due to the lower trading frequency in those markets and also to simplify the data sorting process. As far as the cash market is concerned, there is not a single one minute interval where no trading takes place during the normal trading time. But, the Non-trading probability figures (as in Table 1) shows that no trading had taken place in the index futures market during the one minute intervals for about 2 to 3% (in average) of the overall trading intervals. If there is any missing observation, due to non-trading, in any interval and in any of the market, the common practice is to remove that specific interval (s) from the sample and therefore has been applied here also.

Return on market indices is defined as usual, i.e., the first difference in the log of price indices, such that $R_t = \ln(P_t) - \ln(P_{t-1})$.

Above all, all the relevant data relating to the spot as well as the futures market in India has been collected from the NSE website (www.nse-india.com) and also from the CD-ROM provided by the National Stock Exchange, Mumbai. The intraday price series both in the cash and futures market have been sorted out in MATLAB (Version 6.5) and MS-Excel. A list of macroeconomic and firm specific announcements which came into effect during the proposed study period has been short listed from some reliable sources (e.g., www.indiainfoline.com and www.bseindia.com).

Preliminary Analysis

If we look into the *summary statistics* [3] (as shown in Panel A of Table 2) of NIFTY Cash and NIFTY Futures index returns for the whole sample period, April to September 2004, and also over the two sub-period, April to June 2004 and July to September 2004, then it can be seen that the mean returns has been found to be significantly close to zero. Though during the first sub period in both the markets, the average returns were negative, it turns out to be positive in the second sub period in both the markets. The difference between the maximum and minimum value of return is much higher in the futures market that leads to show higher standard deviation in that market. But it happens only during the whole period and for the first sub period. In the later sub period, the difference in two extreme returns and therefore the standard deviation is comparatively less in the futures market. Though, the standard deviation (as a simple proxy for volatility) in the index futures market is greater than the same in cash index in all the periods. Now, if we look into the skewness figures that represent

[3] The data set considered here is within the trading period from 9:55 a.m. to 3:00 p.m. In order to remove the abnormality (if any) within the first five minute of trading (i.e., from 9:55 to 9:59 a.m.), we have computed the summary statistics for another data set where we have excluded the first five minute of trading. But the summary statistics for the second data set is almost identical with the first one and therefore is not reported here.

the asymmetry in the return series, it can be seen that except the NIFTY Cash return during the later sub period, all the return series are negatively skewed. At the same time, if the kurtosis figures are taken into consideration, then it can be found that all the figures are positive and therefore all the return distributions are said to be leptokurtic. The more the value of the kurtosis of the return in a market, the more destabilize is the market's return. The higher value of kurtosis in the futures market during the whole period and for the first sub period indicate that the futures market is comparatively more destabilised than the cash market during that periods. But the result in the later sub period shows that as time passes on, the cash market shows higher kurtosis and therefore called to be more destabilised than the futures market during July to September 2004. The Jarque-Bera statistics and their probability show that all the return series in all the time periods are non-normal. The summary statistics of five underlying stocks, calculated for the first sub period, is reported in Panel B of Table 2. The result for the underlying stocks also confirms that the mean returns for almost all the stocks (except of INFOSYSTCH) are negative and close to zero. While the standard deviation of the return of those stocks varies from 0.04 to 0.05. The table also reveals that except for INFOSYSTCH and TISCO, the returns for the other three stocks are negatively skewed. Apart from this, the return distributions for all the underlying stocks are found to be leptokurtic. The kurtosis figures tell us that among the five underlying stocks, RELIANCE is found to be highly de-stabilized.

Now, as far as the *trading frequency and non-trading probabilities* [4] of NIFTY cash and futures index along with that of five underlying NIFTY stocks are concerned, it is reported in Table 1. As we know that trading frequency is the average number of trades in one minute interval and non-trading probability refers to the proportion of intervals (here one minute intervals) having no trades [Chan (1992)]. Table 1 confirms that though the trading frequency in NIFTY futures index is more than 10, it shows an increase in the average number of trades in one minute intervals and thereby reduces the non-trading probability from the first sub period to the later sub period. Unlike in case of other country, the percentage of one minute intervals during the whole study period having no trade in the index futures market is only 2.78 % which shows very minor infrequent trading problem in the index futures market in India. Again, in order to examine the lead-lag relationship among the futures and underlying stocks, we have selected five very actively traded NIFTY stocks. Trading frequency and non-trading probabilities of those stocks have been calculated only for the first sub period. The

[4] Trading frequency is the average number of trades in a specified (e.g., one / five minute) interval; Non-trading probability is the proportion of intervals showing no trades and therefore no price change.

table confirms that except in case of Hindustan Petroleum, there is a very high trading frequency and lower non-trading probability (even less than 1 %) for all other stocks.

The autocorrelation figures for one minute cash and futures index returns in different periods are presented in the Panel A of Table 3. The autocorrelation coefficients for NIFTY cash and futures index return have been computed up to tenth order, selected arbitrarily. The serial correlations of the cash and futures index returns for the first lag are significantly large and are relatively very small for the other lags. Though relatively small in magnitude, the autocorrelation figures of the cash index returns for all the periods are significant up to five lags. In contrast, the serial correlations of the NIFTY futures index return are found to be insignificant beyond one lag (except during the later sub period). Consistent with the previous studies, our autocorrelation estimates in the cash index return are found to be positive at the first lag and shifted to a negative serial correlation beyond lag 2. The difference in the result of autocorrelation of cash and futures index return may be attributed to the nonsynchronous trading of underlying NIFTY stocks in both the markets.

IV. METHODOLOGY

Most of the previous studies revealed the fact that underlying cash market and futures / options markets do not react at the same time after the flow of new information. Some lead-lag relationship is commonly observed in most of the cases.

In examining the lead-lag relationship between cash and futures / option market, the first common but important practice is to determine the maximum length of leads or lags which are assumed to be significant in the present context. Such a problem can be solved by running a *cross-correlation* [5] test among the return in spot and futures markets in order to determine the extent to which the two markets are correlated to each other and the significant length of the lead / lag will be determined from the cross correlation coefficients [Stoll and Whaley (1990), Kalok Chan (1992), Abhyankar (1995), Min et al (1999)]. Now, based on the t-test, the length of lead / lags has been selected. It is to be noted here that the asymptotic standard

[5] In order to get the length of lags (i.e., β_{-k}) and the length of lead (i.e., β_{+k}), we have examined the cross correlation coefficient between the current cash returns ($R_{s,t}$) and past futures return ($R_{f,t-k}$), and between the past cash return ($R_{s,t-k}$) and current futures return ($R_{f,t}$) respectively.

errors for the cross-correlation coefficients is approximated as the square root of the reciprocal of the number of observations included in the sample [Chan Kolak (1992)].

After determining the lead-lag length, the next step is to examine the lead-lag behavior between the cash and futures markets by estimating the following regression equations:

The model applied to investigate the lead-lag relation among the spot and the futures market in terms of returns is such that

$$R_{s,t} = \alpha + \sum_{k=-n}^{n} \beta_k R_{f,t+k} + \delta Z_{t-1} + \varepsilon_t \qquad (1)$$

where $R_{s,t}$ and $R_{f,t}$ are cash and futures index returns at time t which have been collected at each one minute interval. The coefficients with negative subscripts (i.e., β_{-1}, β_{-2}, …, β_{-n}) are lag coefficients and those with positive subscripts (i.e., β_{+1}, β_{+2}, …, β_{+n}) are lead coefficients. If the lag coefficients become significant, then it can be inferred that the cash index lags futures, or in other words, futures lead the cash index. In the other way, if the lead coefficients will significant, then it can be proved that cash index lead futures index. If the contemporaneous β coefficient (i.e., β_0) shows the highest value among all other lead-lag coefficients, then it can be concluded that the two markets react simultaneously to much of the information. Along with the highest value of the contemporaneous β coefficient, if both the lead and lag coefficients are found to be significant, then neither market can said to significantly lead the other and therefore both the markets (spot and futures) are proved to be informationally efficient. Z_{t-1} is an *Error Correction Term* [6], taken to be as the first lag of the contemporaneous difference between the cash and futures price levels to account for the possibility that futures and cash return series may be co integrated [Engel and Granger (1987)].

Now, while examining the lead-lag relations between the two markets, one important point that should be taken care off is to test whether such relation is induced by the infrequent trading of component stocks. It is true that most of the component stocks of spot market index are not traded frequently enough to allow prices to update information quickly. So,

[6] The residuals from the equilibrium equation lagged by one period is considered to be the Error Correction Term, such that $ECT_{t-1} = Y_{t-1} - a_0 - a_1 X_{t-1}$. The error correction component in the Error Correction Model (ECM) indicates: (i) the proportion of disequilibrium from one period that is corrected in a later period, and (ii) the relative magnitude of adjustments in each market towards equilibrium.

while analyzing the lead-lag relations, based on intraday price changes, the component stock price (affected by infrequent trading problem) will cause the future prices to appear to lead cash index prices.

Thus, the problem is how to eliminate the infrequent trading components from the price series of spot market index so as to examine the true lead-lag relation between stock index and futures index. Such a problem can be solved by estimating the above regression but based on return innovations instead of simple spot returns [Stoll & Whaley (1990), Chan (1992), Abhyankar(1995), Frino (2000)]. An Autoregressive process *AR (p)* [7] can be estimated for cash index returns in order to extract the serially uncorrelated cash return innovations. This procedure filters out the portion of cash index price changes due to infrequent trading of component stocks and allows analysis of the lead-lag behavior when the infrequent trading bias is reduced.

Apart from this, we have also examined such relation between futures and individual component stocks. The purpose of examining the lead-lag relation at the component stock level is to compare the trading frequency and the non-trading probability [Chan (1992)] of each stock relative to the futures so that it is possible to determine whether the non-synchronous trading of futures and component stocks explain the lead-lag relation. If there is any effect of non-synchronous trading, then the futures should lead only those stocks showing lower trading frequency and higher non-trading probability.

Though there is mounting evidence for the time varying nature of stock return volatility, this model will not account for the variability of the disturbances while estimating the intraday relation between cash index and futures returns. However, since hetroskedasticity generally leads to inconsistent estimates of standard errors and invalidates inference, the t-statistics for all the coefficients have been adjusted using the procedure outlined in *White (1980)* [8] [Chan (1992), Abhyankar (1995), Frino (2000) etc.]

Now, the lead-lag relation among the two markets, in terms of volatility, or in other words, volatility spillover, has been examined through a VAR methodology such that

$$\sigma_{s,t} = c_1 + \sum_{k=1}^{p} \alpha_{sk} \sigma_{s,t-k} + \sum_{k=1}^{q} \beta_{sk} \sigma_{f,t-k} + \upsilon_{st} \qquad (2)$$

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[7] P, the lag length, to adjust for the auto-correlation problem, will be selected based on the significance of the auto-correlation coefficients in cash index returns.

[8] White's (1980) procedure allows estimating the regression using least squares, but then computes a consistent estimate of the covariance matrix allowing for hetroscedasticity that will lead to change the standard errors and therefore the t-statistics, not the coefficients themselves.

$$\sigma_{f,t} = c_2 + \sum_{k=1}^{p} \alpha_{fk} \sigma_{f,t-k} + \sum_{k=1}^{q} \beta_{fk} \sigma_{s,t-k} + \upsilon_{ft} \quad (3)$$

where $\sigma_{z,t}[=(\pi/2)^{1/2} * |\varepsilon_{z,t}|; z = Spot(s), Futures(f) markets]$ (Schwert (1989), Min (1999)) has been considered as the proxies for return volatilities and $\varepsilon_{z,t}$ is the return innovation obtained from the *Granger causality test* [9] among the return series of the spot and the futures market.

Now, the impact of macroeconomic or firm-specific information on the lead-lag relation among the spot and the futures markets' return can be tested through the same equation [Eq.(1)] but including a dummy variable representing the release of information, such that

$$R_{s,t} = \alpha_0 + \sum_{i=-n}^{+n} \alpha_i R_{f,t+i} + \sum_{i=-n}^{+n} \alpha_i' D_{m,t} R_{f,t+i} + \delta Z_{t-1} + \varepsilon_t \quad (4)$$

$$R_{s,t} = \alpha_0 + \sum_{j=-n}^{+n} \alpha_j R_{f,t+j} + \sum_{j=-n}^{+n} \alpha_j' D_{s,t} R_{f,t+j} + \delta Z_{t-1} + \varepsilon_t \quad (5)$$

where Eq. (4) and Eq. (5) estimate the lead-lag relation around the release of market-wide and stock specific information respectively. The dummy variables $D_{m,t}$ and $D_{s,t}$ represent the market wide and stock specific information release respectively and will take on a value of 1 if observation t lies within a half hour time period either side of a major macroeconomic or firm-specific information release, otherwise 0 [Frino (2000)]. It is to be noted here that α_i' and α_j' are the coefficients that can capture the incremental impact of the information (market wide and stock specific) release on the lead-lag relationship among the spot and futures markets [Frino (2000)]. In order to standardize the information, the macroeconomic and stock-specific announcements are proposed to be *prefiltered* [10] through a method suggested by Ederington and Lee (1993) and also applied by Frino (2000). A brief

[9] The Granger Causality test on the spot and futures index return has been applied through a near-VAR approach.

[10] According to Ederington and Lee (1993), the macroeconomic and stock-specific information can be pre-filtered by regressing a measure of volatility on dummy variables corresponding to the different categories of information. Then the information represented by a significant dummy coefficient will be taken in to consideration.

description of the announcements and also the process of such pre-filtering are given in Appendix 1. In order to assess the impact of information release on the volatility spillover among the spot and the futures market, the same equations (Eq. 4 and 5) can be used but using the absolute value of return as the proxy for volatility measure instead of the return series.

V. EMPIRICAL ANALYSIS

As we know that the basic step for examining the lead-lag relationship among the spot and futures market through a regression equation (Equation 1) is to determine the significant length of leads and lags proposed to be included in the equation. By looking into the cross-correlation among the one minute return of cash and futures index, we can assess the possible lead-lag relation among the two markets. The cross-correlations among the one-minute NIFTY cash and futures index returns for three different periods are presented in Panel B of Table 3. The significant cross-correlation figures can suggests the number of leads and lags supposed to include in the regression analysis. The cross-correlation figures have been estimated up to ten leads and lags. The results shows that though the contemporaneous correlation among the cash and futures index returns are found to be significant, the correlations among the current cash returns and future futures returns (or in other words, current futures returns and lagged cash returns) are found to be more significant than the correlation among the current cash return and lagged futures return. In other words, though it is found that the lagged return from both the price series (spot and futures) seem to have a forecast power for the other series [Abhyankar (1995)], the forecasting power of the cash market, in this study, is found to be stronger than that in the futures market. Though the cross-correlation among the cash and futures index return can not depict the true relationship between them, we have considered up to five leads and lags for the proposed regression analysis.

V.1. Lead-Lag Relationship between Cash and Futures Index Returns:

As we have said that the whole study period from April to September 2004 has been divided into two sub periods – April to June 2004, and July to September 2004, and the analysis has been made for the whole period as well as for both the sub periods. Apart from this, the lead-lag relationship has been examined for both simple return and using *cash return innovation*[11], derived from the AR (5) process on the cash index return.

The regression results for all the periods (the whole period and two sub periods) and also for the simple cash returns and for cash return innovations are reported in Table 4. The regression results, as supported by the cross-correlation figures, reveals that unlike in almost all other countries, the lead coefficients in the index futures market in India are found to be more significant than the lagged coefficients in the same market. It is clear from the table that the contemporaneous β coefficient (i.e., β_0) exhibits the highest value in both whole period and for the first sub period and also for both simple cash return and return innovations. This suggests that both cash and futures markets would react simultaneously to much of the information. It is to be noted here that any strong generalization can't be made by looking in to the specific results found in this study, because such results may be restricted only for the specific time period considered in this study and therefore may be time-variant in nature. As far as the whole study period is concerned, the lag (lead) coefficients in the futures market are found to be significant up to 3 lags (4 leads). But the results in two sub periods shows that though the lead coefficients in both the periods are significant up to four leads, the lag coefficients are significant up to 3 lags and 4 lags in the first and second sub period respectively. This suggests that the cash market leads the futures market up to four minute, while the reverse is possible up to three or four minute, depending on the time period. The regression results, using the cash return innovations, exhibits that neither the lead, nor the lag coefficients are found to be significant beyond 2 leads or lags. Though the individual t-statistics for both lead and lag coefficients reveals that there may be a simultaneous and bi-directional flow of information in both the markets, the joint significance tests (F test and Likelihood Ratio test) for all the sample periods and also for both type of returns confirms that the cash market in India plays a comparatively stronger role in the matter price discovery and therefore is leading the futures market at lease for a few minute(s). In other words, though there is a contemporaneous and bi-directional lead-lag relationship among the cash and futures markets in India, the cash market is found to show a stronger leading role than the futures market.

[11] Serially uncorrelated cash return innovations are extracted through an AR (5) process, as indicated by the significant auto correlation in the cash index return up to lag 5. Apart from this, in view of the first-order serial correlation in the futures index return, as indicated in Panel A of Table 3, we have re-estimated the regressions using the futures index return innovations from an AR (2) model along with the cash index return innovations. Since the results from both types of regressions are almost the same, we have reported the results relating to the regressions using only the cash index return innovations.

V.2. Lead-Lag Relation between Futures and Underlying Stocks:

The main purpose behind the examination of the lead-lag relationship among the futures and some underlying stocks is to confirm whether the asymmetric lead-lag relationship (i.e., futures leading the spot market as per existing literature) among the cash and futures market is induced by the infrequent trading of component stocks in the cash market, or such relationship holds even for very heavily traded underlying stocks. But as far as our study is concerned, though there is a strong contemporaneous and bi-directional relationship among the spot and futures markets, the spot or cash market is found to play comparatively stronger leading role, though for a very short period of time, and therefore has been considered to be more efficient than the futures market in India. Therefore, studying the lead-lag relationship at the component stock level is not to confirm that futures lead the cash market not because of the non-synchronous trading of component stocks. Here the purpose is just to examine whether the lead-lag relationship (whoever be the leader) among the cash and futures index return is supported also by the underlying stocks in the cash market. In other words, an effort has been made to investigate whether there is a consistency among the results at the index level and at the component stock level. Table 5 exhibits the regression results of the lead-lag relationship between the futures and some component stocks. Here five actively traded stocks (as depicted by the trading frequency and non-trading probability of those stocks), namely Hindustan Petroleum (HINDPETRO), Infosys Technology (INFOSYSTCH), Maruti Udyog Limited (MARUTI), Reliance (RELIANCE) and Tata Iron & Steel Company Limited (TISCO), have been taken into consideration. The table confirms that the results of lead-lag relationship both at the index level and component stock level are almost the same. The highest value of the contemporaneous β coefficients for almost all the stocks (except of INFOSYSTCH) proved that both cash and futures market reacts simultaneously to much of the information. Apart from this, the lead (lag) coefficients are found to be significant up to four leads (three or four lags). But if we look into the F-statistics and LR-statistics for the joint significance of the lead (lag) coefficients, then it will be clear that the leading role of the cash market is found to be little stronger than the futures market for four out of five component stocks.

V.3. Volatility Spillover among the Cash and Futures Markets:

Table 6 presents the lead-lag relationship among the spot and futures markets in terms of stock return volatility, or in other words, volatility spillover among the cash and futures market in India. Panel A of the table deals with the volatility spillover from the futures market to the spot market, while the volatility spillover from the spot to the futures market is presented in Panel B. As we have told that the volatility measure, in this case, has been calculated from the residuals derived from the pair-wise Granger-causality test on the one minute spot and futures index returns. The table shows that though the left hand side variable, in both the panels, significantly depends on its own lagged value, there is a weak causal relationship among the volatility in spot and futures market, especially in case of causality from the futures to spot market. If we look into the individual significance of the β coefficients, then it can be seen that the futures market volatility only at the first lag shows some significant causal effect on the volatility in the spot market. Though, as far as the causality from the spot to the futures market is concerned, the spot market volatility up to three lags (i.e., $\beta_{f,1}$, $\beta_{f,2}$, $\beta_{f,3}$) has been found to significantly cause the volatility in the futures market in India. Therefore, it can be said that the lead-lag relationship among the spot and futures market, both in terms of returns and volatility, have been found to be consistent, i.e, in a same direction. Apart from the individual t-statistics, if we look into the χ^2 statistics for testing the joint significance of the causal variables, then it will be confirmed that though there is a significant bi-directional causality among the volatility in the spot and futures market, the overall causality from the spot market volatility to the volatility in the futures market is much more stronger than the same in the other direction. Therefore, unlike the studies like Kawaller (1990), Abhyankar (1995) etc., there is a systematic pattern in the volatility spillover among the spot and futures market in India. Apart from examining the volatility spillover at the index level, we have examined the same also at the component stock level the results of which are not reported here, but will be available on request. The results exhibit that though there is a significant bi-directional causality among the futures index return volatility and the volatility of the return of component stocks, the joint significance test on the spillover variables reveals that the volatility in the futures index returns strongly cause the volatility of the underlying stocks.

V.4. Lead-Lag Relationship around the Release of Information:

In order to capture the impact of major macroeconomic or market wide and firm-specific information on the possible lead-lag relationship among the spot and futures market in India, we have used the regression equation (4) and (5). Table 7 reports the results relating to the impact of major market-wide announcements on the lead-lag relationship between the spot and futures returns. While, the impact of some significant stock-specific information on the said relationship is reported in Table 8. The impact of such announcements has been measured both for simple cash index returns and also for cash index returns innovations, reported in two different panels. The analysis related to the significance of futures index returns coefficients (both lags and leads) in both the tables is not of our main concern in this section. Here, we have focused only on the coefficients relating to the market-wide and firm-specific dummies associated with the lead (lag) coefficients and are reported in the last two columns of both the panels in both the tables. As we have mentioned in Appendix A that out of 6 categories of market-wide and 8 categories of stock-specific information, only 4 categories in both the cases are proved to be significant at 1% or 5% level of significance. Therefore, only those categories of information have been included to form the market-wide and firm-specific dummy variables. All the details of different categories of information, the process of pre-filtering [Ederington and Lee (1993)], the test of significance of different categories of information etc. have been mentioned in the Appendix.

If we look into the t-statistics of the market-wide dummy coefficients for simple cash index returns reported in Panel A of Table 7, then it will be clear that both the lead (up to 3) and the lags (up to 2) coefficients are found to be significant. At the same time, we have got the same results for the cash index returns innovations as reported in Panel B of the same table. Apart from the individual t-statistics, the F and LR statistics also confirmed that the lead dummy coefficients are found to be stronger than the lag coefficients of the futures index returns. Unlike the existing literature, these results are quite peculiar in the sense that the lead of futures market wouldn't strengthens even for major macroeconomic information releases.

Now, as far as the impact of some stock-specific information is concerned, the results have been reported in Table 8. The results in both the panels of Table 8 are quite expected in the sense that none of the coefficients for the lagged dummies (i.e., α'_{-1} to α'_{-5}) both for simple cash returns and return innovations have been found to be significant. While, the coefficient for the lead (only by one period) dummy (i.e., α'_1) only for the simple cash index return has been proved to be significant at 5% level. The F and LR statistics also convey the same massage. This result proved that whatever be the leading role (stronger or weaker) played by the futures market during the release of major market-wide announcement, it tends to weakens after the release of major firm-specific information. In other words, the leading role of the futures market tends to disappear (in the present context) just after the disclosure of major firm-specific information.

Apart from examining the impact of different types of announcements on the lead-lag relationship between spot and futures index returns, an effort has also been made to investigate the impact of those information on the volatility spillover among the spot and futures markets. Table 9 reports how the lead-lag relationship among the spot and futures market volatility is affected by the release of market-wide and firm-specific information. If we focused on the results of Panel A of the table, then it will be clear that along with the contemporaneous dummy coefficient, all other lead dummy coefficients (i.e., α'_1 to α'_5) and only one lag dummy coefficient (i.e., α'_{-4}) are found to be significant. But the results in Panel B reveals that none of the lag dummy coefficient has been found to be significant and therefore whatever be the leading role that the futures market has played at the time of market-wide information release, gets disappear at the time of releasing stock-specific information. Thus, it can be said that the leading role (though very weak in nature) of the futures market weakens after the release of firm-specific information.

VI. CONCLUSION

By using intraday (here minute-by-minute) data from April to September 2004, an effort has been made to investigate the possible lead-lag relationship, both in terms of return and volatility, among the NIFTY spot index and index futures market in India and also to explore the possible changes (if any) in such relationship around the release of different types of information, such as market-wide and firm-specific information.

As far as the regression results on the lead-lag relationship between spot and futures index return is concerned, it revealed that unlike in almost all other countries, the lead coefficients in the index futures market in India are found to be more significant (both individually and collectively) than the lagged coefficients in the same market. This suggests that though there is a strong contemporaneous and bi-directional relationship among the spot and futures market in India, the spot market has been found to play comparatively stronger leading role in disseminating information available to the market. We have got almost the same results even for some underlying NIFTY stocks that are very actively traded in the market. As far as our knowledge is concerned, the possible explanation behind such more or less symmetric lead-lag relationship among Indian spot and futures markets may be the joint efficiency of both the markets. As we know that one of the main objective of introducing derivatives product, such as index futures, in Indian market is to enhance the informational efficiency of the underlying cash market. Therefore by looking into such results, one can easily conclude that the informational efficiency of the Indian cash market has really been increased due to the onset of derivative trading, as claimed by the Indian regulators.

Now, the results on the volatility spillover among the spot and futures market in India also reveals that unlike studies like Kawaller (1990), Abhyankar (1995) etc., there is also an interdependence (in both direction) and therefore a symmetric spillover among the stock return volatility in Indian spot and futures market, though the spillover from the spot to the futures market is found to be little stronger than the same in the opposite direction.

The results relating to the informational effect on the lead-lag relationship exhibit that the leading role of the futures market wouldn't strengthen even for major market-wide information releases. But at the same time, it is also proved that whatever role that the futures market plays in the matter of price discovery, tends to weakens and sometime disappear after the release of major firm-specific announcements.

As far as our research is concerned, it may not be feasible to make any strong generalization on the possible lead-lag relationship among the spot and futures market in India by looking at these results. Though our evidence proves that new market information disseminates (may not be equally) in both the spot and futures market and therefore serve an important role in the matter of price discovery, we can get some more strong and reliable results through investigating such relationship for a longer period of time within which the problem (if any) of any periodic effect will be disappeared. Apart from this, a comparison among the results of two longer (at lease one year) periods – one period just after the onset of index futures, and the other is for the recent period, can also exhibit whether there is any change in the informational efficiency of the markets over a period of time. Therefore, a further research in those lines can strongly focus whether there is any real change in the informational efficiency of Indian cash market after the introduction of derivative trading.

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Table 1: Trading Frequency and Non-trading Probabilities of NIFTY Cash and Futures Index and of Some NIFTY Stocks in One-minute intervals

NIFTY Index / Stocks	Trading Frequency			Non-Trading Probability		
	April - June 2004	July - Sept. 2004	April – Sept. 2004	April - June 2004	July - Sept. 2004	April – Sept. 2004
NIFTY Cash Index	NA	NA	NA	0.14	0.1	0.12
NIFTY Futures Index	10.47	12.10	11.29	3.47	2.08	2.78
Underlying NIFTY Stocks:						
HINDPETRO	7.37	NA	NA	5.51	NA	NA
INFOSYSTCH	16.12	NA	NA	0.16	NA	NA
MARUTI	21.30	NA	NA	0.39	NA	NA
RELIANCE	21.55	NA	NA	0.16	NA	NA
TISCO	20.47	NA	NA	0.26	NA	NA

Note: Trading Frequency in Cash index market is much more than that in futures market in one minute interval and therefore is immaterial to show here.
Trading Frequencies are in Number, while Non-trading probabilities are in percentage terms.
Trading time considered here is 9:55 a.m. to 3:00 p.m. for index series and 9:55 a.m. to 2:00 p.m. for underlying stocks to have a consistency in the trading period among the two markets.
Trading frequency and non-trading probabilities for five underlying stocks have been calculated only for the first half, i.e. for the period April to June 2004.
Any abnormal time period when no trading had taken place for a long time in any of the markets is excluded here.

Table 2: Descriptive Statistics of Index Returns and Return of Some Underlying NIFTY Stocks' in Cash and Futures Markets

Panel A:

	April to Sept. 2004:		**April to June 2004:**		**July to Sept. 2004:**	
	NIFTY	FUTIDX	NIFTY	FUTIDX	NIFTY	FUTIDX
Mean	-0.000001	0.000000	-0.000009	-0.000010	0.000008	0.000009
Median	0.000012	0.000000	0.000013	0.000000	0.000012	0.000000
Maximum	0.036509	2.165280	0.036509	2.165280	0.022090	0.366953
Minimum	-0.041342	-2.173990	-0.041342	-2.173990	-0.019289	-0.396742
Std. Dev.	0.000962	0.030596	0.001207	0.039412	0.000633	0.018136
Skewness	-4.306445	-0.333248	-4.664093	-0.293996	1.959728	-0.200161
Kurtosis	386.354800	2111.514000	299.622800	1544.124000	183.733200	50.166280
Jarque-Bera	2.24E+08	6.76E+09	66432039	1.79E+09	25055907	1705786
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	-0.019798	-0.003856	-0.167143	-0.172478	0.147345	0.168622
Sum Sq. Dev.	0.033748	34.170460	0.026365	28.118380	0.007380	6.052071
Observations	36504	36504	18103	18103	18401	18401

Panel B:

	HINDPETRO		**INFOSYSTCH**		**MARUTI**		**RELIANCE**		**TISCO**	
Statistics	Spot	Futures	Spot	Futures	Spot	Futures	Spot	Futures	Spot	Futures
Mean	-0.00002	-0.00001	0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
Median	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Maximum	0.40048	2.16528	0.35895	2.16528	0.37469	2.16528	0.49940	2.16528	0.53167	2.16528
Minimum	-0.42207	-2.17399	-0.35513	-2.17399	-0.38996	-2.17399	-0.51238	-2.17399	-0.50691	-2.17399
Std. Dev.	0.05829	0.04346	0.04541	0.04256	0.04759	0.04259	0.04350	0.04257	0.04771	0.04256
Skewness	-0.01094	-0.28887	0.02318	-0.29406	-0.06068	-0.29389	-0.05188	-0.29356	0.02848	-0.29444
Kurtosis	8.34646	1375.69300	9.07542	1416.05000	9.97655	1415.58200	12.37162	1414.82900	9.93955	1418.36200
Sum	-0.32045	-0.14838	0.18012	-0.14838	-0.14323	-0.14838	-0.16943	-0.14838	-0.16746	-0.14838
Sum Sq. Dev.	46.68082	25.94569	29.91139	26.27959	32.77831	26.25211	27.44335	26.29002	32.98369	26.24442
Observations	13738	13738	14507	14507	14472	14472	14506	14506	14492	14492

Note: Trading period, considered for the index series is from 9:55 a.m. to 3:00 p.m. While, trading period considered for underlying stocks is from 9:55 a.m. to 2:00 p.m. to bring a consistency among the trading period of all the five stocks. The Sample period for stocks is only from April to June 2004.

Table 3: Autocorrelation and Cross Correlation Coefficients of One Minute Returns of NIFTY Cash (S_t) and NIFTY Futures (F_t) Index

Panel A: Autocorrelation

	(April to Sept. 2004) (N = 36504)		**(April to June 2004) (N = 18103)**		**(July to Sept. 2004) (N = 18401)**	
Lag	NIFTY	FUTIDX	NIFTY	FUTIDX	NIFTY	FUTIDX
1	0.254*	-0.493*	0.272*	-0.494*	0.188*	-0.487*
2	0.001	0	0.007	0	-0.019*	0.002
3	-0.089*	-0.002	-0.089*	0.002	-0.093*	-0.02
4	-0.071*	-0.005	-0.065*	-0.01	-0.093*	0.019*
5	-0.037*	0.003	-0.037*	0.006	-0.036*	-0.011
6	-0.037*	-0.003	-0.043*	-0.002	-0.013	-0.004
7	-0.007	-0.001	-0.011	-0.003	0.009	0.008
8	0.02*	0.004	0.022*	0.009	0.011	-0.018*
9	0.018*	-0.003	0.026*	-0.008	-0.011	0.018*
10	0.003	0	0.008	0.001	-0.014	-0.005

Panel B: Cross-Correlation

	(April to Sept. 2004) (N = 36504)	**(April to June 2004) (N = 18103)**	**(July to Sept. 2004) (N = 18401)**
Lag K	$p(S_t, F_{t+k})$	$p(S_t, F_{t+k})$	$p(S_t, F_{t+k})$
-10	0.0086	0.0077	0.0121
-9	-0.0057	-0.0058	-0.0047
-8	0.0076	0.0111	-0.0066
-7	-0.0024	-0.0059	0.0115
-6	-0.0061	-0.0092	0.0065
-5	0.0019	0.0070	-0.0189*
-4	-0.0122*	-0.0150*	-0.0008
-3	-0.0046	-0.0044	-0.0047
-2	-0.0050	-0.0060	-0.0009
-1	0.0129*	0.0143	0.0071
0	0.0243*	0.0239*	0.0260*
1	0.0346*	0.0367*	0.0263*
2	0.0162*	0.0146*	0.0229*
3	-0.0109*	-0.0120	-0.0068
4	-0.0071	-0.0069	-0.0082
5	-0.0149*	-0.0142	-0.0178*
6	0.0089	0.0095	0.0063
7	0.0008	0.0030	-0.0088
8	0.0041	0.0040	0.0047
9	-0.0189*	-0.0232*	-0.0015
10	0.0116*	0.0144	0.0004

Note: Asymptotic standard errors for the autocorrelation and cross correlation coefficients can be approximated as the square root of the reciprocal of the number of observations (i.e., 0.00523 for 36504 observations; 0.00743 for 18103 observations; 0.00737 for 18401 observations). Trading period considered here is from 9:55 a.m. to 3:00 p.m.

* Significant at 1% or 5% level.

Table 4: Lead-lag Relationship among the Spot and the Futures Markets Returns in One Minute Interval

	Panel A: Simple NIFTY Cash Return ($R_{s,t}$)			**Panel B: NIFTY Cash Return Innovations ($R^I_{s,t}$)**		
	$R_{s,t} = \alpha + \sum_{k=-5}^{5} \beta_k R_{f,t+k} + \delta Z_{t-1} + \varepsilon_t$			$R^I_{s,t} = \alpha + \sum_{k=-5}^{5} \beta_k R_{f,t+k} + \delta Z_{t-1} + \varepsilon_t$		
	Whole Period	**April - June 2004**	**July - Sept. 2004**	**Whole Period**	**April - June 2004**	**July - Sept. 2004**
α	0.0000	0.0000	0.0000	0.0000	0.0000**	0.0000**
	(-0.125)	(-0.981)	(1.538)	(-0.006)	(0.062)	(-0.119)
β_{-5}	0.0009	0.0012	0.0000	0.0010	0.0012	0.0001
	(1.929)	(1.802)	(-0.040)	(2.130)	(1.940)	(0.402)
β_{-4}	0.0017	0.0018	0.0012	0.0017	0.0017	0.0015
	(2.398)	(2.075)	(2.098)	(2.436)	(2.020)	(2.721)
β_{-3}	0.0032**	0.0034	0.0024**	0.0029	0.0029	0.0026
	(3.126)	(2.683)	(3.535)	(3.045)	(2.528)	(4.052)
β_{-2}	0.0050**	0.0052**	0.0039**	0.0041*	0.0041	0.0038
	(4.065)	(3.461)	(5.048)	(3.624)	(2.992)	(5.113)
β_{-1}	0.0071**	0.0075**	0.0056**	0.0056**	0.0057**	0.0050**
	(5.050)	(4.304)	(6.685)	(4.317)	(3.606)	(6.203)
β_0	0.0090**	0.0087**	0.0101**	0.0076**	0.0072**	0.0091**
	(6.131)	(4.952)	(9.548)	(5.818)	(4.666)	(8.788)
β_1	0.0091**	0.0089**	0.0100**	0.0079**	0.0077**	0.0089**
	(5.967)	(4.812)	(11.312)	(5.756)	(4.647)	(10.452)
β_2	0.0072**	0.0069**	0.0083**	0.0065*	0.0063	0.0076**
	(5.200)	(4.159)	(10.277)	(5.074)	(4.065)	(9.794)
β_3	0.0044**	0.0042**	0.0053**	0.0041	0.0039	0.0049
	(4.000)	(3.192)	(7.085)	(3.960)	(3.168)	(6.796)
β_4	0.0024**	0.0023*	0.0028**	0.0023	0.0022	0.0026
	(3.260)	(2.637)	(4.706)	(3.301)	(2.683)	(4.947)
β_5	0.0008	0.0007	0.0008	0.0006	0.0006	0.0007
	(1.747)	(1.431)	(1.800)	(1.595)	(1.314)	(1.642)

Contd.

δ	0.0000 (-0.511)	0.0000 (0.290)	0.0000** (-4.481)	0.0000 (-1.374)	0.0000 (-0.645)	0.0000** (-4.668)
F_{Lead}	116.1238** (p = 0.000)	56.7316** (p = 0.000)	60.8723** (p = 0.000)	95.7308** (p = 0.000)	46.5360** (p = 0.000)	51.7620** (p = 0.000)
LR_{Lead}	576.2523** (p = 0.000)	281.6584** (p = 0.000)	302.0821** (p = 0.000)	475.7104** (p = 0.000)	231.3615** (p = 0.000)	257.1865** (p = 0.000)
F_{Lag}	72.3589** (p = 0.000)	41.0353** (p = 0.000)	20.7348** (p = 0.000)	46.7313** (p = 0.000)	25.7421** (p = 0.000)	16.3504** (p = 0.000)
LR_{Lag}	360.1404** (p = 0.000)	204.1679** (p = 0.000)	103.4559** (p = 0.000)	232.9945** (p = 0.000)	128.3467** (p = 0.000)	81.6283** (p = 0.000)

Note: Panel A deals with simple cash index returns, while cash return innovations is used in Panel B
Values in parenthesis are t-statistics that are based on standard errors adjusted for autocorrelation and hetroskedasticity using White's (1980) correction.
F_{Lead} (F_{Lag}) and LR_{Lead} (LR_{Lag}) are the F-statistics and Likelihood Ratio statistics respectively, that test whether the Lead (Lag) coefficients are jointly zero.
** and * Significant at 0.01 and 0.05 level.
NIFTY cash return innovation have been extracted through an AR (5) process on the cash return.

Table 5: Lead-lag Relationship among Underlying Stocks and Futures Index Returns

Regression Model: $R_{s,t} = \alpha + \sum_{k=-5}^{5} \beta_k R_{f,t+k} + \delta Z_{t-1} + \varepsilon_t$; where s = Stocks, f = futures index

	HINDPETRO	INFOSYSTCH	MARUTI	RELIANCE	TISCO
α	0.0000	0.0000	0.0000	0.0000	0.0000
	(-0.0787)	(0.0271)	(-0.0210)	(-0.0521)	(-0.0690)
β_{-5}	-0.0408**	-0.0049	-0.0091	-0.0202	-0.0269*
	(-2.7523)	(-0.4517)	(-0.6181)	(-1.2645)	(-2.3341)
β_{-4}	-0.0577*	-0.0126	-0.0563**	-0.0792**	-0.0367
	(-2.5110)	(-0.8457)	(-2.6675)	(-3.2495)	(-1.5823)
β_{-3}	-0.0893**	0.0189	-0.0627*	-0.1146**	-0.0503*
	(-3.1402)	(1.0391)	(-2.4738)	(-3.9451)	(-2.0544)
β_{-2}	-0.1089**	-0.0053	-0.0935**	-0.1541**	-0.0770**
	(-3.1506)	(-0.2623)	(-3.0924)	(-4.5464)	(-2.9109)
β_{-1}	-0.1601**	-0.0166	-0.1114**	-0.1802**	-0.0892**
	(-3.9593)	(-0.7971)	(-3.5514)	(-4.7350)	(-3.2290)
β_0	0.2224**	0.0151	0.1821**	0.2255**	0.1401**
	(5.1953)	(0.7063)	(5.6513)	(5.5569)	(4.8725)
β_1	0.1886**	0.0034	0.1360**	0.1894**	0.1015**
	(4.8152)	(0.1633)	(4.5010)	(5.1886)	(3.7691)
β_2	0.1636**	-0.0087	0.1164**	0.1428**	0.0901**
	(4.5506)	(-0.4487)	(4.0757)	(4.4503)	(3.5183)
β_3	0.1095**	0.0019	0.0842**	0.1065**	0.0736**
	(3.5979)	(0.1090)	(3.1133)	(3.8015)	(3.1604)
β_4	0.0781**	-0.0070	0.0377*	0.0568*	0.0430*
	(2.8448)	(-0.4919)	(1.9877)	(2.4486)	(2.3300)
β_5	0.0447*	-0.0062	0.0320*	0.0195	0.0168
	(1.9704)	(-0.6004)	(2.1469)	(1.1312)	(1.4616)
δ	-0.0008**	-0.0001**	-0.0007**	-0.0012**	-0.0009**
	(-32.6789)	(-44.2979)	(-34.8915)	(-43.1697)	(-34.1895)
F Lead	12.5638**	0.6277	11.1532**	28.3202**	5.7718**
	(p = 0.0000)	(p = 0.6786)	(p = 0.0000)	(p = 0.0000)	(p = 0.0000)
LR Lead	62.7350**	3.1410	55.7085**	141.0396**	28.8559**
	(p = 0.0000)	(p = 0.6783)	(p = 0.0000)	(p = 0.0000)	(p = 0.0000)
F Lag	9.3656**	3.0166**	8.1943**	26.5108**	4.5144**
	(p = 0.0000)	(p = 0.0100)	(p = 0.0000)	(p = 0.0000)	(p = 0.0004)
LR Lag	46.7927**	15.0885**	40.9502**	132.0696**	22.5748**
	(p = 0.0000)	(p = 0.0100)	(p = 0.0000)	(p = 0.0000)	(p = 0.0004)

Note: Trading time considered here is from 9:55 a.m. to 2:00 p.m. Values in parenthesis (for the lead/lag coefficients) are t-statistics that are based on standard errors adjusted for autocorrelation and hetroskedasticity using White's correction.

F_{Lead} (F_{Lag}) and LR_{Lead} (LR_{Lag}) are the F-statistics and Likelihood Ratio statistics respectively that tests the joint significance of the Lead / Lag coefficients.

Trading period considered for estimating the lead-lag relationship at the underlying stock level is from April to June 2004.

Table 6: Volatility Spillover among the Spot and the Futures Markets in One Minute Interval

Panel A: $\sigma_{s,t} = c_1 + \sum_{k=1}^{5} \alpha_{sk}\sigma_{s,t-k} + \sum_{k=1}^{5} \beta_{sk}\sigma_{f,t-k} + \upsilon_{st}$

Panel B: $\sigma_{f,t} = c_2 + \sum_{k=1}^{5} \alpha_{fk}\sigma_{f,t-k} + \sum_{k=1}^{5} \beta_{fk}\sigma_{s,t-k} + \upsilon_{ft}$

	Whole Period	April - June 2004	July - Sept. 2004		Whole Period	April - June 2004	July - Sept. 2004
c_1	0.0002**	0.0002**	0.0002**	c_2	0.0049**	0.0060**	0.0051**
	(28.6319)	(20.3215)	(22.8703)		(26.5443)	(17.7804)	(27.6940)
$\alpha_{s,1}$	0.2682**	0.2795**	0.1960**	$\alpha_{f,1}$	0.2047**	0.2087**	0.1303**
	(51.4579)	(37.7736)	(26.6107)		(39.1795)	(28.1246)	(17.6910)
$\alpha_{s,2}$	0.1145**	0.1074**	0.1277**	$\alpha_{f,2}$	0.0836**	0.0816**	0.0980**
	(21.2287)	(13.9758)	(17.0297)		(15.7040)	(10.7878)	(13.2152)
$\alpha_{s,3}$	0.0563**	0.0519**	0.0732**	$\alpha_{f,3}$	0.0741**	0.0729**	0.0779**
	(10.3767)	(6.73173)	(9.71175)		(13.9342)	(9.64216)	(10.4904)
$\alpha_{s,4}$	0.0404**	0.0373**	0.0502**	$\alpha_{f,4}$	0.0719**	0.0705**	0.0637**
	(7.48018)	(4.85218)	(6.69403)		(13.5188)	(9.33223)	(8.60321)
$\alpha_{s,5}$	0.0988**	0.1035**	0.0654**	$\alpha_{f,5}$	0.0717**	0.0723**	0.0615**
	(18.9214)	(13.9553)	(8.86901)		(13.7462)	(9.76490)	(8.35484)
$\beta_{s,1}$	0.0008**	0.0007*	0.0007	$\beta_{f,1}$	0.7180**	0.7102**	0.4719*
	(4.02293)	(2.58516)	(2.19520)		(5.22710)	(3.51437)	(2.91056)
$\beta_{s,2}$	0.0005	0.0005	0.0003	$\beta_{f,2}$	0.6705**	0.6779**	0.3422
	(2.48503)	(1.68998)	(0.89950)		(4.71621)	(3.23141)	(2.07292)
$\beta_{s,3}$	0.0004	0.0004	0.0003	$\beta_{f,3}$	0.8583**	0.9573**	0.3696
	(2.06001)	(1.26618)	(0.89837)		(6.00756)	(4.54316)	(2.22746)
$\beta_{s,4}$	0.0003	0.0002	0.0004	$\beta_{f,4}$	0.2592	0.1552	0.3932
	(1.44809)	(0.73279)	(1.16332)		(1.82182)	(0.73892)	(2.38122)
$\beta_{s,5}$	0.0004	0.0004	0.0002	$\beta_{f,5}$	0.2221	0.1630	0.3079
	(2.01393)	(1.58585)	(0.54338)		(1.61403)	(0.80531)	(1.89727)
χ^2_{FUTIDX}	63.1921**	27.1170**	12.6795*	χ^2_{NIFTY}	212.7852**	99.5066**	57.0206**
	[p = 0.0000]	[p = 0.0001]	[p = 0.0266]		[p = 0.0000]	[p = 0.0000]	[p = 0.0000]

Note: Values in parenthesis are t-statistics. χ^2_{FUTIDX} (χ^2_{NIFTY}) are the χ^2 - statistics that test whether the volatility coefficients in the Futures (Spot) market are jointly zero, i.e., insignificant in explaining the volatility in the Spot (Futures) market. ** Significant at the 1% level; * Significant at the 5% level.

Table 7: Market-wide Announcements and Lead-lag Relationship among the Spot and the Futures Markets Returns

Panel A: Simple NIFTY Cash Return

$$R_{s,t} = C_0 + \sum_{i=-5}^{+5} \alpha_i R_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i' D_{m,t} R_{f,t+i} + \delta Z_{t-1} + \varepsilon_t$$

Panel B: NIFTY Cash Return Innovations

$$R_{s,t}^{I} = C_0 + \sum_{i=-5}^{+5} \alpha_i R_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i' D_{m,t} R_{f,t+i} + \delta Z_{t-1} + \varepsilon_t$$

	Panel A		Market wide Dummies		Panel B		Market wide Dummies	
	FUTIDX Coeff.	**t-stat**	**$D_{m,t}$ Coeff.**	**t-stat**	**FUTIDX Coeff.**	**t-stat**	**$D_{m,t}$ Coeff.**	**t-stat**
Intercept	0.0000	-0.4886	-	-	0.0000	-0.2398	-	-
α_{-5}	0.0005	1.9589	0.0066	1.5274	0.0004	1.7711	0.0078*	2.4140
α_{-4}	0.0011**	2.7876	0.0052	0.9837	0.0009*	2.5586	0.0061	1.4406
α_{-3}	0.0019**	3.7206	0.0113	1.5228	0.0016**	3.4267	0.0098	1.6984
α_{-2}	0.0028**	4.7077	0.0214*	2.5157	0.0021**	3.9635	0.0164*	2.3537
α_{-1}	0.0041**	5.8669	0.0321**	3.2595	0.0029**	4.8121	0.0221**	2.7196
α_{0}	0.0054**	7.2363	0.0459**	4.2606	0.0046**	6.6846	0.0306**	3.6181
α_{1}	0.0055**	7.4163	0.0478**	4.3437	0.0047**	6.9846	0.0335**	3.8232
α_{2}	0.0044**	6.2046	0.0355**	3.8731	0.0038**	5.9510	0.0277**	3.6416
α_{3}	0.0029**	4.6029	0.0159*	2.1126	0.0026**	4.4042	0.0133*	2.2550
α_{4}	0.0018**	3.6349	0.0050	1.0166	0.0015**	3.5254	0.0061	1.7027
α_{5}	0.0007*	2.1137	-0.0002	-0.0506	0.0006*	1.9859	-0.0004	-0.1384
ECT	0.0000	-1.2126	-	-	0.0000*	-1.9926	-	-
F_{Lead} (α'_{+1} + ……..+ α'_{+5})				(255.2037) **				(200.0316) **
LR_{Lead} (α'_{+1} + ……..+ α'_{+5})				(1255.0280) **				(987.3386) **
F_{Lag} (α'_{-1} + ……..+ α'_{-5})				(120.7421) **				(84.0170) **
LR_{Lag} (α'_{-1} + ……..+ α'_{-5})				(599.1624) **				(417.9587) **

Note: Figures in parenthesis are F and LR Statistics that test the joint significance of futures returns associated with market-wide dummies. $D_{m,t}$ represents the Dummy variable for market wide announcements. All t-statistics are adjusted with White's procedure. ** Significant at 0.01 level; * Significant at 0.05 level.

Table 8: Stock-specific Announcements and Lead-lag Relationship among the Spot and the Futures Markets Returns

Panel A: Simple NIFTY Cash Return

$$R_{s,t} = C_0 + \sum_{i=-5}^{+5} \alpha_i R_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i' D_{s,t} R_{f,t+i} + \delta Z_{t-1} + \varepsilon_t$$

	FUTIDX Coeff.	t-stat	Stock-specific Dummies $D_{s,t}$ Coeff.	t-stat
Intercept	0.0000	-0.1208	-	-
α_{-5}	0.0010	1.8653	-0.0005	-0.3727
α_{-4}	0.0018*	2.4626	-0.0023	-0.9370
α_{-3}	0.0033**	3.0910	-0.0018	-0.7161
α_{-2}	0.0050**	3.9467	-0.0010	-0.3864
α_{-1}	0.0069**	4.7440	0.0031	1.1493
α_0	0.0087**	5.7778	0.0041	1.5026
α_1	0.0087**	5.5491	0.0063*	2.1276
α_2	0.0069**	4.8931	0.0043	1.5817
α_3	0.0044**	3.8466	0.0006	0.3225
α_4	0.0026**	3.2938	-0.0025	-1.3159
α_5	0.0010*	2.0537	-0.0041	-1.8804
ECT	0.0000	-0.5782	-	-
F $_{Lead}$ **(α´$_{+1}$ + ……..+ α´$_{+5}$)**				(12.7521) **
LR $_{Lead}$ **(α´$_{+1}$ + ……..+ α´$_{+5}$)**				(63.7468) **
F $_{Lag}$ **(α´$_{-1}$ + ……..+ α´$_{-5}$)**				(5.2880) **
LR $_{Lag}$ **(α´$_{-1}$ + ……..+ α´$_{-5}$)**				(26.4479) **

Panel B: NIFTY Cash Return Innovations

$$R^I_{s,t} = C_0 + \sum_{i=-5}^{+5} \alpha_i R_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i' D_{s,t} R_{f,t+i} + \delta Z_{t-1} + \varepsilon_t$$

	FUTIDX Coeff.	t-stat	Stock-specific Dummies $D_{s,t}$ Coeff.	t-stat
Intercept	0.0000	-0.0055	-	-
α_{-5}	0.0010*	2.0081	0.0002	0.1729
α_{-4}	0.0017*	2.4464	-0.0014	-0.5606
α_{-3}	0.0029**	2.9695	-0.0008	-0.3297
α_{-2}	0.0041**	3.5139	-0.0009	-0.3495
α_{-1}	0.0054**	4.0284	0.0028	1.1062
α_0	0.0075**	5.4812	0.0030	1.1595
α_1	0.0076**	5.3362	0.0054	1.9330
α_2	0.0062**	4.7378	0.0043	1.6528
α_3	0.0040**	3.7507	0.0016	0.8713
α_4	0.0024**	3.2944	-0.0010	-0.5484
α_5	0.0009*	1.9750	-0.0042	-1.9568
ECT	0.0000	-1.4032	-	-
F $_{Lead}$ **(α´$_{+1}$ + ……..+ α´$_{+5}$)**				(11.9915) **
LR $_{Lead}$ **(α´$_{+1}$ + ……..+ α´$_{+5}$)**				(59.9479) **
F $_{Lag}$ **(α´$_{-1}$ + ……..+ α´$_{-5}$)**				(4.2410) **
LR $_{Lag}$ **(α´$_{-1}$ + ……..+ α´$_{-5}$)**				(21.2130) **

Note: Figures in parenthesis are F and LR Statistics that test the joint significance of futures returns associated with stock specific dummies. $D_{s,t}$ represents the Dummy variable for stock-specific announcements. All t-stat are adjusted with White's procedure. ** Significant at 0.01 level;* Significant at 0.05 level.

Table 9: Different Types of Announcements and Lead-lag Relationship among Spot and the Futures Markets Volatility

Panel A: Impact of Market-wide Announcements

$$\sigma_{s,t} = C_0 + \sum_{i=-5}^{+5} \alpha_i \sigma_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i{}' D_{m,t} \sigma_{f,t+i} + \varepsilon_t$$

	σ_{FUTIDX} Coeff.	t-stat	$D_{m,t}$ Coeff.	t-stat
Intercept	0.00034**	57.60987	-	-
σ_{-5}	0.00051*	2.74019	-0.00076	-0.95105
σ_{-4}	0.00036	1.62808	-0.00316**	-3.70005
σ_{-3}	0.00056*	2.39994	-0.00010	-0.11510
σ_{-2}	0.00040	1.71796	-0.00051	-0.60520
σ_{-1}	0.00052*	2.20221	0.00038	0.45951
σ_{0}	0.00031	1.30511	0.00564**	6.76785
σ_{1}	0.00075**	3.18699	0.00946**	11.43348
σ_{2}	-0.00013	-0.56572	0.00442**	5.38240
σ_{3}	0.00096**	4.14309	0.00781**	9.49376
σ_{4}	0.00003	0.15410	0.00191*	2.31404
σ_{5}	0.00082**	4.37349	0.00823**	10.95975

Panel B: Impact of Stock-specific Announcements:

$$\sigma_{s,t} = C_0 + \sum_{i=-5}^{+5} \alpha_i \sigma_{f,t+i} + \sum_{i=-5}^{+5} \alpha_i{}' D_{s,t} \sigma_{f,t+i} + \varepsilon_t$$

	σ_{FUTIDX} Coeff.	t-stat	$D_{s,t}$ Coeff.	t-stat
Intercept	0.00032**	51.54263	-	-
σ_{-5}	0.00082**	4.23269	-0.00077	-0.93508
σ_{-4}	0.00033	1.45652	0.00028	0.29650
σ_{-3}	0.00094**	3.97512	-0.00176	-1.87151
σ_{-2}	0.00053*	2.21343	0.00077	0.80635
σ_{-1}	0.00082**	3.39797	0.00018	0.18934
σ_{0}	0.00066*	2.75022	0.00174	1.84224
σ_{1}	0.00137**	5.70411	0.00371**	3.95203
σ_{2}	0.00016	0.64501	0.00086	0.91776
σ_{3}	0.00167**	7.08700	0.00193*	2.07296
σ_{4}	0.00014	0.63013	0.00017	0.17990
σ_{5}	0.00157**	8.15886	0.00405**	4.93892

Note: Here absolute value of return in both the spot and the futures markets has been taken as the volatility measure (σ).$D_{m,t}$ represents the Dummy variable for market wide announcements. $D_{s,t}$ represents the Dummy variable for stock-specific announcements. ** Significant at 0.01 level;* Significant at 0.05 level.

Appendix A

Description of Information Released:

This appendix deals with a sample of market-wide and stock specific information released during the sample period and also the method developed by Ederington and Lee (1993) and applied by Frino (2000) to categories and filter various types of information that are considered to be relevant in the present study. To filter out the major market-wide and stock-specific announcements separately, a specific measure of return volatility is regressed on dummy variables representing different categories of information. Since there is no readymade source to supply such information categorically, an effort is made to categories the available information (both market-wide and stock-specific) based on the type of such information and their importance on the market or on the specific stocks. Absolute value of return both in spot and futures market are taken to be as a proxy for the return volatility in the spot and futures market respectively. Due to the non-availability of sufficient data, only 6 and 8 dummy variables are constructed for the market-wide and stock-specific information respectively. Since the present study deals with minute-by-minute data in spot and futures market, the announcement (whether market-wide or stock-specific) released in the market may have some impact also for some time after the exact time when they are released in the market. Therefore, each dummy variable takes on a value of 1 if observation t (here t denotes each minute's observation) relates to an interval lies within a half an hour either side of a major or significant category of information release and 0 otherwise [Frino (2000)]. In order to find out the relevance of any category of information, volatility measure in the futures market and the volatility measure in the spot market have been regressed separately on the dummy variables representing the market-wide and stock-specific information respectively. Now, based on the t-statistics [adjusted with White's (1980) procedure], as shown in Table A.1, the significant category of information have been filtered out and taken into consideration to find out the impact of market-wide and stock-specific information on the lead-lag relationship among the spot and the futures market.

Different categories of information along with the total number of announcements falls under different category and also the number of company or stocks declared such information, and the regression coefficients along with their t-statistics have been reported in Table A.1. Out of 6 types of market-wide and 8 types of stock-specific information, only 4 types in both the cases are proved to be significant at 1% or 5% level of significance. It is to be noted here that out of fifty most active stocks during 2004 – 2005 (as per NSE Record), thirty-six of them have been considered here.

Table A.1:

Type of Announcements Released in the Market and their Relevance

Panel A: Market wide Information Releases				
	Regression			
Announcement	**Coefficient**	**White adj. t-stat**	**Number**	**Stocks**
Activities of FIIs	0.00328	5.93840**	80	-
Activities of MFs	0.00183	2.29254*	46	-
Change in Inflation Rate	-0.00110	-1.71236	12	-
Change In International Oil Price	0.00125	1.63316	18	-
Change in Foreign Exchange Reserve	0.00415	2.89881**	9	-
RBI Regulation	0.01053	4.42547**	8	-
Panel B: Stock-specific Information Releases				
	Regression			
Announcement	**Coefficient**	**White adj. t-stat**	**Number**	**Stocks**
Takeover and Disinvestment	0.00021	4.30718**	22	14
Quarterly Activities Report	0.00011	5.42077**	68	33
Asset Acquisition and Disposal	0.00043	4.65966**	22	20
Company Administration	0.00000	-0.02182	38	23
Issued (including Bonus Issue) Capital	0.00005	1.34215	8	6
Dividend Announcement	0.00016	4.00909**	26	15
Other	0.00022	1.79432	3	3
Progress Report	-0.00002	-0.83579	7	5

Note: 'Number' represents the total number of announcements under the specific category (either market-wide or stock-specific); and 'Stocks' denotes the number of companies released such information. In panel A the volatility estimator (Absolute value of return) in the Futures market is regressed on the dummies representing the different types of market wide information. Panel B deals with regressing the absolute value of return in the spot market on the dummy variable representing different types of stock-specific announcements.
All the t-statistics are adjusted with white's (1980) correction for hetroskedasticity and autocorrelation.
** Significant at the 0.01 level; * Significant at the 0.05 level.