Chapter-2:

Price Discovery in Equity Derivatives Market: A Literature Survey

2.1 Introduction

Price discovery is the process through which market incorporates new information into asset prices and drives it towards new equilibrium price. In the market microstructure literature, price discovery has been defined as, “process of finding market clearing price” (Madhavan, 2000), and “the search for an equilibrium price” (Schreiber and Schwartz, 1986). The Efficient Market Hypothesis claims that prices reflect all available information with immediacy; therefore, making an abnormal profit is not possible. However, it is well established in the literature that markets lead/lag in impounding information when an asset trades in multiple markets.

The process of impounding new information into prices remains unclear and is referred as “Black Box” in the literature (Madhavan, 2000), particularly when the same or related assets trade at more than one market. No two markets are alike in price discovery due to their differences in types of orders permitted, liquidity, initial cash outlay, transparency (Madhavan, 2000). Trading incentives like reduced capital requirement, lesser transaction cost, absence of short selling restrictions and limited downside risk, make derivatives market a preferred place to trade for informed traders (Black, 1975), thereby, making it to influence the prices in the underlying market. Whether the role of equity derivatives in information transmission is theoretically justified and empirically supported, remains inconclusive even after being the centre of attention of many researchers. This part of the study is an attempt to provide a
comprehensive survey of existing literature (both theoretical and empirical) on the dynamics of interaction between spot and derivatives market.

2.2 Literature Review

Research exploring informativeness of derivatives originates from the theoretical proposition of Black (1975). The author argues that there are compelling reasons like lesser transaction cost, lesser upfront money requirement, lesser trading restrictions and limited downside risk, for growing popularity of options trading and thereby attracting informed traders. Therefore, the prices and trading activity of options market should be informative about future price movements of the underlying assets. An impressive range of researchers have tested Black’s theoretical proposition empirically using different set of variables and have reported conflicting results. The existing studies can be classified into different categories based on variables used and reported findings:

2.2 (a) Studies Based on Price Variable

A series of studies examine the price to price relationship between derivatives market and the market of the underlying assets and show that the prices in derivatives market lead the prices in spot market. Manaster and Rendleman (1982) study the role of call options prices to predict the prices of underlying stocks covering the period of three years immediately after foundation of CBOE (the first US options exchange) in 1973. They use closing price data of all options and underlying stocks (172 stocks) traded on various options exchanges in US during 26th April 1973 to 30th June 1976 and employ Black and Scholes (BS) model of options pricing in their study. They compute implied spot price by inverting the BS\(^1\) equation and calculate pricing

\[ \text{implied spot price} = \frac{\text{call option price}}{\text{strike price}} \]

\(^{[1]}\) To estimate the options market's assessment of the equilibrium stock price, while at the same time avoiding the difficulties associated with errors of measurement in standard deviations, implied stock prices and implied standard
error as the difference between actual and implied prices. They form quintiles based on ranking of errors and subsequently calculate average daily portfolio returns for the entire study period (801 trading days). Based on the argument of options prices being informative (implicit spot prices should guide the actual spot prices); they expect that lower/higher ranked portfolio should give lower/higher returns consistently. They find the means of portfolio returns to be significantly different across portfolios and increasing with portfolio ranks. They alternatively confirm the mean comparison results employing a non parametric chi-square test. They conclude that call options prices are partially informative about future spot market prices.

Chan (1992) studies the intraday lead lag relation using returns of Major Market Index (MMI), MMI futures and S&P 500 futures index. Besides studying the pooled data, the lead lag pattern under different conditions like Good vs. bad news, relative intensity of trading activity and extent of market wide movement are also studied. Multiple regression frameworks are used where lead and lag terms of future index returns are explanatory variables and return on the index is endogenous. Moreover, the study also explores if the relationship for the individual constituent stocks differs from that of the index. Strong evidences of futures market leading or impounding the information first are reported, but the lead pattern is found changing with change in conditions. Two time periods Aug 1984-Jun 1985 and Jan-Sep 1987[^2] are used to investigate the change in relationship with time and it is observed that though futures market still leads but lead span shortens during Jan-Sep1987. This shows that the inefficiency in the market tends to

[^2] The author has not specified any particular reason for the gap between the two periods examined in the study. However, it is mentioned that the auto-correlation of short interval returns is found declining over time in the literature which implies that development in trading rules and practices improves the information processing ability of the markets. They include 1987 period to verify the above along with the robustness of observed lead lag pattern.
disappear as the time progresses and also strengthens the argument of market participants not being indifferent with changing conditions and environment.

Fleming, Ostdiek and Whaley (1996) study the relative rate of price discovery in stock, futures and options market and provide a trading cost based explanation for it. The trading cost hypothesis states that market with smaller trading cost should react faster to the new information. Therefore, firm specific information should be reflected in stock market first because taking a synthetic stock position with similar payoff using derivatives would cost more. On the other hand trading on market wide information should first take place in derivatives market because trading index futures and options is easier and less costly than trading basket of stocks. They mention that trading S&P 500 futures cost only 3% of what trading equivalent portfolio of stocks cost. The trading cost and the leverage hypotheses don't go hand in hand for firm specific information. They compare the trading cost of S&P 500 stock index, S&P 100 stock Index, S&P 500 index futures, S&P 100 Index call and put options and form four hypotheses: First, stocks lead stock options; second, stock futures lead stocks; third, Index options lead stocks and fourth, index futures lead index options. To test the hypotheses they use five minutes interval data for the period January 1988 to March 1991 and employ multiple regression model inclusive of error correction term for both the raw returns and the return innovations (generated using ARMA (2, 3) to control for infrequent trade and micro-structural effect). They use generalized method of moments (GMM) estimation technique and find that results are in alignment with trading cost structure as hypothesized.

Jong and Donders (1998) study the lead lag relationship between Amsterdam Exchange (AEX) cash index, index futures and index options market obtaining data from European Options
Exchange (EOE) over the period July 1992 to June 1993. They compute implied index values from futures and options data inverting cost of carry (COC) and BS options pricing models respectively and use them in separate regression models for futures and options respectively. They employ high frequency near term contract data and use serial and cross correlations measures to determine lag lengths. They report a prominent leading futures market compared to cash and options market however, they also find evidences of strong contemporaneous relationship. The lead of options over cash market is found to be symmetric meaning neither of the markets leads systematically. They attribute the results to the trading benefits associated with derivatives and argue that reason of futures leading both cash and options could simply be the leverage. They argue that the leverage of futures is almost twice as large as that of a short maturity at-the-money call options.

Brooks, Garrett and Hinich (1999) propose an alternative approach to examine the lead lag relationship between stock and stock index futures market using data of FTSE100 and S&P500 index from UK and US markets respectively. They argue that the results using the traditional method of testing lead lag relationship based on Sims (1972) are subject to overstating the strength of the relationship due to presence of nonlinearity\(^3\) in data which is well documented in literature. They point out that other than the nonlinear characteristics, issues like nonsynchronous trading and the stability of parameter assumed for longer periods are also questionable. To test the relationship they split the data into a series of windows of length 35

\(^3\) Besides the literary evidence of time series data exhibiting non linear behaviour, the authors provide economic reason of nonlinearity present in the pricing relationship of spot and futures market. For example, arbitrage triggers when futures price deviates from fair value (given by observed stock price adjusted for dividend and cost of carry) in absence of transaction cost. However, in reality, transaction cost does exist which creates a bound within which any deviation doesn't trigger arbitrage. This creates a threshold wherein the relative difference between the prices of the two markets can fluctuate without triggering arbitrage and can make the relationship nonlinear.
observations and use cross correlation measures of estimation. They conclude that futures market lead cash market for few periods and the lead doesn't last for long. Reported results are contrary to traditional findings and suggest presence of information content in derivatives but doesn't provide significant profitable opportunities.

Booth, So and Tse (1999) use intraday data of DAX Index, its futures (FDAX) and options (ODAX) to examine which of the markets is informationally dominant. They follow Gonzalo and Granger (1995) Information Share approach where the common factor is expressed as a function of prices in different markets. They report that DAX and FDAX jointly contribute 98% to the common factor out of which 50% is contributed by FDAX alone. ODAX contribution is found to be small but statistically significant. They attribute the results to transaction cost hypothesis.

Gwylim and Buckle (2001) study the lead lag relationship between FTSE 100 stock index, its futures and options using hourly return. They report both the futures and options market leading spot market but call market being the most prominent among all three. Hsieh et al. (2008) study the relationship in Taiwan market between spot, futures and options implied price (calculated using Put-Call Parity (PCP) relationship) of index and have reported the derivatives market to be informationally non trivial.

Chen et al (2005) and Chan et al. (2009) study the lead lag relationship between spot returns and trading value ratio[^4] in US and Taiwan markets respectively. Besides studying in aggregate,

[^4]: Chen et al. developed a model and created a measure called VR (ratio of volume weighted price) to discriminate between good and bad news attached to options trades for more details refer Chen et al [2005], page no.5.
they also segregate the sample based on factors like options moneyness, market cycle, and liquidity, and have shown the options market to be informative. Chen et al (2005) develop an analytical framework establishing that trading value ratio of call to put signify the ratio of unobservable probabilities of price increase to price decrease. A ratio greater/smaller than unity would indicate positive/negative information. They use BVAR (Bi-variate auto regressive) model to examine the relationship. OTM\[^{5}\] options are reported to be the favourite of informed traders as lead is found more pronounced in case of OTM options in both the studies. They show that relationship between spot and options market prices is subject to change with different factors and conditions which implies changing preference of informed traders.

Theissen E. (2011) studies the price discovery in spot and futures market using intraday data of DAX Index, its futures and DAX ETF (exchange traded fund) from German market. The author uses modified threshold error correction model (TECM) that allows for arbitrage opportunities to have impact on returns dynamic and accounts for time varying transaction costs. The author points that ECM approach used in previous studies suffer from problems like price staleness (all component stocks of the index not trading frequently) that introduces serial correlation of index return resulting into spurious regression estimates. The assumption of constant co-integration relationship over time may not be holding too. ECM also assumes speed of price adjustment towards equilibrium price is independent of size of deviation which is incorrect because transaction cost creates a bound within which arbitrage is not possible. Using mid quotes, the author removes the problem of serial correlation and defines arbitrage signal as difference in

\[^{5}\] Options can be divided into three categories namely ATM (At-the-Money), OTM (Out-of-the-Money) and ITM (In-the-Money). In both of the studies ITM/OTM call options are options with strike price ranging from 80/105 to 95/120 percent of price in the spot market and ITM/OTM put options are options with strike price ranging from 105/80 to 120/95 percent of underlings’ price. ATM options are options with strike price ranging between 95 to 105 percent of price in underlying market. Data of near month contract was used for the study due to liquidity concerns.
price deviation and time varying transaction cost. Dummy variable take the value of 1 if arbitrage triggers and 0 otherwise to capture the impact of size of deviation. Contribution to price discovery of the markets is computed using common factor weight measure. Using transaction prices in traditional system the study finds the contribution of the futures and the spot market 71.7%, 98.5% and 28.3%, 1.5% for DAX spot and DAX ETF respectively. When mid quotes are used, the ratio changes to 59.8%, 91.1% and 40.2%, 8.9% respectively which provides evidence of spurious estimates in using transaction data.

Bhattacharaya (1987), Stephen and Whaley (1990), Chan, Chung and Johnson (1993), Holowczak, Simman and Wu (2007) have reported conflicting views about information content of derivatives prices. Bhattacharya (1987) criticizes the findings of Manaster and Rendleman (1982) reporting that use of daily data can't trace shorter leads. Using intraday bid and ask quote implied bid and ask quotes are calculated and simulated trading is conducted based on arbitrage signals. The study finds prices in options market informative but not enough to cover even the transaction cost and doesn't provide any profitable opportunities. The author indicates that despite the trading incentives provided by derivatives market, restrictions like prohibiting institutional participants from trading options in many markets works as a counter to options preference argument. Moreover, in absence of budgetary constraint, an informed trader would place his trade in both markets simultaneously. The limited downside risk when the private information turns out to be incorrect, seems to be the only advantage that could give a lead to the options market.
Stephen and Whaley (1990) study relationship between actual spot price and options implied price changes for American firms and report spot market leading. Chan, Chung and Johnson (1993) study options using non linear lead lag regression model where the lead lag coefficient is always multiplied by options delta in the regression model. They report similar results to that of Stephen and Whaley (1990). They argue that the mechanism of tick size deters the options price to move immediately after a small change in spot price due to the fact that the resultant theoretical move in options price itself becomes lesser than the tick size. It takes more than one small move to spot price, in the same direction, for the options to trade which may cause the options market to follow rather than lead.

Holowczak, Simman and Wu (2007) study the price discovery in US stock and stock options market using portfolio approach. They argue that options prices are not only affected by underlying price but also by its volatility and it is difficult to separate the impact of the two. They suggest creating a portfolio by buying a call and selling a put at the same strike price which makes the payoff linear and that depends only on change in price level of underlying assets. They select 40 highly traded stocks with most actively traded options for the period May to July 2002. They calculate \( CP_t = C_t - P_t \) or \( (C_t - P_t) \), where \( C_t \) is call price and \( P_t \) is put price, and regress stock price against \( CP_t \). They use the parameters of the regression to estimate implied stock price and then use actual and implied prices in their price discovery analysis using Hasbrouck's Information Share(IS)\(^6\) approach and Gonzalo and Grangers (1995) common

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\(^6\) Hasbrouck (1995) develops a method to measure the contribution of each market to the total price discovery for an asset if same or closely linked securities are trading at multiple places. He argues that assets trading at more than one place share a common efficient price besides the innovations of the market which they trade on. His information share measure is based on decomposition of variance of changes in the efficient price. He defines information share as proportional contribution of that market’s innovation to the innovations in the common efficient price.
factor approach (CFP). They find evidences of price discovery on the directional movement happening in both markets but the share was less for many stocks in case of options market. They mention that low information share of options may be due to large transaction cost because a trader won’t place his trade until his benefits overweight the cost. They propose a vector error correction model (VECM) conditioned on magnitude of stock price moves and find the options market becoming significantly more informative for large price moves. They also examine if the information content of options market changes with time using a sample of small period i.e. March 2006. They argue that if trading cost is the main reason to trade options then options market should have better information because it has grown faster and has become more efficient with time due to market developments and technological advancements. They find the similar results of stock market containing better information content. Despite the phenomenal growth the trading activity still remains thinner in options (especially stock options) and as the options market maker needs to adjust options quotes after every price change in stock irrespective of options trade, it increases quote to trade ratio dramatically. They conclude that price discovery on directional movement still occurs more in stock market than in options market.

2.2 (b) Studies Based on Trading Activity Variables

Besides price to price linkage of the two markets, several studies have been conducted to ascertain the relationship using other variables that measure options market activity like options volume, open interest, number of transactions (Anthony (1988), Stephen and Whaley (1990), Bhuyan and Chaudhary (2001) Chan, Chung and Fong (2002)) and have revealed mixed results.

[7] It focuses on components of common factor and error correction process.
[8] The total number of options and/or futures contracts that are not closed or delivered on a particular day
Anthony (1988) studies the volume to volume relationship \[^9\] for 25 American firms using pair-wise granger causality test and reports one day lead of options over spot. Bhuyan and Chaudhary (2001) study the information content of options open interest in US market. They argue that the distribution of open interest on different strike prices represent overall belief of traders about equilibrium price of the assets at maturity. They take sample of 30 stocks from different sectors such as technology, healthcare, energy, consumer products, and services which are traded on NASDAQ and NYSE and also represent major market indices. They calculate options open interest based predictors (a weighted average of open interest at different strike prices). They consider various trading strategies after comparing actual and predicted stock prices at maturity and report predicting accuracy. The open interest based trading strategies are found producing significant higher returns than buy and hold strategy.

However, Stephen and Whaley (1990), Chan et al. (2002) have reported contrasting results. Stephen and Whaley (1990), in their study measure trading activity by trading volume and number of transactions alternatively. They use lead lag regression where options market activity is regressed against lead and lag terms of spot market activity and report that trading in call options lags trading in underlying. Chan et al. (2002) study the intraday relationship between quote return and net traded volume of stock and options market and report strong evidence of information flow from Stock market to options market. They use multivariate VAR model having system of six regression equations improving upon Hasbrouck (1991) VAR system of two equations. They use three quote return variables calculated using stock, call and put prices and three corresponding trading volume variables in the model. They argue that stock market is

\[^9\] Volume data for pair-wise causality test were pre-whitened to be free from market effect and were tested for time series properties.
leading due to less illiquid options market that restrains informed traders from trading options. They report little evidence of information trade in options market and conjecture that if at all informed traders place their trade in options market, they submit limit orders due to higher spread of options that may reduce their information benefit of the trade substantially. When the order improves market bid or ask due to trade initiation by uninformed or liquidity traders, the quote revision may be informative. They deny aggressive trade of options by informed traders.

2.2 (c) Studies Based on Measures of Market Turbulence

Measures of market turbulence like implied volatility, conditional volatility have been used in many studies examining the link between the spot and the options market (i.e. Latane and Rendleman (1975), Chiras and Manaster (1978), Beckers (1981), Day and Lewis (1992), Canina and Figlewski (1993), Chen, Cuny and Haugen (1995), Kyriacou and Sarno (1999), Mayhew and Stivers (2002), Sarwar (2005), Ni, Pan and Poteshman (2008)). Studies on this stream are based on the argument that a trader having private information about future volatility can only bet on information in options market which in turn affects the trading activity in options market.

Latane and Rendleman (1975) examine the information content of implied volatility about options prices. They employ weighted implied standard deviation (WISD) as a measure of market forecast of return variability computed by weighting the implied volatility of series of options on a given day by sensitivity of options price to implied volatility. They use options data of 24 companies listed on CBOE and address three main objectives. First, they study the usefulness of WISD in identifying over or under priced options and thereby reducing risk in hedge positions. Second, they examine relationship between WISD and ex-post volatility and third, they test the stability of the cross sectional average of WISD. The portfolio based on WISD
price projections produces significant abnormal returns which confirms the usefulness of WISD in determining proper hedge positions and identifying over and under priced options. They report significant correlation between WISD and ex-post volatility which proves WISD as a better estimate of future volatility. Regarding the stability of cross sectional average of WISD they report tendency of volatility to move together with time.

Chiras and Manaster (1978) compare the predictability of historical volatility and weighted implied volatility for future stock return variance using a simple regression model. They report that options implied volatility is a better predictor of realized stock returns volatility. Beckers (1981) studies the predictive accuracy of implied standard deviation (ISD) for future price variability by regressing the standard deviation of daily stock returns against the implied standard deviation in a simple regression framework. They report that options implicit standard deviation is an efficient measure of future price variability. However, Canina and Figlewski (1993) study the S&P 100 Index options for the period March 15, 1983 to March 28, 1987 and document that implied volatility (IV) computed using BS options pricing formula results in inferior estimate of market's future volatility forecast, when compared to historical volatility.

Chen et al. (1995) study the relationship between stock volatility, basis [10] and open interests in futures market using S&P 500 Index. They base their study on the intuition that when volatility increases in the market, investors prefer to entice more people in the market for risk sharing. Those investors reduce their risk exposure not only by selling their stock upholding alone but also by selling related futures contract. Such activity may result in decreasing basis and

[10] They define *basis* as the difference between the market futures price and fair futures price where fair futures price is cash price index grossed up by risk free rate and adjusted for expected dividends.
increasing open interest due to enhanced participation into the market. They run separate regressions for basis and open interest and find that increase in expected volatility results in decrease in basis and increase in open interest.

Kyriacou and Sarno (1999) examine the dynamic relationship between derivatives trading and volatility of the underlying asset using daily data of FTSE 100 Index, its futures and options. The trading activity is measured by daily futures and options volume standardized by open interest whereas cash index volatility is estimated alternatively by adjusted daily price changes (ADPR), daily price changes (DPR), squared return (SQRET) and GARCH(1,1). They follow Koch (1993) and use simultaneous equation model to examine the relationship as opposed to vector-auto regression (VAR) which doesn't allow for simultaneity and possibly can cause misspecification problems. They report that expected future volatility, futures volume and options volume are determined in a system of equations that allows for both simultaneity and feedback.

Mayhew and Stivers (2002) study the information content of implied volatility about firm level volatility using options data on 50 most highly traded stocks listed on CBOE during 1988-1995. They report that for most actively traded options the implied volatility subsumes almost all information about firm level volatility. However, their results are termed biased and cannot be generalized across all the stocks traded in the market as the sample of the study involves only actively traded stocks. Sarwar (2005) studies the relationship between expected future volatility of S&P 500 Index and aggregate options volume. He conducts the study separately for call and put options and also for moneyness classes. He reports strong feedback relationship between the
options volume and expected future volatility overall however, results for at-the-money (ATM) and out-of-the-money (OTM) options are found to be more pronounced.

Ni, Pan and Poteshman (2008) study whether options volume is informative about future volatility of the underlying assets. They employ unique dataset of stock options trade provided by CBOE over the period of 1990 to 2001. They argue that if the options volume is informative about future stock volatility then non market maker net demand for volatility should be positively related with future stock volatility. They compute the non market maker demand for volatility by aggregate sum of net (buy-sell) options volume (both call and put) weighted by options vega\(^{11}\) across strike prices. They test the relationship using multiple regression framework where realized volatility is regressed against non market maker demand for volatility along with a set of control variables (i.e. lags of RV, lags of implied volatility, dummy for earning announcement date, stock volume and options volume). They report significant positive relationship between options non market maker demand for volatility and subsequent realized volatility. They further argue that some options market trades represent bets both on volatility and direction (for example, a call buyer benefits both from increasing stock price and increase in volatility) whereas other trades like straddle\(^{12}\) primarily bet only on volatility. If the predictability reported earlier is due to informed volatility trading then the straddle type of trades should have stronger predictability. They conduct tests for the above argument and find evidence in support.

\(^{11}\) Vega is defined as the sensitivity of options prices towards changes in the volatility of the underlying assets. Vega is most sensitive for at-the-money options.

\(^{12}\) Straddle is an options trading strategy where a trader buys a call and sells a put with same strike price and maturity.
2.3 Conclusions

In this study, we survey the literature on the role of equity linked derivatives in information diffusion leading to the price discovery of underlying assets. We don't find a complete consensus among researchers about the direction and speed of information flow between the spot market and the equity derivative markets i.e. Futures market and Options market. However, the corroborative empirical evidences about information content in prices and trading activities of equity linked derivatives dominates the literature. On methodological ground most of the studies are found to be using variants of granger causality and similar techniques to examine the interrelation in terms of information diffusion between the two markets despite its shortcomings as cited by Koch (1993). As far as Indian derivatives markets are concerned, it's considerable share in derivatives trading across exchanges (for example NSE, India ranked second in terms of trading index options contracts and its turnover and S&P CNX Nifty Index became the second most actively traded index around the world as per World Federation of Exchanges Survey Report of 2011) makes it attractive for similar studies and particularly for volatility informed trading which yet remains to be examined in the Indian context.

The important implications of this literature review on the function of derivatives (Figure-2.1 presents the important literature at a glance) can be highlighted as follows.

- Derivatives can no more be referred as redundant securities despite the fact that derivatives prices are primarily based on prices of underlying assets.

- It is possible that there are additional factors that affect the prices of derivatives securities but not given proper consideration in literature. Recent empirical evidences
may help in determining such factors to improve on the possible misspecification in existing pricing models leading to better understanding of functions of derivatives.

- Most of the research in this area is found to be focussed on examination of directional informed trading in derivatives. Studies examining trading of derivatives based on volatility informed trading are very few and are specific to developed markets. It would be useful to examine the information about future volatility in derivatives trading in the context of emerging markets due to their different efficiency levels and lax regulatory structure.

**Figure-2.1: Literature on the Informational Role of Derivatives at a Glance**
Theoretical Prediction: Options Markets are Venue for Information Based Trading. Black (1975),

Empirical Question: To what extent derivatives market affect price discovery on the spot market?

In the above figure we classify important previous studies based on the use of key variables and approaches and reported findings. We list them in chronological order in the flow chart.