Price Discovery in the Equity Derivatives Market : A Literature Survey

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Abstract

Price discovery is the process of incorporating new information to the price of the assets traded at a marketplace and determining the new equilibrium price. When homogeneous or closely linked securities trade at more than one market place, it is important to identify the market where price discovery takes place. Prominent role of derivatives market in price discovery has been recognized in literature by numerous researchers, resulting in conflicting empirical evidence. This study surveys the literature on the role of equity linked derivatives in information diffusion leading to the price discovery of underlying assets. We provide a comprehensive coverage of studies on information content of equity linked derivatives prices and trading activity vis-à-vis the direction of price movement and the return volatility of the underlying assets. The existing literature was not found to be in complete agreement about the direction and speed of information flow between the spot market and the equity derivatives markets, however, it substantiates that derivatives should no more be referred to as redundant securities either. The study provides an appendage on how the research area on functions of derivatives has evolved with a focus on its informational role.

Keywords: equity derivatives, information diffusion, price discovery

JEL Classification: G12, G13, G14

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Price discovery is the process through which the market incorporates new information into asset prices and drives it towards new equilibrium price. In the market microstructure literature, price discovery has been defined in ways such as, "process of finding market clearing price" (Madhavan, 2000), "the search for an equilibrium price" (Schreiber & 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 to as "Black Box" in the literature (Madhavan, 2000), particularly when the same or related assets trade in more than one markets. No two markets are alike in price discovery due to their differences in types of orders permitted, liquidity, initial cash outlay, and transparency (Madhavan, 2000). Trading incentives like reduced capital requirement, lesser transaction cost, absence of short selling restrictions, and limited downside risk make the derivatives market a preferred place to trade for informed traders (Black, 1975), thereby, making it influence the prices in an underlying market.

Whether the role of equity derivatives in information transmission is theoretically justified and empirically supported remains inconclusive even after being the center of attention of many researchers. The paper is an attempt to provide a comprehensive survey of existing literature (both theoretical and empirical) on the dynamics of interaction between the spot and derivatives market.

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Review of Literature

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

➲ **Studies Based on Price Variable :** A series of studies have examined the price to price relationship between the derivatives market and the market of the underlying assets and have showed that the prices in the derivatives market lead the prices in the spot market. Manaster and Rendleman (1982) studied the role of call options prices to predict the prices of the underlying stocks covering a period of 3 years immediately after the foundation of CBOE (the first U.S. option exchange) in 1973. They took a sample of 172 stocks and used the Black and Scholes (BS) model in their study. They computed implied spot prices by inverting the BS [1] equation and calculated the pricing error as the difference between the actual and implied prices. They formed quintiles based on ranking of errors and subsequently calculated the 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 expected that lower/higher ranked portfolios should give lower/higher returns consistently. They found the means of portfolio returns to be significantly different across portfolios and the means increased with portfolio ranks. They alternatively confirmed the mean comparison results by employing a non parametric chi-square test. They concluded from their study that call options prices are partially informative about future spot market prices.

Chan (1992) studied the intraday lead lag relation using indices. The author used returns of MMI cash index, MMI futures index, and S&P 500 futures index in the study. Besides studying the aggregated data, the lead lag pattern under different conditions like good vs. bad news, relative intensity of trading activity, and extent of market wide movement were also studied. Multiple regression frameworks were used where lead and lag terms of future index returns were the explanatory variables and return on the index was endogenous. Moreover, the study also explored whether the relationship for the individual constituent stocks differed from that of the index. Strong evidence of the futures markets leading or impounding the information first have been reported, but the lead pattern was found changing with change in conditions. Two time periods - August 1984- June 1985 and January - September 1987 were used to investigate the change in relationship with time, and it was observed that though the futures market still leads, but the lead span shortened during Jan- Sep1987. This shows that the inefficiency in the market tends to disappear as the time progresses, and this evidence also strengthens the argument of market participants not being indifferent to changing conditions and environment.

Fleming, Ostdiek, and Whaley (1996) studied the relative rate of price discovery in stock, futures, and options markets and provided a trading cost based explanation for it. The trading cost hypothesis states that the market with smaller trading cost should react faster to new information. Therefore, firm specific information should be reflected in the 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 the derivatives market because trading index futures and options is easier and less costlier than trading a basket of stocks. They mentioned that trading S&P 500 futures would cost only 3% of what trading equivalent portfolio of stocks cost. The trading cost and the leverage hypotheses do not go hand in hand for firm specific information. They compared 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 formed four hypotheses: First, stocks lead stock options; second, stock futures lead stocks; third, index options lead stock; and fourth, index futures lead index options. To test the hypotheses, they used 5-minute interval data for the period from January 1988 to March 1991 and employed the multiple regression model inclusive of the 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 used the generalized method of moments (GMM) estimation technique and found that as hypothesized, the results were in alignment with the trading cost structure.

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

Brooks, Garrett, and Hinich (1999) proposed 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 the U.K. and U.S. markets respectively. They argued that the results using the traditional method of testing the lead lag relationship are subject to overstate the strength of the relationship due to the presence of nonlinearity in the data, which is well documented in literature. They reasoned that arbitrage is triggered when futures prices deviate from fair value (given by observed stock price adjusted for dividend and cost of carry) in the absence of transaction costs. However, in reality, transaction costs do exist, which create a bound within which any deviation does not trigger arbitrage. Other than the explanation of nonlinear characteristics, issues like non-synchronous trading and the stability of parameters assumed for longer periods were also questioned by the authors. To test the relationship, they split the data into a series of windows of length 35 observations and used cross correlation and cross bi-correlation measures of estimation. They concluded that the futures market leads the cash market for a few periods, and the lead does not last for long. The reported results were contrary to traditional findings and suggested the presence of information content in derivatives , but did not provide significant profitable opportunities.

Booth, So, and Tse (1999) used intraday data of DAX Index, its futures (FDAX), and options (ODAX) to examine which of the markets is informationally dominant. They followed Gonzalo and Granger's (1995) information share approach, where the common factor is expressed as a function of prices in different markets. They reported that DAX and FDAX contributed 98% to the common factor led by FDAX constituting 50%. ODAX's contribution was found to be small, but statistically significant. They attributed the results to the transaction cost hypothesis.

Gwylim and Buckle (2001) studied the lead lag relationship between FTSE 100 stock index, its futures, and options using hourly returns. They reported that both the futures and options markets lead the spot market, with the call market being the most prominent among all three. Hsieh, Lee, and Yuan (2008) studied the relationship in the Taiwan market between spot, futures, and options implied price (calculated using Put-Call Parity (PCP) relationship) of index and reported the derivatives market to be informationally non - trivial. Chen, Lung, and Tay (2005) and Chan, Chang, and Lung (2009) studied the lead lag relationship between spot returns and trading value ratio [2] in the U.S. and Taiwan markets respectively. Besides studying in aggregate, they also segregated the sample based on factors like option moneyness, market cycle, and liquidity, and showed the options market to be informative. Chen et al. (2005) developed 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 used the BVAR (bi-variate auto regressive) model to examine the relationship. OTM [3] options were reported to be the favourite of informed traders as lead was found to be more pronounced in case of OTM options in both the studies. The researchers showed that the relationship between spot and options market prices is subject to change with different factors and conditions, which imply changing preferences of informed traders.

Theissen (2011) studied the price discovery in spot and futures market using intraday data of DAX Index, its futures, and DAX ETF (exchange traded fund) from the German market. The author used the modified threshold error correction model (TECM) that allows for arbitrage opportunities to have an impact on returns dynamic and accounts for time varying transaction costs. The author pointed out that the ECM approach used in previous studies suffers from problems like price staleness (all component stocks of the index not trading frequently) that introduces serial correlation of index returns resulting into spurious regression estimates. The assumption of constant co-integration relationship over time may not be holding too. ECM also assumes that the speed of price adjustment towards equilibrium price is independent of size of deviation, which is incorrect because the transaction cost creates a bound within which arbitrage is not possible. Using mid quotes, the author removed the problem of serial correlation and defined an arbitrage signal as the difference in price deviation and time varying transaction cost. Dummy variables took the value of 1 if arbitrage triggered, and 0 otherwise to capture the impact of size of deviation. Contribution to price discovery of the markets was computed using the common factor weight measure proposed by Schwarz and Szakmary (1994). Using transaction prices in the traditional system, the study found the contribution of the futures and the spot markets to be 71.7%, 98.5% and 28.3%, 1.5% for DAX spot and DAX ETF respectively. When mid quotes were used, the ratio changed to 59.8%, 91.1% and 40.2%, 8.9% respectively, which provided evidence of spurious estimates in using transaction data.

Bhattacharaya (1987), Stephan and Whaley (1990), Chan, Chung, and Johnson (1993), Holowczak, Simman and Wu (2007) reported conflicting views about information content of derivatives prices. Bhattacharya (1987) criticized the findings of Manaster and Rendleman (1982) reporting that the use of daily data cannot trace shorter leads. Using intraday bid and ask quote implied that bid and ask quotes are calculated and simulated trading is conducted based on arbitrage signals. The study found that prices in the options market are informative, but are not enough to cover even the transaction costs and did not provide any profitable opportunities. The author said that despite the trading incentives provided by the derivatives market, restrictions like prohibiting institutional participants from trading options in many markets works as a counter to the option preference argument. Moreover, in the absence of budgetary constraints, an informed trader would place his trade in both markets simultaneously. The limited downside risk, when private information turns out to be incorrect, seems to be the only advantage that could give a lead to the options market.

Stephan and Whaley (1990) studied the relationship between actual spot prices and options implied price changes for American firms and reported spot market leading. Chan et al. (1993) studied options using nonlinear multivariate regression model and reported findings similar to that of Stephan and Whaley (1990). They argued that the mechanism of tick size deters the option price to move immediately after a small change in spot prices due to the fact that the resultant theoretical move in option prices itself becomes lesser than the tick size. It takes more than one small move to the spot price, in the same direction, for the options to trade, which may cause the options market to follow rather than lead.

Holowczak et al. (2007) studied the price discovery in the U.S. stock and stock options market using the portfolio approach. They argued that the options prices are not only affected by the underlying prices, but also by their volatility, and it is difficult to separate the impact of the two. They suggested 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 the change in price level of the underlying assets. They selected 40 highly traded stocks with the most actively traded options for the period from May to July 2002. They calculated $CP_t = C_t - P_t$ and regressed the stock price against CP_t. They used the parameters of regression to estimate the implied stock price and then used the actual and implied prices in their price discovery analysis using Hasbrouck's information share (IS) [4] approach and Gonzalo and Granger's (1995) common factor approach (CFP) (It focuses on the components of common factor and the error correction process.) . They found evidence of price discovery on the directional movement happening in both markets, but the share was less for many stocks in case of the options market. They mentioned that low information share of options may be due to large transaction costs, because a trader will not place his trade until his benefits outweigh the cost. They proposed a vector error correction model (VECM) conditioned on magnitude of stock price moves and found the options market becoming significantly more informative for large price moves. They also examined if the information content of the options market changed with time using a small sample for the month of March 2006. They argued that if the trading cost is the main reason, the options market should have better information because the options market has become more efficient, and it has grown faster too. They found similar results of stock market containing better information content. Despite the phenomenal growth, trading activity still remains thinner in options (especially stock options), and as the options market maker needs to adjust the options quotes after every price change in stock irrespective of option trade, this increases the quote to trade ratio dramatically. They concluded that price discovery on directional movement still occurs more in the stock market than in the options market.

➲ **Studies Based on Trading Activity Variables** : Besides price to price linkage of the two markets, several studies have examined the relationship using other variables that measure the options market activity like options volume, open interest [5], number of transactions (Anthony, 1988 ; Bhuyan & Chaudhary , 2005; Chan, Chung, & Fong, 2002 ; Savitha & Deepika, 2013 ; Stephan & Whaley, 1990) and have revealed mixed results.

Anthony (1988) studied the volume to volume relationship [6] for 25 American firms using pair-wise causality test and reported one day lead of options over spot. Bhuyan and Chaudhary (2005) studied the information content of options open interest in the U.S. market. They argued that the distribution of open interest on different strike prices represents the overall belief of the traders about the equilibrium price of the assets at maturity. Choosing 30 stocks from different sectors, which also represented major market indices (MMI), they calculated options open interest based predictors (a weighted average of open interest at different strike prices). They considered various trading strategies after comparing the actual and predicted stock prices at maturity and reported good predicting accuracy. The open interest based trading strategies were found to be producing significantly higher returns than the buy and hold strategy.

However, Stephan and Whaley (1990) and Chan et al. (2002) have reported contrasting results. Stephan and Whaley (1990) measured trading activity by two ways, namely trading volume and number of transactions. Using both variables, they reported that trading in call option lags trading in underlying. Chan et al. (2002) studied the intraday relationship between quote return and net traded volume of stock and options market and reported a strong evidence of information flow from the stock market to the options market. They used multivariate VAR model having a system of 6 regression equations improving upon Hasbrouck's (1991) VAR system of 2 equations. They used 3 quote return variables (calculated using stock, call, and put prices) and 3 corresponding trading volume variables in the model. They argued that the stock market was found to be leading due to less illiquid options market that restrains informed traders from trading options. They reported little evidence of information trade in the options market and conjectured that if at all informed traders place their trade in the options market, they submit limited 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 denied aggressive trade of options by informed traders.

Savitha and Deepika (2013) studied the efficiency of the sentimental indicators of financial derivatives in forecasting the movement of the market (NIFTY index) using open interest as a determinant of the price of the contract. Using the data from August 2011 to February 2012, they examined the correlation between the cumulative percentage changes in open interest and cumulative percent change in the price of the futures contract of the NIFTY index. They reported that the put call ratio is a useful contrarian indicator for future stock market behaviour.

➲ **Studies Based on Measures of Market Turbulence :** Measures of market turbulence like implied volatility and conditional volatility have been used in many studies examining the link between the spot and the options market (Beckers, 1981 ; Canina & Figlewski, 1993 ; Chen, Cuny, & Haugen, 1995 ; Chiras & Manaster, 1978 ; Day & Lewis, 1992 ; Jiang & Tian, 2005 ; Kyriacou & Sarno, 1999 ; Latane & Rendleman, 1976 ; Mayhew & Stivers, 2002 ; Ni, Pan, & Poteshman, 2008 ; Sarwar , 2005). Studies in this stream are based on the argument that a trader having private information about future volatility can only bet on information in the options market, which in turn affects the trading activity in the options market.

Latane and Rendleman (1976) examined the information content of implied volatility about option prices. They employed 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 the option price to implied volatility. They used options data of 24 companies listed on CBOE and addressed three main objectives. First, they studied the usefulness of WISD in identifying over or under priced options and thereby reducing risk in hedge positions. Second, they examined the relationship between WISD and ex-post volatility and third, they tested the stability of the cross-sectional average of WISD. The portfolio based on WISD price projections produced significant abnormal returns, which confirmed the usefulness of WISD in determining proper hedge positions and identifying over and under priced options. They reported significant correlation between WISD and ex-post volatility, which proved WISD to be a better estimate of future volatility. Regarding the stability of cross sectional average of WISD, they reported strong tendency of volatility to move together with time.

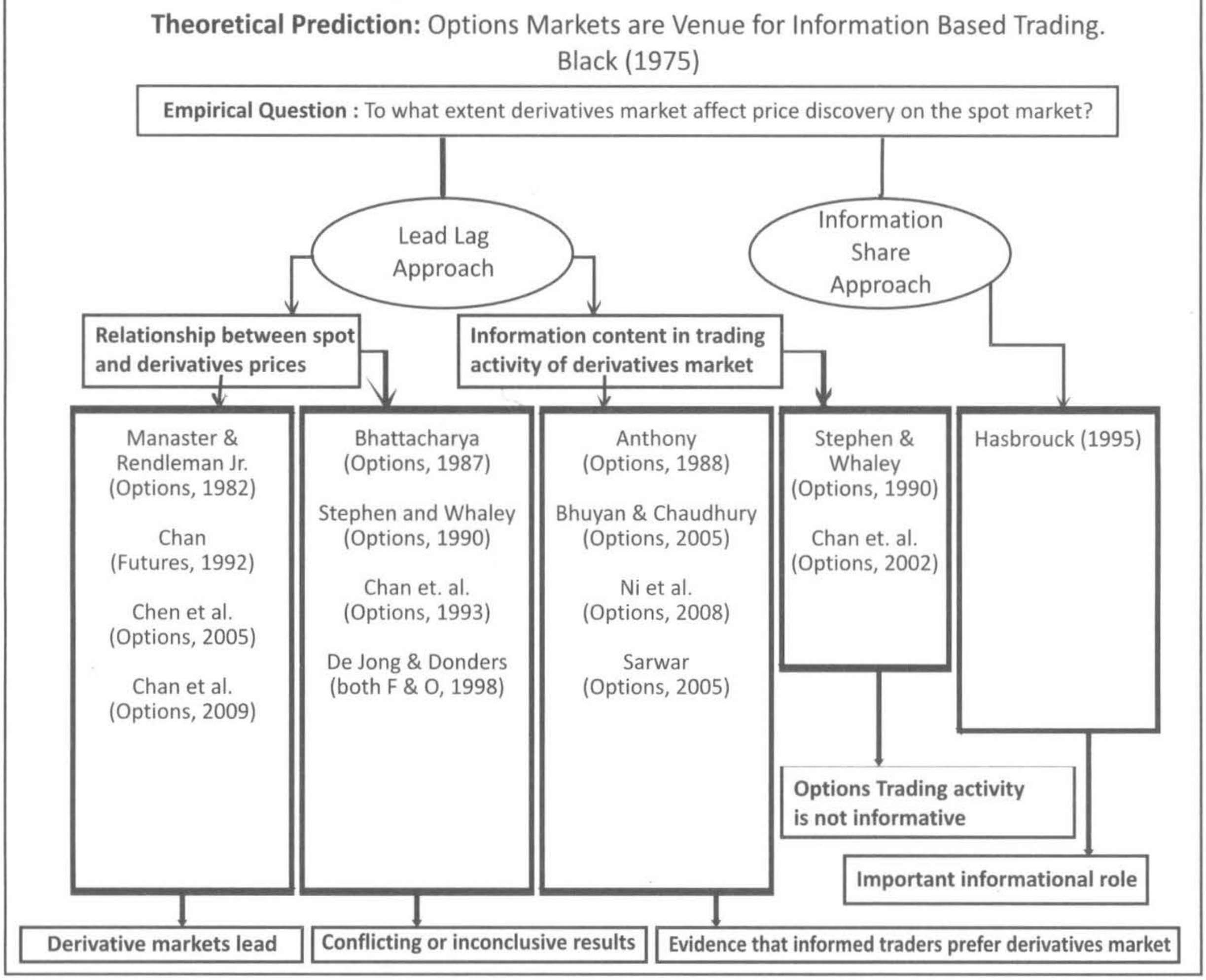
Chiras and Manaster (1978) compared the predictability of historical volatility and weighted implied volatility for future stock return variance using a simple regression model. They reported that options implied volatility is a better predictor of realized stock returns volatility. Beckers (1981) studied the predictive accuracy of implied standard deviation (ISD) for future price variability and found that option implicit standard deviation is an efficient measure of future price variability. However, Canina and Figlewski (1993) studied the S&P 100 Index options for the period from March 15, 1983 to March 28, 1987 and documented that implied volatility (IV) computed using BS options pricing formula was inefficient, biased, and an inferior estimate of the market's future volatility forecast when compared to historical volatility.

Chen et al. (1995) studied the relationship between stock volatility, basis [7], and open interests in futures market using S&P 500 Index. They based their study on the intuition that when volatility increases in the market, investors prefer to entice more people in the market for risk sharing. These investors reduce their risk exposure not only by selling their stock upholding alone, but also by selling related futures contracts. Such activity may result in decreasing basis and increasing open interest due to enhanced participation in the market. They found that an increase in expected volatility resulted in decrease in basis and increase in open interest. Kyriacou and Sarno (1999) examined 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 was measured by daily futures and options volume standardized by open interest, whereas cash index volatility was estimated alternatively by adjusted daily price changes (ADPR), daily price changes (DPR), squared return (SQRET), and GARCH(1,1). They followed Koch (1993) and used the simultaneous equation model to examine the relationship as opposed to vector-auto regression (VAR) which does not allow for simultaneity and possibly can cause misspecification problems. They reported 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) studied the information content of implied volatility about firm level volatility using options on 50 most highly traded stocks listed on CBOE during 1988-1995. They reported that for most actively traded options, the implied volatility subsumes almost all information about firm level volatility. However, their results were biased towards actively traded stocks and cannot be generalized. Sarwar (2005) studied the relationship between expected future volatility of S&P 500 Index and aggregate options volume. He conducted the study separately for call and put options and also for moneyness classes. He reported a strong feedback relationship between the options volume and expected future volatility. However, results for at-the-money (ATM) and out-of-the money (OTM) options were found to be more pronounced.

Ni, Pan, and Poteshman (2008) studied whether options volume is informative about future volatility of the underlying assets. They employed a unique dataset of stock options trade provided by CBOE over the period from 1990 to 2001. They argued that if the option volume is informative about future stock volatility, then non market maker net demand for volatility should be positively related with future stock volatility. They computed the non market maker demand for volatility by an aggregate sum of net options volume (both call and put) weighted by options vega [8] across strike prices. They tested the relationship using multiple regression framework, where the realized volatility was regressed against non market maker demand for volatility along with a set of control variables. They reported a significant positive relationship between options non market maker demand for

Figure 1. Literature Review at a Glance



volatility and subsequent realized volatility. They further argued that some options market trades represent bets both on volatility and direction (for example, a naked call buyer benefits both from increasing stock prices and increase in volatility), whereas other trades like straddle [9] are 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 conducted tests for the above argument and found evidence in support of their argument.

Research Implications

The important implications of this literature review on the function of derivatives (Figure 1 presents the important literature at a glance) are as follows :

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

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

➲ Most of the research in this area is found to be focused on examination of directional informed trading in derivatives. Studies examining trading of derivatives based on non linear information such as 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 context of emerging markets due to their different efficiency levels and lax regulatory structure.

Conclusion

In this study, we survey the literature on the role of equity linked derivatives in information diffusion leading to price discovery of the underlying assets. We provide a comprehensive coverage of the studies on information content of equity linked derivatives prices and trading activity vis-à-vis the direction of price movement and the return volatility of underlying assets. We did not find a complete consensus among researchers about the direction and speed of information flow between the spot market and the equity derivatives markets, that is, the futures and options market. However, the corroborative empirical evidences about information content in prices and trading activities of equity linked derivatives dominate the literature. Empirically, most of the studies were 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 their shortcomings, as cited by Koch (1993).

Limitations of the Study and Scope for Future Research

Though this study presents a detailed survey of literature on one of the important functions of derivatives, that is, price discovery, but it does not involve any empirical analysis to substantiate the findings in literature. Moreover, due to differing regulatory setup and microstructure of the markets across the globe, particularly emerging economies, it would be informative to empirically reconfirm the evidence of informed trading into derivatives by considering different instruments and variables. Furthermore, studies on volatility informed trading in options market remain to be examined in length across markets. It would be interesting to explore the same in future research.

Notes

[1] To estimate the option 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 deviations were calculated simultaneously using data from several options on the same stock and then were solved numerically using Newtonian search. For more details, refer to Manaster and Rendleman (1982), p. 1047.

[2] 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 option trades. For more details, refer to Chen et al (2005), p. 5.

[3] 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 % of price in the spot market and ITM/OTM put options are options with strike price ranging from 105/80 to 120/95 % of the underlying price. ATM options are options with strike price ranging between 95 to 105 % of the price in the underlying market. Data of near month contract was used for the study due to liquidity concerns.

[4] Hasbrouck (1995) developed 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 argued 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 was based on decomposition of variance of changes in the efficient price. He defined information share as a proportional contribution of that market's innovation to the innovations in the common efficient price.

[5] The total number of options and/or futures contracts that are not closed or delivered on a particular day.

[6] Volume data for pair-wise causality test were pre-whitened to be free from market effect and were tested for time series properties.

[7] They defined 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.

[8] Vega shows the sensitivity of options prices to changes in the volatility of the underlying assets. Vega is most sensitive for at-the-money options.

[9] Straddle is an option trading strategy where a trader buys a call and sells a put with the same strike price and maturity.

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