Derivative Markets in India

Trading, Pricing, and Risk Management

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Tata McGraw Hill Education Private Limited
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Tata McGraw Hill

Published by Tata McGraw Hill Education Private Limited,

7 West Patel Nagar, New Delhi 110 008

ISBN (13): 978-0-07-133295-8
ISBN (10): 0-07-133295-2

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Typeset at Shubham Composer, WZ-437 Madipur Village, New Delhi 110063 and printed at Rajkamal Electric Press, Plot No. 2, Phase IV, HSIIDC, Kundli, Sonepat, Haryana - 131028

Cover Printer: Rajkamal Electric Press

Cover Designer: Kapil Gupta

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To

The Almighty
and
Our Family Members

Preface

Financial Derivatives, amongst their other functions, provide a variety of tools for managing/tailoring risk for all types of investors in a financial market. It is empirically observed that many equity funds are created based on the practice called 'indexing'. Indexing is an investing style wherein an equity portfolio is benchmarked to the leading index of the economy. And, therefore, the portfolio is expected to be in strong association with the benchmarked index. The observed high correlation in the portfolio returns with those of the benchmarked index makes index derivatives a natural choice for hedging risk of equity portfolios.

Amongst the index derivatives, index options play an important role in the economy as they provide a better hedging mechanism to the investors compared to index futures. The perceived superiority of index options is generally observed in the times of global uncertainty when the markets experience periods of high volatility. The options contracts, unlike futures, allow fund managers to take advantage of favourable movements in the market along with the protection against the unfavourable movements. In sum, these financial instruments help investors to ensure stable earnings tailored to their risk appetite and, therefore, facilitate in mobilization of funds from the domestic as well as foreign investors.

Empirically, the performance of options market at its well identified functions, namely, risk hedging, price discovery and enhancement of liquidity in the underlying's market depends, to a greater extent, on its efficiency (Ackert and Tian, 2000). Consequently, the efficiency of options market has been of equal interest to the academics as well as practitioners and a number of studies have been carried out across the globe in different options markets.

In view of the perceived advantages of such financial innovations and the nascent stage of derivatives market in India, it is desired to carry out a comprehensive study to examine the pricing efficiency of the index options market. In response to this and lack of adequate literature on the subject in the context of Indian options market, the present study attempts to assess the efficiency of the S&P CNX Nifty index options, the options which are traded on the leading index of the National Stock Exchange (NSE).

The issue of market efficiency has been dealt with by using a comprehensive research methodology. The methodology adopted consisted of a two-pronged approach which built on the analysis of secondary as well as primary data to ascertain the state of index options market in Indian. The secondary data analysis has been carried out using select 'model-free' as well as 'model-based' approaches. For the purpose, the study used the data for a period of six years from June 04, 2001 (starting date for index options in India) to June 30, 2007. Moreover, a survey amongst the trading member organizations based at National Capital Region (NCR) and Mumbai has also been conducted to corroborate the findings from the secondary data analysis.

The 'model-free' approaches to assessing the options market efficiency include the test of two popularly known conditions on options prices, namely, (i) test of lower boundary conditions on the options prices and (ii) test of put-call parity relationship. Likewise, the 'model-based' approaches have dwelt upon, (i) test of rational expectations hypothesis on the term structure of implied volatilities and (ii) examination of the informational efficiency of implied volatilities vis-à-vis estimates from the select conditional volatility models. In addition, the survey assessed the opinion of respondents on five major dimensions relating to the state of options prices in Indian derivatives market. These dimensions include: (i) level of usage of the options; (ii) understanding of put-call parity relationship; (iii) awareness and use of models for options valuation; (iv) correctness of options pricing, its impact, and existence and exploitability of arbitrage opportunities; and (v) need of regulations and educational initiatives for the betterment of the market.

Empirically, the findings of the 'model-free' approaches have been corroborated with those of 'model-based' approaches. One of the notable findings is that put options market is more inefficient compared to call options market. Precisely, the put options have been overpriced in relation to call options. The lopsided pattern (more inefficiency in the case of put options vis-à-vis call options) of violations could be attributed to 'short-selling constraint' in Indian securities market during the period under reference. This is borne out by the fact that the arbitrage strategy requires taking a short position in the underlying asset to correct such anomalies, i.e., overpricing of put options. And, it may be noted that the short-selling was not allowed in Indian market during the period under reference.

However, it is generally argued that futures market can ideally be used in case short-selling is banned in the market given that the futures are available on the underlying asset. In view of this, the model free approaches were also tested using S&P CNX Nifty futures prices. The major findings of the analysis show that the futures market could identify only some of the mispricing signals as the futures themselves were underpriced. The underpricing of futures can be traced to the absence of short-selling facility in the market as the correction of under-pricing of futures requires short-selling in place. Therefore, it would be reasonable to conclude that the short-selling constraint has emerged as one of the major reasons for the typical pattern of violations in Indian options market.

Another notable finding of the research is that a majority of violations both in the cases of call and put options could not be exploited on account of the dearth of liquidity in such contracts. An adequate level of liquidity in options as well as underling's market is needed to execute the appropriate arbitrage strategy successfully. The lack of liquidity causes a risk called immediacy-risk; that is, inability of the arbitrageur to execute the strategy within the required timeframe. Failing which, the observed arbitrage profits could turn into losses. Besides, higher bid-ask spreads are observed for the contracts having low liquidity and vice versa. And, therefore, the lower level of liquidity reduces the observed profits as well.

In nutshell, the major findings presented in this book reveal that the Indian investors are not exhibiting rational behaviour while valuing index options during the period under reference. This is indicative of price inefficiency in index options market in India. The revealed state of options pricing in the derivatives market can be attributed to the short selling constraints, dearth of liquidity and lack of proper understanding of the market amongst market participants/investors.

In addition, a brief sketch of the recent initiatives taken by SEBI and their possible impact on the market efficiency has been delineated in the book. Besides, the need of further initiatives warranted to restore efficiency of the options market in India has been given in the form of recommendations.

This book is expected to be useful for the academic community (especially MBA/M.com students and the researchers who are working in the area of Futures and Options), industry, the regulatory body (SEBI) and the major exchanges of the country. The book can also be used for the class room teaching, especially to explain the arbitrage mechanism in options market. In addition, the book provides insight into the future research that can be attempted in the domain of Futures and Options market. Besides, the regulators and stock exchanges of the other countries which have recently introduced the Futures and Options in their markets may find this book useful.

Acknowledgements

At the outset, we would like to thank the Almighty for His blessings to inspire us to accomplish this academic endeavour. This work has been possible because of the help, encouragement, cooperation and guidance of many people and we convey our heartfelt thanks to all of them.

We are grateful to Prof. Surendra Prasad, Ex-Director, IIT Delhi, Prof. R.K. Shevgaonkar, Director, IIT Delhi, and Prof. Devi Singh, Director, IIM Lucknow for their kind cooperation and support. We are also thankful to all the colleagues in Department of Management Studies, IIT Delhi, and in IIM Lucknow for their good wishes for this endeavour.

In addition, we are deeply obliged to all the respondents of the survey, who took out time from their busy schedules to provide data for this work.

Dr. Alok Dixit takes this opportunity to express his deepest gratitude to respected guides (*gurus*) and co-authors, Prof. Surendra S. Yadav and Prof. P.K. Jain, for their valuable guidance, inspiration, motivation, and untiring efforts in completion of this project.

Last but not the least, we are thankful to our family members and loved ones for their continuous encouragement and support.

ALOK DIXIT
SURENDRA S. YADAV
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Contents

Abbreviations

AACF	Autocorrelation Function
AIC	Akaike Information Criterion
AOM	Australian Options Market
ARCH	Autoregressive Conditional Heteroscedasticity
ARIMA	Autoregressive Integrated Moving Average
BSE	Bombay Stock Exchange
CBOE	Chicago Board Options Exchange
CME	Chicago Mercantile Exchange
EGARCH	Exponential Generalized Autoregressive Conditional Heteroscedasticity
EOE	European Options Exchange
F&O	Futures and Options
FOM	Finnish Options Market
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GED	Generalized Error Distribution
IV	Implied Volatility
LBC	Lower Boundary Condition
LIFFE	London International Financial Futures Exchange
LR	Likelihood Ratio
LTOM	London Traded Options Market
NSE	National Stock Exchange
OSE	Oslo Stock Exchange
OTC	Over The Counter
PACF	Partial Autocorrelation Coefficient
PCP	Put-Call Parity
PHLX	Philadelphia Stock Exchange
SIC	Schwarz Information Criterion
VIX	Volatility Index
VXN	CBOE Nasdaq Volatility Index
VXO	CBOE OEX Volatility Exchange

Units of Measurement

1 Lac	**= 100 thousand**
10 Lac	**= 1 million**
1 Crore	**= 10 million**
100 Crore	**= 1 billion**
1000 Crore	**= 10 billion**

CHAPTER 1

Financial Derivatives

1.1 INTRODUCTION

Financial markets play a vital role in capital creation in an economy. Precisely, these markets are essential for raising capital through long-term sources of finance, for example, equity shares and debentures/bonds. This is in view of the fact that these markets not only facilitate in raising the fresh capital but also ensure the trading of the investment vehicles. Trading in the investment vehicles provides flexibility to the investors to liquidate their investments virtually any time (to be on the safer side, any day) they want. However, financial markets are largely subject to market risk. Market risk represents summative effect of the economic forces (inflation, exchange rate, GDP growth, etc.), which are unpredictable to a marked extent, and could cause substantial alteration in the value of the assets traded in the open market. In view of this, an investor (hedger) in the market looks for some instrument that could provide him protections against such risk. At the same time, there are participants (speculators) in the market who are willing to take this risk. In a financial market, derivative instruments work as link between the two entities; namely *hedger* (one who wants to transfer its risk) and *speculator* (the other willing to take this risk). Besides, derivatives instruments are identified with their contribution in terms of price discovery and increased liquidity in the underlying's market. In sum, derivative instruments are expected to provide three major benefits in a financial market, viz. (i) transfer of risk from one party to another party (hedging), (ii) better price discovery in the underlying's market and (iii) increase in liquidity of the underlying asset. In turn, these benefits lead to better capital allocation in an economy.

Derivatives, also known as financial innovations, are defined as those instruments that derive their value from the changes in the value of the underlying asset; that is, in itself it does not have any value, unlike stock and bonds. Rather, their value depends on typical characteristics/ behaviour of the underlying asset. The underlying asset can be a financial asset (e.g. individual shares, bonds and indices thereof), commodity (e.g. grains, metal, etc.) or reference rate (e.g. interest rate, exchange rate, etc.). In their simplest form, known as plain-vanilla instruments, derivatives include Forward Contracts, Futures, Options and Swaps. Moreover, over the period of time, with the increased complexity of financial markets, a variety of advanced derivative instruments have been developed. Some of such instruments are Swaptions, Barrier Options, Collaterlised Debt Obligations (CDOs), Collaterlised Bond Obligations (CBOs), Credit Default Swaps (CDS), etc.

Financial derivatives, in particular, are those instruments that have financial assets as the underlying. Naturally, these instruments become an obvious choice for managing/tailoring financial risk of the assets being traded in the market. Amongst financial derivatives, the instruments that are based on indices (e.g. index futures and index options) serve as a natural choice to the portfolio (fund) managers for tailoring the market exposure of funds based on the risk appetite of their clients.

1.2 TYPES OF FINANCIAL DERIVATIVES

With increased complexity of financial markets and demand from different types of investors, a variety of financial derivatives have been developed. Some of the most popularly known basic financial derivatives include Forwards, Futures, Options and Swap contracts. Based on one of the most common classifications offered to derivatives contacts, these are classified in two major categories: Exchange-traded and Over-the-counter (OTC) derivatives. Exchange-traded derivatives, as evident from the name, are those standardized products that are traded on an exchange; e.g. Futures and Options contracts. In contrast, OTC derivatives are those derivative contracts that are trailed products (usually a bilateral agreement to trade the underlying at a future trade) and are not traded on any exchange. Some of the most common examples of OTC derivatives products are Forward and Swap contracts.

Another popular classification of derivatives is drawn based on the underlying asset. For example, ***Equity derivatives*** – derivatives on shares and indices thereof (NSE Nifty in the context of Indian capital market), namely stock futures, stock options, index futures and index options; ***Foreign Exchange (Forex) derivatives*** – those based on foreign exchange rate or involves exchange of sums denominated in more than one currency, e.g. currency forwards, currency futures (US Dollar and Indian National Rupee futures, USDINR futures contract available in Indian capital market), currency options and cross-currency swaps, etc.; ***Credit derivatives*** – instruments that are designed to provide shield against the credit/default risk, viz. CDS, CBO, CDO, etc.; ***Interest rate derivatives*** – these instruments involve promise to invest/borrow certain amount in future at the interest rate locked-in now, e.g. interest rate futures, interest rate swaps, etc.

Having discussed some major categories of financial derivatives, let us move on to the discussion of some of the most commonly known financial derivatives, viz. Forwards, Futures, Options and Swap contracts.

1.2.1 Forward Contracts

A forward contract is an agreement between two parties to transact (buy/sell) the underlying asset in future at a certain price, which is decided now. A forward contract is an OTC derivatives instrument, and therefore, it is a tailored instrument negotiated by the two parties involved in the contract. Such contracts are not traded on any exchange, and therefore, it is not easy (nearly impossible) for either party to square-off its position before the maturity of contract. Forward contracts are more commonly traded in the foreign exchange market and fixed income securities market. In forex market, these are used to hedge the foreign exchange risk, in general, and transactional risk, in particular. Likewise, in fixed income securities market, these instruments help in hedging against the interest rate risk (e.g. Forward rate agreements, FRA).

Example 1.1 *Suppose an Indian firm exported some goods worth 1,00,000 Euros (€) to a French firm. The French firm promised Indian firm to pay three months from now. Further, suppose that the Euro is currently traded at ₹ 58.50/58.80 (per €) and the Indian firm expects that Euro will weaken in due course. The intuition of depreciation of foreign currency gets corroborated when it looks at the forward rates quoted by the forex dealers. These quotes are as under:*

Spot rate (₹/ €)	*1 month forward Rate (₹/ €)*	*2 months forward Rate (₹/ €)*	*2 months forward Rate (₹/ €)*
58.50/80	*57.10/40*	*56.50/80*	*55.50/80*

The exporter can make use of forward market by selling Euros 3-months forward in the market. This can be achieved by entering into a 3-months forward contract, and therefore, the exporter can avoid the foreign currency exposure due to unfavourable movements in Euro by selling it at ₹ 55.50 per Euro. Now, whatever happens to forex rates three months from now, he will receive a certain amount, i.e., ₹ 55,50,000 (1,00,000 × ₹ 55.50).

1.2.2 Futures Contracts

A futures contract, alike forward contract, is an agreement between two parties to buy/sell the underlying asset at a future date at a price which is decided now. Amongst other differences, the major characteristic that differentiates futures from forwards is that these are exchange-traded instruments. Given the fact that futures are traded on an exchange, these are no longer tailored products; rather, these are standardized contracts in terms of contract size and maturity date. Another important feature of futures contract is that, as a risk containment measure, these instruments require some initial margin to be deposited with the exchange to take a position in the market. Further, the margin amount keeps on fluctuating due to 'marking to market' feature of futures contracts. Marking-to-market connotes daily settlement of futures, i.e., loss (gain) generated over the previous day closing price of the futures is debited (credited) in the respective accounts of parties. Once the margin money goes below a specified limit due to such fluctuations, a margin call is made.

Major application of futures contracts are seen in Equity market, viz. Futures contracts on individual shares and those on indices of such stocks. Besides, these instruments are also traded in fixed income securities market, as they provide shield against the interest rate risk (Interest Rate Futures). Futures serve as a tool for hedging exposure in the financial markets. Besides, these are heavily used for speculating in the market as well.

Example 1.2 *For example, an investor holds 1000 shares of TATASTEEL, which are currently traded at ₹ 610. He fears that the market may go down in next one month's time, and therefore, he wants to hedge himself against the likely adverse movements in the market. Suppose that a futures contract on TATASTEEL scheduled to expire one-month from now is traded at ₹ 610. One futures contract includes 100 shares of TATASTEEL. Therefore, the investor needs to sell 10 futures contracts short in the market to hedge against market risk. For taking this position, he will be required to deposit the margin amount as notified by the exchange. In the meantime, his futures position will be 'marked to market' on daily basis (i.e. his account will be debited {credited} if the futures price rises {declines} compared to the previous day's future price) up to maturity of the contract.*

At maturity date, suppose the TATASTEEL's share as well as futures contract thereof close at ₹ 580[1]*. The investor will end up making a loss of ₹ 30,000 on the spot market; at the same time, he will make a gain of ₹ 30,000 on the futures leg of the transaction. In sum, loss on spot market will be fully offset by the gain on futures leg of the transaction, in case he closes out his position in the market. Had he not taken any position in futures market, he would have made a loss of ₹ 30,000.*

1.2.3 Options Contracts

Options are the contracts that give a right to its holder to buy/sell the underlying asset at a specified price (called as strike/exercise price) on or up to the maturity date of contract. It is important to note that options, unlike futures, do not entail any obligation to buy/sell the underlying asset when market turn out to be

[1] If the market is efficient, we expect that the closing price of the futures contract should be the same as that of the underlying's price. That is, both the prices should converge at maturity date of the contract.

favourable. That is, these instruments protect an investor against unfavourable movements in the market; at the same time, offer the opportunity to tap the favourable movements in the market as well.

Depending on timing of exercising the contract, these instruments are put to a dichotomous classification, namely European options and American options. European options are those contracts that give a right that can be exercised only at maturity, whereas American options are the contracts that can be exercised anytime up to maturity. Another important classification of these contracts is made based on the right that they provide, i.e., to buy/sell the underlying asset. An options contract which gives a right to its holder to buy the asset is called a *call options*, and the one which offers a right to sell the underlying asset is called a *put option*.

In the case of options, it is important to note that these are traded as OTC as well as exchange-traded instruments. In an option contract, be it OTC or exchange-traded, there are two parties involved, namely, *holder of the option* and *writer of the option*. Holder of option is the investor who buys the right to buy/ sell the underlying asset. In contrast, the writer of the options is an investor who promises to sell/buy the underlying asset at the strike price (irrespective of the market condition), in case the contract is exercised by the holder of the option. He is obliged to honour his position once the contract is assigned. Naturally, holder of option has to compensate writer for the risk that he takes by promising to buy/sell at fixed price irrespective of the market situation at maturity. The compensation that an option writer gets is called *option premium*. The option premium (price of the options contract) depends on certain factors as pointed out by Fisher Black and Myron Scholes in 1973. They developed a model, popularly known as Black–Scholes (1973) model—a milestone in finance, by using these factors to value an option contract. These factors include, strike price, spot price, volatility of the underlying, maturity time and risk-free rate of return. Further, Merton (1973) added another factor to this list, i.e., dividend (yield/ absolute amount), if any, declared during the maturity period of the options contract.

Options are very useful instruments for portfolio managers, especially when the financial markets are experiencing very high volatility. However, their speculative appeal to trades is relatively less compared to that in the case of futures contracts. Most common application of options contract is seen in Equity market (stock and index options) and Forex markets (currency options).

Example 1.3 *In addition to data given in Example 1.2, further suppose that an option contract on TATASTEEL, scheduled to expire one-month from now and with the strike price of ₹ 610, is currently traded at ₹ 30 per contract. Say, the contract size is 100 shares. Now suppose that the investor is willing to choose options route to hedge against the unfavourable movements in the market. He needs to buy*

10 put option contracts (Total no. of shares/No. of shares per contract, 1000/100), and it will cost him ₹ 300 upfront.

At maturity (in the case of European options) or up to maturity (in the case of American options), if the price of TATASTEEL shares goes down below ₹ 610, the investor can exercise the option and can sell these shares at ₹ 610. For example, the options that the investor purchased are European in nature and at maturity TATASTEEL closes at ₹ 580. The investor will incur a loss of ₹ 30000 on his position in the spot market. At the same time, he will exercise the option and sell the shares at ₹ 610. Therefore, he will be able to recover ₹ 30000 from his position in options market and his effective loss will be the premium that he paid upfront, i.e., ₹ 300.

It is important to note that he would have done the same by using futures as well (refer to Example 1.2). However, the advantage of option is that investor has the flexibility not to sell his shares at ₹ 610 when market values TATASTEEL at more than ₹ 610, say ₹ 640. In contrast, in the case of futures, he has to sell the shares at ₹ 610 even if the market value of share turns out to be more than ₹ 610.

1.2.4 Swaps Contracts

Swap, an OTC derivative instrument, is an agreement between two parties to exchange cash flows (interest or principal cum interest) for a specified period of time. Swaps are most commonly used in forex and fixed income securities markets. Some common applications of swaps are seen in terms of currency swaps and interest rate swaps. A currency swap is an agreement between two parties to exchange cash flows *denominated in different currencies* for a specified period of time. An interest rate swap involves exchange of interest amounts between two parties for a stipulated time period, wherein interest amounts are calculated based on fixed and floating interest rates for the two legs of swap transaction, respectively. The amount of interest exchanged between the two parties is calculated on a *notional principal amount*. In the case of interest rate swap, it is important to note that, in general, principal amount is not exchanged between the parties. Normally, such transactions are routed through an intermediary financial institution.

Example 1.4 *Suppose a firm wants to raise some capital through debt market. The firm finds that it can raise the desired amount based on floating interest rate, i.e., MIBOR[2] plus 100 basis points; however, it is interested in getting it exchanged for a fixed interest rate loan for whatsoever reason (may be the firm is new and does not want to take this risk). At the same time, there is another firm that could raise the debt amount at the fixed rate of interest, say at 8% p.a., but was willing to exchange it for floating rate of interest. Both such firms can explore the possibility of swapping their respective interest liability through the*

[2] MIBOR stands for Mumbai Inter Bank Offered Rate. This is a reference rate used for lending and borrowing among banks.

financial intermediary dealing in swap agreements for a suitable time period and, therefore, can have access to desired loan scheme, i.e., fixed/floating interest rate. Once the deal is finalized for a stipulated time period, the interest liabilities are routed through the financial intermediary and the intermediary charges its commission from both the parties for the services provided. In this regard, it is important to note that only interest liabilities are exchanged and principal amounts remain with the original parties.

1.3 USE OF FINANCIAL DERIVATIVES

The use of financial derivatives can be classified in three major categories, namely (i) hedging the financial risk or financial risk management, (ii) speculating through different profit strategies and (iii) as *ex-ante* forecast of underlying's value.

Hedging refers to process of managing risk/variations in the value of the asset or portfolio of assets. In hedging, an investor tries to confine expected variations in the value of asset within a tolerable limit (may be set by himself or imposed by clients) by taking suitable position in the derivatives market. Some of the examples of hedging have already been discussed in the previous section while enumerating types of financial derivatives. Another use of derivatives is made to generate profit by speculating on direction and magnitude of direction in the market. Speculation essentially involves the views/take of the investor on the direction of market and magnitude thereof in near future. Based on his expectation about the future, the speculator tries to generate profit in the derivatives market by taking a suitable position/positions in the market. It is important to note that a speculator is always exposed to risk, as his expectation may well be reversed, i.e., market may turn just opposite to his expectations. Both hedging and speculation in derivatives market, especially using equity derivatives market, have been covered in **Chapter 2**.

The third use of derivatives market is to generate *ex-ante* forecast of the underlying's value. There have been many studies which attempted to test the same across the globe in different financial markets. The results suggest that derivatives market perform as a good predictor of future's value. For example, in majority of developed financial markets, interest rates implied from interest rate futures and volatilities implied from equity options have been found to be superior forecast of future vis-à-vis those generated by historical data based models. The forecasting ability of Indian index options market (in terms of forecasting volatility) has been thoroughly examined in **Chapter 6**.

1.4 FACTORS CONTRIBUTING TO THE GROWTH OF DERIVATIVES

Financial derivatives play a variety of roles in a financial market, from restoring stability in the market to better price discovery. By virtue of functions they perform, derivatives have witnessed phenomenal growth in Indian capital market. The same holds true for global scenario as well. Some of the major factors that help derivatives grow in a financial market are as follows:

- Financial derivatives help in transfering of risk from one party to another party and, therefore, are expected to increase participation in the financial market, which in other words, leads to better capital allocation. These instruments make financial market a more viable option for a variety of investors who, otherwise, might not have participated in the market. For example, a risk-averse investor, in presence of derivatives products in a market, has an option to transfer risk once volatility in the market hits a level beyond his tolerance. Similarly, it provides an opportunity to risk-takers as well; this is in view of the fact that participants can take leveraged positions, i.e., they can achieve desired exposure in the market with relatively very less initial investment (compared with spot market). In sum, it is expected to increase participation in the market and, therefore, expedite the process of capital creation in an economy.
- Another important factor that has contributed towards growth of derivatives is cross-border integration of economies. Since economic integration of countries, amidst variety of benefits, transfers various risks of from one economy to another, it results in increased risk (volatility) in the financial markets of integrated economies. Since derivatives provide a shield against such risks, growth in this segment of financial markets (derivatives) becomes imperative.
- Derivatives help portfolio managers to provide their clients with a variety of structured financial products, which are best suited to their risk appetite. For example, an investor demands for an investment opportunity with very high risk and return profile. Such a strategy can be developed using the spot market itself; but the manager would prefer a route through derivatives market, given the less amount of investment required in latter to have same level of exposure. Therefore, the usage of derivatives products in serving variety of investors (through structured financial products), amongst other benefits, leads to growth of this segment of financial markets.

In sum, the perceived benefits of derivatives to participants in a financial market, clubbed with cross-border economic integration, can be designated as major building blocks for the growth of derivatives in an economy. *Per-se*, this seems true for Indian derivatives market as well.

1.5 EVOLUTION OF DERIVATIVES MARKET IN INDIA

In view of the empirically established advantages of derivatives and in response to the long-felt need of hedging facility in the Indian securities market, the derivatives market officially took off in the Indian securities market on June 11, 2000, with the launch of futures contracts on the leading index of National Stock Exchange (NSE) and Bombay Stock Exchange (BSE). The derivatives were started in the Indian market in response to the report of L.C. Gupta Committee. The committee conducted a survey amongst the market participants to gauge the need of derivatives market in India and found that there has been a well-awaited need of having a derivatives market for hedging their financial risk. The derivatives segment in Indian securities market has registered remarkable growth in its nearly 11 years of existence. The data on the growth of derivatives segment are summarized in Table 1.1 and Fig. 1.1.

It may be deciphered from the data (Table 1.1 and Fig. 1.1) that the derivatives market has experienced a whopping growth, evident from the current volumes which amounts to many times of its initial trading volume in the very first year of its existence.

Another notable observation from the data on the growth of derivatives market is that the majority of trading in derivatives market has been seen in the futures segment compared to that in the options market. The reason behind this could be the ease of trading in futures market as options are comparatively difficult to understand, and moreover, the market has got less experience of the derivatives market, as it has been launched recently in Indian securities market. Some facts on the development of derivatives market in India along with its growth story has been summarized in following sub-section.

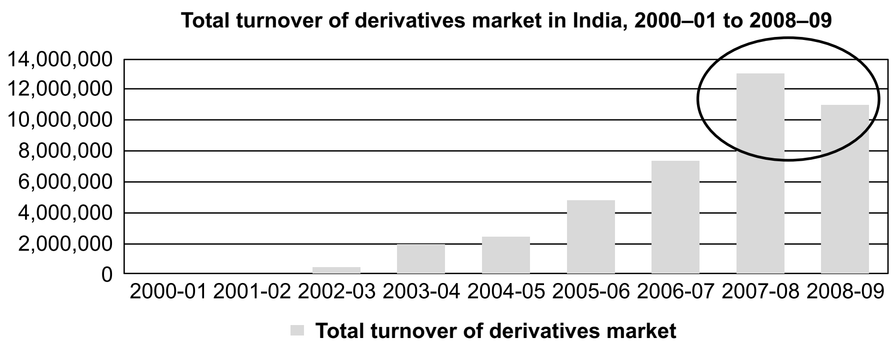


Figure 1.1 Trading volume of Indian derivatives market (in rupees) from 2000–01 to 2008–09

1.5.1 Some Stylised Facts about Indian Derivatives Market

- *Futures* on the indices of BSE and NSE (BSE Sensex and NSE Nifty, respectively) were allowed as a first derivative in India in June, 2000.
- Likewise, *Index options* on indices of BSE and NSE (BSE Sensex and NSE Nifty, respectively) were first allowed for trading in June 04, 2001.
- *Options on individual stocks* were introduced in July 2001.
- *Futures on individual stocks*, a peculiar feature of Indian derivatives market, were started in November 2001.

Table 1.1 Business Growth in Indian Derivatives Segment, 2000–01 to 2008–09

Year	*Index futures*	*Stock futures*	*Total turnover of futures market*	*Index options*	*Stock options*	*Total turnover of options segment*	*Total turnover of derivatives market (F&O segment)*
2000–01	2,365	0	2,365	0	0	0	2,365
2001–02	21,483	51,515	72,998	3,765	25,163	28,928	1,01,926
2002–03	43,952	2,86,533	3,30,485	9,246	1,00,131	1,09,377	4,39,862
2003–04	5,54,446	13,05,939	18,60,385	52,816	2,17,207	2,70,023	21,30,610
2004–05	7,72,147	14,84,056	22,56,203	1,21,943	1,68,836	2,90,779	25,46,982
2005–06	15,13,755	27,91,697	43,05,452	3,38,469	1,80,253	5,18,722	48,24,174
2006–07	25,39,574	38,30,967	63,70,541	7,91,906	1,93,795	9,85,701	73,56,242
2007–08	38,20,667	75,48,563	1,13,69,231	13,62,111	3,59,137	17,21,247	1,30,90,478
2008–09	35,70,111	34,79,642	70,49,753	37,31,501	2,29,226	39,60,728	1,10,10,482

Source: www.nse-india.com

- *Interest rate futures* took off in June 2003.
- In India, only equity and currency Options are being traded as of now.
- Presently, Options and Futures are available on more than 230 individual stocks and 8 indices.
- Trading volume of derivatives market has registered a whopping increase from ₹ 2.37 thousand crores in 2000–01 to ₹ 110.10 lakh crores in 2008–09.
- Turnover of Index Options in Indian market rose from ₹ 3.8 thousand crores in 2001–02 to ₹ 37.315 lakh crores in 2008–09.
- Turnover of Index Futures has recorded a notable increase as the trading volume has risen from ₹ 2.37 thousand crores in 2000–01 to ₹ 3570.11 thousand crores in 2008–09.
- In India, Index Options have been more popular in last four years than the options on individual stock, as more than 65% of the total volume in options segment has consistently been recorded in terms of Index Options.

The rest of the book is divided into six chapters. Equity derivatives with an emphasis on Index option have been discussed in Chapter 2. Chapters 3 and 4 discuss two most commonly used conditions on options price. Further, these conditions have been tested in the context of Indian derivatives market, in general, and index options, in particular. Chapter 5 and 6 enumerate implied volatility in detail. The implied volatilities have been extracted from closing prices of index options by using Black–Scholes (1973) options pricing model. Chapter 5 examines its behaviour with respect to different maturities. The forecasting ability of implied volatility to predict futures volatility and its comparative performance vis-à-vis historical volatility models have been examined in Chapter 6. In the last chapter (Chapter 7), evidences borne out by the secondary data analysis have been further corroborated by the opinion of Trader Member Organisations (brokerage firms) on pricing related issues. For this purpose, a questionnaire had been administered amongst the brokerage houses, actively involved in Future and Options segment, based in National Capital Region and Mumbai.

CHAPTER 2

Equity Options and Risk Management

2.1 INTRODUCTION

Equity options serve, amongst other functions, as an important tool for managing risk for investors dealing with equity shares and/or portfolio thereof. These are the derivative contracts that give their holders a right but not an obligation to buy or sell the underlying asset (equity share or index of such shares) at a predetermined price called strike/exercise price on or up to a maturity date. The options market is expected to serve as a tool for risk hedging, price discovery, enhancing liquidity in the market and, therefore, facilitate better allocation of capital in an economy. The risk hedging function of options is invariably claimed as the most important amongst all their functions. This is in view of the fact that the availability of such financial innovations in a market helps in transferring risk from one party to another (from buyer of the options to the seller of the option), and therefore, it helps investors to take risk which is tailored to best suited their risk appetite.

In addition, it is generally believed and has been demonstrated empirically across the world that the options market leads the underlying's market, i.e. the information gets reflected first in the derivatives market, in general, and options market, in particular, and then spills over to the underlying's market. It would be appropriate to note here that the flow of information is bidirectional; however, the option market is expected to lead the underlying's market in an efficient market environment. This function of the options market can be traced to the fact that it takes an investor considerably less to have the same exposure through the options market compared to what it takes in the spot market to have the same exposure in a financial asset. This is borne out by the fact that options market entails lower transaction costs and provides leveraged position to the investors. It is for this reason that the information is expected to get reflected in the options market prior to the spot market.

Another function of the options market is to enhance liquidity of the underlying's market. However, such impacts are difficult to generalize and, therefore, are subject to empirical scrutiny. In sum, these functions of the options market facilitate allocation of the capital to its most productive usage, which in fact, is needed for an economy to grow at a faster pace.

Based on the underlying asset, equity options are classified in two categories—index options and stock options—options on individual stocks.

2.1.1 Index Options

Index options are those derivative contracts that have an index as underlying asset. Naturally, in case of equity options, index options are floated on an index of equity shares. In general, such options are floated on the leading index/ indices of equity shares in an economy. For example, in Indian derivatives market, the most popularly known index option is NSE CNX nifty index options. These options are floated on one of the leading equity indices of the Indian economy, i.e. NSE CNX nifty. It is an index of 50 most liquid shares from different sectors of the economy, which are weighted based on their free floated market capitalization. The weights of different sectors in the index are chosen in such a way that the index becomes a proxy for economic activity of the whole economy. Depending upon the demand in an economy, index options can be floated on a variety of indices. For example, these may be floated on sector-specific indices like Banking, Telecom, IT, Infrastructure, Oil & gas, etc. Besides, indices are also constructed for shares based on their market capitalization, viz. LARGECAP, MIDCAP and SMALLCAP. The definition of these categories varies from market to market. Further, these categories get different definition from time to time, depending upon change in market size. In Indian derivatives market, NSE offers a total number of eight index options, e.g. NIFTY-leading index of equity shares, /market index, Bank Nifty, CNX 100, CNXIT, etc. Nifty index options are the most traded amongst all types of exchange-traded options floated in Indian derivatives market. Guidelines for floating options on various indices are circulated by SEBI from time to time.

Index options are useful for speculating as well as hedging marker exposure. Particularly, these options are very useful in managing risk of a variety of funds, as the options are normally floated on leading indices of an economy and not on such customized funds. Further, these funds are expected to have very strong association with the leading index since majority of funds are benchmarked to leading funds of an economy. Therefore, options on such leading indices become a natural choice for hedging market exposure of such tailored funds.

2.1.2 Option on Individual Securities

Options on individual stocks, as the name suggests, are options which have individual shares as underlying asset. Currently, in Indian derivatives market, NSE offers options on individual stocks on more than 200 shares from different sectors of the economy. The securities are included in or excluded from the Futures & Options (F&O) segment list based on the different criteria notified by SEBI from time to time. Some of such criteria include, average daily market capitalization and average daily traded value of the security for previous six months, the market-wide position limit in the security, the quarter sigma values, etc.

Options on individual stocks are used for speculating as well as hedging purposes. However, the hedging provided by such options is limited compared with that provided by index options, as these options can be used to hedge exposure of underlying security or some other security having strong correlation with the underlying. On the other hand, index options can be used to hedge exposure of a variety of funds, since options are not available on such tailored funds. At the same time, these funds are expected to have strong association with the leading index/indices on which options are normally floated in an economy.

In the case of index options, it is important to note that these are essentially settled in cash. The cash settlement in the case of index options happens because non-deliverable underlying asset (index), and therefore, physical settlement becomes impossible. In Indian derivatives market, both types of options, namely index and stock options, are settled in cash only.

Another important feature of Indian options market is that index as well as stock options are European in nature, i.e. these can be exercised only at maturity. It is important to note that options on individual stocks trading at NSE were being offered as American options till October 2010. In October 2010, NSE decided to move to European style options with an expectation to improve dearth of liquidity in options on individual stocks.

Further, with respect to maturity of options contracts, both types of options (i.e. index and stock options) have three variants in terms of their maturity time: Near the month (NTM)—options having less than or equal to 30 days to maturity; Next the month (NXTM)—options which are having 31–60 days to maturity and Far the month (FTM)—options which have more than 60 days to maturity. In addition, March onwards, Long Dated Options (LDO) were allowed to trade in Indian options market. However, such options could not attract significant activity due to liquidity and pricing issues.

2.2 TRADING STRATEGIES USING OPTION FOR PROFIT MAKING (SPECULATION)

Trading in options with intent to earn profits (profit or trading strategies using options) is basically speculating in the options market unlike hedging wherein an investor attempts to protect himself against unfavourable movements in the market. Speculation essentially dwells upon the view(s) of a trader, primarily, on two important market characteristics/parameters, viz. (i) view on the direction of the market (i.e. bullish or bearish trend will follow) and (ii) volatility of the market (whether market is going to experience larger/ smaller moves; in other words, high or low volatility). Predominantly, based on these two important characteristics, a trader devices strategy which will be most profitable, given his views on the market. Some select studies based on these two parameters have been summarized in Table 2.1.

Table 2.1 Select Trading/ Profit Strategies Using Options: A Classification Based on Market Direction and Volatility

	VOLATILITY	
MARKET DIRECTION	*Low volatility*	*High volatility*
Bullish	Bullish call spread	Call option
Bearish	Bearish put spread	Put option
No view on direction/neutral	Butterfly spread	Straddle
	Box Spread	

A detailed discussion on trading strategies summarized in Table 2.1 has been covered in the following section by dividing them into two major categories: (i) Directional Strategies and (ii) Non-directional or Neutral strategies. Further, within a given classification (i.e. directional or non-directional), these strategies have been clubbed based on trader's view on volatility.

It is important to note that these strategies can be formed with the help of European as well as American options. However, in the case of American options, some of the complex strategies, which include more than one option contract, may deviate substantially from the expected payoffs. It may happen on account of the possibility that the two legs of the transaction may not be exercised at the same time. And, therefore, the actual profit (loss) may differ substantially from the expected profit, even if the traders view on the market turns out to be correct. Notably, this risk does not emerge in the case of European options, as there is no possibility of exercising the option before maturity.

2.2.1 Directional Trading Strategies Using Options

The directional strategies are those strategies wherein a trader has certain view on the direction of the market in near future. Since the market can either go up or down, the traders can have their own view on the market. That is, a trader who thinks that the market is likely to go up in near future is said to have ***bullish view*** on the market. On the contrary, a trader who thinks market will go down in near future is said to possess a ***bearish view***. Some of the bullish and bearish strategies clubbed with traders' view on volatility are discussed in following subsection.

2.2.1.1 Bullish strategies

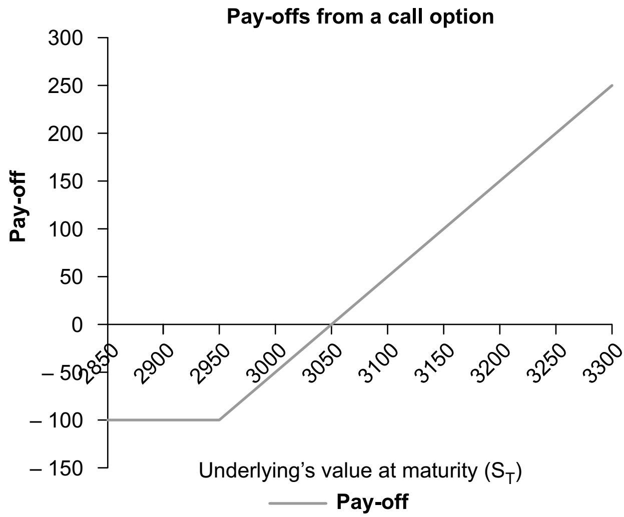
The strategies that assume upward direction of the market has further been classified based on expected magnitude of volatility:

(*a*) **Bullish and high volatility—Call option:** In this case a trader thinks that the market will go up and, at the same time, he believes that the magnitude of fluctuations will be quite high. In other words, the market will be on the rising trend and is likely to experience larger moves. In this situation, the trader should go for a long position in call option to get maximum benefits in case his views on the market turn out to be correct.

Example 2.1 *Suppose a speculator believes that in a month's time, the market will experience a rising trend with fair probability of larger moves. To exploit this opportunity, he takes long position in a European call option, which is scheduled to expire one-month from now. The option has a strike price of ₹ 2950 and is currently available at ₹ 100. Further, suppose the underlying share is currently traded at ₹ 3000. Since he has purchased a call option, he will be benefited by upside movement in the market which is large enough to surpass the ₹ 3050 mark. Since he has paid ₹ 100 upfront as premium for the call, the price has to advance by ₹ 50 from its current level to reach an equilibrium position.*

As we know, a call option will be exercised when the underlying assets price is more than that of the strike price. At maturity, the price can take any value, given the random nature of the underlying asset; some of such values have been taken to examine a trader's profit position for different price scenarios. The calculation of profit under different price scenarios has been reported in the following table. Further, for better understanding of the profit position from the strategy , the payoffs from the strategy have been plotted for select possible prices/ scenarios at maturity.

Underlying's price at maturity (S_T)	*Action*	*Value*	*Pay-off (Value-call premium)*
2900	Abandon	0	–100
2950	Abandon	0	–100
3000	Exercise	50	–50
3050	Exercise	100	0
3100	Exercise	150	50
3150	Exercise	200	100
3200	Exercise	250	150
3250	Exercise	300	200
3300	Exercise	350	250
3350	Exercise	400	300

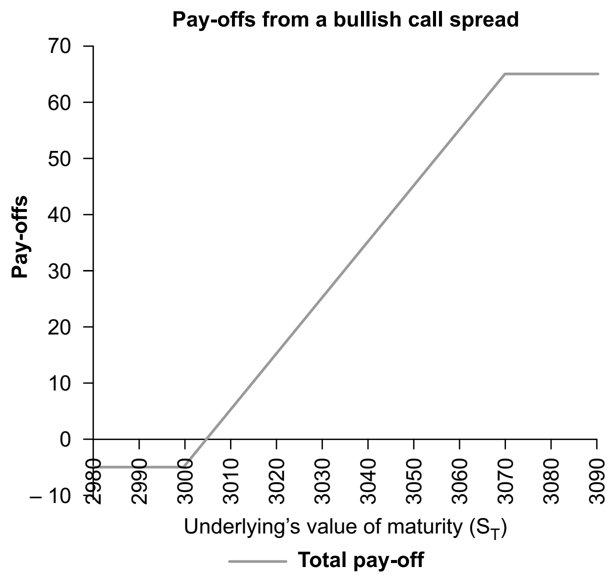


From the data, it can be easily inferred that the trader will be benefited only if the market shows an advancing trend. Further, it should move up by at least ₹ 50 to break-even. He will start generating profit only if the market moves beyond ₹ 3050. It is evident from the data that the trader will be benefited only by large moves; for example, if market reaches at ₹ 3350 mark. In this scenario, he will make a profit of ₹ 250. It becomes a possibility only if the market goes up by ₹ 350, which is equivalent to nearly 40% {(350/3000) × $\sqrt{12}$ *} annualized volatility. In this strategy, the maximum loss that a trader is going to incur is the premium amount he paid initially; however, profit potential is theoretically unlimited.*

(*b*) **Bullish and low volatility—Bullish call spread:** A bullish call spread is an appropriate trading strategy when a trader expects market to go up but he expects volatility to be low. It combines two call options, which are similar in all the aspects (maturity, underlying asset, etc.) *except strike prices*. Since the trader thinks that market will go up, he takes a long position in the call option; simultaneously, he takes a shot position in the other call option (with higher strike price), as he expects that larger moves are unlikely. Therefore, he can reduce his initial investment by selling a call option with higher strike price. In sum, this strategy involves a long position in a call option with the lower strike price and simultaneously a short position in a call option with higher strike price.

Example 2.2 *Suppose a trader expects that, one month from now the market will be on the rising trend but large moves are unlikely. To exploit this scenario, he goes long in a bullish call spread. For the purpose, he takes long position in a call option having maturity of one month and strike price of ₹ 3000 (X_1),* *available at ₹ 60 (C_1). At the same time, he takes a short position in another call option with the same characteristics except the strike price, which he chooses at ₹ 3070 (X_2), currently traded at ₹ 55 (C_2).*

Underlying's price at maturity (S_T)	*Value Bullish call spread*			*Pay-off {Total value – (C_1 – C_2)}*
	X_1 (Long)	*X_2 (Short)*	*Total*	
2980	0	0	0	–5
2990	0	0	0	–5
3000	0	0	0	–5
3010	10	0	10	5
3020	20	0	20	15
3030	30	0	30	25
3040	40	0	40	35
3050	50	0	50	45
3060	60	0	60	55
3070	70	0	70	65
3080	80	10	70	65



This strategy results in an initial cash outlay of ₹ 5, i.e. call premium paid (on the option the trader is long) net of the premium received from the short position ($C_1 - C_2$). Further, suppose the underlying share/index is currently traded at ₹ 3000.

From the data it is evident that the trader will start generating profit only if share price moves beyond ₹ 3005. Once the price reaches at ₹ 3005, the trader will breakeven. Beyond this point, every increase will add to the profit of the trader until the price reaches ₹ 3070. As the price advances beyond this point, *the call option you are short in will also be exercised against you and your profit will stabilize at ₹ 65 (that is, ₹ 3070 – 3000 - 5). That is, this strategy will result to a maximum profit of {$X_1 - X_2 - (C_1 - C_2)$}.*

From the data it may be inferred that the trader will be benefited by adopting this strategy if the market shows bullish trend and, at the same time, shows mild moves. In case price moves beyond ₹ 3070, the trader is no longer benefited as his profit stabilizes at rupee 65. Therefore, such a strategy is the most suitable one when the market is expected to advance, at the same time large moves are unlikely. In this systematically the maximum loss that he is going to incur is the difference between call premiums, i.e. ($C_1 - C_2$). This strategy reduces the maximum loss as well as the maximum profit compared with call option. In case the market is expected to advance along with larger moves, a long position in call option becomes more profitable strategy compared with a bullish call spread.

2.2.1.2 Bearish strategies

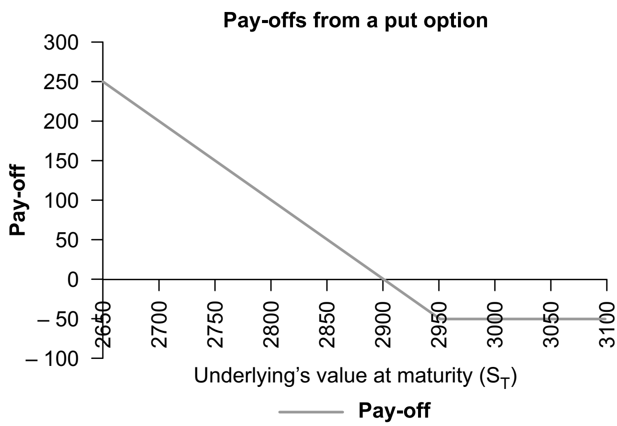
(*a*) **Bearish and high volatility—Put option:** In case a trader believes that market will experience bearish trend with fair probability of larger moves (i.e. high volatility), or in other words, the market will be on the declining trend and is likely to experience larger moves; a long position in put option becomes most suitable strategy.

Example 2.3 *Suppose a trader expects bearish trend in the market clubbed with larger moves in next one month's time. To exploit this opportunity, he takes long position in a European put option, which is scheduled to expire one-month from now. The option has a strike price of ₹ 2950 and is currently available at ₹ 50. Further, suppose the underlying share is currently traded at ₹ 3000. Since he has purchased the put option, he will be benefited by a downside movement in the market that is large enough to surpass the 2900 mark. Since he has paid ₹ 50 upfront as put premium, the price has to go down by more than hundred points from its current level to fetch an equilibrium position.*

We are aware that a put option will be exercised when the underlying assets price is lower than that of the strike price. At maturity, the price can attain any value; some of such values have been taken to examine the traders profit position on their different price scenarios. The calculation of profit payoff of the trader under different price scenarios has been summarized in the following table. Further, for better understanding of the position from the strategy, the payoffs from the strategy have been plotted for different possible prices at maturity.

It is evident from the data that the trader will be benefited only if the market shows a declining trend. Further, it should move down by at least ₹ 100 to bring him to no profit no loss situation. He will start generating profit only if the market moves below by more than ₹ 100. From the data it is clear that the trader will be benefited only by large moves; for example, market touches ₹ 2650

Underlying's price at maturity (S_T)	*Action*	*Value*	*Pay-off (Value-put premium)*
2650	Exercise	300	250
2700	Exercise	250	200
2750	Exercise	200	150
2800	Exercise	150	100
2850	Exercise	100	50
2900	Exercise	50	0
2950	Abandon	0	–50
3000	Abandon	0	–50
3050	Abandon	0	–50
3100	Abandon	0	–50

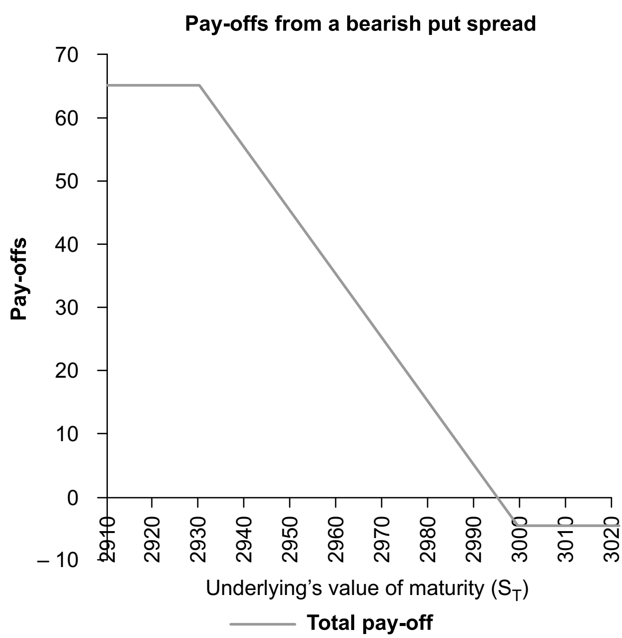


mark. In this situation, he will end up with a profit of ₹ 250. It is possible only if the market goes down by ₹ 350, which is equivalent to nearly 40% annualized volatility. In this strategy, the maximum loss that a trader is going to incur is the premium amount he paid initially; however, profit potential can theoretically reach up to the strike price.

(*b*) **Bearish and low volatility—Bearish put spread:** A Bearish Put spread is an appropriate trading strategy when a trader expects market to decline; however, larger moves are unlikely. A Bearish Put spread combines two put options, which are similar in all the aspects (maturity, underlying asset etc.) *except strike prices*. Since the trader speculates that market will go down, he takes a long position in put option to benefit from down movements; simultaneously, he takes a shot position in the other put option (with lower strike price) as he thinks that larger moves are unlikely. As a result, he reduces his initial investment by selling a put option with lower strike price. In sum, this strategy involves a long position in one put options with the higher strike price and simultaneously a short position in a put option with lower strike price.

Example 2.4 *Suppose a trader speculates that one month from now, the market will be on the declining trend but the volatility will remain low. A bearish put spread will be an appropriate strategy to get maximum benefit in case the trader's expectation turns correct. For the purpose, he takes long position in a put option having maturity of one month and strike price of ₹ 3000 (X_2), available at ₹ 55 (P_2). Simultaneously, he goes short in another put option with the same characteristics but lower strike price, which he chooses at ₹ 2930 (X_1), currently traded at ₹ 50 (P_1).*

Underlying's price at maturity (S_T)	Value Bearish put spread			Pay-off {Total value-($P_2 - P_1$)}
	X_1 (Short)	X_2 (Long)	Total	
2910	20	90	70	65
2920	10	80	70	65
2930	0	70	70	65
2940	0	60	60	55
2950	0	50	50	45
2960	0	40	40	35
2970	0	30	30	25
2980	0	20	20	15
2990	0	10	10	5
3000	0	0	0	–5
3010	0	0	0	–5
3020	0	0	0	–5



This strategy entails an initial cash outlay of ₹ 5, i.e. put premium paid (on the option having higher strike price) net of the premium received from the short position ($P_2 - P_1$). Further, suppose the underlying share is currently traded at ₹ 3000.

From the data, it is evident that the trader will start earning profit in case the share price moves below ₹ 2995. Once the price hits ₹ 2995 mark, the trader will breakeven. Beyond ₹ 2995 mark, every decrease will add to the profit of the trader until the price reaches ₹ 2930. As the price declines beyond ₹ 2930, the other put option (that you sold) will also be exercised against you and your profit will stabilize at ₹ 65 (that is, ₹ 3000 – 2970 – 5). That is, in this strategy, maximum profit will be $\{X_2 - X_1 - (P_2 - P_1)\}$.

From the example, it may be deciphered that this strategy will be appropriate if the market is likely to decline and, at the same time, larger moves are unlikely. In case price moves below ₹ 2930, the trader is no longer benefited as his profit remains ₹ 65 beyond this point. Thus, such an strategy is the most suitable one when the market is expected to decline; however, is likely to exhibit lower volatility. In a bearish put spread, the maximum loss a trader is expected to incur is the difference between put premiums, i.e. ($P_2 - P_1$). In sum, this strategy reduces the maximum loss as well as the maximum profit compared with put option.

In case the market is expected to experience larger moves along with the bearish sentiment, a long position in put option will be more profitable compared with a bearish put spread.

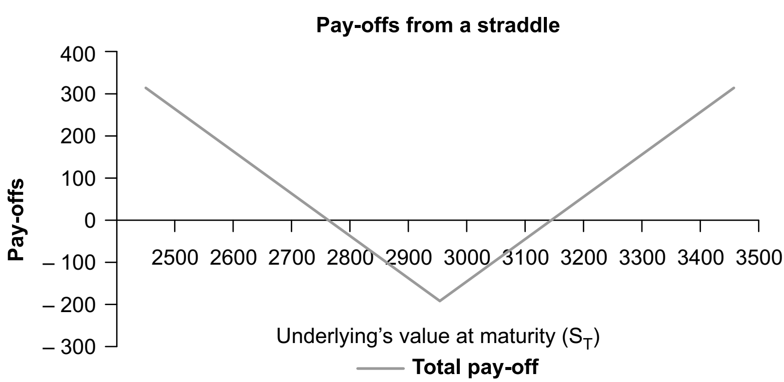
2.2.2 Non-directional or Neutral Trading Strategies Using Options

Contrary to directional strategies, Neutral strategies assume that the trade is neither bullish nor bearish on the market direction. That is, the speculator thinks that the market can move to either side. A variety of neutral strategies have been developed in an attempt to maximize profit from the scenarios where market direction is unpredictable. However, such strategies have been classified based on trader's view on volatility of the market—low, high and neutral volatility. Based on expectation of volatility in the market, some of popular neutral trading strategies are Straddle, Butterfly Spread and Box Spread strategy.

(*a*) **Neutral on direction with high volatility—Straddle:** Straddle is a strategy wherein the trader does not assume any direction of the market; however, he thinks that the larger movers are quite likely. That is, the market is likely to swing heavily to either direction. In view of this, a straddle attempts to generate profits in case market experiences larger moves to either direction. For the purpose, the trader has to take long position in a call, as well as put option with the same characteristics. A call will ensure maximum profit in case the market turns bullish and experience larger moves; on the contrary, if market declines and exhibits high volatility, a long position in put will maximize profit for the trader. It is important to note that the trader will be able to maximize his profit only if the market experiences large moves irrespective of their direction.

Example 2.5 *Suppose a trader has no view on the direction of the market, i.e. he fears that the market can go either way in a month's time; however, he believes that the volatility is going to be high. To generate profit in this scenario, he takes a long position in a **straddle.** For the purpose, he goes long in a call as well as a put option having strike price of ₹ 3000 and scheduled to expire one month from now. The call and put options are currently available at ₹ 100 and 90, respectively. Further, suppose the current market price of the underlying share is ₹ 3000.*

Underlying's price at maturity (S_T)	*Value* Straddle X_C	X_P	*Total value*	*Pay-off {Total value – (C + P)}*
2500	0	500	500	310
2600	0	400	400	210
2700	0	300	300	110
2800	0	200	200	10
2900	0	100	100	–90
3000	0	0	0	–190
3100	100	0	100	–90
3200	200	0	200	10
3300	300	0	300	110
3400	400	0	400	210
3500	500	0	500	310



In the above case, it is evident that the trader will start earning profit if the market moves up/ down by more than ₹ 190 from its current level. As long as market rages with ₹ 2810–3190, he will incur losses. The trader will breakeven *in case the market reaches either of the following two points: ₹ 2810 and 3190. The moment market crosses this range to either side, it will start generating profit to the trader. Further, it is important to note that the trader will be able to maximize his profit in case the market experiences high volatility. The higher it move from its current level, higher will the profit that he earns. For example, the market touches either ₹ 2500 or 3500 mark, which is possible in case market exhibits more than 50% volatility, the trader will earn good amount of profit, i.e. ₹ 210.*

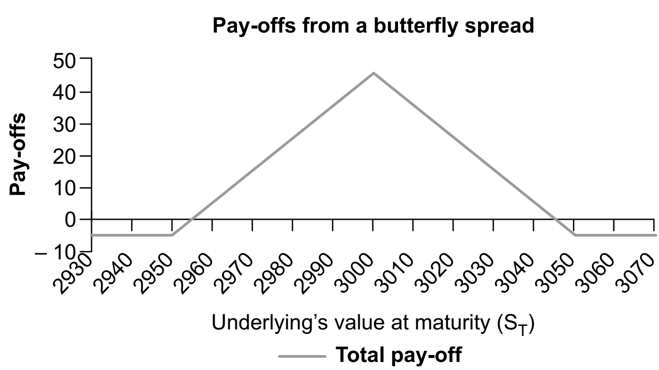
Since this strategy attempts to exploit both the possible directions, it naturally will cost higher to the trader compared with directional strategies. In this strategy, maximum loss that a trader can incur will be equal to ₹ 190 (C + P) in case market remains at the same level at maturity. In case the market is likely to experience moderate moves, it is not a suitable strategy. A suitable strategy for mild moves/low volatility has been discussed next.

(*b*) **Neutral on direction with low volatility—Butterfly spread:** A butterfly spread is an appropriate strategy when a trader has no clue about the market direction; however, he believes that larger moves are unlikely. This strategy involves long position in two call options with different strike prices and short position in the same two call options with the only difference that the strike for short positions is fixed somewhere in between the long positions' strike prices. In doing so, this strategy results in reduced initial outlay, as a trader takes short position as well. However, the profit potential promised by the strategy remains limited. This strategy works well as long as the market swings on either direction within a moderate limit.

Example 2.6 *Suppose a trader who has no idea where the market can move a month from now is sure that large moves are unlikely. Based on his view, he takes long position in butterfly spread strategy. For this purpose, he goes long in two call options—scheduled to expire a month from now—having strike prices of ₹ 2950 and 3050, respectively. The options are currently traded at ₹ 110 and 95, respectively. A the same time, he takes short position in two call option with the same characteristics with the only difference that the strike price which he chooses is at ₹ 3000. This option is currently traded at ₹ 100. Further, suppose the underlying share is currently traded at ₹ 3000. This strategy will result in an initial cash outlay that is considerably less compared with straddle; at the same time, profit will also be limited, as it can go up to ₹ 45, whereas in the case of straddle it can be substantially high.*

From the data, it is evident that this strategy will generate profits as long as the price remains within moderate limit (exhibits low volatility) irrespective of direction it takes. It can be easily deciphered from the data that the trader will *remain in profitable position in case prices rises/declines by ₹ 50 from its current level. Beyond this level, any further movement in the same direction (that is, the price further declines once it hits ₹ 2955 mark; or on the other side, it further advances once it reaches at rupees 3045) will result into loss.*

Underlying's price at maturity (S_T)	*Value Butterfly spread*			*Total value*	*Total pay-off*
	X_1 (Long)	*2^*X_2 (Short)*	*X_3 (Long)*		
2930	0	0	0	0	–5
2940	0	0	0	0	–5
2950	0	0	0	0	–5
2960	10	0	0	10	5
2970	20	0	0	20	15
2980	30	0	0	30	25
2990	40	0	0	40	35
3000	50	0	0	50	45
3010	60	20	0	40	35
3020	70	40	0	30	25
3030	80	60	0	20	15
3040	90	80	0	10	5
3050	100	100	0	0	–5
3060	110	120	10	0	–5
3070	120	140	20	0	–5



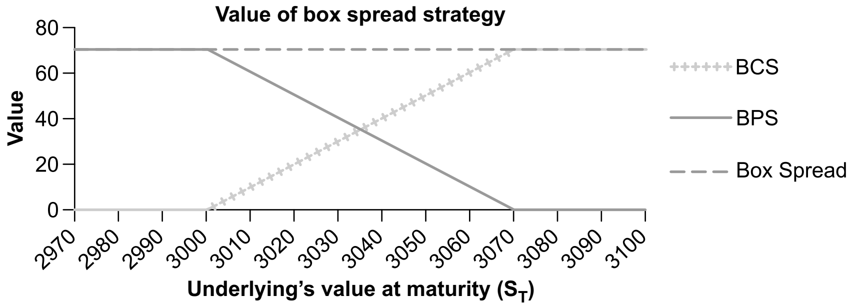
From the example, it is clear that the strategy generates maximum profit when the price remains at the same level, i.e., ₹ 3000. Further it remains profitable as long as price moves up or down by less than ₹ 45. In other word, this strategy ensures profit in case the market exhibits low volatility irrespective of its direction.

(c) **Neutral on both direction and volatility—Box spread:** Box spread is a suitable strategy when an investor has no clue about the direction as well as the volatility that market might experience in a given span of time. This strategy is basically a combination of bullish call spread and bearish put spread. This combination is unique in the sense that it provides uniform values irrespective of price that the underlying share takes at maturity. This strategy basically becomes a risk-free strategy as its profit always remain at a constant level; at the same time, it never results in loss.

Example 2.7 *Suppose a speculator fears that the market can move to either direction and can experience large as well as small/moderate moves. Based on his view on the market, he goes long in a box-spread strategy. For this purpose, he goes long in a bullish call spread as well as in a bearish call spread. For bullish call spread, consider the same data as discussed in Example 2.2. Further, assume that a bearish put spread has been constructed with the same strike prices for the same maturity dates. Assume that such put options with strike prices of ₹ 3000 and 3070 were traded at ₹ 58 and 68, respectively. This strategy results in an initial cash outlay that equals to outlays of the bullish call spread and bearish put spread added together, i.e.* $(C_1 - C_2) + (P_2 - P_1)$. *It will be ₹ 15 {(60 – 55) + (68 – 58)} in the above mentioned case.*

Values of the box-spread strategy for different possible prices/values of the underlying asset at maturity has been summarized in the following Table. For better understanding of the behaviour of values from the strategy, these have been portrayed across various price levels in the figure.

Underlying's price at maturity (S_T)	*Value*						
	Bullish call spread			*Bearish put spread*			*Box spread*
	X_1 *Long*	X_2 *(Short)*	*Total*	X_1 *(Short)*	X_2 *Long*	*Total*	
2970	0	0	0	30	100	70	70
2980	0	0	0	20	90	70	70
2990	0	0	0	10	80	70	70
3000	0	0	0	0	70	70	70
3010	10	0	10	0	60	60	70
3020	20	0	20	0	50	50	70
3030	30	0	30	0	40	40	70
3040	40	0	40	0	30	30	70
3050	50	0	50	0	20	20	70
3060	60	0	60	0	10	10	70
3070	70	0	70	0	0	0	70
3080	80	10	70	0	0	0	70
3090	90	20	70	0	0	0	70
3100	100	30	70	0	0	0	70
3110	110	40	70	0	0	0	70



From the data, it is clear that the combination of a bullish call spread and a bearish call spread leads to the same value irrespective of the price underlying asset takes. For this strategy, it is important to note that a trader should go long in case the value of from the strategy (₹ 70 in the above-mentioned case) is more that the initial cash outlay (₹ 15); otherwise, the trader should shorten the box spread.

In all the profit strategies discussed, it is very important to note that it would be safer to go with the European options (especially for combinational strategies), as in the case of American options, the possibility of early exercise may distort the expected profit pay-offs.

2.3 USE OF OPTIONS FOR HEDGING RISK

Equity options are extensively used for hedging financial risk/exposer. In fact, options are introduced with intent to provide suitable risk hedging facility to the participants in a financial market. Amongst equity options, index options are of great use to the portfolio managers for managing risk of a variety of equity funds. An investor who holds a long (short) position in equity share/portfolio thereof can hedge his risk by taking short (long) position in appropriate option contract (option on particular equity share/index option) to hedge against adverse movements in the market.

By virtue of risk hedging facility, options market is claimed to have an increasing effect on the liquidity of the underlying's market, as it helps Portfolio Management Services (PMS) to offer more sophisticated structured/tailor-made financial products to a variety of investors and, therefore, facilitates in increasing the mobilization of funds in the capital market. Moreover, the risk hedging facility provided by the options market motivates risk-averse investors to invest in the capital market.

2.3.1 Hedging with Index Options

Availability of options on the major indices of the economy helps different institutional investors (especially, mutual fund organization) to ensure stable earnings to their customers. The derivative products based on the indices of an economy, e.g. index options, provide an ideal hedging facility to the fund managers to hedge their market risk, as most of the equity portfolios are constructed based on the concept of indexing. That is, in some way or other, their portfolios are the manifestations of the leading index of the country. In other words, the returns of these funds, in general, show a high correlation with those of leading indices that makes these derivative instruments on leading indices an ideal choice for the fund managers to hedge against the market risk. And therefore, the availability of such financial innovations in the market helps in restoring confidence amongst the investors even in tough times, which in turn, facilitates movement of capital and liquidity in the capital market.

Therefore, these innovations help different types of investors to take a position in the market, depending upon their risk appetite. That is, an investor can use these instruments to increase or decrease the otherwise unavoidable risk (systematic risk or beta) of their portfolios, depending upon his choice to take higher or lower risk.

2.3.2 Changes in the Volume in Options vis-à-vis Futures Considering the Economic Environment: A Paradigm Shift

The data summarized for the year 2008–09 in Table 2.1 have shown a dramatic change in the typical pattern of trading in the Indian derivatives market. It is evident from the fact that the trading volume pertaining to index futures has been lower compared with that of index options in the year 2008–09. Further, it may be noted that the trading volume of index futures has consistently been substantially higher compared to that of index option for the first six years of its existence. In other words, the index futures market continued with its typical trend (dominated) in F&O segment from the year 2001–02 to 2007–08; however, the year 2008–09 has experienced a noticeable shift in the trading volumes from index futures to index options market. This paradigm shift in the Indian derivatives market has put this market at par with the developed markets, which prefer options contracts to futures.

A further examination of the development has been carried out to understand the reason of this development. For this purpose, the monthly data on index futures and index options has been collected for the period from April 2008 to June 2009. The data have been summarized in Table 2.1. It is clear for the first two months of trading, index futures market has clearly dominated the index options market. However, the index options market started picking up in volume from June 2008 onwards and has surpassed the index futures market in the month August 2008. Moreover, the index options market has consistently been dominating the index futures market thereafter.

Table 2.1 Business Growth in Derivatives (F&O) Segment, April 2008 to March 2009 (in crores)

Month	*Turnover of index futures*	*Notional turnover of index options*	*Total turnover of derivatives market*	*Share of index futures*	*Share of index options*
8-Apr	280100	133565	766431	**37**	**17**
8-May	267641	129067	797908	**34**	**16**
8-Jun	377939	308709	1084064	**35**	**28**
8-Jul	395380	357209	1160174	**34**	**31**
8-Aug	300449	312102	957445	**31**	**33**
8-Sep	380198	461623	1197872	**32**	**39**
8-Oct	324962	364510	941646	**35**	**39**
8-Nov	256950	292134	745356	**34**	**39**
8-Dec	269997	313615	829166	**33**	**38**
9-Jan	234141	309271	778118	**30**	**40**
9-Feb	205679	305599	712370	**29**	**43**
9-Mar	276677	444099	1039930	**27**	**43**

Source: www.nse-india.com

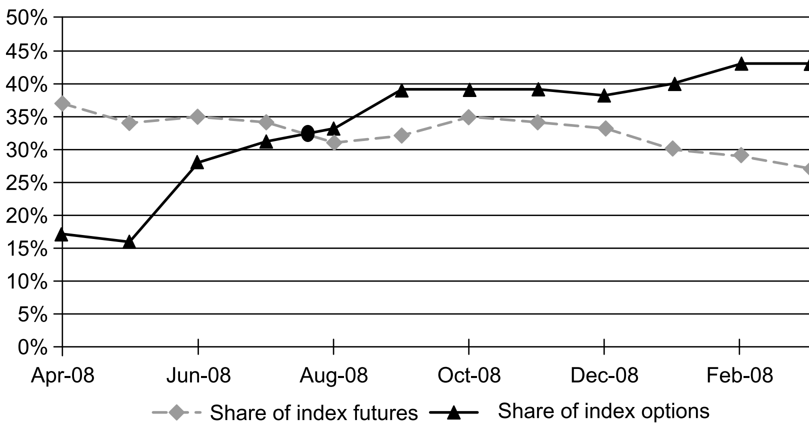


Figure 2.1 Relative volume of index options to index futures vis-a-vis total volume of F & O segment during 2008-09: A paradigm shift

It would be appropriate to note here that the index derivatives (futures and options) are primarily used for hedging the portfolios against the unfavourable movement in the market, which may result in substantial reduction in the value of the portfolio. Such financial innovations are predominantly used by the fund managers, who are responsible for ensuring stable earnings to their clients. The use of index derivatives as a hedging tool can be traced to the fact that most of the funds are created using the concept of indexing. The concept of indexing connotes benchmarking the portfolio to the best portfolio in the market, which is the leading index of the economy. Therefore, the derivatives on such indices are the natural choice for hedging risks that may reduce the value of the portfolio.

In view of the change in the trading pattern of index futures and options market, it would be appropriate to infer that the investors has shifted their preferences to the index options for hedging their portfolios. Moreover, the perceived change in the choice of hedging vehicle can be traced to the dramatic change in the financial markets across the globe in terms of high volatility of returns on account of devastative meltdown, which occurred as a result of the sub-prime crisis. Therefore, it would be appropriate to say that the Indian investors have shifted from index futures to index options in the wake of high volatility in the market in view of the fact that the options provide far better hedging mechanism compared with that of index futures. Major advantage of hedging through options market (in addition to protection of the portfolio from an unfavourable movement) is that it allows hedger to take the advantage of a favourable movement as well.

CHAPTER 3

Testing Lower Boundary Conditions for the S&P CNX Nifty Index Options

3.1 INTRODUCTION

The options markets play a central role in an economy as they enhance better allocation of capital in securities market by virtue of their functions to facilitate risk hedging and price discovery. In today's parlance, where the demand for the structured finance (which requires excessive use of options contracts) is booming in India, the role of such markets has acquired greater significance. The 'open interests' in the options segment of Indian derivatives market has even surpassed that of futures market for last few months since April, 2008. This development has put the Indian derivatives market at equal footings with the other international (developed) markets, where the options are preferred to futures.

There could be two major reasons for such a development. First, increase in the portfolio management services (PMS), which provide structured financial products (using options market) to high profile investors. Secondly, an increase in the variety of the products (in terms of maturity period) has taken place on account of the introduction of long-dated options on 3rd March, 2008. These options enable an investor to take a position up to 5 years.

Considering the increasing importance of the options market in India, it is desired that the market should carry out its required functions in the best possible way. For the purpose, it is imperative that the market should be efficient. The reason is that well-functioning financial markets are vital to a thriving economy, as these markets facilitate price discovery, risk hedging and allocation of capital to its most productive uses. Inefficiency of a financial market (e.g. options market in this study) indicates that it is not performing the best possible job at above-mentioned important functions (Ackert and Tian, 2000).

The present study attempts to assess the pricing efficiency of the index options in India using both the spot prices of the underlying asset (i.e. the daily closing value of the S&P CNX Nifty index) and the futures prices, which are traded on the same underlying asset, the S&P CNX Nifty index. The use of futures market has been proposed in view of the fact that (i) it helps, to a marked extent, in ensuring the exploitability of arbitrage opportunities when underlying asset is an index; (ii) the use of futures markets helps in doing away with the short-selling constraint as a futures can easily be shorted and (iii) it costs an investor less to exploit the arbitrage opportunities through futures market because of the lower transaction costs attached to it and the leverage they provide.

Notably, the use of futures prices on the same underlying asset instead of spot prices essentially makes this approach a test of joint market efficiency, as opined by Fung *et al*. (1997). At the same time, use of the futures prices facilitates in assessing the degree of integration or pricing interrelationships between the different derivative instruments being traded in the financial market (Lee and Nayar, 1993). In other words, this approach helps in addressing the question whether market participants consider **important pricing interrelationships** while pricing the index options. The scope of the present study is confined to the pricing interrelation between index options and index futures. In sum, the use of futures market has been proposed in order to examine the role of futures market in the absence of short-selling facility in the underlying's cash market. In other words, whether the futures market could work as an equally good alternative to short-selling facility and, therefore, help in restoring equilibrium in the options market even in the absence of short-selling facility.

The use of futures prices, however, puts one restriction on the otherwise model-free approach, i.e. it assumes cost-of-carry model to hold. Therefore, this approach cannot be designated as 'model-free' unlike the test of the boundary condition using spot prices. However, the approach still remains less restrictive compared with those based on certain pricing models, e.g. Black and Scholes (1973), which assumes that the stock price and volatility are governed by some stochastic processes.

In the chapter, the violations or mispricing signals observed from the test procedures using spot values have been examined as per the specified levels of liquidity and maturity of options. Also, the violations classified as per the specified levels of maturity have further been sub-classified according to the three specified levels of liquidity. The classification facilitates a meaningful explanation to the exploitability of such violations and, therefore, is very crucial in assessing the efficiency of the market. This has been done in view of the fact that mere presence of violations does not indicate market inefficiency; it is the unexploitability and persistence of such violations which pose serious concerns/threats to the market efficiency.

Moreover, the learning behaviour of the investors in options markets has also been examined. This has been done by analysing the number of violations (from the test of LBCs using spot values) vis-à-vis the number of observations analysed over the years under reference for both the call and put options. The learning hypothesis, which requires that the number of violations should go down over the years, has been proposed to gauge the developments related to the efficiency of the market. The analysis of violations over the years under reference is in line with Mittnik and Rieken (2000a), a study in the context of German stock index options market.

The Section 3.2 of this chapter discusses lower boundary condition using spot as well as futures prices on the same index that has been tested for options contracts. The data have been discussed in Section 3.3. Section 3.4 presents analysis and results. The chapter ends with the concluding observations in Section 3.5.

3.2 THE LOWER BOUNDARY CONDITIONS

The lower boundary condition, first proposed by Merton (1973a) and further extended by Galai (1978), plays a crucial role in assessing the options market efficiency. A number of research studies have been carried out in different options markets using the lower boundary condition to assess the efficiency of the markets, including the first one by Galai (1978). The other studies which tried to diagnose the options market efficiency based on the violation of lower boundary condition include Bhattacharya (1983), Halpern and Turnbull (1985), Shastri and Tandon (1985), Chance (1988), Puttonen (1993), Berg *et al*. (1996), Akert and Tian (2001), Mittnik and Rieken (2000a).

The lower boundary condition of option prices denotes the minimum price of an options contract at a given point of time during the life of that options contract. The violation of the condition indicates arbitrage opportunities. Therefore, the price for an options contract should necessarily be equal to or higher than that suggested by the lower boundary condition. In order to ensure correct pricing in an options market, this is a necessary condition that needs to be satisfied to uphold the well-known no-arbitrage argument of options pricing. In literature, the lower boundary condition has been defined for the European options as well as American options. In this study, as we are analysing the **S&P CNX Nifty** index options, which are European (that can be exercised only at maturity) in nature, the condition defined for European options constitutes the basis of the study.

3.2.1 The Lower Boundary Conditions Using Spot Values

The lower boundary conditions defined for the call and put options are given in the Eqs (3.1) and (3.2), respectively, which need to be satisfied in an efficient market.

$$c_t \geq \max\,[0, \{I_t - Ke^{-r(T-t)} - TTC_t\}] \tag{3.1}$$

$$p_t \geq \max\,[0, \{(Ke^{-r(T-t)} - T_t) - TTC_t\}] \tag{3.2}$$

In the above equations,

c_t is the market price of a call option at time t,

p_t is the market price of a put option at time t,

I_t is the level of underlying index (S&P CNX Nifty) at time t,

K is the strike price of the option contract,

is the expiration time of the option at the time when it was floated,

r is the continuously compounded annual risk-free rate of return,

TTC_t is the total transaction costs (i.e. transaction costs relating to trading in options and spot market) at time t and

$(T - t)$ is the time to maturity of the option at time t (measured in years).

The Eqs (3.1) and (3.2) describe the lower boundary conditions where the underlying asset is not expected to pay any dividends during the life of the option. Since, in general, almost all the financial assets pay dividends, the Eqs (3.1) and (3.2) need to be modified by incorporating dividends. The treatment of dividends in the test varies based on the assumption made about the payment of dividends. Some of the studies treated it as a discrete payment, e.g. Smith (1976), and others as a continuous yield, e.g. Chance (1988). In the present study, since S&P CNX Nifty index (which includes 50 scrips) based options are being analysed, it would be difficult to test the lower boundary condition assuming discrete dividends. Therefore, following Chance (1988), it has been assumed that dividends are paid as continuously compounded yield. The lower boundary condition equations for call and put options, assuming that the index is paying continuously compounded annual dividend yield (δ), are given in the Eqs (3.3) and (3.4), respectively.

$$c_t \geq \max\,[0, \{(e^{-\delta(T-t)}\, I_t - Ke^{-r(T-t)}) - TCC_t\}] \tag{3.3}$$

$$p_t \geq \max\,[0, \{(Ke^{-r(T-t)} - e^{-\delta(T-t)}\, I_t) - TTC_t\}] \tag{3.4}$$

The testable forms of the Eqs (3.3) and (3.4), which have been used in the present study to assess the efficiency of the options market, are given in the next sub-section.

3.2.1.1 Testable form of the lower boundary conditions using spot values

Equations (3.3) and (3.4) given above have been rearranged in order to make them testable to gauge the efficiency of the options markets. The testable form, to test the Efficient Market Hypothesis (EMH) in terms of lower boundary condition, is given in the Eqs (3.5) and (3.6) for call and put option, respectively.

$$\varepsilon_t^c = [\{(e^{-\delta(T-t)}\, I_t - Ke^{-r(T-t)}) - TTC_t\} - c_t] \tag{3.5}$$

$$\varepsilon_t^p = [\{(Ke^{-r(T-t)} - e^{-\delta(T-t)} I_t) - TTC_t\} - p_t] \tag{3.6}$$

In the above equations, ε_t^c and ε_t^p are the absolute amount of abnormal profits (ex-post) or mispricing signals from call and put options, respectively, if the violation of lower boundary condition takes place. A violation of the lower boundary condition is recorded if $\varepsilon_t^c > 0$ and $\varepsilon_t^p > 0$ for call and put options, respectively.

Example 3.1 *Exploiting arbitrage opportunities indicated by violation of Lower Boundary Condition using the underlying's spot market: A case of Call Option*

On November 10, 2010, a call option contract on S&P CNX Nifty index, with strike price of ₹ 6200 and scheduled to expire on November 25, 2010, is available at ₹ 90. In spot market, the index is currently being traded at ₹ 6290. Suppose that continuously compounded risk-free rate of return is 7.5% p.a., and each transaction in F&O segment is subject to transaction cost of 0.05% on notional value of the contract, i.e. (strike price + premium) × size of the contract. An option contract on Nifty includes 50 nifty.

Solution *As mentioned in the discussion on lower boundary condition, the minimum price of a call option contract at any given point in time should be*

$$c_t \geq \max\left[\{(I_t - K^{-r(T-t)}) - TCC_t\}, 0\right]$$

Therefore, the minimum price for the above-mentioned call option should be

$$= \text{Max}\left[\{(6290 - 6200 \times e^{-(0.075 \times 16/365)}) - (0.0005 \times (6200 + 90))\}, 0\right] = ₹\ 107.21^{*}$$

Since the price quoted in market (₹ 90) is lower than that suggested by lower boundary condition (under-valuation of the call option), it indicates an arbitrage opportunity. In case such an opportunity appears, following steps can be taken to ensure arbitrage gains.

Steps required now (on spot):

All steps required now need to be taken simultaneously to lock-in arbitrage profit. This will hold true for Examples 3.1–3.3.

Step 1: *Purchase the call option as it is undervalued.*

Step 2: *Short-sell the underlying asset (index) at current market price.*

Step 3: *Invest the remaining amount ₹ 6,196.85 (₹ $6290_{Spot\ value}$ – ₹ $90_{Call\ premium}$ – ₹ $3.15_{Transaction\ cost}$) at risk-free rate for the remaining life of the contract.*

Steps required at maturity:

Step 4: *Liquidate your investment in the risk-free asset. You will realize a sum of ₹ $6196.85 \times e^{(0.075 \times 16/365)}$; that is, ₹ 6217.26.*

Step 5: *Square off your short position in the underlying asset. For this, (a) exercise the option contract and buy it at ₹ 6200 if the underlying asset is being traded at more than ₹ 6200. (b) On the contrary, if the underlying is traded at*

[*] It is important to note that dividend yield and transaction cost related to the spot market have been ignored in determining minimum price of the option contract in order to avoid further complexity.

a lower price, e.g. ₹ 6150, abandon the option to purchase the underlying asset at ₹ 6200, and purchase it directly from the spot market.

From the above, it is clear that, in any case, maximum amount required to square off the short position is ₹ 6,200. Since you received ₹ 6,217.26 from your initial investment, you end up generating a profit of ₹ 17.26 (₹ 6,217.26 – 6,200). And, on the whole contract (which includes 50 Nifty), you will end up with the profit of ₹ 863.

Example 3.2 *Exploiting arbitrage opportunities indicated by violation of Lower Boundary Condition using the underlying's spot market: A case of put option*

On November 10, 2010, a put option contract on S&P CNX Nifty index, with strike price of ₹ 6200 and scheduled to expire on November 25, 2010, is currently available at ₹ 70. In the spot market, the index is currently being traded at ₹ 6090. Suppose that continuously compounded risk-free rate of return is 7.5% p.a., and each transaction in F&O segment is subject to transaction cost of 0.05% on notional value of the contract.

Solution *As mentioned in the discussion on lower boundary condition, the minimum price of a put option contract at any given point in time should be*

$$p_t \geq \max\,[\{(Ke^{-r(T-t)} - I_t) - TTC_t\}, 0]$$

Therefore, the minimum price for the above-mentioned put option should be

$$= \mathrm{Max}\,[\{(e^{-(0.075 \times 16/365)} \times 6200 - 6090) - (0.0005 \times (6200 + 70))\}, 0] = ₹\ 86.52$$

Since the price quoted in the market (₹ 70) is lower than that suggested by lower boundary condition (under valuation of put option), it indicates an arbitrage opportunity. In case such an opportunity appears, following steps need to be taken to ensure arbitrage gains.

Steps required now (on spot):

***Step 1**: Purchase the put option as it is undervalued.*

***Step 2:** Take long position (purchase) in the underlying asset (index) at current market price.*

***Step 3**: Borrow a sum of ₹ 6,163.15 (₹ $6{,}090_{Spot\ value}$ + ₹ $70_{Put\ premium}$ + ₹ $3.15_{Transaction\ cost}$) at risk-free rate for the remaining life of contract.*

Steps required at maturity:

***Step 4:** Square off your long position in the underlying asset. For this, (a) in case the underlying asset is being traded at less than ₹ 6200, exercise the put option and sell the underlying asset at ₹ 6200; (b) On the contrary, if the underlying is traded at a higher price, e.g. ₹ 6250; abandon the option to sell the underlying asset at ₹ 6200 and sell it directly in the spot market.*

Step 5: *Pay off the borrowed sum along with the accrued interest for the period. The amount payable is ₹ 6183.45 (₹ 6163.15 × $e^{(0.075 \times 16/365)}$).*

From the above, it is clear that, in any case, you will realize ₹ 6,200 or more by selling the underlying asset (squaring off your long position); whereas, amount needed to pay off the borrowed sum is ₹ 6183.45. As a result, you will make a profit of ₹ 16.55 (₹ 6,200 – ₹ 6183.45). And, on the whole contract (which includes 50 Nifty),; you will book a profit to the tune of ₹ 827.50.

Note: *In the case of index derivatives, it is important to note that final settlement takes place in terms of cash, as physical settlement (delivery of the underlying asset) is not possible. The cash settlement is entailed in view of the nature of underlying asset, i.e. index, and the whole index cannot be delivered. Therefore, the price differences are settled instead of delivery/receipt of the underlying. For example, holder of a call option exercises his option when value of the underlying index is ₹ 6,300; he will get a difference of ₹ 100 in case the strike price was ₹ 6,200. Similarly, in the case of put option with the same characteristics, the holder will receive a sum of ₹ 50 on exercising his option in case the value of underlying index turns out ₹ 6150.*

3.2.2 The Lower Boundary Conditions Using Futures Prices

The test of lower boundary condition using futures prices is in line with Puttonen (1993)—a study done in the Finnish index options market. Moreover, the test of options market efficiency using futures prices (on the same underlying asset) is in line with Lee and Nayar (1993), Fung and Chang (1994), Fung *et al*. (1997), Fung and Fung (1997), Fung and Mok (2001), etc. with the only difference that the condition tested in the study is the lower boundary condition for the options prices, whereas all above studies focus on the put-call-futures parity condition.

The lower boundary conditions using corresponding futures prices (with the same maturity date) are given in the Eqs (3.7) and (3.8), respectively, for the call and put options. These conditions are expected to hold in an efficient options market.

$$c_t \geq \max\,[0, \{e^{-r(T-t)}\,(F_t - K) - TTC_t^*\}] \tag{3.7}$$

$$p_t \geq \max\,[0, \{e^{-r(T-t)}\,(K - F_t) - TTC_t^*\}] \tag{3.8}$$

In the above equations, F_t is the value of the S&P CNX Nifty futures (with same expiration date as of the option under consideration) at time t and TTC_t is the total transaction costs (i.e., transaction costs relating to trading in options and futures contracts) at time t. All other variables are the same as in Eqs (3.1) and (3.2).

The dividends expected from the underlying asset during the life of the option have been ignored, since the underlying asset used in the test is futures prices/values of the index instead of the spot prices/values. This has been done due to the fact that the futures prices (in an efficient market) are expected to have impounded the effect of dividends on the prices of the underlying asset.

3.2.2.1 Testable form of the lower boundary condition using futures prices

The Eqs (3.7) and (3.8) have been rearranged in order to make them testable to gauge the efficiency of the options market. The testable form, to gauge the EMH using lower boundary condition, is given in the Eqs (3.9) and (3.10) for call and put option, respectively.

$$\varepsilon_t^c = [\{(e^{-r(T-t)}(F_t - K)) - TTC_t^*\} - c_t] \tag{3.9}$$

$$\varepsilon_t^p = [\{(e^{-r(T-t)}(K - F_t)) - TTC_t^*\} - p_t] \tag{3.10}$$

In the above equations, ε_t^c and ε_t^p denote the absolute amount of abnormal profits (ex-post) or mispricing signals from call and put options, respectively, if the violation of lower boundary condition occurs. A violation of the lower boundary condition is recorded if $\varepsilon_t^c > 0$ and $\varepsilon_t^p > 0$ for call and put options, respectively. Though the presence of such profits is indicative of market inefficiency, it should not be treated as a conclusive remark on the efficiency of the market.

It may be noted that all equations relating to test of LBCs using spot as well as futures prices have been specified considering the transaction costs but assuming zero or negligible bid-ask spread. In view of this, there is always a chance that the arbitrage opportunities suggested by these equations may disappear in the presence of the bid-ask spread, especially, for the options traded relatively less frequently. Therefore, due consideration has been given to the bid-ask spreads while interpreting the violations to draw inferences regarding the market efficiency. The details on the transaction costs included in the analysis have been summarized in the data section. On the contrary, given the fact that the bid-ask spread for options is not included in the transaction database provided by NSE and the difficulty to estimate such costs, it has been excluded in the above equations. In operational terms, our study is in line with that of Halpern and Turnbull (1985).

In this regard, commenting upon the exploitability of observed mispricing signals, Trippi (1977) and Chiras and Manaster (1977) concluded that the signals so observed were exploitable using a specified trading strategy to ensure *ex-ante* exploitation of such profit opportunities. However, in the present study, no strategy has been executed to ensure *ex-ante* exploitability of abnormal profits suggested by mispricing signals, as the test procedure applied is *ex-post* in nature.

Example 3.3 *Exploiting arbitrage opportunities by using the underlying's future market: A case of call option*

In addition to the data given in Example 3.1, assume that a futures contract on NSE CNX Nifty index, scheduled to expire on November 25, 2010, is traded *at ₹ 6310. Examine the arbitrage opportunity, if any. Determine the profit which can be generated by exploiting this opportunity.*

Solution *As mentioned in the discussion on LBC using futures prices, the minimum price of a call option contract at any given point in time should be*

$$c_t \geq max\ [\{e^{-r(T-t)}\ (F_t - K) - TTC_t^*\},\ 0]$$

Therefore, the minimum price for the above-mentioned call option should be

$$= Max\ [\{e^{-(0.075 \times 16/365)} \times (₹\ 6310 - ₹\ 6200) - (0.0005 \times (6200 + 90 + 6310))\},\ 0] = ₹\ 103.34^*$$

Since the price quoted in market (₹ 90) is lower than that suggested by the boundary condition, it indicates an arbitrage opportunity. In case such an opportunity appears in the market, the following steps need to be taken to ensure arbitrage gains.

Steps required now (on Spot):

Step 1: *Buy the call option at the current market price as it is undervalued.*

Step 2: *Short (sell) the future contract at current market price.*

Step 3: *Borrow ₹ 96.30 (₹ $90_{Call\ premium}$ + ₹ $6.30_{Transaction\ cost}$) at risk-free rate for the remaining time to maturity.*

Steps required at maturity: *At maturity, price of the underlying asset will follow one of the following three scenarios: (i) less than the strike price of the option contract, (ii) more than the strike price but less than or equal to future price (F_t) and (iii) more than futures price (F_t).*

Scenario 1: *Less than the strike price of call option contract, i.e. price of the underlying index turns out to be less than ₹ 6,200. For example, at maturity, the index is traded at ₹ 6150.*

Step 4: *You will not exercise the call option as market price of the asset is less than strike price (₹ 6200) of the contract.*

Step 5: *You will make a gain of ₹ 160 (₹ 6310 – ₹ 6150) on short position in futures. Since you entered into a futures contract to sell the underlying asset at ₹ 6310 on the maturity of the contract irrespective of price of the underlying asset in spot market at maturity and as the current market price in the spot market turns out to be ₹ 6150, you will make a gain as you will be able to sell the asset at ₹ 6310.*

Scenario 2: *More than the strike price of call option contract but less than or equal to the price of the futures contract. For example, at maturity, the index is traded at ₹ 6250.*

Step 4: *You will exercise the call option, as the price of the asset is more than the strike price (₹ 6200) of the contract. And, you will gain ₹ 50 on exercising*

* It may be noted that the margin needed to take a position in futures market and cost thereof have been ignored in determining minimum price of the option contract in order to avoid further complexity.

the call option, as you have the right to purchase the asset at ₹ 6200, which is currently traded at ₹ 6250.

Step 5: *Similarly, you will make a gain of ₹ 60 on the short position in futures.*

In sum, you will make a total gain of ₹ 110 from your portfolio (long in call and short in futures). Further, it may be noted that this portfolio will generate ₹ 110, in case price of the underlying asset ranges between ₹ 6200 and ₹ 6310.

Scenario 3: *More than the price of the futures contract. For example, at maturity, the index is traded at ₹ 6400.*

Step 4: *You will exercise the call option as the price of the asset is more than the strike price (₹ 6200) of the contract. And, you will gain ₹ 200 on exercising the call option.*

Step 5: *However, you will lose ₹ 90 on the short position in futures.*

In sum, you will make a total gain of ₹ 110 from your portfolio (long in call and short in futures). It is important to note that this portfolio will generate a profit of ₹ 110, in case price of the underlying asset turns out to be more than ₹ 6310.

Finally, from all the three possible scenarios for the price of the underlying asset, it is evident that an arbitrageur will always earn ₹ 110 or more.

Step 6: *You need to pay off the borrowed sum along with the accrued interest, i.e. ₹ 96.62 (₹ 96.30 × $e^{(0.075 \times 16/365)}$).*

From the above, it is clear that although, in any case, you earn ₹ 110 or more, you require ₹ 96.62 to pay off your borrowings. In other words, you make a minimum profit of ₹ 13.38 (₹ 110 – ₹ 96.62). And, on the whole contract (which includes 50 Nifty); you will end up with the profit of ₹ 669.

Example 3.4 *Exploiting arbitrage opportunities by using the underlying's future market: A case of put option*

In addition to the data given in Example 3.2, further assume that a futures contract on NSE CNX Nifty index, scheduled to expire on November 25, 2010, is traded at ₹ 6110. Examine the arbitrage opportunity, if any. Determine the profit which can be generated by exploiting this opportunity.

Solution *As mentioned in the discussion on LBC using futures prices, the minimum price of a put option at any given point in time should be*

$$p_t \geq \max [\{e^{-r(T-t)} (K - F_t) - TTC_t^*\}, 0]$$

Therefore, the minimum price for the above-mentioned call option should be

$$= \text{Max} [\{e^{-(0.075 \times 16/365)} \times (₹\ 6200 - ₹\ 6110) - (0.0005 \times (6200 + 90 + 6110))\}, 0] = ₹\ 83.50$$

Since the price quoted in the market (₹ 70) is lower than that suggested by the boundary condition, it indicates an arbitrage opportunity. In case such *an opportunity appears in the market, the following steps need to be taken to ensure arbitrage gains.*

Steps required now (on Spot):

Step 1: *Buy the put option at the current market price, as it is undervalued.*

Step 2: *Take long position in the futures contract at current market price.*

Step 3: *Borrow ₹ 76.20 (₹ 70Put premium + ₹ 6.20Transaction cost) at risk-free rate for the remaining time to maturity.*

Steps required at maturity: *At maturity, price of the underlying asset will follow one of the following three scenarios: (i) less than the price of the futures contract (F_t), (ii) more than the futures price (F_t) but less than or equal to strike price of the put options and (iii) more than the strike price of the options.*

Scenario 1: *Less than the price of the futures contract. For example, at maturity, the index is traded at ₹ 6050.*

Step 4: *You will exercise the put option, as current price of the asset is less than the strike price (₹ 6200) of the contract. And, you will make a gain of ₹ 150 (₹ 6200 – ₹ 6050).*

Step 5: *On the other hand, you will incur a loss of ₹ 60 (₹ 6110 – ₹ 6050) on long position in futures. Since you entered into a futures contract to purchase the underlying asset at ₹ 6110 on maturity of the contract, irrespective of its price at maturity, and as the current market price in the spot market turns out to be ₹ 6050, you incur a loss as you have to buy the asset at ₹ 6110, which is currently selling at ₹ 6050 in the spot market.*

In sum, you will make a total gain of ₹ 90 from your portfolio.

Scenario 2: *More than the futures price but less than or equal to the strike price of the put options contract. For example, at maturity, the index is traded at ₹ 6150.*

Step 4: *You will exercise the put option as the price of the asset is still less than the strike price (₹ 6200) of the contract. And, you will gain ₹ 50 on exercising the option as you have the right to sell the asset at ₹ 6200, which is currently traded at ₹ 6150.*

Step 5: *Similarly, you will make a gain of ₹ 40 on the long position in futures.*

In sum, you will make a total gain of ₹ 90 from your portfolio.

Further, it is important to note that this portfolio will generate ₹ 90, in case price of the underlying asset is less than or equal to ₹ 6200.

Scenario 3: *More than the strike price of the put option. For example, at maturity, the index is traded at ₹ 6250.*

Step 4: *You will not exercise the put option as the price of the asset is more than the strike price (₹ 6200) of contract.*

Step 5: *However, you will make a gain of ₹ 140 on the long position in futures.*

In sum, you will make a total gain of ₹ 140 from your portfolio.

Finally, from all the three possible scenarios for the price of the underlying asset, it is evident that an arbitrageur will always earn ₹ 90 or more.

Step 6: *You need to pay back the borrowed sum (along with the accrued interest), i.e. ₹ 76.45 (₹ 76.20 × $e^{(0.075 \times 16/365)}$).*

From the above, it is clear that, in any case, you will earn ₹ 90 or more; whereas, you require ₹ 76.45 to pay off your borrowings. In other words, you will make a minimum profit of ₹ 13.55 (₹ 90 – ₹ 76.45). And, on the whole contract (which includes 50 Nifty), you will end up with a profit of ₹ 677.50.

> ***Note:*** *While assessing options market using futures market, it is assumed that futures market is efficient. That is, it will converge to spot price at the maturity of the contract.*

3.4 THE DATA

This study has attempted to analyse secondary as well as primary data on the options market. The secondary data have been collected from the websites of National Stock Exchange of India Ltd. and Reserve Bank of India (RBI). The primary data have been collected through a survey conducted among the brokerage firms.

3.4.1 The Secondary Data

3.4.1.1 Data related to options contracts, spot market, futures market and interest rates

The secondary data considered for the analysis can be broadly classified into four categories: (i) data related to S&P CNX Nifty index options contracts, (ii) daily closing values of the S&P CNX Nifty index, (iii) data related to the futures contracts, i.e. the S&P CNX Nifty index futures, and (iv) data on the risk-free rate of return.

The first dataset relates to options, it consists of daily closing prices of options, strike prices, deal dates, maturity dates and number of contracts of call and put options, respectively. In order to minimize the bias associated with *nonsynchonous trading*[i], only *liquid option quotations*[ii] are being considered for the analysis. The next data set consists of the daily closing values of the S&P CNX Nifty index. The third data set is regarding the futures contracts. It includes daily closing prices of S&P CNX Nifty index futures, deal dates, maturity dates and number of contracts traded. The fourth data set constitutes of monthly average yield on 91-days Treasury-bills. The yield on T-bills has been converted into continuously compounded annual rate of return using the relationship given in Eq. (3.1).

$$r = \ln(1 + r^*) \tag{3.11}$$

Where, r is the proxy for continuously compounded annual risk-free rate of return and r^* is the average annual yield on 91-days T-bill of the maturity corresponding to the maturity date of the options contact.

The data for all the four mentioned categories have been collected from June 4, 2001 (starting date for index options in Indian securities market), to June 30, 2007. The first, second and third data sets have been collected from the website of NSE, and the fourth category of data set has been collected from website of RBI.

3.4.1.2 Transaction costs

The testing of model-free approach, i.e. Lower Boundary Conditions (LBCs) and Put-Call Parity (PCP) provides the flexibility of directly incorporating the transaction costs, which need to be reckoned in order to have true assessment of market efficiency. In view of this, the transaction cost has been estimated by interacting with the trading members located at Delhi. Moreover, some of the Indian studies on the subject, e.g. Vipul (2008), have been referred to in order to have a justifiable estimate of transaction costs.

The transaction costs typically include brokerage charged by the brokerage houses/trading members of the exchanges, service tax on the brokerage, stamp duty, opportunity cost of the margin deposits required in the case of futures contracts and short options positions, etc. In Indian capital market, another charge, namely Securities Transactions Tax (STT), was introduced and implemented with effect from October 1, 2004. Notably, such charges were to be levied only on the sell side of the transactions in the derivatives market unlike the equity market transactions, where STT was proposed to be levied on both legs of the transactions. In view of this, the transaction costs considered in the study typically include brokerage, service tax on the brokerage and STT (October 1, 2004, onwards).

Since the transaction costs constitute a major constraint to arbitrage (Ofek *et al.*, 2004), an attempt has been made to have an estimate of such costs in Indian derivatives market. For the purpose, interviews were conducted with the senior employees of brokerage houses based at Delhi, India. A consensus was arrived at an estimate of brokerage of 0.05% (including service taxes) for Futures and Options (F&O) in the case of retail investors. Such costs are charges at *'(strike price + premium) × lot size'* for options contracts and *'Futures price at the time of the transaction × lot size'* for futures contracts. However, it may be noted that such costs may go down to 0.03% (including service taxes) for the institutional investors. Besides, another category of investors who are more likely to get benefited from such arbitrage opportunities, the brokerage houses, bear the least cost of trading amongst all types of investors/players in the market, as they are not required to pay any brokerage. However, it would be reasonable to consider the opportunity cost for the brokerage house, and a logical estimate could be the cost incurred by the institutional investors, i.e. 0.03% in the case of F&O segment, as pointed out by Vipul (2008). Moreover, with respect to the transaction costs pertaining to spot market transactions for the trading member organizations, an estimate of 0.15% (excluding STT) of the traded value has been arrived at, based on the interaction with different trading member organizations based at Delhi and as suggested by Vipul (2008). Based on these estimates, the violations have been calculated using the transaction costs applicable to the trading member organization, given their least cost structure.

Besides, the STT charge of 0.01% (on the sell side of the transactions in F&O segment) has also been included in the transaction costs. Likewise, the STT charge of 0.125% has been considered for the spot market transaction, notably, for both legs of the transaction. Since the STT was introduced in October, 2004, it has been considered as part of the transaction costs for the arbitrage opportunities that occurred after 1st October, 2004. In sum, for the analysis purpose, the major constituents of the transaction costs have been the brokerage and the service tax on it before October, 2004; and it additionally includes STT October 1, 2004, onwards. The definition of the transaction costs have been confined to the brokerage and STT (wherever applicable) as these constitute, in general, more than 90% of the transaction costs (excluding bid-ask spread). Though the analysis has been conducted ignoring the bid-ask spread and opportunity cost of the margin deposits, these have been given due consideration while ensuring the exploitability of mispricing signal. This has been done in view of the fact that bid-ask spread, in particular, plays a very important role in assessing the options market efficiency, as opined by Baesel *et al*. (1983) and Phillips and Smith (1980).

3.5 ANALYSIS AND EMPIRICAL RESULTS

3.5.1 Analysis of Magnitude of the Violations

The *ex-post* analysis of the call and put options has been carried out on the basis of the Eqs (3.5) and (3.6) for the period of 6 years starting from June, 2001, to June, 2007. In other word, the analysis of LBCs using spot market has been the basis of the study. The condition has been tested for 40,298 and 35,171 daily liquid quotes for call and put options, respectively. The results summarized in Table 3.1 reveal that the total number of violations observed were 7019 out of total observations of 40,298 in the case of call options that amounts to 17.42% of total number of observations analysed. Likewise, 1,544 violations were found out of 35171 observations for put options that accounts for 4.39% of the total number of observations examined. It may be noted that these violations (i.e. the value of ε_t^c and ε_t^p turn out to be positive) were recorded when no transaction costs were reckoned. However, these numbers reduced substantially to 2892 and 707 on account of introduction of transaction costs. And, therefore, the violations after reckoning the transaction costs (the additional cost an arbitrageur has to incur while trying to exploit such opportunities) have been taken up for further analysis in view of their empirical appeal.

Table 3.1 Violations of the Lower Boundary Condition and Liquidity Levels, June 2001–07

Particulars	*Call options (Percentage)*	*Put options (Percentage)*
Total number of observation analysed	40,298	35,171
Total number of violations observed **before transaction costs**	7019 (17.42)	1544 (4.39)
Total number of violations observed **after transaction costs**	2892 (7.18)	707 (2.01)
Violations relating to the three specified levels of liquidity		
(a) Thinly traded options	2523 (87.24)	654 (92.50)
(b) Moderately traded options	278 (9.61)	46 (6.51)
(c) Highly traded options	91 (3.15)	7 (0.99)
Total	**2892**	**707**

In the table, thinly, moderately and highly traded options, respectively, denote those option contracts which have 100, 101–500, more than 500 contracts traded per day.

As far as the frequency of violations is concerned, the results indicate that it (mispricing signals) is significantly higher for the call options (about 7.18% of the total observation analysed) compared with those in the case of put options (about 2.01% of the total observation analysed). Further, in order to have better insights about the behaviour of the mispricing signals obtained from the LBC, the violations (after reckoning the transaction costs) have been examined with respect to liquidity and maturity of the options contracts. Liquidity of the options has been decomposed into three levels based on the trading volume: (i) **thinly traded** options, which have 1–100 contracts traded per day; (ii) **moderately traded** options, which have 101–500 contracts traded per day; and (iii) **highly traded** options, which have more than 500 contracts traded per day. Likewise, Maturity of the options has been classified into four levels: (i) **0-7** days to maturity; (ii) **8-30** days to maturity; (iii) **31-60** days to maturity; and (iv) **61-90** days to maturity.

Notably, the violations so classified as per the specified levels of maturity have further been sub-classified as per the three specified levels of liquidity due to the fact that liquidity constitutes the basis for exploitation of arbitrage opportunities. The proposed classifications and their sub-classifications facilitate in drawing some meaningful inferences about the exploitability of the observed mispricing signals, which in turn, help to assess the role of the existing market-microstructure in restoring market efficiency in Indian derivative market. The results related to the violations, classified as per specified levels of liquidity and maturity along with their sub-classifications, are summarized in Tables 3.2 and 3.3, respectively.

It may be pertinent to note that the results across specified levels of liquidity have direct implications for the exploitability of the observed mispricing signals, as the higher the liquidity is, the lower would be the trading cost and bid-ask spread. Also, higher liquidity ensures execution of the trading strategy required to tap such abnormal profits. In contrast, the different specified levels of maturity have an indirect impact since these primarily influence the liquidity and, hence, the exploitability of such violations. Therefore, the behaviour of violations with respect to maturity has been interpreted in light of the liquidity levels corresponding to their specified levels.

The frequency of violations regarding the different levels of liquidity is summarized in Table 3.1 and the analysis of their magnitudes is reported in Table 3.2. A vast majority of the violations in this category, i.e. about 87% and 93% of the violations in the case of call and put options, respectively, are confined to the thinly traded options, which can be designated as unexploitable because of (i) higher bid-ask spread and (ii) difficulty in implementation of the strategy.

Also, it may be noted that the magnitude of violations decreases as the liquidity increases. Precisely, for the highly liquid contracts (which are approximately 3 in the case of call options, and a meager 1% in the case of put options), where the possibility of exploitability is quite high as the bid-ask spread is expected to be considerably low, the mean of abnormal profits per lot are merely Rs. 91 for the violations pertaining to call options; however, a relatively higher magnitude has been recoded in the case of put options, i.e. Rs. 341. In general, such meagre exploitable profit opportunities are clearly not attractive propositions for the retail arbitrageurs as they are subject to higher transaction costs. However, these opportunities might be exploitable for the institutional investors and the trading member organizations (Brokerage firms).

Moreover, amongst the violations relating to highly liquid contracts, only 25% observations, i.e. the third quartile (as reported in the Table 3.2), seem to be exploitable as these offer relatively higher profit of more than 338 and 510 for call and put options, respectively, which is quite likely to be profitable after reckoning the bid-ask spread. The remaining 75% observations amongst highly liquid category yield returns that could be designated as fairly below the exploitable level in the presence of bid-ask spread costs. Similarly, in

Table 3.2 Liquidity-wise Descriptive Statistics for Violations of the Put-call Parity Condition for Under-priced and Over-priced Put Options in Indian Securities Market, June 2001–07

Liquidity	*Call options*						*Put options*					
	Number of violations (Percentage)	*Magnitude of violations (₹)*					*Number of violations (Percentage)*	*Magnitude of violations (₹)*				
		Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
Thinly traded	2523 (87.24)	1165	2576	156	404	963	654 (92.50)	1375	2966	150	399	1268
Moderately traded	278 (9.61)	341	411	83	231	462	46 (6.51)	1183	3172	81	244	533
Highly traded	91 (3.15)	269	292	70	159	338	7 (0.99)	341	211	192	281	510
Total	**2892**	**1058**	**2427**	**139**	**368**	**1136**	**707**	**1352**	**2965**	**145**	**382**	**1254**

S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e. median) and third quartile, respectively.
The values have been rounded off to zero decimal places.

the case of moderately traded options, the third quartile seems to offers relatively attractive profits (more than ₹ 462 and 533 for call and put options, respectively), and in the presence of bid-ask spread are quite likely to be exploited. In sum, nearly 3% (25% of 12.76%) of the violations for the call options seems to be exploitable by trading member organizations. Likewise, a relatively lower proportion of violations, i.e. less than 2% (25% of 7.50%), can be designated as exploitable in the case of put options.

In another significant observation, the frequency of violations across different levels of maturity signifies a decreasing trend with an increase in time to maturity when the first two levels (0–7 and 8–30 day to maturity) are clubbed together. The results are reported in Table 3.3. In addition, a majority of the mispricing signals are confined to the options having 0–7 and 8–30 days to maturity—approximately 83% in call options and 91% in put options. However, for the next two levels, i.e. 31–60 and 61–90 days to maturity, the combined percentage is merely 17% and 9% for call and put options, respectively. The concentration of the violations in the 0–30 days to maturity category and, especially, in 0–7 days to maturity is similar to that reported by Bhattacharya (1983), a study in the context of US market where 42% of the total violations had one week or less to maturity.

The concentration of violations in 0–7 days to maturity category (especially in the case of put options) can be attributed to the fact that most of the arbitrageurs, in general, try to unwind their arbitrage positions when the options are nearing maturity. On account of this, the liquidity in such options is expected to be very thin, as there are only a few or no buyers. This, in turn, causes the transaction costs, especially the bid-ask spread, to be considerably high. Therefore, the lack of liquidity and less time to maturity might be cited as the major reasons for the observed mispricing signal remaining unexploited. This is eloquently borne out by the fact that the majority of violations in this category (viz. 87% in the case of call options and 91% in the case of put options) belong to the thinly traded options category and, therefore, may safely be designated as unexploitable.

Moreover, if we look at the violations in this category, which had high traded volume, offer very low profit opportunities as the third quartile start with profits as low as ₹ 147 in the case of call options; however, the figure is relatively attractive, ₹ 423, in the case of put options but with the very low frequency. Likewise, the third quartile of such violation having moderately traded volume offers possibly exploitable opportunities in the light of bid-ask spread.

The behavior of violations pertaining to the 8–30 days to maturity category is quite similar to that of 0–7 days to maturity category, as the violations belonging to the highly liquid category are nearly 3% in the case of call options and less than 1% in the cases of put options (of the total violations

Table 3.3 Maturity-wise Descriptive Statistics for Violations of the Put-call Parity Condition for Under-priced and Over-priced Put options in Indian Securities Market, June 2001–07

Days to maturity	Liquidity	*Call options*						*Put options*					
		Number of violations (Percentage)	Magnitude of violations (₹)					Number of violations (Percentage)	Magnitude of violations (₹)				
			Mean	S.D.	Q_1	Q_2	Q_3		Mean	S.D.	Q_1	Q_2	Q_3
0–7 Days	Thinly traded	617 (87.39)	1569	3173	169	437	1326	359 (91.35)	1222	2542	144	374	1217
	Moderately traded	66 (9.35)	232	277	50	118	321	29 (7.38)	1491	3847	56	236	562
	Highly traded	23 (3.26)	136	165	50	89	147	5 (1.27)	341	185	249	281	423
	Overall	**706 (24.41)**	**1397**	**3002**	**139**	**369**	**1143**	**393 (55.59)**	**1231**	**2640**	**135**	**372**	**1164**
8–30 Days	Thinly traded	1448 (86.14)	990	2117	137	390	815	234 (93.60)	1632	3579	154	453	1394
	Moderately traded	177 (10.53)	345	348	96	259	462	14 (5.60)	710	1530	122	256	368
	Highly traded	56 (3.33)	262	259	95	208	336	2 (0.80)	343	361	87	343	598
	Overall	**1681 (58.13)**	**898**	**1982**	**131**	**356**	**731**	**250 (35.36)**	**1570**	**3488**	**151**	**425**	**1335**
31–60 Days	Thinly traded	415 (89.83)	1119	2962	193	443	888	55 (94.83)	1175	2611	151	350	1285
	Moderately traded	35 (7.57)	524	736	138	300	656	3 (5.17)	421	412	194	317	596
	Highly traded	12 (2.60)	559	421	257	518	749	Zero	NA	NA	NA	NA	NA
	Overall	**462 (15.98)**	**1059**	**2821**	**189**	**440**	**853**	**58 (8.20)**	**1136**	**2548**	**146**	**349**	**1265**

Days to maturity	*Liquidity*	*Call options*						*Put options*					
		Number of violations (Percentage)	*Magnitude of violations (₹)*					*Number of violations (Percentage)*	*Magnitude of violations (₹)*				
			Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
61–90 Days	Thinly traded	43 (100)	1739	2496	262	933	2091	6 (100)	2289	3168	643	1242	1944
	Moderately traded	Zero	NA	NA	NA	NA	NA	Zero	NA	NA	NA	NA	NA
	Highly traded	Zero	NA	NA	NA	NA	NA	Zero	NA	NA	NA	NA	NA
	Overall	**43 (1.48)**	**1739**	**2496**	**262**	**933**	**2091**	**6 (0.85)**	**2289**	**3168**	**643**	**1242**	**1944**

In the table, S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e., median) and third quartile, respectively.

registered in this category). Equally revealing observation is that the majority of violations belong to the relatively lower levels of liquidity. Empirically, for the call options, one-fourth of such violations belonging to the highly liquid contracts seem to be exploitable (though relatively lower magnitude of profits) in the presence of bid-ask spread. In contrast, nearly 50% of such violations in the case of put options, *per-se*, could be exploitable, as the second quartile shows a profit of ₹ 343 and more. Likewise, one-fourth of the moderately traded category for such options seem to be exploitable, as the third quartile offers profit of more than ₹ 462 and 368 in the cases of call and put options, respectively. In sum, nearly 3% and 2% of violations which had 8–3 days to maturity can be designated as exploitable in light of the profit magnitude they offer and the bid-ask spread costs, respectively, in the cases of call and put options.

In addition to the above, the last two levels of time to maturity, i.e. 31–60 and 61–90 days to maturity clearly depicts lack/negligible number of the highly and moderately traded contracts for put options. To put it in other words, the violation in the case of put options having 31–90 days to maturity belong to the thinly traded category and, therefore, can safely be referred to as unexploitable. Similarly, in case of call options, the contracts that are having 61–90 days to maturity do not contain a single moderately/highly traded options contract and, thus, are unexploitable; however, as far as violations with maturity period of 31–60 days are concerned, negligible number of violations with moderately and highly traded category can be identified. Such violations, *per se*, seem to be exploitable. However, the relatively long holding period and relatively less trading in such options could have been the reasons for their unexploitability.

In short, as far as the exploitability of the observed mispricing signals is concerned, the results regarding maturity are in line with those in case of liquidity, as the majority of violations pertain to the relatively illiquid categories for all the four levels of maturity, for call as well as put options.

3.5.2 Statistical Significance of the Differences in the Magnitude of Violations

From the above findings, it can be observed that there seems to be a difference in the mean magnitudes of violations among the specified levels of liquidity for call as well as put options. To validate the finding statistically, a well known statistical test—Analysis of Variance (ANOVA)—was proposed initially. However, before applying the test statistics on the data, the main assumption of ANOVA, i.e. the samples have been drawn from a normally distributed population has been tested using the one-sample Kolmogorov–Smirnov statistics. The results are summarized in Table 3.4.

Table 3.4 Summary of the One-sample Kolmogorov–Smirnov Statistics to Assess the Normality

Options		*Call options*	*Put options*
Number of observations		2892	707
Normal parameters (a), (b)	Mean	1057.85	1351.98
	Std. deviation	2426.71	2965.31
Most extreme differences	Absolute	0.33	0.32
	Positive	0.30	0.28
	Negative	−0.33	−0.32
Kolmogorov–Smirnov Z		17.83	8.62
Asymp. Sig. (2-tailed)		**0.000**	**0.000**

(a) Test distribution is normal; (b) Calculated from data.

Since the results depict severe departure from the normality (revealed by the Kolmogorov–Smirnov, KS, statistics), ANOVA cannot be applied, as it requires data to follow the normal distribution. Therefore, the differences have been analysed using a non-parametric statistics that does not require the data to follow any specified distribution. The test statistics applied in the present study is Kruskal–Wallis (H-statistics) test, which is a non-parametric substitute for the one-way ANOVA. In addition, *Dunn's multiple comparison test* has been used for *post hoc* analysis of all possible pairs in the analysis. The results of H-statistics and Dunn's test for the differences across the specified levels of liquidity are summarized in Tables 3.5 (a) and (b), respectively.

Table 3.5(a) Kruskal–Wallis (H-statistics) Test for the Differences in Means (Magnitude) of Violations across the Specified Levels of Liquidity for Call and Put Options, June 2001–07

Liquidity	*Call options*					*Put options*				
	Rank		*Test statistics (a), (b)*			*Rank*		*Test statistics (a), (b)*		
	N	*Mean rank*	*Chi-square*	*df*	*Sig.*	*N*	*Mean rank*	*Chi-square*	*df*	*Sig.*
Thinly traded	2523	1502.72				654	359.20			
Moderately traded	278	1096.80	91.568	2	**0.000**	46	288.07	5.688	2	**0.058**
Highly traded	91	956.24				7	301.14			

(a) Kruskal–Wallis Test (b) Grouping variable—liquidity.

The significance value given in Table 3.5 (a) clearly indicate that the difference among the specified levels of liquidity is significant at even 1% level of significance for call options; however, the difference could not be supported statistically in the case of put options at 5% level of significance.

As a result of significant results of H-statistics in case of call options, the *post hoc* diagnosis, i.e. *Dunn's multiple comparison test*, has been carried out to find the pair-wise differences. Notably, the *post hoc* analysis has not been applied in case of put options as the differences amongst the specified levels of liquidity were not found to be significant at the first stage itself, i.e. the Kruskal–Wallis test. The results of the *post hoc* analysis in the case of call options summarized in Table 3.5 (b) signify that average magnitude of violations for the thinly traded options is significantly different from that for the moderately traded, as well as highly traded options. However, average magnitude of moderately traded options is not significantly different from that of highly traded options at 5% level of significance.

Table 3.5(b) Dunn's Test for the Multiple Comparisons amongst the Specified Levels of Liquidity for the Call Options, June 2001–07

Dunn's multiple comparison test	*Call Options*		*Summary*
	Difference in rank sum	*Significant ($P < 0.05$)*	
Thinly traded vs. Moderately traded	405.9	–	Yes
Thinly traded vs. Highly traded	546.5	–	Yes
Moderately traded vs. Highly traded	140.6	Not significant	No

In operational terms, the results imply that the average magnitude of violations for exploitable options contracts is significantly different from those for options contracts that can be designated as unexploitable. Empirically, the finding validates that the magnitude of exploitable violations is significantly less than that for unexploitable options. It demonstrates a good sign for the market as the truly exploitable mispricing opportunities were meager in magnitude, and significantly noticeable violations existed only in the cases of contracts that could not be exploited due to lack of liquidity in such options.

3.5.3 The Learning Curve

This part of the chapter attempts to test the ***learning hypothesis*** for call as well as put options markets in Indian context over the period under reference. The hypothesis warrants improvement in the market efficiency over the years as investors are expected to be more familiar/experienced with the new market year after year and, thus, are expected to behave more rationally in pricing the options contracts. To put it explicitly, it has been hypothesized that the mispricing signals should depict a declining trend for call as well as put options. The examination of the violations over the years under reference is similar with the study carried out by Mittnik and Rieken (2000a) in the context of German index options market.

In this respect, the results (summarized in Table 3.6 and Fig. 3.1) indicate that the percentage of violations in call options has shown a decreasing trend in the first year (from 12% to nearly 8%). However, it remained almost persistent for next four years as the percentage of violations kept on hovering around 8% and showed a declining trend in the last year, as the percentage of violations reduced to nearly 4% of the total observations analysed for the year. That is, the violations pertaining to the call options have shown an improvement in the first year of trading; however, no significant improvement could be recorded during the next four years of the trading. Notwithstanding the persistence in the percentage of violations, the last year under reference, i.e. 2006–07, has shown considerable improvement in the state of market efficiency.

Table 3.6 Year-wise Frequencies of the Violations of LBC for Call and Put Options, June 2001–07

Year	*Call options*			*Put options*		
	No. of observations analysed	*No. of violations observed*	*Percentage (%)*	*No. of observations analysed*	*No. of violations observed*	*Percentage (%)*
2001-02	3496	422	12.07	2557	114	4.46
2002-03	3898	301	7.72	3376	151	4.47
2003-04	7173	455	6.34	6189	228	3.68
2004-05	7010	629	8.97	6702	61	0.91
2005-06	9323	735	7.88	7931	92	1.16
2006-07	9398	350	3.72	8416	61	0.72
Total	**40298**	**2892**	**7.18**	**35171**	**707**	**2.01**

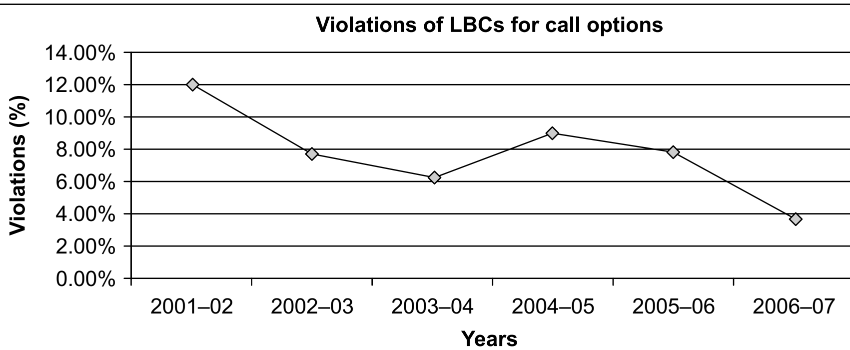


Figure 3.1 Percentage of violations in relation to the total observations analysed across the years for the call options.

In contrast, the percentage of violations over the years has shown a clearly declining trend in the case of put options except for the first two years of trading, where the percentage of violations remained nearly at the same level (as is evident in Table 3.6 and Fig. 3.2). The third year of trading showed a modest learning effect amongst the investors, as the percentage of violations registered a decline of less than 1%. However, it may be noted that the next year of trading registered an exemplary decline, as the percentage of violations reduced to just nearly 1%. Moreover, the next two years have shown favorable response and the percentage of violations finally reached the level of 0.72%.

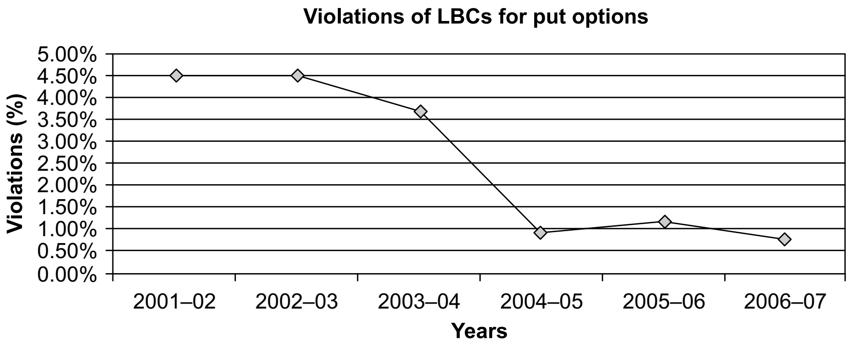


Figure 3.2 Percentage of violations in relation to the total observations analysed across the years for the put options.

Based on these observations, it may be appropriate to conclude that the put options market has clearly demonstrated the learning effect amongst the market participant as there has been a considerable decrease in the percentage of violations, which finally reduced to 0.72% of observations analysed in the last year. This clearly supports the learning hypothesis in the put options market. In contrast, the call options market, however, has shown a decline but the persistence of violations across four years of the study and a relatively significant percentage of violations in the last year (i.e. 3.72% in 2006–07) do not provide very convincing evidences on the learning behavior in the market. The so observed differences in the trends of violations in the two markets have been explained in the next subsection.

Also, the magnitude of the violations across the years has been examined in order to have a better idea about the exploitability of violations. The results in this regard have been summarized in Table 3.7. It is satisfying to note that the first three (2001–02 to 2003–04) years of trading in the options market had zero/negligible number of violations belonging to the highly traded category for both call and put options.

Moreover, the violations traded in moderately traded category remained negligible in case of put options for the first two years (2001–02 to 2002–03) of trading. In contrast, though such violations for call options have shown higher frequencies compared with those in the case of put options, the magnitude of profits they offered can be referred to as unexploitable in the presence of bid-ask spread. In the year 2003–04, the number of violations under the moderately traded category has been nearly equal for the call and put options. As far as the exploitability of such violations is concerned, nearly one-fourth

Table 3.7 Year-wise Magnitude of Violations of the LBC and their Sub-classification as per the Specified Levels of Liquidity in Indian Options Market for Call and Put Options, June 2001–07

Years	*Liquidity*	*Call options*						*Put options*					
		Number of violations	*Magnitude of violations (INR)*					*Number of violatious*	*Magnitude of violations (INR)*				
			Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
2001–02	Thinly traded	387 (91.71)	402	480	115	288	516	111 (97.37)	434	696	71	154	395
	Moderately traded	34 (8.06)	149	117	44	137	226	3 (2.63)	63	16	54	56	69
	Highly traded	1 (0.24)	67	NA	NA	NA	NA	Zero	NA	NA	NA	NA	NA
	Overall	**422 [14.5.0]**	**381**	466	**108**	**264**	497	**114 [16.12]**	**424**	**690**	**62**	**144**	**394**
2002–03	Thinly traded	264 (87.71)	337	469	81	213	442	143 (94.70)	351	475	62	212	396
	Moderately traded	32 (10.63)	145	125	61	78	224	7 (4.64)	131	115	32	105	244
	Highly traded	5 (1.66)	225	123	163	243	335	1 (0.66)	87	NA	NA	NA	NA
	Overall	**301 [10.41]**	**314**	**445**	73	**1.92**	419	**151 [21.36]**	**33.9**	**466**	**61**	**211**	**372**
2003–04	Thinly traded	422 (92.75)	928	1978	130	333	822	201 (88.16)	1410	2053	218	562	1467
	Moderately traded	27 (5.93)	188	252	52	102	191	24 (10.53)	466	823	103	278	452
	Highly traded	6 (1.32)	60	42	35	40	104	3 (1.32)	334	252	192	249	433
	Overall	**455 [15.73]**	**874**	**1916**	**121**	**309**	768	**228 [32.25]**	**1294**	**1970**	**1970**	**514**	**1273**

Years	Liquidity	Call options						Put options					
		Number of violations	*Magnitude of violations (INR)*					*Number of violatious*	*Magnitude of violations (INR)*				
			Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
2004–05	Thinly traded	505 (80.29)	974	1515	149	374	1054	60 (98.36)	1013	1294	162	441	1302
	Moderately traded	76 (12.08)	381	263	161	378	542	Zero	NA	NA	NA	NA	NA
	Highly traded	48 (7.63)	266	327	74	140	328	1 (1.64)	598	NA	NA	NA	NA
	Overall	**629 [21.75]**	**848**	**1387**	**137**	**344**	839	**61 [8.63]**	**1006**	**1284**	**166**	**443**	**1301**
2005–06	Thinly traded	637 (86.67)	1436	2551	230	565	1324	86 (93.48)	3827	6314	535	1327	3541
	Moderately traded	82 (11.16)	473	599	105	323	629	5 (5.43)	243	325	85	87	217
	Highly traded	16 (2.18)	259	242	95	148	398	1 (1.09)	423	NA	NA	NA	NA
	Overall	**735 [25.41]**	**1303**	**2408**	**202**	**532**	1190	**92 113.01]**	**3595**	**6166**	**402**	**1271**	**3457**
2006–07	Thinly traded	308 (88,00)	2912	5173	421	925	2761	53 (86.89)	2404	3102	445	1373	2769
	Moderately traded	27 (7.71)	449	431	180	317	545	7 (11.48)	5847	6535	1139	2171	10089
	Highly traded	15 (4.29)	404	280	227	337	612	1 (1.64)	281	NA	NA	NA	NA
	Overall	**350 [12.10]**	**2615**	**4920**	**323**	**770**	2221	**61 18.631**	**2764**	**3733**	**490**	**1404**	**3047**

1. Figures in parentheses indicate percentage.
2. In the table, S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e., median) and third quartile, respectively.

of the violations seem to be exploitable in the presence of bid-ask spread for put options, as suggested by the third quartile; however, such options are not exploitable in the case of call options.

In the next three years of the study (i.e. 2003–04 to 2006–07), the frequency of violations in the case of put options belonging to highly and moderately traded category has been negligible, and majority of violations fall into the thinly traded category, which can be designated as unexploitable. The finding further corroborates the earlier finding that the put options market has shown considerable improvement and therefore clearly demonstrated the learning process amongst the market participants. In contrast, the number of violations for highly and moderately traded call options has been significant for the years 2003–04 to 2006–07. Moreover, nearly half of the violations belonging to moderately traded category can be labelled as exploitable for all the three years as the second quartiles suggest a profit of more than ₹ 317 per lot for rest of the 50% of observations. Similarly, nearly one-fourth of the violations pertaining to highly traded category seem to be exploitable for the fourth and fifth year; nearly 50% of such violations appear to be exploitable in the last year.

In sum, the call options market has shown some initial evidences of lack of warranted improvement in the market efficiency unlike put options, which have shown considerable improvement.

3.5.4 Comparison of Call and Put Options

In order to ascertain the levels of pricing efficiency in the two markets, namely call options market and put options market, a comparison has been drawn between these markets. The number of violations is 2,892 out of total observations of 40,298 in the case of call options. Likewise, 707 violations have been observed out of 35,171 observations in put options. As far as the frequency of violations is concerned, the call options market seems to be more inefficient compared with put options market as the number as well as the percentage (7.18% of total observations analysed in call options compared with 2.01% in put options) of violations are higher vis-à-vis put options. Moreover, the percentage of violations over the period under reference has demonstrated a persistent pattern in case of call options market unlike the put options market, which has shown a considerable decline in the percentage of violations over the years under reference.

The results based on the absolute figures are more revealing as all the exploitable violations seem to be negligible for put options; however, such violations in case of call options remained significant. It is eloquently borne out by the fact that there are only 13 cases for put options whereas more than 90 for call options (one-fourth of the total violation in moderately and highly liquid category for call as well as put options as suggested by third quartiles,

Table 3.2) that can be designated as exploitable; all the remaining violations might have remained unexploited due to the lack of liquidity. Our finding that the LBC for call options is violated more frequently compared with put options is similar with one documented by Puttonen (1993), a study done in the Finnish index options market.

In this respect, explaining the higher frequency of violations in case of call options, Mittnik and Rieken (2000a) opined that selling the asset short, particularly when the asset is an index, becomes very difficult. Notably, the strategy needed to exploit the arbitrage on account of the violations of LBC in case of call options requires shorting of the underlying asset unlike that in case of put options, which requires a long position in the underlying asset. In view of this, the comparatively higher frequency of violations in the case of call options can be reasonably attributed to the short-selling constraint in the Indian securities market for the period under reference.

3.5.5 Violations Using Futures Market

Besides, an attempt has been made to identify the violations of LBCs using futures prices of the underlying assets. This has been done in view of the facts that

(*i*) the facility of short-selling the financial assets was absent in the Indian securities market during the period under reference and futures market easily provides this facility;

(*ii*) in case of index options market, it becomes very difficult to execute the operations required to be taken in the underlying's cash market (i.e. short-sell/ purchase of the index) as all the shares in the index need to be sold/ purchased in the proportion in which these have been included in the index, and

(*iii*) transactions costs associated with trading in futures market are relatively less compared with the spot market.

The results on the violations of LBCs using futures contracts are reported in Table 3.8.

The results summarized in Table 3.8 reveal that the number of violations of LBC remained quite high for call options compared with those for put options even when the futures market has been used. Notably, unlike identifying violations of LBCs using spot market, short-selling constraint could not be a correct explanation to the higher frequency of violations in call options since to exploit the arbitrage opportunities using futures market, the arbitrageur does not have to short the stock basket; rather, he needs to sell the futures that is easily possible.

Table 3.8 Violations of the LBC Using Spot Values and Futures Prices, June 2001–07: A Comparison

Particulars	*Using spot values*		*Using futures prices*	
	Call options	*Put options*	*Call options*	*Put options*
Total number of observation analysed	40,298	35,171	40,298	35,171
Total number of violations observed **before transaction costs**	7019 (17.42)	1544 (4.39)	3593 (8.49)	1815 (5.16)
Total number of violations observed **after transaction costs**	2892 (7.18)	707 (2.01)	2838 (7.04)	1492 (4.24)

Figures in parentheses denote percentages.

Moreover, it may be noted that use of futures market has shown a negligible improvement in the call options market as the number of violations has slightly decreased from 2892 to 2838; however, the put options market has registered a counterintuitive increase in the number of violation from 707 to 1492. The reason behind the decrease (increase) in the number of violation for the call (put) options could be the underpricing of futures contracts. Moreover, another reason for the increase in the number of violations in the case of put options could be the comparatively lower transaction costs in F&O segment. However, there should have been an increase in the case of call options as well to assign lower transaction costs as a major reason. Notably, there has been a negligible decline in the case of call options, and therefore, the lower transaction costs cannot be assigned as the sole reason behind this development.

The picture becomes clearer when we identify the violations without considering any transaction cost for both the strategies, i.e. using the spot market and futures market for identifying the violations of LBCs (as reported in Table 3.8). The results demonstrate that the use of futures market has caused a decrease (increase) in the frequency of violations pertaining to call (put) options compared with those using spot market. In view of this, it would be reasonable to conclude that the above-mentioned development in the state of options market efficiency can be designated to the underpricing of futures market. This may further be traced to the fact that as far as the correction of underpricing of the futures market is concerned, the short-selling of the stock basket is needed to exploit such arbitrage opportunities and to restore equilibrium in the futures market. In short, the underpricing of the futures can, therefore, be attributed to the fact that short-selling have been banned during the period under reference in Indian securities market.

In sum, it may be concluded that the futures market has failed to provide an equally good substitute for shorting the assets in the absence of short-selling facility in the Indian securities market during the period under reference. Thus, the futures market could not succeed in restoring equilibrium in the options market.

In view of this, it is reasonable to conclude that the indirect impact of the short-selling constraints on the efficiency of the options market on account of the interrelationship of the index options and index futures market has been one of the major reasons, amongst others (e.g. liquidity), for the existence of mispricing signals in the Indian options market. In short, the impact of short-selling constraints cannot be ignored even if the violations are identified using futures contracts, as the efficiency of futures market does impact the efficiency of options market and, which in turn, can be ensured when short-selling is allowed.

3.6 CONCLUDING OBSERVATIONS

The study attempts to test the LBC for the S&P CNX Nifty index options prices using the futures prices on the same index in the Indian securities market. The results of the study are, more or less, in line with those drawn in the case of US market (e.g. concentration of violations in 0–7 days to maturity category), except for magnitude and frequency of violations, which have been observed to be more pronounced in Indian options market, alike the Finnish index options market. Also, the frequency of violations in call options have been found to be more pronounced compared with that in put options. The violation of lower boundary indicates underpricing of options in Indian securities market. The finding that the options are underpriced is consistent with that of Varma (2002), a study carried out in Indian context.

Though the frequency of violations remained quite high in Indian options markets compared with that in the US market, the exploitability of such violations remained confined to a negligible number on account of the dearth of liquidity. In other words, a significant number of violations remained unexploitable, plausibly on account of the lack of liquidity and the direct as well indirect (through the futures market) impact of short-selling constraints.

The study is equally revealing as far as the behaviour of the investors dealing with the options market in India is concerned. It has been observed that the number of violations in call options market has been persistent instead of showing a warranted declining trend. In other words, it implies that the irrationalities in the behaviour of investors, particularly in call options market, could not improve significantly over the years. However, it is satisfying to note that the put options market has behaved in a way that is consistent with the learning hypothesis, i.e. the number of violations has reduced with the passage of time. Thus, the findings indicate that the put options market is emerging to be more efficient vis-à-vis the call options market.

Another notable finding of the study is that the futures market could not provide an equally good substitute for the short-selling facility in the Indian securities market. This is evident from the fact that the number of violations in case of call options remained nearly same even when the futures market has been used to identify the violations. On the other hand, the put options market has shown an increase in the number of violations for such an arbitrage strategy. Such a development can be traced to the fact that the futures themselves remained underpriced in the absence of short-selling facility in the market and, therefore, registered a negligible decrease in the case of call options and an increase for the put options market. In sum, it may be reasonable to infer that the futures market failed to restore equilibrium in options market in the absence of short-selling facility in Indian securities market for the time period under reference.

Therefore, in short, it is reasonable to conclude that majority of violations in call options could not be exploited on account of the existing market-microstructure in India during the period under reference (i.e. short-selling constraint that caused underpricing in futures to persist). Besides, the dearth of liquidity in the options market appears to be another major constraint to arbitrageurs, in case of call as well as put options market, in view of the fact that a vast majority of violations occurred in the thinly traded category.

END NOTES

1. Nonsynchonous trading refers to the phenomenon of different timings of closing transactions in the two markets (the options market and the underlying's cash market in this case).
2. In the study, the liquid options quotations have been defined as those quotations that have at least one contract traded. Though the definition of liquid contracts is not useful in ensuring exploitability of arbitrage opportunities on account of the high bid-ask spread for such options, this has been done to gauge the total number of violations in Indian options market. Moreover, while ensuring the exploitability of the arbitrage opportunities, due consideration has been given to the liquidity.

CHAPTER 4

A Test of Put–Call Parity Relationship on S&P CNX Nifty Index Options Market

4.1 INTRODUCTION

Efficiency of the options markets is of great importance to the academicians as well as practitioners. Well-functioning financial markets are vital to a thriving economy, as these markets facilitate price discovery, risk hedging and allocation of capital to its most productive usage. Inefficiency of a financial market (e.g. options market) indicates that it is not performing the best possible job at above-mentioned important functions (Ackert and Tian, 2000). Therefore, it is imperative to test the state of options market efficiency, especially when the market is in its nascent stage of development.

In view of this, this chapter attempts to investigate the market efficiency of the Indian index options market by testing the Put–Call Parity (PCP) relationship on daily closing observations of call and put options. The PCP relationship in line with the lower Boundary conditions (LBCs) is a necessary but not sufficient condition for the efficiency of the options market. However, it is a more rigorous condition on options market efficiency compared with the LBCs approach, as it requires the relationship between call and put options to hold. The efficiency of the market, in this respect, connotes pricing efficiency. The PCP for the option prices (as specified in the literature) has been used extensively as a tool to gauge the efficiency of options market across the globe. The violation of PCP implies that the call (put) options are not priced correctly in relation to the corresponding put (call) options and, therefore, indicates the arbitrage opportunities in the market that are expected to be absent in an efficient market.

Moreover, the futures market on the same underlying asset (S&P CNX Nifty Index) has also been used to test the PCP relationship, i.e. Put-Call-Futures Parity (PCFP). This has been done in view of the fact that (i) the futures market is a better alternative in exploiting the arbitrage opportunities when underlying asset is an index; (ii) it is generally argued that the futures market helps in doing away with the short-selling constraint as a futures can easily be shorted; and (iii) it costs an investor less to exploit the arbitrage opportunities through futures market because of the lower transaction costs associated with it and the leverage it provides. In sum, the futures market becomes a more convenient and profitable route in the case of index options to exploit the arbitrage opportunities.

Notably, the use of futures prices on the same underlying asset instead of spot prices essentially makes this approach a test of joint market efficiency, as opined by Fung *et al*. (1997). At the same time, use of the futures prices facilitates in assessing the degree of pricing interrelationships between the different derivative instruments/markets traded in the financial market (Lee and Nayar, 1993). In other words, this approach helps in addressing the question whether market participants consider **important pricing interrelationships** while pricing the index options. The scope of the present study has been confined to the pricing interrelationship between index options and index futures.

In sum, the very purpose of using futures market has been to examine its role in the absence of short-selling facility in underlying's market. In other words, whether the futures market could work as an equally good alternative to short-selling facility and, therefore, help in restoring equilibrium in the options market even in the absence of short-selling facility.

The use of futures market imposes one restriction on the otherwise model-free approach as it assumes 'cost-of-carry' model to hold. Therefore, it would not be appropriate to call this approach as a 'model-free' approach unlike the test procedure which uses spot values. However, the approach still remains less restrictive compared with those based on certain pricing models, e.g. Black and Scholes (1973), which assumes that the stock price and volatility are governed by some stochastic processes.

The method applied to test the efficiency of the options market is in line with other studies conducted in different markets for the same purpose. The test procedure has taken care of the dividends expected from the underlying asset during the life of the options. Moreover, the transaction costs (excluding bid-ask spread) have been incorporated while identifying the violations of PCP relationship. Though the analysis has been conducted ignoring the bid-ask spread, the results have been interpreted cautiously. This has been considered in view of the fact that the bid-ask spread plays a very important role in assessing the options market efficiency as it results in significant transactions costs (Baesel *et al*.,1983; Phillips and Smith, 1980).

The violations or mispricing signals observed from the test procedures have further been classified as per the specified levels of 'liquidity' and 'time to maturity' in order to draw some meaningful results from such violations. The classification so made facilitates a logical explanation to the exploitability of such violation, which is very crucial in assessing the efficiency of the market.

This has been done in view of the fact that mere presence of violations does not indicate market inefficiency; it is the exploitability and persistence of such violations that pose serious threat to the market efficiency.

Besides, the learning behaviour of the investors in options markets has also been examined. This has been done by analysing the number of violations vis-à-vis the number of observations analysed across the subsequent years, for both the call and put options. The learning hypothesis warrants that the number of violations should go down over the years. This has been proposed with intent to gauge the desired improvements in the understanding of the options market amongst market participants.

The rest of the chapter is divided into four main sections. The Section 4.2 of this chapter discusses PCP relationship using spot as well as futures prices on the same index. The data has been summarized in Section 4.3. Section 4.4 presents analysis and empirical results. The chapter ends with the concluding observations in Section 4.5.

4.2 PUT–CALL PARITY (PCP) RELATIONSHIP

The PCP theory that constitutes a central role in options pricing, was first put forth by Stoll (1969) and Merton (1973b). Stoll (1969) tested this theory on over-the-counter (OTC) market in the American context for the very first time. This theory using **'conversion mechanism'** establishes a relationship between the premium on a call option and that of the corresponding put option having same characteristics (in terms of strike price, trade date and maturity date). The conversion mechanism allows converting a call (put) in to a put (call) using long and short positions in call, put and their underlying asset. The process of conversion is risk-less as it results into a completely hedged position. Moreover, the mechanism is assumed costless in the absence of transaction costs. In literature, it has been documented that this theory essentially holds for the European options and not for the American options in its strict sense.

Notably, the PCP relationship indicates the equilibrium price of a call (put) option given the price of a corresponding put (call) option. That is, it indicates whether the call options are priced correctly in relation to the price of a corresponding put options and vice-versa. However, it does not comment upon the correctness of their prices when seen individually. That is, the parity relationship may hold even when both the put and call options are underpriced or correctly priced or overpriced. Therefore, from the pricing viewpoint, it is a necessary condition but not a sufficient one.

Given the importance of parity relationship in assessing the pricing efficiency of the options market, a number of studies have been attempted to test the options market efficiency (using this relationship) in various markets around the globe. The model-free approach of this efficiency test, i.e. no dependence on any particular options pricing model (which makes certain assumptions about the movement of the underlying asset and volatility during the life of the options, e.g. Black–Scholes model), makes it of particular importance to assess the efficiency of options markets. Some of the studies that have used this test to assess the efficiency of different options markets are Stoll (1969), Merton (1973), Gould and Galai (1974), Klemkosky and Resnick (1979), Goh and Allen (1984), Evine and Rudd (1985), Bodurtha and Courtdon (1986), Gray (1989), Taylor (1990), Frankfurter and Leung (1991), Wilson and Fung (1991), Finucane (1991), Brown and Easton (1992), Nisbet (1992), Marchand *et al*. (1994), Sternberg (1994), Easton (1994), Kamara and Miller Jr. (1995), Wagner *et al*. (1996), Berg *et al*. (1996), Broughton *et al*. (1998), Mittnik and Rieken (2000b), Cavallo and Mammola (2000) , Li (2006), Zhang and Lai (2006).

Likewise, a few studies have used put-call-futures relationship (which is the test of PCP relationship using futures prices on the same underlying asset instead of spot market values) to examine the options market efficiency and the degree of pricing interrelationship between the two markets. The leading study in this respect, Lee and Nayar (1993), for the very first time proposed this relationship and tested it in the context SPX options and S&P 500 futures traded on Chicago Board Options Exchange (CBOE) and Chicago Mercantile Exchange (CME) of USA. Other studies that used this framework to assess options market efficiency include Fung and Fung (1997), Fung and Mok (2001), Draper and Fung (2002), Vipul (2008), etc.

4.2.1 The PCP Relationship Using Spot Values

The PCP relationship using the spot values for the European type options contracts is given in Eq. (4.1). The relationship given in the equation has been established assuming no bid-ask spread.

$$C_t = [P_t + (I_t - e^{-r(T-t)} K) \pm TTC_t] \tag{4.1}$$

Where,

C_t is the market price of a call option at time t,

P_t is the market price of a put option at time t,

I_t is the level of underlying index (i.e. S&P CNX Nifty) at time t,

K is the strike price of the options contracts,

T is the expiration time of the option at the time when it was floated,

r is the continuously compounded annual risk-free rate of return,

TTC_t is the Total transaction costs (i.e. transaction costs relating to trading in options and spot market) at time t and

$(T - t)$ is the time to maturity of the option at time t in years.

In addition to the assumption of no transaction costs, the Eq. (4.1) for parity relationship also assumes that the underlying asset is payout protected, i.e. it is not expected to pay any dividends during the life of the option. However, the assumption of payout protection is violated quite frequently as almost all the financial assets pay dividends. Equation (4.1) needs to be modified by incorporating the effect of dividends. Empirically, the treatment of dividends in the test varies based on the assumption made about the payment of dividends. In this respect, Klemkosky and Resnick (1979), for the very first time, incorporated effect of absolute amount of dividends to modify the parity relationship.

A number of studies in literature have used discrete amount of dividends to gauge the effect of dividends on the parity relationship. However, in the present chapter, since the underlying asset is a stock index (S&P CNX Nifty index), which is based on 50 stocks, the dividend yield has been used to incorporate the effect of dividends on the parity relationship following Fung and Fung (1997) and Li (2006). This has been done in view of the fact that incorporation of discrete dividends becomes difficult when the underlying asset is a stock index. Also, a stock index can be treated as a financial asset that generates a continuous stream of dividends (Guo and Su, 2006). The PCP relationship for the S&P CNX Nifty index options, assuming that the index is paying continuously compounded annual dividend yield (δ), is given in the Eq. (4.2).

$$C_t = [P_t + (-e^{-\delta(T-t)} I_t - e^{-r(T-t)} K) \pm TTC_t] \tag{4.2}$$

The testable form of the Eq. (4.2), which constitutes the basis of the present study in assessing the efficiency of the options market in India, is given in the next sub-section.

4.2.1.1 Testable form of the PCP relationship using spot values

Equation (4.2) given above has been rearranged in order to make it testable to gauge the efficiency of the options market. The testable forms are given in the Eqs (4.3) and (4.4) for identifying overpricing and underpricing of put options relative to the corresponding call options with same contract specifications (assuming that the call is correctly priced).

$$\varepsilon_t^{\text{Overpriced}} = \left[P_t^{\text{Market}} - \left\{C_t^{\text{Market}} - (e^{-\delta(T-t)} * I_t - e^{-r(T-t)} * K) + TTC_t\right\}\right] \tag{4.3}$$

$$\varepsilon_t^{\text{Underpriced}} = \left[C_t^{\text{Market}} - \left\{P_t^{\text{Market}} + (e^{-\delta(T-t)} * I_t - e^{-r(T-t)} * K) - TTC_t\right\}\right] \tag{4.4}$$

In the above equations, $\varepsilon_t^{\text{Overpriced}}$ and $\varepsilon_t^{\text{Underpriced}}$ are the absolute amount of abnormal profits (*ex-post*) or mispricing signals, if the violation of PCP takes place. A violation of PCP is recorded if $\varepsilon_t^{\text{Overpriced}} > 0$ or $\varepsilon_t^{\text{Underpriced}} > 0$. Though the presence of such profits is merely indicative of market inefficiency, it should not be treated as a conclusive remark on the efficiency of the market, as their exploitability needs to be examined to draw correct inferences about the market efficiency.

Example 4.1 *Exploiting arbitrage opportunity indicated by violation of PCP condition: A case of relative underpricing of put option*

On December 1, 2010, a call option contract on S&P CNX Nifty index with strike price of ₹ 6200 and scheduled to expire on December 31, 2010, is currently available at ₹ 200. At the same time, a put option contract with ***the same characteristics*** *is traded at ₹ 50. In the spot market, the index is currently being traded at ₹ 6290. Suppose that continuously compounded risk-free rate of return is 7.5% p.a., and each transaction in F&O segment is subject to transaction cost of 0.05% on notional value of the contract, i.e. (strike price + premium) × size of the contract. An option contract on Nifty includes 50 Nifty.*

Solution *As mentioned in the discussion on PCP relationship, corresponding price of a put option contract (given the price of a call option with the same characteristics) at any given point in time should be*

$$P_t^{Theoretical} = \left[C_t^{Market} - (I_t - e^{-r(T-t)}\ K) + TTC_t\right]$$

In the above-mentioned equation, it is important to note that the transaction cost has been subtracted. This has been done in view of the fact that we are trying to trace underpricing of the put option, and therefore, we need to arrive at the lower bound of the price range that will exist in the presence of transaction costs.

Based on the above-mentioned relationship, the theoretical price of a put option, given that a corresponding call option with the same characteristics is currently traded at ₹ 200, should be

$$= \{200 - (6290 - e^{-(0.075 \times 31/365)} \times 6200) - (2 \times 6200 + 200 + 50) \times 0.0005\} = ₹\ 64.31^{1}$$

Since current market price of the put option (₹ 50) is lower than that warranted by PCP relationship; it indicates an arbitrage opportunity. In case such an opportunity appears, following steps can be taken to ensure arbitrage gains.

Steps required now (on spot):

All steps required now need to be taken simultaneously to lock-in arbitrage profit. This will hold true for Examples 4.1–4.4.

Step 1*: Purchase the put option as it is undervalued; and sell the call option as it seems to be overvalued in relation to put option. This will lead to synthetic short-position in the underlying asset.*

Step 2: *Take long position in the underlying asset.*

[1] It is important to note that the transaction costs related to spot market as well as dividend yield have been ignored in determining the relative price of the put option in order to avoid further complexity.

***Step 3**: Borrow ₹ 6,146.33 (₹ $6290_{SPOT\ PRICE}$ + ₹ $50_{PUT\ OPTION\ PRICE}$ – ₹ $200_{CALL\ OPTION\ PRICE}$ + ₹ $6.325_{TRANSACTION\ COST}$) at risk-free rate for the remaining life of the contract.*

Steps required at maturity:

***Step 4:** Square off your long position in the underlying asset.*

In this respect,(a) call option will be exercised against you, and you have to sell the asset (you are long in) at ₹ 6200, in case underlying asset is being traded at more than ₹ 6200. (b) On the contrary, if the underlying is traded at a lower price, e.g. ₹ 6150; you can sell it at ₹ 6200 by exercising the put option. In either case, you will end up receiving ₹ 6200 by selling the underlying asset you are long in.

***Step 5:** Pay back the borrowed sum along with the accrued interest. You need to pay a sum of ₹ 6146.33 × $e^{(0.075 \times 31/365)}$; that is, ₹ 6185.61.*

From the above, it is evident that, in any case, you will receive ₹ 6,200 by selling the underlying asset. Since you need to pay ₹ 6,185.61 for the initially borrowed sum of money, you end up generating a profit of ₹ 14.39 (₹ 6,200 – ₹ 6,185.61). Thus, on the whole contract (which includes 50 Nifty), you will earn an arbitrage profit of ₹ 719.50.

Example 4.2 *Exploiting arbitrage opportunity indicated by violation of PCP condition: A case of relative overpricing of put option*

*On December 1, 2010, a call option contract on S&P CNX Nifty index with strike price of ₹ 6200 and scheduled to expire on December 31, 2010, is currently available at ₹ 200. At the same time, a put option contract with **the same characteristics** is traded at ₹ 90. In the spot market, the index is currently being traded at ₹ 6290. Suppose that continuously compounded risk-free rate of return is 7.5% p.a., and each transaction in F&O segment is subject to transaction cost of 0.05% on notional value of the contract, i.e. (strike price + premium) × size of the contract. An option contract on Nifty includes 50 Nifty.*

Solution *As mentioned in the discussion on PCP relationship, corresponding price of a put option contract (given that a call option with the same characteristics is currently traded at ₹ 200) at any given point in time should be*

$$P_t^{Theoretical} = \left[C_t^{Market} - (I_t - e^{-r(T-t)}\ K) + TTC_t\right]$$

In the above-mentioned equation, it is important to note that transaction cost has been added while determining price of the put options. This has been done in view of the fact that we are trying to trace the overpricing of put option, and therefore, we need to consider upper bound of the price range.

Therefore, corresponding price of a put option, given that a corresponding call optionwith the same characteristics is currently traded at ₹ 200, should be

$$= \{200 - (6290 - e^{-(0.075 \times 31/365)} \times 6200) + (2 \times 6200 + 200 + 80) \times 0.0005\} = ₹\ 76.97$$[2]

Since the current market price of the put option (₹ 90) is greater than that required by PCP relationship; it indicates an arbitrage opportunity. In case such an opportunity emerges, following steps can be taken to ensure arbitrage gains.

Steps required now (on spot):

***Step 1**: Sell the put option as it is overvalued and buy the corresponding call option. This will lead to synthetic long position in the underlying asset.*

***Step 2:** Sell the underlying asset short.*

***Step 3:** Invest the amount received by constructing the above-mentioned portfolio, i.e.* ₹ *6,173.66 (*₹ $6290S_{Top\ price}$ + ₹ $90_{Put\ option\ price}$ − ₹ $200_{Call\ option\ price}$ − ₹ $6.34_{Transaction\ cost)}$ *at risk-free rate of return for the remaining life of the contract.*

Steps required at maturity:

***Step 4:** Liquidate your investment. You will realize a sum of* ₹ $6173.66 \times e^{(0.075 \times 31/365)}$. *That is,* ₹ *6213.11.*

***Step 5:** Square off your short position in the underlying asset.*

For the purpose, (a) exercise the call option contract and buy the underlying asset at ₹ 6200, in case the underlying asset is being traded at more than ₹ 6200. (b) On the contrary, if the underlying is traded at a lower price, e.g. ₹ 6150; the put option (that you sold initially) will be exercised against you. In a nutshell, you will end up purchasing the underlying asset at ₹ 6200.

From the above, it is clear that, in any case, the amount required to square off the short position is ₹ 6,200. Since you received ₹ 6,213.11 from your initial investment, you end up generating a profit of ₹ 13.11 (₹ 6,213.11 − ₹ 6,200). And, on the whole contract (which includes 50 Nifty), you will earn a profit of ₹ 655.50.

4.2.2 The PCP Relationship Using Futures Prices

The test of PCP relationship using futures prices is in line with Lee and Nayar (1993), Fung and Chang (1994), Fung *et al*. (1997), Fung and Fung (1997), Fung and Mok (2001), etc. The PCP relationship for the options using the corresponding futures prices (with the same maturity date) is given in the Eq. (4.4). This condition is expected to hold in an efficient options market and, therefore, has been used to test the options market efficiency.

$$C_t = [P_t + e^{-r(T-t)} (F_t - K) \pm TTC_t^*] \qquad (4.5)$$

In the above equations, F_t is the value of the S&P CNX Nifty futures (with same expiration date as of the options under consideration) at time t and

[2] It is important to note that the transaction costs related to spot market as well as dividend yield have been ignored in determining the relative price of the put option in order to avoid further complexity.

TTC_t is the Total transaction costs (i.e. transaction costs relating to trading in options and futures contracts) at time t. Besides, all other variables are the same as in Eq. (4.1).

With respect to the treatment of dividends, it may be noted that the futures prices (in an efficient market) are expected to have impounded the effect of dividends expected to be distributed during the life of the contract. And, it is for this reason that the dividends expected from the underlying asset during the life of the option have not been included as the underlying asset used in the test is futures prices/values of the index instead of the spot values.

4.2.2.1 Testable form of the PCP relationship using futures prices

Equation (4.5) has been rearranged in order to make it testable to gauge the efficiency of the options market. The testable form of the PCFP relationship has been provided in the Eqs (4.6) and (4.7).

$$\varepsilon_t^{\text{Overpriced}} = \left[P_t^{\text{Market}} - \left\{ C_t^{\text{Market}} - e^{-r(T-t)} * (F_t - K) + TTC_t^* \right\} \right] \quad (4.6)$$

$$\varepsilon_t^{\text{Underpriced}} = \left[C_t^{\text{Market}} - \left\{ P_t^{\text{Market}} - e^{-r(T-t)} * (F_t - K) - TTC_t^* \right\} \right] \quad (4.7)$$

In the above equations, $\varepsilon_t^{\text{Overpriced}}$ and $\varepsilon_t^{\text{Underpriced}}$ are the absolute amount of abnormal profits (*ex-post*) or mispricing signals, if the violation of PCP takes place. A violation of PCP is recorded if $\varepsilon_t^{\text{Overpriced}} > 0$ or $\varepsilon_t^{\text{Underpriced}} > 0$.

It may be noted that all equations relating to test of PCP using spot as well as futures prices have been specified considering the transaction costs, but assuming zero or negligible bid-ask spread. In view of this, there is always a chance that the arbitrage opportunities suggested by these equations may disappear in the presence of the bid-ask spread, especially for the options traded relatively less frequently. Therefore, due consideration has been given to the bid-ask spreads while interpreting the violations to draw inferences regarding the market efficiency. The details on the transaction costs included in the analysis have been summarized in the data section. On the contrary, given the fact that the bid-ask spread for options is not included in the transaction database provided by NSE and the difficulty to estimate such costs, it has been excluded in the above equations. In operational terms, our study is in line with that of Halpern and Turnbull (1985).

Example 4.3 *Exploiting arbitrage opportunity indicated by violation of PCFP condition: A case of relative underpricing of put option*

In addition to the data given in Example 4.1, assume that a futures contract on NSE CNX Nifty index, scheduled to expire on December 30, 2010, is traded at ₹ 6330. Examine the arbitrage opportunity, if any. Determine the profit that can be generated by exploiting this opportunity.

Solution *As mentioned in the discussion on PCP using futures prices, the corresponding price of a put option, given the price of a corresponding call option with the same characteristics, should be*

$$P_t = [C_t - e^{-r(T-t)}\,(F_t - K) - TTC_t^*]$$

As we are aware from the previous examples that we need to subtract transaction cost while tracing underpricing. Therefore, the relative price for above-mentioned put option should be

$$= [200 - e^{(-0.075 \times 31/365)}\{6330 - 6200\}$$
$$- (2 \times 6330 + 6200 + 50) \times 0.0005] = ₹\ 61.37$$[3]

Since the price quoted in market (₹ 50) is lower than that suggested by parity condition, it indicates an arbitrage opportunity. In case such an opportunity appears in the market, following steps need to be taken to make arbitrage profit.

Steps required now (on Spot):

Step 1: *Buy the put option at the current market price as it is undervalued and sell the call option at the current market price. It will lead to a synthetic short position in futures, which is traded at ₹ 6200 (strike price).*

Step 3: *Take long position in futures on the same index with the same maturity.*

Step 4: *From the above-mentioned portfolio, you will receive a sum of ₹ 140.54 (₹ $200_{Call\ option}$ – ₹ $50_{Put\ option}$ – ₹ $9.46_{Transaction\ cost}$). Invest it at risk-free rate for the remaining time to maturity.*

Steps required at maturity:

At maturity, price of the underlying asset may follow any of the following three scenarios:

(i) less than the strike price of the option contracts,

(ii) more than the strike price but less than or equal to the current future price (F_t) and

(iii) more than the current futures price (F_t).

Scenario 1: *Less than the strike price of option contract, i.e. price of the underlying index turns out to be less than ₹ 6,200. For example, at maturity, the index is traded at ₹ 6150.*

Step 4: *You will exercise the put option as the current price of underlying asset is less than strike price (₹ 6200) of the contract. However, the call option will not be exercised against you. From your overall position in options market, you will make a gain of ₹ 50 (₹ 6200 – ₹ 6150).*

Step 5: *On the contrary, you will incur a loss of ₹ 180*[4] *(₹ 6330 - ₹ 6150) on long position in futures, since you entered into a contract to buy the underlying asset at ₹ 6330 which is currently traded at ₹ 6150 .*

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[3] It may be noted that the margin needed to take a position in futures market and cost thereof have been ignored in determining relative price of option contract in order to avoid further complexity.

[4] In settlement of futures contracts, it has been assumed that futures prices converge to the spot price at maturity. This will hold true in case futures are priced correctly.

In sum, you will incur a loss of ₹ 130 (₹ 180 – ₹ 50), in case price turns out to be less than the strike price of options contract.

Scenario 2: *More than the strike price of call option contract but less than or equal to futures price. For example, at maturity, the index is traded at ₹ 6250.*

Step 4: *The call option will be exercised against you as the price is more than strike price (₹ 6200) of the contract. As a result, you will incur a loss of ₹ 50. On the other hand, you will not exercise put option given the market conditions.*

Step 5: *Similarly, you will incur a loss of ₹ 80 on the long position in futures.*

In sum, you will incur a loss of ₹ 130 from you position in options and futures markets.

Scenario 3: *More than the price of futures contract (the price at which we purchased the futures). For example, at maturity, the index is traded at ₹ 6400.*

Step 4: *The call option will be exercised against you as the price more than strike price (₹ 6200) of the contract, and you will incur a loss of ₹ 200. On the other hand, you will not exercise put option given the market conditions.*

Step 5: *However, you will gain ₹ 70 on the long position in futures.*

In sum, you will incur a loss of ₹ 130.

Thus, from all the three possible scenarios for the price of underlying asset, it is evident that you will end up with the loss of ₹ 130.

Step 6: *Liquidate your investment, and you will have ₹ 141.44 (₹ 140.54 × $e^{(0.075 \times 31/365)}$).*

From the above, it is clear that, in any case, you incur a loss of ₹ 130; at the same time, you will receive ₹ 141.44 from your initial investment. In other words, you make a profit of ₹ 11.44 (₹ 141.44 – ₹ 130). Thus, on the whole contract (which includes 50 Nifty), you will end up with the profit of ₹ 572.

Example 4.4 *Exploiting arbitrage opportunity indicated by violation of PCFP condition: A case of relative overpricing of put option*

In addition to the data given in Example 4.3, assume that the put option is traded at ₹ 90 instead of ₹ 50.

Solution *As mentioned in the discussion on PCP using futures prices, the corresponding price of a put option, given the price of a corresponding call option with the same characteristics, should be:*

$$P_t = [C_t - e^{-r(T-t)} (F_t - K) - TTC_t^*]$$

It is important to note that we have added transaction cost as we need the upper bound of price range in order to trace overpricing.

Therefore, the relative price for above-mentioned call option should be

$$= [200 - e^{(-0.075 \times 31/365)}\{6330 - 6200\} + (2 \times 6330 + 6200 + 50) \times 0.0005] = ₹\ 80.30$$[5]

Since the price quoted in the market (₹ 90) is greater than that suggested by the parity condition, it indicates an arbitrage opportunity. In case such an opportunity appears in the market, following steps need to be taken to make arbitrage profit.

Steps required now (on Spot):

Step 1: *Sell the put option at the current market price as it is undervalued and buy the call option at the current market. It will lead to a synthetic long position in futures, which is traded at ₹ 6200 (strike price).*

Step 2: *Take short position in futures on the same index with the same maturity.*

Step 3: *To create the above-mentioned portfolio, you need to borrow a sum of ₹ 100.52 (₹ $200_{Call\ option}$ – ₹ $90_{Put\ option}$ + ₹ $9.48_{Transaction\ cost}$) at risk-free rate for the remaining time to maturity.*

Steps required at maturity: *At maturity, price of the underlying asset may follow either of the following three scenarios:*

(i) less than the strike price of the option contracts,

(ii) more than the strike price but less than or equal to the current future price (F_t) and more than the current futures price (F_t).

Scenario 1: *Less than the strike price of option contract, i.e. value of the underlying index turns out to be less than ₹ 6,200. For example, at maturity, the index is traded at ₹ 6150.*

Step 4: *The put option will be exercised against you as the price of the asset is less than strike price (₹ 6200) of the contract. However, you will not exercise the call option. From your positions in options market, you will incur a loss of ₹ 50 (₹ 6200 – ₹ 6150).*

Step 5: *On the other hand, you will make a profit of ₹ 180*[6] *(₹ 6330 – ₹ 6150) on short position in futures since you entered into a contract to sell the underlying asset at ₹ 6330 at maturity. As the current market price in the spot market turns out to be ₹ 6150, you will make a profit.*

In sum, you will make a profit of ₹ 130 (₹ 180 – ₹ 50), in case price turns out to be less than strike price of options contract.

Scenario 2: *More than the strike price of call option contract but less than or equal to futures price. For example, at maturity, the index is traded at ₹ 6250.*

Step 4: *You will exercise the call option as the price of the asset is more than the strike price (₹ 6200) of the contract. Thus, you will make a profit of ₹ 50.*

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[5] It may be noted that the margin needed to take a position in futures market and cost thereof have been ignored in determining relative price of option contract in order to avoid further complexity.

[6] In settlement of futures contracts, it has been assumed that futures prices converge to the spot price at maturity. This will hold true in case futures are priced correctly.

On the other hand, the put option will not be exercised against you given the market conditions.

Step 5: *Similarly, you will make a profit of ₹ 80 on the short position in futures.*

In sum, you will make a profit of ₹ 130 from you position in options and futures markets.

Scenario 3: *More than the price of futures contract. For example, at maturity, the index is traded at ₹ 6400.*

Step 4: *You will exercise the call option as the price of the asset is more than the strike price (₹ 6200) of the contract. You will make a profit of ₹ 200. However, the put option will not be exercised against you given market conditions.*

Step 5: *However, you will incur a loss of ₹ 70 on the short position in futures.*

In sum, you will gain ₹ 130.

Thus, from all the three possible scenarios for the price of underlying asset, it is evident that you will make ₹ 130 or more.

Step 6: *Pay back your borrowed sum (along with interest) of ₹ 101.16 (₹ $100.52 \times e^{(0.075 \times 31/365)}$).*

From the above, it is clear that, in any case, you earn ₹ 130 and you need to pay ₹ 101.16. In other words, you make a profit of ₹ 28.84 (₹ 130 – ₹ 101.16). And, on the whole contract (which includes 50 Nifty), you will end up with the profit of ₹ 1442.

Note *While assessing options market using futures market, it assumed that futures market is efficient. That is, it will converge to spot price at the maturity of the contract.*

4.3 DATA

4.3.1 Data Related TO Options Contracts, Spot Market, Futures Market and Interest Rates

The PCP relationship has been tested on a data set containing data pertaining to the four major categories, namely (i) data related to S&P CNX Nifty index options contracts, (ii) data related to S&P CNX Nifty index futures, (iii) data related to the underlying asset, i.e. the S&P CNX Nifty index and (iv) data on the risk-free rate of return. The data relates to the first 6 years of trading in Indian options market, i.e. from June 04, 2001 (the date on which index options were launched in Indian derivatives market) to June 30, 2007.

Unlike the LBCs where the call and put options quotes are analysed individually, the PCP requires pairs of the call and put options matched to each other on the basis of three criteria—'deal date', 'date of expiration' and 'strike price'. Therefore, the total number of quotes of call options (40,298) has been matched with those of put options (35,172) based on the above-mentioned three criteria, for all the 6 years under reference. The matching so carried out resulted into 28,839 pairs of call and put options having identical 'deal date', 'expiration date' and 'strike price'. Moreover, since the study also attempts to test the PCFP, these pairs have further been matched to the data relating to index futures based on the 'deal date' and 'expiration date'. The matching so carried out resulted into the same number of triplets (i.e. 28,839), as each pair of options could find a futures contract having the same 'deal date' and 'expiration date'.

4.3.2 Transaction Costs

The transaction costs applicable to trading member organization have been used to test the PCP relationship and to identify the arbitrage opportunities/mispricing signals, if any. Since the brokerage firms are privileged with the least cost (transaction cost) structure in the market amongst all categories of participants, it would be appropriate from the standpoint of the assessment of market efficiency to use 'transaction costs applicable to such organizations' as a proxy for the transaction costs.

This has been done in view of the fact that such transaction cost would facilitate in identifying those arbitrage opportunities that, otherwise, could have remained unidentified, had we used some other proxy for the transaction costs (e.g. the transaction costs applicable to retail investors). In sum, such estimates of transaction costs will facilitate in assessing the true state of options market efficiency in Indian derivatives market.

4.4 ANALYSIS AND EMPIRICAL RESULTS

The violations of the 'put-all parity (PCP) relationship' have been identified in terms of underpricing and overpricing of put options relative to corresponding call options with same contract specifications. A violation has been termed as overpriced put option when the theoretical price of the put option (arrived at based on PCP relationship using market price of the corresponding call options) is found to be less than the market price of that put option. Similarly, underpricing of put option has been registered when the market price of the put option is less than the theoretical price of that put option. The violations so identified have been analysed with respect to the specified levels of liquidity, maturity and years under reference for both underpriced and overpriced put options.

In the chapter, three levels of liquidity have been specified considering the liquidity (number of contracts traded) of both call and put options with same contract specifications. This has been done in view of the fact that the arbitrage strategy required to exploit the mispricing signals identified using PCP relationship makes use of both call option and put option along with the underlying asset (referred to as 'triplet' in literature). Therefore, the levels of liquidity have been specified based on the liquidity of both call and put options as it becomes important in ascertaining the exploitability of the observed mispricing signals. These levels are, namely (i) **thinly traded,** where the number of contracts traded per day for call (put) options are less than or equal to 100, with corresponding put (call) options having any number of contracts traded; (ii) **moderately traded,** where call (put) options are having 101–500 contracts traded per day along with the corresponding put (call) options having more than 100 contracts traded per day and (iii) **highly traded,** where call as well as put options having more than 500 contracts traded per day.

Similarly, four levels have been specified for the maturity of options contracts. The specified levels of maturity are—(i) 0–7 Days to maturity; (ii) 8–30 Days to maturity; (iii) 31–60 Days to maturity and (iv) 61–90 Days to maturity.

4.4.1 Analysis of the Behavior of Violations from the PCP Relationship

The summary of overall results regarding the violations of parity condition is reported in Table 4.1. It can be deciphered from the results that a large number of violations, which are nearly 96% of the observations analysed, have been recorded before considering the transaction costs. However, the violations have shown a sharp decline after reckoning the transaction costs that are applicable to the most privileged category of investors, i.e. brokerage firms. This is borne out by the fact that total number of violations have reduced to 15,259 (2,224 + 13,035), which amounts to 52.91% of the total number of pairs analysed. The violations identified after reckoning the transaction costs constitute the basis of the study on account of their practical appeal and, therefore, have been analysed subsequently to draw inferences about the options market efficiency.

The frequency of violations, *per-se*, seems to be alarming as the violations identified after reckoning the transaction costs applicable to the trading member organizations represents more than half of the observations analysed. Moreover, it is interesting to note that majority of the violations have been recorded in terms of the relative overpricing of put options as it represents a major chunk of total violations identified, i.e. 45.20% out of the total 52.91% of the violations belong to the overpriced put options. However, the remaining violations (i.e. 7.71% of the violations) connote the underpricing of put options. Besides, the classification of violations in terms of the three levels of liquidity demonstrates that a vast majority of violations in underpriced puts belong to the thinly traded category, which can reasonably be designated as unexploitable on account of the high bid-ask spread and high immediacy/

liquidity risk. In this respect, Ofek *et al*. (2004) aptly opined that the lack of liquidity imposes another significant cost to arbitrageurs in terms of the bid-ask spread, as it is higher for illiquid contracts and could turn out to be a major constraint to arbitrageurs.

Likewise, the overpriced puts tread the same path as far as the frequency of thinly traded violations is concerned, however, with the lower percentage (68% of total violations in terms of overpriced puts) compared with that in case of underpriced puts. Naturally, the percentage of violations belonging to the relatively exploitable category, namely moderately and highly traded category, is considerably higher for the overpriced put options compared with that observed in the case of underpriced put options. That is, 32% of the overpriced puts pertain to the 'moderately and highly traded' category compared with 16% in the case of underpriced put options.

Table 4.1 Violations of the PCP Relationship and Liquidity Levels, June 2001–07

Particulars	*Underpriced put options (Percentage)*	*Overpriced put options (Percentage)*	*Total (Percentage)*
Total number of observation analysed	28,839	28,839	28,839
Total number of violations observed **before transaction costs**	6413 (22.24)	21309 (73.89)	27,722 (96.13)
Total number of violations observed **after transaction costs**	2,224 (7.71)	13,035 (45.20)	15,259 (52.91)
Violations relating to the three specified levels of liquidity			
(a) Thinly traded options	1873 (84)	8881 (68)	10754 (71)
(b) Moderately traded options	304 (14)	2187 (17)	2491 (16)
(c) Highly traded options	47 (2)	1967 (15)	2014 (13)
Total	**2,224**	**13,035**	**15,259**

The results on the frequency of violations suggest that majority of violation have been recorded in terms of overpriced put options. However, it would be appropriate to look at their magnitudes of profit for ensuring the exploitability of such options. In view of this, the magnitudes of overpriced as well as underpriced put options have been classified as per the specified categories of liquidity. The analysis so made has been reported in Table 4.2. The results clearly demonstrate that the overpriced put options offer higher magnitude of profit along with the comparatively higher frequency of violations. It is evident from the fact the average profit for the moderately and highly traded categories in case of overpriced puts are ₹ 653 and ₹ 705 per contract, respectively; on the other hand, these categories offer a considerably lower profit of ₹ 209 and ₹ 239, respectively, per contract in the case of underpriced put options. Based on these observations, it may, *prima-facie*, be concluded that the overpriced put options are more likely to be exploited compared with underpriced put options on account of higher magnitude of profits they offer.

Thought, it may be noted that the higher standard deviations both in the cases of overpriced and underpriced put options (for both the categories) defy the credibility of the mean as a correct statistical measure as these indicate the presence of outliers in the data. Therefore, it would be reasonable to use positional measures (i.e. median, percentiles, etc.) instead of the arithmetical measures (i.e. mean). In view of this, the quartiles have been calculated for the magnitude of profit and are reported in Table 4.2.

The results summarized in Table 4.2 clearly indicate that the violations belonging to highly and moderately traded category in the underpriced put options amount to just 351 (304 + 47) observations. In operational terms, such violations in underpriced puts category can be designated as exploitable since the bid-ask spread is expected to be relatively lower on account of the higher trading in such violations. Moreover, the information contained in the quartiles suggests that nearly one-fourth of the highly traded underpriced puts (as indicated by the third quartile) can be designated as exploitable as the third quartile offers a profit magnitude of more than ₹ 361. However, the proportion of exploitable violations in moderately traded underpriced puts category goes further down since the third quartile offers a starting profit of less than ₹ 300. Further, in order to have a better idea about the percentage of exploitable violations in this category, the 80^{th}, 85^{th} and 90^{th} percentiles have been calculated. The results suggest that nearly 20% of violations in 'moderately traded underpriced put' category can be reasonably designated as exploitable because the 80^{th} percentile reported a starting profit of ₹ 346 per contract.

In sum, it would be reasonable to conclude that a total number of 72 cases (12 cases from the highly traded category and 60 from the moderately traded underpriced puts) out of the total number of (2,224) violations identified in terms of underpriced futures can be designated as exploitable. In other words, the exploitable number of underpriced put options amounts to just 0.25% of total pairs analysed. The rest of the violations in underpriced puts belong to thinly traded category and amount to 84% of the total violations in this category. Such violations can be termed as unexploitable on account of low liquidity, which causes the bid-ask spread to be significantly higher.

Given the meagre percentage of exploitable violation in uderpriced puts category, it would be reasonable to conclude that the put options are not underpriced or call options are not relatively overpriced. This finding defies the popular belief that call options, in general, are costlier than the put options.

In contrast, a significantly noticeable number of violations have been observed in terms of overpriced put options. It is well manifested in the fact that a total number of 4,154 (2,187 + 1,967) violations belonging to highly and

Table 4.2 Liquidity-wise Descriptive Statistics for Violations of the PCP Condition for Underpriced and Overpriced Put Options in Indian Securities Market, June 2001–07

Liquidity	*Underpriced put options*						*Overpriced put options*					
	Number of violations (Percentage)	*Magnitude of violations*					*Number of violations (Percentage)*	*Magnitude of violations*				
		Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
Thinly traded	1,873 (84)	563	966	89	237	611	8,881 (68)	789	1,056	196	483	1023
Moderately traded	304 (14)	209	335	43	101	274	2,187 (17)	653	689	176	**421**	**887**
Highly traded	47 (2)	239	230	58	169	**361**	1,967 (15)	705	630	238	**539**	**997**
Total	**2,224**	**508**	**905**	**76**	**211**	**534**	**13,035**	**754**	**950**	**197**	**480**	**999**

In the table, S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e. median) and third quartile respectively.

moderately traded category have been identified. These violations amount to 32% of total number of violations in overpriced put options. Since the bid-ask spread is expected to be considerably low for such options, it would be reasonable to designate these violations as exploitable. In addition, the finding is revealing that nearly 50% of such mispricing opportunities seem exploitable as the second quartiles report a starting profit of ₹ 421 and ₹539 per lot for moderately and thinly traded categories, respectively. In sum, it may be appropriate to conclude that a significantly alarming/higher number of violations in terms of overpriced put options can be labelled as exploitable in light of the magnitude of profits they offer. It is eloquently borne out by the fact that the exploitable violations in this category turn out to be more than 2000 (half of the violation in moderately and traded category), which represent nearly 7% of the total observations anlysed.

However, the remaining violations in terms of overpriced put options remained unexploited because of lower liquidity they possessed (i.e. thinly traded options). Such violations accounts for the more than two-third of the violations in this category. In this respect, commenting upon the unexploitability of such options, Kamara and Miller Jr (1995) observed that such violations essentially mirror the liquidity or immediacy risk deriving from the possibility of unfavourable price shifts between the time when the decision to build strategies is made and the actual execution of the orders. And, it further cautioned that the liquidity risk is particularly high in the case of index options since arbitrage portfolios often require trading the stock basket which constitutes the index.

In view of the above-mentioned findings, it may aptly be concluded that the mispricing identified using PCP analysis revealed the relative overpricing of put options to the corresponding call options, as a significantly noticeable number of violations pertaining to the overpriced put category could be designated as exploitable.

Besides, the violations so observed in terms of overpricing and underpricing of put options have further been analysed with respect to the maturity time they had. This has been attempted with intent to understand the clustering of violations as it helps to draw some meaningful inferences for the betterment of the market as well as helps to find more reasons for the existence of violations in the market. Moreover, the classification so made has further been sub-classified within each category as per the three specified levels of liquidity. The sub-classification so made aims at ensuring the exploitability of the violations contained in the four specified levels of maturity and, thus, facilitates in assessing the state of efficiency across the different levels of maturity. The results in this respect have been reported in Table 4.3.

The results summarized in the table indicate that majority of violations both in the case of underpriced and overpriced put options are clustered in

Table 4.3 Maturity-wise Descriptive Statistics for Violations of the PCP Condition for Underpriced and Overpriced Put Options in Indian Securities Market, June 2001–07

Days to maturity	Liquidity	*Underpriced put options*						*Overpriced put options*					
		Number of violations	*Magnitude of violations*					*Number of violations*	*Magnitude of violations*				
			Mean	*S.D.*	Q_1	Q_2	Q_3		*Mean*	*S.D.*	Q_1	Q_2	Q_3
‘0–7’ Days	Thinly traded	561	585	926	93	263	657	879	646	1386	106	283	666
	Moderately traded	94	285	515	60	116	353	147	357	504	83	208	379
	Highly traded	24	245	254	41	171	355	107	462	620	109	244	414
	Overall	**679**	**532**	**872**	**84**	**231**	**604**	**1133**	**591**	**1253**	**104**	**265**	**590**
‘8–30’ Days	Thinly traded	925	556	985	88	230	604	4689	602	847	166	376	722
	Moderately traded	190	171	171	41	97	250	1229	453	511	139	309	598
	Highly traded	23	233	207	60	167	373	1351	571	488	212	466	792
	Overall	**1138**	**485**	**903**	**71**	**195**	**503**	**7269**	**571**	**745**	**167**	**379**	**720**
‘31–60’ Days	Thinly traded	366	867	867	82	211	503	2734	964	1031	304	735	1330
	Moderately traded	20	396	396	11	60	207	716	916	719	334	789	1340
	Highly traded	Nil	Nil	Nil	Nil	Nil	Nil	437	989	673	474	931	1418
	Overall	**386**	**484**	**851**	**68**	**199**	**497**	**3887**	**958**	**946**	**323**	**770**	**1345**
‘61–90’ Days	Thinly traded	21	1413	2007	411	872	1766	579	1695	1445	759	1489	2255
	Moderately traded	Nil	Nil	Nil	Nil	Nil	Nil	95	1712	994	861	1702	2422
	Highly traded	Nil	Nil	Nil	Nil	Nil	Nil	72	1841	945	1178	1811	2560
	Overall	**21**	**1413**	**2007**	**411**	**872**	**1766**	**746**	**1711**	**1353**	**782**	**1544**	**2348**

In the table, S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e. median) and third quartile, respectively.

the 0–60 days to maturity category, i.e. the first three levels of maturity, viz. 0–7, 8–30 and 31–60 days to maturity. As already revealed in the analysis of violations in relation to different levels of liquidity, the number of exploitable violations in terms of the underpricing of puts seems to be negligible across all the categories of maturity. It is empirically evident from the fact that the magnitudes of the violations pertaining to highly and moderately liquid categories are very low. The very first category in the 0–7 days to maturity have a total number of 118 violations including cases of both moderately and highly traded categories. Moreover, only the third quartiles of such violations offer a starting amount of magnitudes (viz. ₹ 353 and ₹ 355, respectively) that can be designated as worth exploiting in the presence of bid-ask spread. Therefore, it may reasonably be deciphered that only one-fourth of such violations (nearly 30 cases) are exploitable.

Similarly, for category 8–30 days to maturity of underpriced put options have a total number of 213 violations aggregately in moderately and highly liquid categories. However, if we look at the exploitability of such violations, the number must certainly go down as only the third quartile of highly traded category offers a potentially exploitable starting profit of ₹ 373. Besides, the third quartile in case of moderately traded category offers a lower profit margin, which *per-se*, suggests that even less than one-fourth of such violations may be exploitable. Therefore, to have precise idea about the number of exploitable cases in this category, 80th, 85th and 90th percentile were calculated. The 80th percentile for such options suggested a starting profit of ₹ 317, which indicates that 20% of the cases in this category can be designated as exploitable. In sum, a total number of 44 cases of violations in 8–30 days to maturity can be designated as exploitable, which is again a meagre number.

Moreover, the last two categories of maturity for the underpriced put options revealed negligible to zero exploitable cases as there are no cases in the highly liquid category for both the maturity levels. Besides, the moderately traded category have negligible cases in the case of violations having 31–60 days to maturity and no cases for the last category.

In sum, it may be inferred from the above discussion that the number of exploitable violations remained negligible for the first two levels of maturity. Moreover, such violations remained virtually absent for the last two categories. A vast majority of such cases across all the levels of maturity remained unexploited in view of their profit magnitudes and the immediacy risk.

In sharp contrast to the underpriced put options, the overpriced put options seem to offer noticeable number of exploitable violations across all the categories of maturity. Moreover, such violations predominately appeared in the second and third level of maturity, i.e. 8–30 and 31–60 days to maturity. It is empirically corroborated from the fact that the magnitude of profits in case of overpriced put options are substantially higher compared with those in the case of underpriced puts across all the categories. In the 0–7 days to maturity category, one-fourth of the total cases in moderately and highly traded category (nearly 60 cases); based on the magnitudes of profit they offer can be referred to as exploitable. The finding is revealing as long as the number of exploitable violations in the next two maturity levels are concerned. This is evident from the fact that half of the violations in moderately as well as highly traded category for the maturity level 8–30 days to maturity (which amount to more than 1250 cases) could be designated as exploitable based on the profit magnitude they offer. Moreover, nearly an equal number of violations for the next maturity level, i.e. 31–60 days to maturity can be designated as exploitable, as all such violations belonging to moderately and highly traded category offered attractive profit potentials. Besides, unlike the underpriced put options, the overpriced put options experienced the existence of a significant number of violations in the 61–90 days to maturity category as well.

In sum, it may be concluded that the overpriced put options had a noticeable number of exploitable violations across all the four categories of time to maturity unlike the underpriced puts, where negligible number of violations were recorded across all the four levels. The violations predominantly occurred in 8–30 and 31–60 days to maturity categories.

4.4.2 Statistical Significance of the Difference in the Magnitude of Violations

In view of the above findings, it can be observed that there seems to be a difference in the mean magnitudes of violations among the specified levels of liquidity for underpriced as well as overpriced put options. Therefore, to validate the difference statistically, **Kruskal–Wallis (H-statistics) test**, which is a non-parametric substitute for the one-way ANOVA, has been applied. It has been done in view of the fact that the main assumption of ANOVA, i.e. all the samples have been drawn from a normally distributed population, could not be validated for the data under consideration. The normality assumption for all the samples has been tested using 'one-sample Kolmogorov–Smirnov statistics'. The results reported in Table 4.4 reveal severe departure from the normality. And, therefore, it would not be appropriate to apply ANOVA for testing the differences of magnitudes across all the three levels of liquidity. Therefore, the differences have been analysed using a non-parametric statistics, which does not require the data to follow any specified distribution.

In addition to this, ***Dunn's multiple comparison statistics*** has been used for *post-hoc* analysis of all possible pairs in the analysis. The results of H statistics and Dunn's test for the differences across the specified levels of liquidity, respectively, are summarized in Tables 4.5 (a) and 4.5 (b).

The significance value given in Table 4.5 (a) clearly indicates that the difference among the specified levels of liquidity is highly significant, as it has been found to be significant even at 1% level of significance for underpriced as well as overpriced put options. As a result of significant results of H statistics, the *post-hoc* diagnosis, i.e. *Dunn's multiple comparison test*, has been carried out to find the pair-wise differences.

Table 4.4 Summary of the One-Sample Kolmogorov–Smirnov Statistics to Assess the Normality

		Underpriced put options	*Overpriced put options*
Number of observations		2224	13035
Normal parameters (a), (b)	Mean	507.739	753.657
	Std. deviation	905.019	949.9734
Most extreme differences	Absolute	0.288	0.214
	Positive	0.242	0.162
	Negative	− 0.288	− 0.214
Kolmogorov–Smirnov Z		13.562	24.426
Asymp. Sig. (2-tailed)		0.000	0.000

(a) Test distribution is Normal; (b) Calculated from data.

The results of the *post-hoc* analysis in the case of call options summarized in Table 4.5(b) signify that average magnitude of violations for the thinly traded options is significantly different from that for the moderately traded but not significaltly different from the highly traded category in the case of underpriced put options. Besides, there has been no significant difference between the magnitudes of moderately and highly traded category as well. In contrast, all the pairs were found to have significantly different magnitude of profits except for the one pair, i.e. Thinly vs. Highly traded pair in the case of overpriced put options.

In operational terms, the results imply that the average magnitude of violations for exploitable options contracts is significantly different from those for options contracts that can be designated as unexploitable. Moreover, it may be noted that in both underpriced and overpriced put options, the magnitude of highly traded options is not significantly different from those of thinly traded options, but the latter could not be designated as exploitable in light of the higher bid-ask spread and immediacy risk.

The finding, *per-se*, indicates that the profit potential of exploitable opportunities has been quite high, especially for overpriced put options, as the profit for highly traded options has been found to be higher than that for thinly traded category; however, the increase was not statistically significant at 5% level of significance. Moreover, the profit of highly traded category for overpriced put options has been considerably higher than that of moderately traded category. It, therefore, indicates that the exploitable opportunities in case of overpriced put options offered quite high amount of profit.

Table 4.5 (a) Kruskal–Wallis (H-statistics) Test for the Differences among the Violations across the Specified Levels of Liquidity for Underpriced and Overpriced Put Options, June 2001–07

Liquidity	*Underpriced put options*					*Overpriced put options*				
	Rank		*Test statistics (a), (b)*			*Rank*		*Test statistics (a), (b)*		
	N	*Mean rank*	*Chi-square*	*df*	*Sig.*	*N*	*Mean rank*	*Chi-square*	*df*	*Sig.*
Thinly liquid	1873	1164.98				8881	6562.72			
Moderately liquid	304	815.46	80.86	2	**0.000**	2187	6135.00	30.873	2	**0.000**
Highly liquid	47	942.35				1967	6741.90			

(a) Kruskal Wallis Test; (b) Grouping Variable—Liquidity

Table 4.5 (b) Dunn's Test for the Multiple Comparisons amongst the Specified Levels of Liquidity for Overpriced as well as Underpriced Put Options, June 2001–07

Dunn's multiple comparison test	*Call options*			*Call options*		
	Difference in rank sum	*Significant (P < 0.05)*	*Summary*	*Difference in rank sum*	*Significant (P < 0.05)*	*Summary*
Thinly traded vs. Moderately traded	349.5	–	Yes	427.7	–	Yes
Thinly traded vs. Highly traded	222.6	Ns	No	−179.2	Ns	No
Moderately traded vs. Highly traded	−126.9	Ns	No	−606.9	–	Yes

4.4.3 Learning Experience in the Indian Options Market

This part of the chapter has attempted to examine the ***learning behavior*** of the investors in the Indian options markets over the period under reference. For the purpose, it has been hypothesized that number of violations in the market should go down over the years as the investors are expected to be familiar with the market in due course of time. Precisely, the hypothesis warrants improvement in the market efficiency over the years as the investors are expected to behave more rationally in pricing the options contracts. The examination of the violations over the years under reference is in line with Mittnik and Rieken (2000), a study carried out in the context of German index options market.

The results summarized in Table 4.6 and Fig. 4.1 clearly indicate that the percentage of mispricing signals relative to the total number of observations analysed has shown a considerable decline over the years for 'underpricing of put options'. The decrease in the frequency of such mispricing signals demonstrates that the underpricing of put options (as suggested by PCP relationship) has improved significantly over the years. In contrast, the observed overpricing of put options shows an almost constant to increasing trend in the percentages of mispricing signals over the years (Table 4.6 and Fig. 4.2). The observed persistence in these mispricing signals evidently rules out the improvement in the efficiency of the options market (as warranted by the learning hypothesis) over the years.

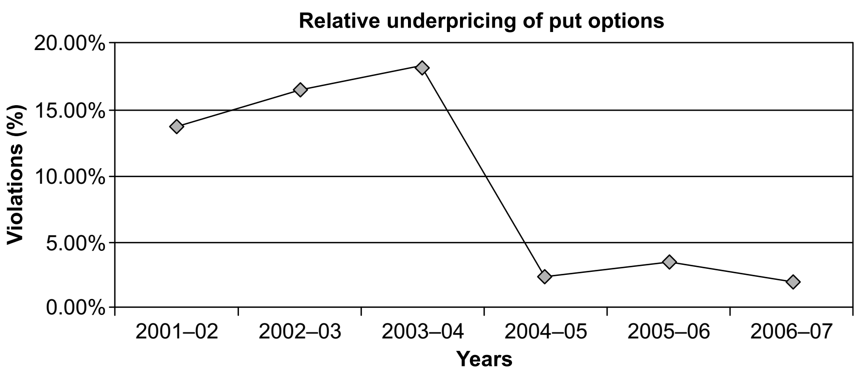

Figure 4.1 Percentage of relatively underpriced put options in relation to the number of pairs analysed in the year over the sample period

In addition, the magnitude of the violations across the years has been examined with intent to ensure exploitability of violations over the years. The results have been summarized in Table 4.7. It is satisfying to note that the frequency of exploitable violations in the case of underpriced put options remained negligible across all the years except the year 2003–04. Moreover, the year 2003–04 accounts for more than two-fifth of the total violations occurred in underpriced put category. For the rest of five years, the frequency of exploitable violations remained negligible in view of the magnitude of profit they offered for the exploitable category, i.e. the moderately and thinly traded category.

Table 4.6 Year-wise Frequencies of the Violations of PCP Relationship, June 2001–07

Year	*Total number of pairs analysed*	*Total violations*		*Put options underpriced*		*Put options overpriced*	
		No. of violations	*Percentage of violations (%)*	*No. of violations*	*Percentage of violations (%)*	*No. of violations*	*Percentage of violations (%)*
2001–02	2226	1347	60.51	303	13.61	1044	46.90
2002–03	2922	1509	51.64	480	16.43	1029	35.22
2003–04	5296	3020	57.02	964	18.20	2056	38.82
2004–05	5390	2414	44.79	127	2.36	2287	42.43
2005–06	6368	3690	57.95	222	3.49	3468	54.46
2006–07	6637	3279	49.40	128	1.93	3151	47.48
Total	**28839**	**15259**	**52.91**	**2224**	**7.71**	**13035**	**45.20**

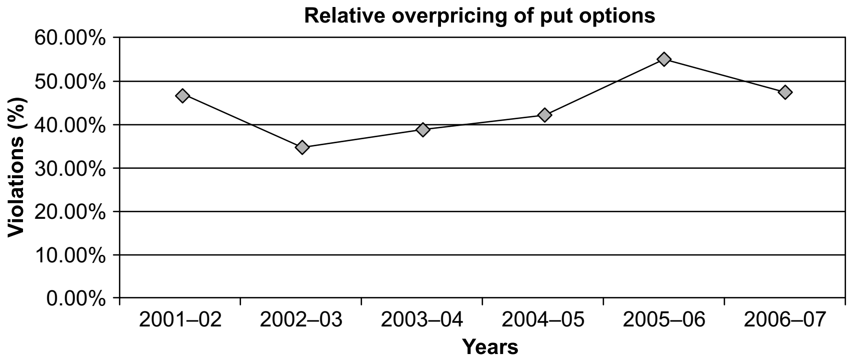

Figure 4.2 Percentage of relatively overpriced put options in relation to the number of pairs analysed in the year over the sample period

In sum, it would be appropriate to state that the number of exploitable violations remained negligible for underpriced put options for all the years except the year 2003–04. However, the year 2003–04 revealed noticeable number of exploitable violations as the third quartiles for moderately as well as highly traded category offered a reasonable starting profit of ₹ 336 and 346, respectively.

In contrast, a significantly noticeable number of exploitable violations have been recorded in case of overpriced put option over the years. Moreover, the finding is revealing as the number of exploitable violations in this category has shown an increasing trend over the years. Empirically, the increase in the number of exploitable violation is evident from the results summarized in Table 4.7. The results demonstrate that the number of exploitable violations (i.e. violations contained in the moderately and highly traded categories with the reasonable profit magnitude) have been nearly 35, 150 and 180 in the first three years of trading. Notably, there has been an alarming increase in the frequency of exploitable violations in the next three years of trading, i.e. 2004–05 to 2006–07.

The number of exploitable violations recorded in the year 2004-05 showed an increase of more than 100% compared with last years, as the number of cases increased from 150 to 340. Likewise, the next year registered an increase of more than 50% compared with the year 2004–05. Empirically, the last year under reference, i.e. 2006–07 has shown a dramatic increase in the number of violations, as it registered a total number of more than 1200 cases, which can be designated as exploitable in light of the profit magnitude they offered.

In sum, the violations in terms of overpriced puts have registered a significant increase in the number of exploitable violations over the years compared with underpriced put options where the number of exploitable violations remained negligible in all the years except the year 2003–04. This finding has further corroborated the trend of violations revealed initially by the percentage of violations vis-à-vis the number of pairs analysed (reported

Table 4.7 Year-wise Descriptive Statistics for the Magnitude of the PCP Condition for Underpriced and Overpriced Put Options in Indian Securities Market, June 2001–07

Years	Liquidity	Underpriced put options						Overpriced put options					
		Number of violations	Magnitude of violations (INR)					Number of violations	Magnitude of violations (INR)				
			Mean	S.D.	Q_1	Q_2	Q_3		Mean	S.D.	Q_1	Q_2	Q_3
2001–02	Thinly traded	280	250	446	45	142	268	971	379	321	139	289	551
	Moderately traded	23	95	88	39	45	154	73	427	245	238	394	651
	Highly traded	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	Overall	**303**	**246**	**433**	**45**	**138**	**245**	**1044**	**382**	**316**	**140**	**291**	**554**
2002–03	Thinly traded	394	188	218	54	106	250	797	254	237	88	193	m
	Moderately traded	82	98	107	41	61	97	219	186	160	51	147	292
	Highly traded	4	316	179	226	405	405	13	207	167	54	109	294
	Overall	**480**	**174**	**206**	**48**	**95**	**241**	**1029**	**239**	**223**	**58**	**188**	**343**
2003–04	Thinly traded	744	529	737	111	300	652	1569	604	677	168	387	817
	Moderately traded	187	246	379	58	153	336	363	415	410	130	273	528
	Highly traded	33	219	238	35	102	346	124	480	363	171	371	792
	Overall	**964**	**464**	**681**	**76**	**250**	**560**	**2056**	**563**	**627**	**163**	**370**	**776**
2004–05	Thinly traded	125	604	824	110	334	754	1599	587	631	196	406	721
	Moderately traded	1	80	Nil	Nil	Nil	Nil	361	453	405	153	348	616
	Highly traded	1	830	Nil	Nil	Nil	Nil	327	531	423	208	422	696
	Overall	**127**	**602**	**819**	**109**	**334**	**761**	**2287**	**558**	**576**	**196**	**401**	**706**
2005–06	Thinly traded	206	1315	1662	295	728	1766	2310	1042	1257	298	739	1375
	Moderately traded	9	551	517	129	353	853	556	833	809	271	577	1120
	Highly traded	7	222	120	161	220	246	602	659	690	172	447	870
	Overall	**222**	**1250**	**1622**	**269**	**687**	**1651**	**3468**	**942**	**1124**	**262**	**649**	**1296**
2006–07	Thinly traded	121	1383	1678	338	820	1735	1635	1313	1494	417	970	1733
	Moderately traded	5	518	477	297	431	431	615	942	797	278	770	1394
	Highly traded	2	193	206	47	193	338	901	836	653	344	724	1159
	Overall	**128**	**1330**	**1685**	**45**	**142**	**268**	**3151**	**1104**	**1205**	**374**	**840**	**1496**

In the table, S.D., Q_1, Q_2 and Q_3 denote standard deviation, first quartile, second quartile (i.e. median) and third quartile, respectively.

in Table 4.6, Figs 4.1 and 4.2). In short, a vast majority of exploitable violations appeared in the case of overpriced put options and, therefore, failed to show the warranted improvement in the market efficiency unlike the underpriced put options, which were found consistent with the learning hypothesis.

4.4.4 Comparison of Underpriced and Overpriced Put Options

The analysis of PCP has clearly demonstrated that the number of exploitable violations in the form of overpriced put options have consistently been higher compared with those in the case of underpriced put options. This finding is in line with a number of studies varied out across the globe, e.g. Goh and Allen (1984) and Mittnik and Reiken (2000b). In view of this, an attempt has been made to trace the reason behind the lopsided tendency of violations. The phenomena can be offered a plausible explanation if we look at the arbitrage strategies required to correct such pricing anomalies. The strategy required to exploit profit opportunities emanating from the relative underpricing of put options entails a long position in the underlying asset. However, the exploitability of mispricing signals in case of 'overpriced put options' requires taking a short-position in the underlying asset.

Commenting upon the difficulty in shorting an index, Mittnik and Reiken (2000b) opined that the short position in the assets, especially when the asset is an index, is more difficult compared with a long position and requires higher transaction costs. In addition to this, the short-selling constraint on financial assets has been reported as the major reason for such a development in various financial markets across the world. In view of the above, the observed relative overpricing of the put options in Indian options market can be attributed to the market-microstructure which did not allow to short-sell the financial assets during the period under reference. As already mentioned, an arbitrageur needs to sell the underlying asset short to exploit an arbitrage opportunity in the form of relative-overpricing of puts, the short-selling constraint in Indian options market caused the relative overpricing of puts to persist.

These findings are consistent with those of Evnine and Rudd (1985), Finucane (1991), Brown and Easton (1992), Bharadwaj and Wiggins (2001) and Ofek *et al*. (2004) for different markets.

4.4.5 Violations Using Futures Market

In addition, an attempt has been made to identify the violations using put-call futures parity condition, i.e. test of parity condition using futures prices of the underlying assets instead of the spot values. This has been done in view of the facts that

(*i*) the short-selling of the financial assets was not permitted in the Indian securities market during the period under reference and futures market easily provides this facility;

(*ii*) in case of options having index as the underlying asset, it becomes very difficult to short-sell/purchase of the index as all the basket of shares which constitute the index need to be sold/purchased in the proportion in which these have been included in the index and

(*iii*) relatively less transactions costs associated with trading in futures market compared with the spot market. The results on the violations of put-call-futures condition are reported in Table 4.8.

The results reported in Table 4.8 reveal that the number of violations of PCFP remained quite high, predominantly, in terms of overpricing of put options, as a vast majority of violations belong to this category. Notably, unlike identifying violations of PCP, short-selling constraint, *prima-facie,* could not be a correct explanation to the higher frequency of violations in call options since to exploit the arbitrage opportunities using futures market, the arbitrageur does not have to short the stock basket, rather he needs to sell the futures that is easily possible.

Moreover, another notable finding is that the violations of the parity condition remained nearly at the same level as revealed by the analysis using the spot market (Table 4.8). It is borne out by the fact that such violations have shown a negligible decline from 13,035 to 13,016. Notwithstanding the trend in overpriced put options, a substantial increase has been recorded in violations labelled as underpriced put options. The violations in terms of the under pricing of put has been as high as four times of those in the case of parity analysis using spot market values. As such, violations have increase from 2224 to a whopping 9612.

An intuitive explanation to such a development could be traced to the fact that the transaction costs for the trading in the futures market are substantially lower compared with those for spot market transactions. It seems to be a plausible reasoning for the observed increase in the number of underpriced put options. However, there should have been a corroborating development (increase) in the overpricing of puts as well to make this explanation tenable. Empirically, this is not the case as the violations in terms of the overpricing of put options have shown a negligible decline and, therefore, discards this explanation to above-mentioned development in the frequency of violations. Moreover, the frequency of violations without considering the transaction costs (both in the case of PCP and PCFP, Table 4.8) offers strong corroborating evidences to the above-mentioned finding, i.e. the transaction costs cannot be offered a major reason for the observed decline (increase) in the number of overpriced (underpriced) puts options.

Notably, another more plausible explanation in terms of the **'underpricing of futures contracts'** can be offered for the observed change in the trend of violation while using futures market instead of the spot market. It is for this reason that there has been an increase (decrease) in the number of underpriced

Table 4.8 Violations of the PCP Relationship Using Spot Values and Futures Prices, June 2001–07: A Comparative Analysis

Particulars	*Using spot values*			*Using futures prices*		
	Underpriced put options (Percentage)	*Overpriced put options (Percentage)*	*Total (Percentage)*	*Underpriced put options (Percentage)*	*Overpriced put options (Percentage)*	*Total (Percentage)*
Total number of observation analysed	28,839	28,839	28,839	28,839	28,839	28,839
Total number of violations observed **before transaction costs**	6,413 (22.24)	21,309 (73.89)	27,722 (96.13)	12,176 (42.22)	16,600 (57.56)	28,776 (99.78)
Total number of violations observed **after transaction costs**	2,224 (7.71)	13,035 (45.20)	15,259 (52.91)	9,612 (33.33)	13016 (45.13)	22,628 (78.46)

(overpriced) put options. The effect of underprricing of futures on the relative overpricing/underpricing of put options can be understood with the help of Eq. (4.8).

$$\uparrow P_t = C_t - e^{-r(T-t)} (\downarrow F_t - \mathrm{K}) \tag{4.8}$$

The equation demonstrates that the underpricing of futures is liable to cause an increase in the theoretical price of the put options, given the market price of the call option. And, therefore, the put options that have been found to be correctly priced or overpriced in the test of PCP using spot prices are likely to be converted into the underpriced or correctly priced put options given the magnitude of increase in the theoretical price of the put option. The process of conversion of correctly priced and overpriced put options into the underpriced/correctly priced ones has been well documented in the number of violations without considering the transaction costs, as reported in Table 4.8. The results show that there has been an increase in the number of underpriced puts from 6,413 to 12,176 on account of the use of futures market. Similarly, there has been a decrease in the number of overpriced puts from 21,309 to 16,600 on account of the use of futures market instead of the spot market. In sum, the use of futures market, essentially on account of the underpricing of futures contracts, has registered an increase in the underpriced puts by 5,763 and, at the same time, a decrease in the overpriced put options by 4,709. In other words, the underpricing of futures contracts has converted 4,709 overpriced put options into the underpriced put options. Likewise, a total number of 1054 put options contracts, which were found to be correctly priced (in the test of PCP using spot price), have been designated as underpriced on account of the underpricing of futures contracts. In sum, the decrease (increase) in the number of overpriced (underpriced) can appropriately be designated to the underpricing of futures contracts in the Indian derivatives market, for the period under reference.

The observed underpricing of futures contracts may be traced to the short-selling constraint in the Indian securities market during the period under reference. The non-availability of the short-selling facility can be designated as the primary reason for the underpricing of the futures contracts because of fact that the arbitrage strategy needed to correct such pricing anomalies required short-selling of the underlying asset. In short, the underpricing of the futures can, therefore, be attributed to the fact that short-selling has been banned during the period under reference in Indian securities market.

Thus, it may be concluded that the futures market has failed to provide a good substitute for shorting the assets in the absence of short-selling facility in the Indian securities market during the period under reference. Therefore, the futures market could not succeed in restoring equilibrium in the options market.

In view of this, it is reasonable to conclude that the indirect impact of the short-selling constraints on the efficiency of the options market on account of the interrelationship of the index options and index futures market has been one of the major reasons amongst others (e.g. liquidity) for the existence of mispricing signals in the Indian options market. In short, the impact of short-selling constraints cannot be ignored even if the violations are identified using futures contracts, as the efficiency of futures market does impact the efficiency of options market, which in turn, can be ensured when short-selling is allowed.

4.5 CONCLUDING OBSERVATIONS

This chapter attempted to examine the PCP condition for the (European type) S&P CNX Nifty index options prices using the spot as well as futures prices on the same index in the Indian securities market. The results are revealing as, empirically, more than half of the pairs analysed violated the PCP condition after accounting for the transaction costs. Out of the total number of violations observed, a vast majority of violations were identified in terms of relative overpricing of put options; a relatively meagre number of violations showed underpricing of put options. The number of violations is alarming in view of the fact that the frequency of violations identified in Indian market is substantially higher compared with those found in developed economies. For example, Wagner *et al*. (1996), a study in the US context, reported that 21.1% of the pairs violated PCP in S&P index options market. However, it may be noted that such violations demonstrated a sharp decline when seen in terms of required liquidity to designate them exploitable. The lack of adequate liquidity indicates higher bid-ask spread as well as immediacy risk/liquidity risk. The finding that the options are underpriced is consistent with that of Varma (2002), a study carried out in Indian context.

Besides, the concentration of violations both for underpriced as well as overpriced put options have been in the overall category of 0–60 days to maturity, which primarily appeared in the category 8–30 and 31–60 days to maturity.

The study is equally revealing as far as the behaviour of the investors dealing with the options market in India is concerned. It has been observed that the number of violations in call options market has been persistent instead of showing a warranted declining trend. In other words, it implies that the irrationalities in the behavior of investors, particularly in call options market, could not improve significantly over the years. However, it is satisfying to note that the put options market has behaved in a way that is consistent with the learning hypothesis, i.e. the number of violations has reduced with the passage of time. Thus, the findings indicate that the put options market is emerging to be more efficient vis-à-vis the call options market.

Another notable finding of the study is that the futures market could not provide a good substitute for the short-selling facility in the Indian securities market. This is eloquently borne out by the fact that the number of violations in terms of relative overpricing of put options remained nearly same even when the futures market has been used to identify the violations. Moreover, the no. of violations in terms of underpricing of put options have shown a whooping increase when identified using futures market. The development so observed can be traced to the fact that the futures themselves remained underpriced in the absence of short-selling facility in the market and, therefore, registered a negligible decrease in overpriced put options and an increase for the underpriced put options. In short, it may be appropriate to conclude that in the absence of short-selling facility in Indian securities market for the time period under reference, the futures themselves traded away from the equilibrium prices. It is for this reason that the futures market failed to restore equilibrium in options market.

In sum, it is reasonable to conclude that majority of violations identified using PCP relationship could not be exploited on account of the existing market microstructure in India during the period under reference (i.e. short-selling constraint that caused underpricing in futures to persist). Moreover, the futures market failed to restore efficiency in options market due to its own inefficiency in terms of underpricing for the period under reference because of the lack of short-selling facility during the same period. Besides, the dearth of liquidity in the options market appears to be another major constraint to arbitrageurs because a vast majority of violations occurred in the thinly traded category.

CHAPTER 5

Testing the Expectations Hypothesis on the Term Structure of Volatilities Implied by S&P CNX Nifty Index Options

5.1 INTRODUCTION

Term structure of implied volatilities connotes the relationship of implied volatility with time. The pattern of implied volatility across time to expiration is known as the term structure of implied volatility, and the pattern across strike prices is referred to as the volatility smile (Dupire, 1994; Derman and Kani, 1994 and Rubinstein, 1994). Term structures are helpful in pricing the options for which the volatility of the underlying asset can be assumed to be a deterministic function of time. It has been well documented in the available literature that different restrictions have been imposed on the term structure of implied volatility, considering the nature of underlying asset's volatility.

In this chapter, a restriction on the term structure of implied volatility, assuming rational expectations to hold, will be tested in line with the study done by Stein (1989), Diz and Finucane (1993), Heynen *et al.*(1994), Campa and Chang (1995) and Takezaba and Shiraishi (1998). The restriction is arrived at assuming mean-reversion in implied volatility. The mean-reversion in implied volatility connotes that, in long run, it will return to its long-term average, which is assumed to be constant. Before testing the restriction on the term structure, the mean-reversion property of the implied volatility has been validated. In short, this chapter addresses two empirical questions, viz. (a) whether the implied volatilities, in the case of short-dated as well as long-dated options, are mean reverting and (b) whether the volatilities implied by the long-dated options are consistent with the future volatilities estimated based on the volatilities implied by corresponding short-dated options, as warranted by rational expectations to hold. This has been operationalized by measuring the empirical elasticity coefficients, which reveal observed or empirical causal relationship between the volatilities implied by short-dated and long-dated options, and comparing it with the theoretical elasticity coefficient derived from the theoretical restriction on the implied volatility.

Since derivatives market, in general, and options market, in particular, is in nascent stage in India, the chapter aims at diagnosing the inefficiencies in pricing the index options. The inefficiencies has been diagnosed through analysis of implied volatility, as volatility is the only unobservable variable in valuation of the index option contracts while using the theoretical formula suggested by Black and Scholes (1973).

The rest of the chapter has been organized in four sections. Section 5.2 discusses the methodology, which is divided in two sub-sections, namely 5.2.1 and 5.2.2. The sub-section 5.2.1 deals with the statistical techniques used to test the mean-reversion in the implied volatilities, while sub-section 5.2.2 describes the restriction on the term structure of implied volatilities to test the rational expectations hypothesis (REH). The data and calculation of implied volatility have been discussed in sub-sections 5.3.1 and 5.3.2, respectively. Section 5.4 presents the results relating to the mean-reversion and rational expectations. The concluding observations are contained in the Section 5.5.

5.2 EXPECTATIONS HYPOTHESIS ON THE TERM STRUCTURE OF IMPLIED VOLATILITIES

5.2.1 Mean-Reversion in Implied Volatilities

To test whether implied volatilities are mean reverting or not, we essentially have to test the stationarity of the series of implied volatilities. A time series is said to be stationary provided its mean, variance and autocovariance (at different lags) remain the same irrespective of the point of time at which the measurement is made. Such a stationary series is expected to return to its mean in long run, technically termed as *mean-reversion*, Gujrati (2004).

In order to test the stationarity of a series, various techniques have been developed. The two techniques which have been used widely are (1) correlograms and (2) unit root tests. Of these, unit root test is considered more useful statistical technique. The two tests mentioned are being discussed in detail and will be applied to test the stationarity of the implied volatilities.

The correlogram is a graphical technique where autocorrelation and partial autocorrelation coefficients are plotted against their respective lags. The graphs so created are popularly known as autocorrelation functions (ACF) and partial autocorrelation functions (PACF). In correlograms, ACF_k, which specifies autocorrelation at lag k, is nothing but the simple correlation between Y_t and Y_{t+k}, where Y is a time series being analysed. Likewise PACF_k, which connotes partial autocorrelation at lag k, is the simple correlation between the Y_t and Y_{t+k} minus that part explained linearly by intermediate lags.

Based on the examination of the patterns of ACF and PACF, it can be decided whether a series is stationary or not. In addition to this, values of the

Ljung-Box statistics, also referred to as Q-statistics, help us to know the lag length for which the values of ACF and PACF are statistically significant. It is very important to decide the lag length for which ACFs and PACFs should be plotted to test the stationarity of the series. Empirically, it can be decided by resorting to the thumb rule, which suggests that the ACFs and PACFs should be computed up to one-forth to one-third of the length of the series being analysed (Gujrati, 2004).

On account of the subjectivity involved in correlograms, it is better to use a more objective technique called *unit root test*, which is a very popular tool to test the stationarity. In the unit root test, we try to find out whether a series contains a unit root or not. If a series contains a unit root, such a series is called as a non-stationary series and vice versa. The starting point for the unit root test is the unit root process, which is given in the Eq. (5.1).

$$Y_t = aY_{t-1} + u_t \tag{5.1}$$

where the value of a ranges between −1 and +1, and u_t is a white noise error term. A variable is referred to as a white noise when it has zero mean, constant variance and is serially uncorrelated.

In Eq. (5.1), if the value of $a = 1$ (this is the case of unit root), the series Y_t becomes a non-stationary series. This is achieved by regressing Y_t on its lag Y_{t-1} and then testing if the estimated value of a is statistically equal to 1 or not. In practice, Eq. (5.1) is not tested directly but it is manipulated by subtracting Y_{t-1} from both sides of the equation (Gujrati, 2004). The testable form of the Eq. (5.1) is given in Eqs (5.2) and (5.3).

$$\begin{aligned} Y_t - Y_{t-1} &= aY_{t-1} - Y_{t-1} + u_t \\ &= (a-1)\, Y_{t-1} + u_t \end{aligned} \tag{5.2}$$

Equation (5.2) can be alternatively written as

$$\Delta Y_t = \lambda Y_{t-1} + u_t \tag{5.3}$$

where, $\lambda = (a - 1)$ and Δ is the first difference operator.

Therefore, in practice, Eq. (5.3) instead of Eq. (5.2) is estimated, which in turn, facilitates testing of the null hypothesis whether $\lambda = 0$ against the alternate hypothesis $\lambda < 0$. By doing this, we indirectly test if $a = 1$, i.e. the series contains a unit root or not. In other words, whether the series under consideration is non-stationary or not. In the unit root test, the statistical test used to find if the estimated coefficient of Y_{t-1} (i.e. λ) differs significantly from zero, is known as the Tau (τ) statistics or Tau test. In the literature, the Tau statistics or Tau test is formally known as the Dickey–Fuller (DF) test.

Empirically, the DF test is estimated in different forms considering the nature of the time series data being analysed. While estimating each one of the testable forms of DF test, it is assumed that the error term u_t is serially uncorrelated. To resolve the problem of observed serial correlation, if any, in the error term, Dickey and Fuller (1979) have developed a test known as

Augmented Dickey Fuller (ADF) test. In ADF test, the basic DF test equation is augmented by adding lagged values of the dependent variable ΔY_t . The ADF test, in our case, will be based on the estimation of Eq. (5.4).

$$\Delta Y_t = \beta_1 + \beta_2 t + \lambda Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t \tag{5.4}$$

where ε_t is a pure white noise error term, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, and so on. The number of lagged variables to be added is determined empirically such that the error term becomes serially uncorrelated. In ADF test, we still test if $\lambda = 0$ against the alternate hypothesis, i.e. $\lambda < 0$.

5.2.2 Testing the Rational Expectations Hypothesis (REH)

In this section, following Stein (1989), we have derived a restriction on average expected volatilities implied by the options with short-dated and long-dated maturities, respectively. To derive the restriction, it has been assumed that the value of the underlying asset (stock price or index value) and volatility thereof are stochastic processes and the volatility is mean reverting in nature. The value of the underlying asset and its volatility can be characterized by the following continuous-time stochastic processes:

$$dS_t = \mu S_t d_t + \sigma_t S_t dz_1 \tag{5.5}$$

$$d\sigma_t^2 = -\alpha(\sigma_t^2 - \sigma^2)\, dt + \beta \sigma_t dz_2 \tag{5.6}$$

where S_t is the stock price or index level at time t, μ is the mean return on the stock price or index , σ_t is the volatility of returns on stock/index, dz_1 and dz_2 are the wiener processes and $\bar{\sigma}^2$ is the *mean-reversion level*[1] or long-run average volatility towards which the *instantaneous volatility*[2] is expected to revert back (geometrically) and converge in the long-run.

From the Eqs (5.5) and (5.6), the average expected volatility at time t for the time period T, $\sigma_{AV}^2 (t, T)$, can be defined as given in the Eq. (5.7):

$$\sigma_{AV}^2 (t, T) = \bar{\sigma}^2 + \frac{1}{\alpha T} (\sigma_t^2 - \bar{\sigma}^2) [1 - e^{\alpha T}] \tag{5.7}$$

Equation (5.7) clearly explains the mean-reversion process. It indicates that when the instantaneous volatility σ_t^2 is above its mean level volatility $\bar{\sigma}^2$, the average expected volatility should be decreasing with time to maturity and vice versa. It may be noted that the instantaneous volatility in the Eq. (5.7) is not direcltly observable. However, a relationship between average volatilities differing in maturities only, can be derived by eliminating instantaneous volatility from both volatility processes (Stein, 1989). Following the argument, a relationship between average expected volatilities of two differing maturities/ time periods (T_1 and T_2, where $T_2 > T_1$) has been derived. It is generally referred to as the term structure of average expected volatility, in case volatility is mean reverting (Stein, 1989). The relationship is given in the Eq. (5.8).

$$[\sigma^2_{AV}(t,T) - \bar{\sigma}^2] = \frac{T_1(\rho^{T_2}-1)}{T_2(\rho^{T_1}-1)}[\sigma^2_{AV}(t,T_1) - \bar{\sigma}^2] \tag{5.8}$$

Where $\sigma^2_{AV}(t, T_1)$ and $\sigma^2_{AV}(t, T_2)$ are the average expected volatility with short (T_1 days) and long (T_2 days) maturities respectively, and ρ is the first order (daily) autocorrelation coefficient of volatility.

Assuming a constant difference between the maturities ($T_2 - T_1 = \Delta T$) of average expected volatilities, Eq. (5.8) can be expressed in an empirically testable form (Diz and Finucane, 1993). It is given in Eq. (5.9).

$$[\sigma^2_{AV}(t,T_2) - \bar{\sigma}^2] = \beta(T_1,\rho)[\sigma^2_{AV}(t,T_1) - \bar{\sigma}^2] \tag{5.9}$$

where, $$\beta(T_1,\rho) = \frac{T_1(\rho^{T_2}-1)}{T_2(\rho^{T_1}-1)} \tag{5.10}$$

The relationship of the average expected volatilities given in the Eqs (5.9) and (5.10) can be extended to the implied volatilities estimated from the option price quotations of at-the-money options including *near-the-money*[3] *(NTM)* options. This can be done because the average expected volatility generally turns out to be approximately equal to the volatility implied by inverting the Black–Scholes (BS) model for at-the-money options and NTM options as shown by Hull and White (1987) and Feinstein (1989). Following this, the relationship of average expected volatilities with differing maturities can be extended for implied volatilities as well. This relationship has been tested by Stein (1989), Diz and Finucane (1993), Heynen *et al*. (1994), Campa and Chang (1995), Takezaba and Shiraishi (1998) and Poteshman (2001).

Besides, Mixon (2007) has tested the expectations hypothesis on the term structure of implied volatility of index options for five indices using over-the-counter options data using Heston's model. In another study, Das and Sundaram (1999) made an effort to explain observed shapes of the term structure of implied volatilities by examining two different volatility models (jump-diffusion and stochastic volatility).

In case of implied volatilities, the above relationship is arrived at by substituting $\sigma^2_{AV}(t,T_1)$ and $\sigma^2_{AV}(t,T_2)$ by IV^n_t (the volatility of the underlying asset implied by short-dated options) and IV^d_t (the volatility of the underlying asset implied by long-dated options), respectively. The option price quotations, for which implied volatilities have been studied as a relationship, are similar in all respects except the maturity time.

In order to test the restriction empirically, Eq. (5.8) has been examined by regressing IV^d_t on the corresponding IV^n_t (with the same specifications in terms of strike price, spot price, deal date, etc.) instead of regressing $(IV^d_t - \sigma^{-2})$ on $(IV^n_t - \sigma^{-2})$.Equation (5.8) can be estimated in the way mentioned above because of the *'free from shift of origin'* property of traditional regression equation, i.e. if we subtract a constant value from both dependent and independent variables, e.g. σ^{-2} in our case, the results of the estimated regression equation will remain intact.

Since the property *'free from shift of origin'* holds only for *traditional regression equation*[4], which includes an intercept term in the equation, the next challenge is how to make it applicable in estimation of Eq. (5.8), which is essentially a *regression through origin*[5], i.e. a model without an intercept term. This can be done if we could estimate the traditional regression equation in such a way that the intercept term turns out to be *statistically insignificant*[6], as mentioned by Gujrati (2004). This can be achieved by taking first difference of both dependent and independent variables.

The equation that has been estimated empirically is given in the Eq. (5.11).

$$IV_t^d = \alpha + \beta IV_t^n + \varepsilon \tag{5.11}$$

In the above equation, α is the intercept term, β is the *empirical elasticity coefficient*[7], and ε is a *white noise error term*[8]. In order to test the REH on the implied volatilities, β (beta) that connotes the empirical value of the elasticity coefficient needs to be compared whith the theoretical value of β (beta) derived on the basis of Eq. (5.10). In Eq. (5.10), amongst all the inputs required for the calculation of the theoretical value of the beta, ρ (first order autocorrelation coefficient of the volatility) is the only unobservable variable and needs a proxy variable. The proxy variable for the above purpose has been estimated by calculating the first-order autocorrelation coefficient of the series of volatility implied by short-dated option contracts, as suggested by Stein (1989).

5.3 DATA AND ESTIMATION OF IMPLIED VOLATILITY

5.3.1 Data

The data considered for the analysis can be broadly classified into three categories: data related to option contracts; data related to the underlying asset, i.e. the main index of National Stock Exchange (NSE), formally known as S&P CNX NIFTY index, and data on risk-free rate of return. The data on the options consist of daily closing prices of options, strike prices, deal dates, maturity dates and number of contracts of call and put options. The second data set, i.e. regarding the underlying asset, includes daily closing value of S&P CNX NIFTY index and dividend yield on the index. The third data set consists of monthly average yield on 91-days Treasury-bills. The data for all the three mentioned categories have been collected from June 04, 2001, (starting date for index options in Indian securities market) to June 30, 2007.

In order to minimize the bias associated with *nonsynchonous trading*[9], only *liquid option quotations*[10], i.e. contracts which are having at least 100 contract traded, are being considered for the analysis. In addition to this, another filter has also been used. That is, only near-the-money (NTM) contracts have been selected. In this context, NTM contracts are those contracts that satisfy a specified range of moneyness ($0.90 \le (S_t/X) \le 1.10$) for all the three levels of time to expiration or maturity, namely (a) time to expiration ≤ 30 days, (b) time to expiration 31–60 days and (c) time to expiration 61–90 days.

Besides, another problem related to the presence of multiple contracts (having same deal date, maturity time and strike price) on a single date. This required objective selection criteria to zero down such multiple contracts to a single contract. To address this problem, a short-listing criterion was developed to select the option quotation that was *nearest to the money*[11] amongst all such multiple contracts available for a particular date.

To test the REH, two data sets have been prepared across all the level of moneyness, namely out-of-the-money, at-the-money and in-the-money option quotations. Each data set for given level of moneyness consists of a pair of implied volatility (estimated from the option quotations with *short-dated* and *medium/long-dated maturities*[12], respectively, which were same in all other respects, viz. deal date, strike price, etc.). The pair for the first data set (for a given level of moneyness) consists of (a) implied volatility estimated from option quotations with time to expiration ≤ 30 days and (b) implied volatility estimated from option quotations with time to expiration 31–60 days. Likewise, another pair of the second data set (for the given level of moneyness) includes (a) implied volatility estimated from option quotations with time to expiration ≤ 30 days and (b) implied volatility estimated from option quotations with time to expiration 61–90 days. While creating the pairs for the analysis, problem of non-simultaneity of data have been addressed by selecting only matching data points. Matching has been done on the basis of date and strike prices.

In addition to this, several short-listing criteria were used to exclude uninformative option price quotations. These short-listing criteria are:

(i) Options quotations with moneyness outside the range $\{0.90 \le (S_t/X) \le 1.10\}$ in case of a call option and $\{0.90 \le (X/S_t) \le 1.10\}$ in case of put options have been excluded from the analysis. This filtering has been done because most of the trading volume is concentrated in the options belonging to the specified range only.

(ii) Secondly, the option quotations which remained untraded (for which number of contacts traded was zero) have been excluded from the analysis because these quotations do not contain any relevant information about the market.

(iii) Thirdly, we have excluded those option quotations for which the lower boundary condition for option prices has been violated. The violation of the lower boundary condition occurs when $(S_t - e^{-r(T-t)} X)$ in case of call options and $(e^{-r(T-t)} X - S_t)$ in case of put options, are greater than the price of call and put options, respectively.

5.3.2 Estimation of Implied Volatility

In addition to the model-free approach, select model-based approach has been proposed to assess the options market efficiency. This has been operationalized by formulating two objectives addressing options market efficiency using such approaches. The model-based approach dwells upon some model of options pricing, e.g. BS model, to have an estimate of implied volatilities, which are treated as the proxy for all the information traded in the options market.

For the purpose, the volatilities implied by the options prices (implied volatilities) have been calculated using the adjusted version of BS model, also known as Black-Scholes-Merton model (1973). The formulae, given in the Eqs (5.12) and (5.13), incorporate constant dividend yield on the underlying asset to value the options contract and has been used to estimate the implied volatilities.

$$c = S_0 \times e^{-\delta T} N(d_1) - X \times e^{-rrT} N(d_2) \tag{5.12}$$

$$p = X \times e^{-rT} N(-d_2) - S_0 \times e^{-\delta T} N(-d_1) \tag{5.13}$$

where,

$$d_1 = \frac{\ln(S_0 \times e^{-\delta T}/X) + (r_f + \sigma^2/2)T}{\sigma\sqrt{T}}\ ;\ d_2 = d_1 - \sigma T^{1/2},$$

c and p are price of the call and the put option, respectively, T is the maturity period, σ is the volatility of the underlying asset, S_0 is the spot price of the underlying asset, X is the Strike price of the option contract, δ is the constant continuous dividend yield, r_f is the risk-free rate of return and $N(x)$ is the Normal cumulative probability distribution.

As the BS model has been used to estimate the implied volatilities, it might give rise to a problem of systematic bias in the estimates of implied volatility because of its inherent assumptions. It assumes volatility to be constant over time. On the contrary, time varying behaviour of volatility is well documented in literature. In addition, the ARCH models (used in analysis) are based on the empirical premise of time varying volatility. Therefore, the use of BS model might result into systematic bias in the estimates of implied volatilities. Fortunately, the problem of systematic bias in the estimates of implied volatility is less likely to occur as the data on option price quotations that have been used essentially pertain to the NTM options. Following Claessen and Mittnik (2002), NTM options have been defined as the options that are up to 10% in-out-of-the-money. Also, Hull and White (1987) demonstrated empirically that BS model performs equally well in case of at-the-money options, as the prices of such option quotations are almost linear in volatilities across all the maturities.

In this respect, Feinstein (1989) and Takezaba and Shiraishi (1998) made a similar observation that the implied volatility estimated from BS model can be used as an unbiased approximation of the expected average volatility for at-the-money options. Takezaba and Shiraishi (1998) further carried out the analysis by extending it to the NTM options. In addition, Day and Lewis (1988 and 1992) also concluded, considering both Black–Scholes (1973) and Hull and White (1987) model, that the specification error can be minimized by focusing on at-the-money options because Hull–White and BS models are linear in average volatility for such options. In view of the above, the present study has used NTM options in order to minimize the noise in estimating implied volatilities using BS model.

Besides, efforts have been made to reduce the bias due to non-synchronous trading, which is likely to distort the quality of implied volatility estimates derived from the options prices. For the purpose, following Day and Lewis (1992), all the contracts having at least 100 contracts traded per day have been chosen for the analysis. The bias due to non-synchronous trading emerges from the fact that closing prices for the thinly traded contracts are more likely to represent the transactions that occur before the close of the trading (Day and Lewis, 1988).

On the selection of appropriate model to estimate the implied volatility, Stein (1989) mentioned that the use of incorrect model to estimate the implied volatilities might result into a systematic bias in the estimates. As the model discussed above has been used to estimate the implied volatilities, it might give rise to a problem of systematic bias in the estimates of implied volatility because of its inherent assumptions. The BS model assumes volatility to be a strictly deterministic function of time. On the contrary, to establish a theoretical relationship between near-the-month (short-dated) and far-the-month (long-dated) options, the volatility is assumed to be a stochastic variable. Thus, use of the BS model might result in systematic bias in the estimates of implied volatilities and might lessen the authenticity of the results derived from such estimates of implied volatility.

Fortunately, the problem of systematic bias in the estimates of implied volatility due the use of the BS model might not occur in our case since the data on option price quotations that have been used essentially pertain to the NTM options. Hull and White (1987) in their study have shown empirically that BS model performs equally well since the prices of such option quotations are almost linear in volatilities across all the maturities.

Commenting upon this, Feinstein (1989) and Takezaba and Shiraishi (1998) made a similar observation that the implied volatility, estimated from BS model, can be used as an unbiased approximation of the expected average volatility for at-the-money options. Takezaba and Shiraishi (1998) further carried out the analysis by extending it to the NTM options. This study is similar to their work since NTM options (with the same definition) have been the focus of analysis in this chapter. Day and Lewis (1988, 1992) also concluded, considering both Black–Scholes (1973) and Hull and White (1987) model, that the specification error can be minimized by focusing on at-the-money options because Hull–White and BS models are linear in average volatility for such options.

Besides, efforts have been made to reduce the bias due to non-synchronous trading. The bias due to non-synchronous trading or non-simultaneity has been offered as a potential explanation of apparent mispricing of option contracts by Easton (1994). The bias due to non-synchronous trading emerges from the fact that closing prices for the thinly traded contracts are more likely to represent the transactions that occur before the close of the trading (Day and Lewis, 1988).

In the study, the NTM option price quotations refer to those for which the moneyness indicators, namely (Spot price/Strike price) for the call options and (Strike price/Spot price) for the put options, ranges from 0.90 to 1.10. The explanation for the action taken above is quite explicit from the nature of the data on option price itself, which is presented graphically in Figs 5.1 and 5.2 for call options and put options, respectively.

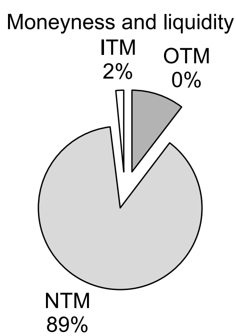

Figure 5.1 Moneyness and liquidity for call option

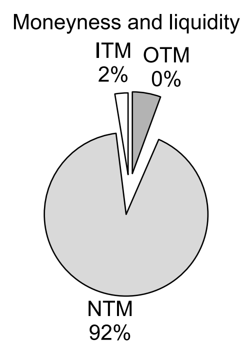

Figure 5.2 Moneyness and liquidity for put option

As evidenced by Day and Lewis (1988 and 1992), at NYSE, trading volume tends to be concentrated in the options that are NTM. It is also apparent from Figs 5.1 and 5.2 for the Indian options market that 92% and 88% of the total traded volume pertains essentially to the near-the-month call and put option price quotations, respectively. Since only near-the-month option price quotations are being considered for the study, it automatically ensures that the bias due to non-synchronous trading is minimized. This happens because any lack of synchronization between the closing index level and closing option price is less likely to occur.

Following Xu and Taylor (1995), the implied volatilities have been calculated separately for both call and put options. Besides, following Stein (1989) and Diz and Finucane (1993), the average implied volatilities (taking an average of implied volatilities of the underlying estimated from call and put options) have also been calculated. The reason behind the analysis of average implied volatility has been the possibility of stale index levels that might induce potential biases in the estimation of implied volatility when done separately for call and put options (Diz and Finucane, 1993).

In short, the study focuses on the estimation procedure that assigns greatest weight on the option price quotations that are affected least by specification error or bias. This happens because the trading tends to concentrate in NTM options. This approach is similar to Stein (1989), Harvey and Whaley (1991), Day and Lewis (1988 and 1992), Takezaba and Shiraishi (1998), Diz and Finucane (1993) and Campa and Chang (1995).

5.4 ANALYSIS AND EMPIRICAL RESULTS

5.4.1 Descriptive Statistics and Mean-Reversion Property of implied volatilities

This section deals with the analysis part and some meaningful results drawn from the data on implied volatilities estimated from index options discussed in Section 5.3.1. To analyse the data, the methodology described in Section 5.2.1 has been used with a view to test the mean-reversion in implied volatilities; albeit some other statistical measures have also been used to describe the basic characteristics of the implied volatility.

The descriptive statistics of implied volatilities have been summarized in Table 5.1, and Figs. 5.3–5.5 depict the mean volatilities for all the three levels of maturity pertaining to call options, put options and on the average basis, respectively. The results indicate that the mean implied volatilities do not reflect any consistent pattern, as generally warranted by term structure of implied volatilities, for all the three levels of moneyness and maturity. The analysis and results so derived can be summarized as:

(a) starting with the out-of-the-money options, the mean implied volatility in case of call options is increasing with maturity. However, the mean implied volatilities, when analysed for put options as well as on average basis (average of implied volatilities estimated from call and put options), are decreasing first and then increasing again with the maturity;

(b) In case of at-the-money options, similar to the out-of-the-money options, the mean implied volatilities are increasing with maturity for the call options. However, these seem to be decreasing first and then increasing again with the maturity for put options as well as on average basis;

(c) lastly, in case of in-the-money options, contrary to the (a) and (b), the mean implied volatilities slightly increase first and then decrease slightly with the maturity for call options. However, in case of the put options as well as on average basis, the mean implied volatility is showing a decreasing trend.

Table 5.1 Descriptive Statistics for Implied Volatilities of Call, Put and at an Average Level

Implied volatility	*Descriptives*	*Options* Out-of-the-money			At-the-money			In-the-money		
		$T \le 30$ Days	*$31 \le T \le 60$ Days*	*$61 \le T \le 90$ Days*	*$T \le 30$ Days*	*$31 \le T \le 60$ Days*	*$61 \le T \le 90$ Days*	*$T \le 30$ Days*	*$31 \le T \le 60$ Days*	*$61 \le T \le 90$ Days*
Implied volatility estimated from call options	Mean	0.0485	0.0592	0.0632	0.0460	0.0502	0.0557	0.0525	0.0543	0.0530
	Std. Dev.	0.0489	0.1345	0.0706	0.0549	0.0881	0.0452	0.0779	0.0969	0.0482
	Skewness	6.81	7.78	4.79	7.45	8.55	2.03	9.74	6.98	4.31
	Kurtosis	87.78	68.39	47.58	80.97	88.43	9.53	144.66	58.39	39.73
	Jarque–Bera	375377.4	189217.9	40203.4	278533.3	211290.4	654.7604	1029120	125916.1	27279.06
	Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Observations	1222	1005	464	1061	668	266	1208	926	460
Implied volatility estimated from put options	Mean	0.0694	0.0678	0.0713	0.0641	0.0586	0.0645	0.0823	0.0675	0.0573
	Std. Dev.	0.0841	0.0567	0.0297	0.0675	0.0416	0.0262	0.3996	0.0687	0.0290
	Skewness	8.74	7.55	1.26	6.87	3.00	1.79	32.92	9.72	0.65
	Kurtosis	117.60	117.49	7.34	80.68	18.10	14.28	1132.11	162.37	5.65
	Jarque–Bera	735736.70	505128.50	357.86	298411.90	5918.93	484.63	66253583.00	697089.40	42.47
	Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Observations	1314	909	341	1151	538	83	1243	649	117
Average implied volatility*	Mean	0.0585	0.0490	0.0529	0.0515	0.0452	0.0542	0.0581	0.0524	0.0499
	Std. Dev.	0.0772	0.0313	0.0174	0.0561	0.0239	0.0178	0.0751	0.0284	0.0208
	Skewness	6.25	2.69	-0.59	6.79	1.66	1.61	6.78	1.58	1.66
	Kurtosis	56.93	15.64	3.39	81.53	8.24	9.65	66.70	7.03	9.01
	Jarque–Bera	75335.45	2888.26	3.85	133664.10	506.28	138.95	106940.20	610.95	228.00
	Probability	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00
	Observations	590	367	60	505	315	61	605	558	116

Likewise, the mean-reversion in the implied volatilities of call options, put options and on average basis has also been examined. To have some-early evidences of mean-reversion, i.e. whether the series under consideration is stationary or not, the correlograms (ACFs and PACFs) for all the three levels of maturity and the moneyness have been plotted separately for call options, put options, and on their average.

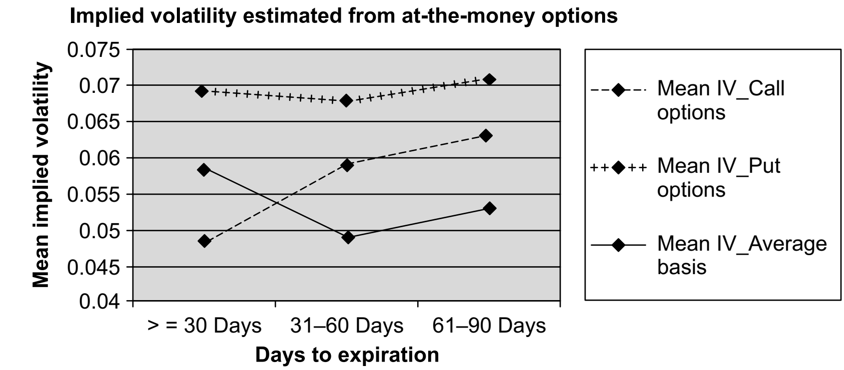

Figure 5.3 Mean implied volatility estimated from out-of-the-money options

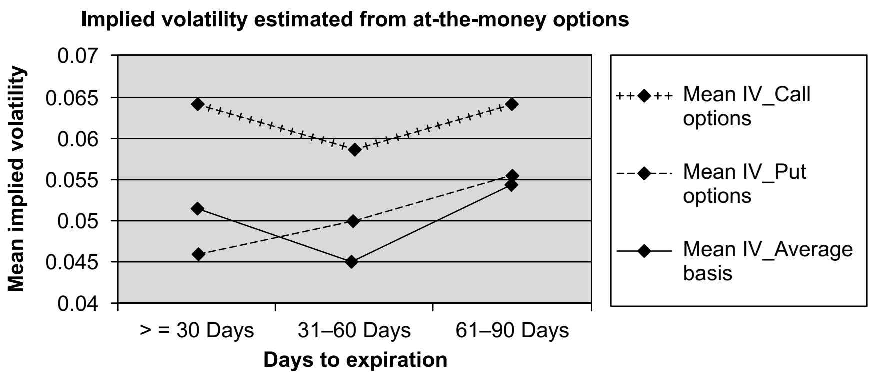

Figure 5.4 Mean implied volatility estimated from at-the-money options

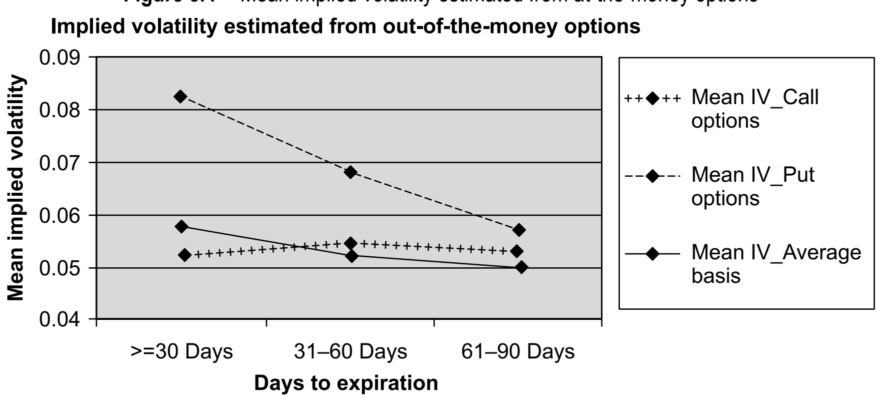

Figure 5.5 Mean implied volatility estimated from in-the-money options

In addition to correlograms, ADF test has been applied for all the three levels of maturity and the moneyness separately for call options, put options and on their average. The results of ADF test are reported in Tables 5.2, 5.3 and 5.4 for call options, put options and on their average basis, respectively. In order to make error term a pure white noise, the number of lags of dependent variable to be added in the equation of ADF test has been decided on the basis of *Akaike information criterion* (AIC) and/ or *Schwarz information criterion* (SIC).

The results of the ADF test clearly demonstrate that the implied volatilities do not contain a unit root. The null hypotheses that the series of implied volatilities are having a unit root have been tested at 5% as well as 1% level of significance. In the tables, the significance levels provided in parentheses (*p*-values) along with the empirical value of tau statistic connote that almost all the implied volatilities for call options, put options and on their average are significant at even 1% level of significance except a few, which are significant only at 5%. The rejection of the null hypotheses that the implied volatilities are having a unit root makes the series of implied volatilities stationary, i.e. the implied volatilities, in fact, are mean reverting in nature.

The stationarity so observed validates mean-reversion in implied volatilities and indicates that the investors price options considering mean-reversion property of the volatility. However, the mean reversion in itself does not ensure that the expectations regarding the evolution of volatilities are being formed in the way as warranted by REH. In view of this, the empirical test of the restriction has been carried out too, and the results are summarized in the next section.

5.4.2 Test of the Rational Expectations Hypothesis (REH) on Implied Volatilities

In this section, the REH is tested on the basis of methodology discussed in Section 5.2.2. Test of the RHE can be classified into three stages, namely (a) estimations of empirical elasticity coefficients by regressing implied volatilities estimated from the long-dated option on the corresponding implied volatilities estimated from the short-dated options for all possible pairs discussed in Section 5.3.1; (b) calculation of theoretical elasticity coefficient for the same and (c) comparison of empirical elasticity coefficient against the theoretical elasticity coefficient.

The estimation of empirical elasticity coefficient involves regression of the implied volatility estimated from long-dated option on corresponding implied volatility estimated from the short-dated options. We have estimated the elasticity coefficient for all the possible pairs discussed in the Section 5.3.1. Besides, another classification (within pair) that has been made for the regression analysis is on the basis of the constant difference between the maturities of long-dated and corresponding short-dated option quotations.

Table 5.2 Testing Mean-Reversion (Stationarity) of the Implied Volatilities of Call Options

S. no.			*Description of options*	*Empirical value of τ*	*Augmented Dickey Fuller t/τ-test*			
					Critical value of τ		*Inferences*	
					at $\alpha = 5\%$	*at $\alpha = 1\%$*	*at $\alpha = 5\%$*	*at $\alpha = 1\%$*
1	**Near-the-money options [$0.90 \le (S_0/X) \le 1.10$]**	**Out-of-money**	Near-the-month call option	−6.1577 (0.0000)	−2.8637	−3.4355	Mean reverting	Mean reverting
2			Far-the-month[1] call option	−7.2353 (0.0000)	−2.8642	−3.4367	Mean reverting	Mean reverting
3			Far-the-month[2] call option	−3.0198 (0.0338)	−2.8676	−3.4444	Mean reverting	Non-mean reverting
4		**At-the-money**	Near-the-month call option	−5.9855 (0.0000)	−2.8641	−3.4363	Mean reverting	Mean reverting
5			Far-the-month[1] call option	−8.2594 (0.0000)	−2.8657	−3.4399	Mean reverting	Mean reverting
6			Far-the-month[2] call option	−3.2777 (0.0169)	−2.8724	−3.4553	Mean reverting	Non-mean reverting
7		**In-the-money**	Near-the-month call option	−8.4945 (0.0000)	−2.8637	−3.4356	Mean reverting	Mean reverting
8			Far-the-month[1] call option	−30.4295 (0.0000)	−2.8644	−3.4372	Mean reverting	Mean reverting
9			Far-the-month[2] call option	−21.4476 (0.0000)	−2.8676	−3.4443	Mean reverting	Mean reverting

Note: The figures in parentheses show 'level of significance' / 'p value'.

[1] Options having 31–60 days to maturity.
[2] Options having 61–90 days to maturity.

Table 5.3 Testing Mean-Reversion (Stationarity) in the Implied Volatilities of Put Options

S. no.			Description of options	Empirical value of τ	Augmented Dickey Fuller t/τ-test: Critical value of τ		Inferences	
					at $\alpha = 5\%$	at $\alpha = 1\%$	at $\alpha = 5\%$	at $\alpha = 1\%$
1	Near-the-money options [$0.90 \le (S_0/X) \le 1.10$]	Out-of-money	Near-the-month put option	−6.1981 (0.0000)	−2.8638	−3.4358	Mean reverting	Mean reverting
2			Far-the-month[1] put option	−3.9069 (0.0021)	−2.867	−3.4423	Mean reverting	Mean reverting
3			Far-the-month[2] put option	−6.4729 (0.0000)	−2.8972	−3.5123	Mean reverting	Mean reverting
4		At-the-money	Near-the-month put option	−35.4276 (0.0000)	−2.8636	−3.4354	Mean reverting	Mean reverting
5			Far-the-month[1] put option	−24.4757 (0.0000)	−2.8658	−3.4402	Mean reverting	Mean reverting
6			Far-the-month[2] put option	−5.6345 (0.0000)	−2.8658	−3.4876	Mean reverting	Mean reverting
7		In-the-money	Near-the-month put option	−5.6886 (0.0000)	−2.8635	−3.4351	Mean reverting	Mean reverting
8			Far-the-month[1] put option	−4.5421 (0.0002)	−2.8645	−3.4373	Mean reverting	Mean reverting
9			Far-the-month[2] put option	−2.8796 (0.0488)	−2.8699	−3.4496	Mean reverting	Non-mean reverting

[1] Options having 31–60 days to maturity.
[2] Options having 61–90 days to maturity.

Table 5.4 Testing Mean-Reversion (Stationarity) of the Average Implied Volatilities*

S. no.			*Description of options*	*Empirical value of τ*	*Augmented Dickey Fuller t/τ-test*			
					Critical value of τ		*Inferences*	
					at α = 5%	*at α = 1%*	*at α = 5%*	*at α = 1%*
1	**Near-the-money options [0.90 ≤ (S_0/X) ≤ 1.10]**	**Out-of-money**	Near-the-month option	−8.6483 (0.0000)	−2.8662	−3.4412	Mean reverting	Mean reverting
2			Far-the-month[1] option	−18.3613 (0.0000)	−2.8692	−3.4480	Mean reverting	Mean reverting
3			Far-the-month[2] option	−3.7731 (0.0053)	−2.9117	−3.5461	Mean reverting	Mean reverting
4		**At-the-money**	Near-the-month option	−4.7362 (0.0001)	−2.8671	−3.4432	Mean reverting	Mean reverting
5			Far-the-month[1] option	−16.2688 (0.0000)	−2.8705	−3.4510	Mean reverting	Mean reverting
6			Far-the-month[2] option	−8.7377 (0.0000)	−2.9109	−3.5441	Mean reverting	Mean reverting
7		**In-the-money**	Near-the-month option	−14.3506 (0.0000)	−2.8661	−3.4410	Mean reverting	Mean reverting
8			Far-the-month[1] option	−24.9652 (0.0000)	−2.8665	−3.4419	Mean reverting	Mean reverting
9			Far-the-month[2] option	−11.9199 (0.0000)	−2.8867	−3.4881	Mean reverting	Mean reverting

*Average implied volatility = (Implied volatility of call option + Implied volatility of put option)/2

[1] Options having 31–60 days to maturity.
[2] Options having 61–90 days to maturity.

This has been done because the calculation of theoretical elasticity coefficients requires that the difference of maturities has to be constant (Diz and Finucane, 1993). The classification of implied volatilities so arrived at as per levels of moneyness, maturities and constant maturity differences is presented in Tables 5.5a, 5.5b, 5.6a, 5.6b, 5.7a and 5.7b, respectively.

While estimating the empirical elasticity coefficients, the traditional regression equation (including an intercept term) has been estimated in such a way that the intercept term does not come out to be significantly (statistically) different from zero, or in other words, the intercept term is zero, and the residual or error term becomes a white noise. To do the same, the methodology that has been adopted is *ARIMA* (n, 1, 0)[13], i.e. a traditional regression equation, which includes n lags of dependent variable as independent variables as well as first order differencing in order to get a zero intercept term.

The precondition to estimate the ARIMA model is that the series under consideration should be stationary. Since the prerequisite of stationarity of implied volatilities have already been ensured in the Section 5.4.1, the next issue in the estimation of ARIMA model is to decide upon the number of lags to be included in the model. To respond to the issue, ACF and PACF for the implied volatilities have been plotted to have an initial idea about the probable lag structure of the model. Besides, AIC and SIC have been used to select the best model with a zero intercept term and a white noise error term. In addition to this, the calculation of coefficient of determination has been done separately for the regression pairs of average basis implied volatility. This has been done to draw a comparison with the similar study done by Stein (1989). The coefficient of determination has been calculated as[15]:

$$R^2 = 1 - \frac{\text{Residual sum of squares}}{\text{Total sum of squares}}$$

After estimating the ARIMA (n, 1, 0), we have also examined the error term to ensure that the model has fitted the data well, and the error term is a white noise. In order to ensure that the error term is a white noise, it has been examined whether (a) the error term is serially uncorrelated up to the one forth of its lag length and (b) its mean is zero. To test the serial independence in error term, the correlograms and a statistics put forth by Ljung and Box (1978) have been used. To test the mean value of the error term, t-test was used to see whether it is statistically different from zero. The estimates of empirical elasticity coefficients so arrived are given in Tables 5.5b, 5.6b and 5.7b.

Next to the estimation of the empirical elasticity coefficients, calculation of the theoretical coefficients of elasticity was done. The calculation of the theoretical elasticity coefficients has been done on the basis of the formula given in the Eq. (5.10). From the formula, it is clear that all the variables required for the calculation of the theoretical coefficients of the volatilities are known except one variable—the autocorrelation coefficient of the volatilities.

Table 5.5 (a) Calculation of the Theoretical Elasticity Coefficient of the Implied Volatilities of Call Options

Options	*Constant maturity difference[3] (in days)*	*Average maturity of short-dated options (T_1) (in days)*	*Average maturity of long-dated options (T_2) (in days)*	*First order auto correlation coefficient (ρ)*	*Theoretical elasticity coefficient (β)*
CALL OTM (30–60)	28	14.61	42.61	0.766	0.350
	35	10.15	45.16	0.663	0.228
CALL OTM (30–90)	56	16.78	72.78	0.601	0.231
	63	13.11	76.16	0.55	0.172
CALL ATM (30–60)	28	14.65	42.65	0.716	0.346
	35	16.33	45.35	0.291	0.360
CALL ATM (30–90)	56	18.06	74.06	0.531	0.244
	63	12.5	75.64	0.251	0.165
CALL ITM (30–60)	28	14.31	42.32	0.618	0.338
	35	11.3	46.32	0.024	0.244
CALL ITM (30–90)	56	17	73	0.529	0.233
	63	11.86	74.92	0.093	0.158

[3] Constant maturity difference signifies the difference between maturities of 'near-the-month' and 'far-the-month' options. Such differences have been calculated for each pair, i.e., between '8–30 days to maturity and 31–60 days to maturity', and between '8–30 days to maturity and 61–90 days to maturity'. Moreover, within each pair, the data has been arranged in two sub-groups for further analysis.

Table 5.5 (b) Theoretical and Empirical Elasticity Coefficients of the Implied Volatilities of Call Options

Options	*Constant maturity difference* (in days)*	*Values of elasticity coefficient of mean-reversion (β) under REH*		*Conclusion*
		Theoretical values	*Empirical values from detrended series*	
CALL OTM (30–60)	28	0.350	No causality	NA
	35	0.228	0.183	Underreaction*
CALL OTM (30–90)	56	0.231	2.596	Overreaction*
	63	0.172	0.922	Overreaction

Options	*Constant maturity difference* (in days)*	*Values of elasticity coefficient of mean-reversion (β) under REH*		*Conclusion*
		Theoretical values	*Empirical values from detrended series*	
CALL ATM (30–60)	28	0.346	0.496	Overreaction
	35	0.360	0.305	Underreaction
CALL ATM (30–90)	56	0.244	1.796	Overreaction
	63	0.165	0.488	Overreaction
CALL ITM (30–60)	28	0.338	0.656	Overreaction
	35	0.244	0.032	Underreaction
CALL ITM (30–90)	56	0.233	1.261	Overreaction
	63	0.158	0.320	Overreaction

*When the long-dated volatility turns out to be more/less than that is expected based on short-dated volatility, assuming rational expectations to hold, this is termed as Overreaction/ Underreaction of long-dated volatility.

Table 5.6 (a) Calculation of the Theoretical Elasticity Coefficient of the Implied Volatilities of Put Options

Options	*Constant maturity difference* (in days)*	*Average maturity of short-dated options (T_1) (in days)*	*Average maturity of long-dated options (T_2) (in days)*	*First order auto correlation coefficient (ρ)*	*Theoretical elasticity coefficient (β)*
PUT OTM (30–60)	28	13.01	41.01	0.774	0.329
	35	9.99	45.02	0.285	0.222
PUT OTM (30–90)	56	18.16	74.16	0.697	0.245
	63	13.49	76.6	0.39	0.176
PUT ATM (30–60)	28	12.85	40.84	0.683	0.317
	35	9.15	44.17	0.631	0.210
PUT ATM (30–90)	56	18.72	74.72	0.415	0.251
	63	11.57	74.57	0.565	0.155
PUT ITM (30–60)	28	12.63	40.62	0.547	0.311
	35	9.52	44.53	0.699	0.221

Options	*Constant maturity difference* (in days)*	*Average maturity of short-dated options (T_1) (in days)*	*Average maturity of long-dated options (T_2) (in days)*	*First order auto correlation coefficient (ρ)*	*Theoretical elasticity coefficient (β)*
PUT ITM (30–90)	63	14.25	75.89	0.365	0.188

Table 5.6 (b) Theoretical and Empirical Elasticity Coefficients of the Implied Volatilities of Put Options

Options	*Constant maturity difference (in days)*	*Values of elasticity coefficient of mean-reversion (β) under REH*		*Conclusion*
		Theoretical values	*Empirical values from detrended series*	
PUT OTM (30–60)	28	0.329	0.433	Overreaction
	35	0.222	0.186	Underreaction
PUT OTM (30–90)	56	0.245	1.221	Overreaction
	63	0.176	0.238	Overreaction
PUT ATM (30–60)	28	0.317	0.497	Overreaction
	35	0.210	0.289	Overreaction
PUT ATM (30–90)	56	0.251	0.565	Overreaction
	63	0.155	0.559	Overreaction
PUT ITM (30–60)	28	0.311	0.412	Overreaction
	35	0.221	0.230	Overreaction
PUT ITM (30–90)	63	0.188	0.275	Overreaction

Table 5.7 (a) Calculation of the Theoretical Elasticity Coefficient of the Average Implied Volatilities

Options	*Constant maturity difference* (in days)*	*Average maturity of short-dated options (T_1) (in days)*	*Average maturity of long-dated options (T_2) (in days)*	*First order auto correlation coefficient (ρ)*	*Theoretical elasticity coefficient (β)*
OTM (30–60)	28	12.88	40.86	0.753	0.324
	35	9.3	44.32	0.404	0.210

Options	*Constant maturity difference* (in days)*	*Average maturity of short-dated options (T_1) (in days)*	*Average maturity of long-dated options (T_2) (in days)*	*First order auto correlation coefficient (ρ)*	*Theoretical elasticity coefficient (β)*
OTM (30–90)	56	14.69	73.3	0.252	0.200
ATM (30–60)	28	11.62	39.65	0.564	0.293
	35	8.43	43.47	0.44	0.194
ATM (30–90)	56	18.52	72.74	0.528	0.255
ITM (30–60)	28	13.25	41.27	0.633	0.322
	35	10.81	45.82	0.529	0.236
ITM (30–90)	63	16.84	73.31	0.462	0.230

Table 5.7 (b) Theoretical and Empirical Elasticity Coefficients of Average Implied Volatilities

Options	*Constant maturity difference* (in days)*	*Values of elasticity coefficient of mean-reversion (β) under REH*		*R^2 (%)*	*Conclusion*
		Theoretical values	*Empirical values from detrended series*		
OTM (30–60)	28	0.324	0.801	88.67	Overreaction
	35	0.210	0.388	85.29	Overreaction
OTM (30–90)	56	0.200	0.252	72.60	Overreaction
ATM (30–60)	28	0.293	0.667	85.51	Overreaction
	35	0.194	0.450	66.92	Overreaction
ATM (30–90)	56	0.255	0.528	73.68	Overreaction
ITM (30–60)	28	0.322	0.296	79.59	Underreaction
	35	0.236	0.372	63.72	Overreaction
ITM (30–90)	63	0.230	0.462	72.00	Overreaction

As suggested by Stein (1989), the estimated autocorrelation coefficient of implied volatilities estimated from the short-dated options can be used as a proxy for the autocorrelation coefficient of average volatilities. Thus, the autocorrelation coefficient estimated from the short-dated implied volatilities was used as a proxy for autocorrelation coefficient in the calculation of the theoretical elasticity coefficient.

Though use of a proxy autocorrelation coefficient might lessen the authenticity of the results, relatively less sensitivity of theoretical coefficient to the change in the autocorrelation coefficient (as explicit from the formula given in Eq. 5.10) reduces the possibility of such outcomes. As tested empirically, even large variations in the value of the estimated autocorrelation coefficient are no how affecting the decisions regarding the rational expectations. That is, the theoretical elasticity coefficient will not be significantly affected by even large variations in the value of autocorrelation coefficient, as evident from Eq. 5.10. This further motivated us to accept estimated autocorrelation coefficient of implied volatilities as a proxy for autocorrelation coefficient of short-dated average volatility. The calculation of the theoretical elasticity coefficients is given in the Tables 5.5a, 5.6a and 5.7a.

After the estimation of the empirical and theoretical elasticity coefficients, a comparison has been drawn. The comparison drawn is given in the Tables 5.5b, 5.5b and 5.7b. The results so arrived clearly indicate that the implied volatility of long-dated options, in general, is overstated vis-à-vis the expected volatility of long-dated options, estimated on the basis of implied volatility of corresponding short-dated options assuming rational expectations to hold. As explicitly given in the tables, the implied volatility of long-dated options is overreacting, since 8 out of 11 pairs in case of implied volatility of call option, 10 out of 11 in case of implied volatility of put options and overall 8 out of 9 in case of the average implied volatility seem to be biased in favour of overreaction. The findings are in line with the findings of the study done by Stein (1989) but just opposite to the results of Poterba and Summers (1986).

The overreaction of long-dated implied volatility seems to be more pronounced because in majority of the cases, the empirical coefficients are more than double compared whit theoretical coefficients and in few cases it is even as high as 10 times of the theoretical elasticity coefficient. Apart from this, the autocorrelation coefficients of short-dated implied volatility are relatively small compared with those in the study done by Stein (1989).

The observation clearly differentiates the behaviour of Indian investors from their counterparts in the developed world. From the findings, it can be observed that the Indian investors seem to give less importance to the volatility of short-dated options for forecasting the volatilities of corresponding long-dated options to value the option contracts since the R^2 values are coming out to be relatively less compared with the study done by Stein (1989).

Besides, in most of the cases, values of empirical elasticity coefficients seem to be much lower than unity and, thus, in contrast with the findings of Stein (1989), where these came out to be quite close to unity in majority of the cases. These observations reinforce that Indian investors are not assigning much importance to the volatility of short-dated options while arriving at an estimate of long-dated volatility to value a long-dated option contract unlike their counterparts in the developed world.

5.5 CONCLUDING OBSERVATIONS

The study reveals that the implied volatility estimated from the short-dated as well as long-dated options is mean reverting. This is a good sign for the development of derivatives market in India. However, the mean implied volatility does not exhibit a consistent pattern across all the three categories; namely call options, put options and their average basis. The patterns of volatility are similar for put and options based on the average basis. The mean implied volatility in case of call options has shown an opposite pattern.

Another notable finding is that the implied volatilities estimated from the long-dated index options do not evolve as expected (assuming rational expectations to hold) on the basis of volatility implied by the short-dated index options. The results, in general, depict severe violation of REH on the term structure of implied volatilities. These findings are in conformity with those of Stein (1989) and Byoun *et al*. (2003). In specific terms, the violation of the hypothesis has been seen in terms of the overreaction of long-dated implied volatility; the conclusion is quite similar to that of Stein (1989).

In addition to this, relatively weak coefficients of determination and empirical autocorrelation coefficients, compared with that in Stein (1989), indicate that Indian investors assign relatively less importance to the volatility implied by short-dated option to arrive at an estimate of the volatility to be used in valuing long-dated options. In operational terms, it indicates that the Indian investors either do not use term structure approach to price the option contracts, or they might not be aware of this due to the inadequate experience of derivatives market.

In a nutshell, it may be reasonable to conclude that the Indian investors are not exhibiting rational behaviour while valuing index options. This indicates price inefficiency in index options market in India and might have serious impact on the development of derivatives market, in general, and options market, in particular.

END NOTES

1. Mean-reversion level connotes that level of long-run average volatility to which the instantaneous volatility is expected to return in a long period of time.

2. This refers to the current level of volatility at any specified point of time.
3. In the study, near-the-money (NTM) options stand for those option contracts that lie within the specified range ($0.90 \leq (S_0/X) \leq 1.10$) of moneyness.
4. A regression equation which includes an intercept term and regression coefficients along with the corresponding independent variables to explain the variations in the dependent variable.
5. A regression equation which does not include an intercept term or a traditional regression equation where the intercept terms comes out to be zero/statistically insignificant.
6. An acceptable percentage of error while rejecting the null hypothesis that is expected to occur purely due to chance. The most preferable levels of significance are 5% and 1%.
7. Empirical elasticity coefficient denotes the degree of causal relationship between the short-dated and long-dated volatility that is observed empirically by regressing long-dated volatility on the corresponding short-dated volatility.
8. An error term is said to be a white noise when it is normally distributed and remains serially uncorrelated up to a significant lag length.
9. In this context, non-synchronous trading refers to the phenomenon of different closing timings of the two markets, i.e. the options market and the underlying's market.
10. In the study, the liquid options stand for those option contracts, which, at least, have one contract traded.
11. Nearest-to-the-money options imply those option quotations which, within the specified range of moneyness, are most close to one (at-the-money option) or, in other words, the option quotation for which the difference between their strike price and spot price is the least amongst all given on a particular date and level of maturity. For example, if on July 15, 2007, when the spot price stands at ₹ 4257.5; there are three contracts with the strike prices ₹ 4250, 4255 and 4265, respectively (assuming that all the contracts are having same maturity). The contract with the strike price ₹ 4255 will be said to be nearest-to-the-money.
12. In the study short-dated maturity refers to the period of less than equal to the time period of 30 days, a time period between 31days to 60 days belongs to the medium-dated option contracts, and Long-dated option contracts cover the time period of greater than 60 days and less than or equal to 90 days.
13. ARIMA (n, 1, 0) stands for Autoregressive Integrated Moving average model with n autoregressive terms in the model as independent variables, with first order level of differencing.

14. In the formula, residual sum of squares is given in the SPSS generated solution for ARIMA models in the table called residuals diagnostics and total sum of squares has been calculated by measuring variation in the long-dated implied volatility (dependent variable) around its mean value.

*Average implied volatility = (Implied volatility of call option + Implied volatility of put option)/2

CHAPTER 6

Informational Efficiency of Implied Volatilities of S&P CNX Nifty Index Options

6.1 INTRODUCTION

The implied volatilities (IVs) of options contracts represent the market's *ex-ante* forecast of the average volatility of the underlying asset over the remaining life of the option contract (Merton, 1973; Hull and White, 1987). The IVs have been of equal interest to academics as well as practitioners because of the information they contain about the near future of the market and their usage for valuation of options, risk hedging, portfolio selection, etc. These aspects facilitate in assessing the informational efficiency of the options market in that whether the options market is performing satisfactorily on its well-identified function, viz. risk hedging, price discovery in the underlying's market and allocation of capital, as pointed out by Ackert and Tian (2001).

The informational efficiency of IVs has been tested by a number of studies across the globe. For this purpose, it is hypothesized that the IVs impound all the information contained in the historical returns. Therefore, in an informational efficient options market, the forecasts based on IVs should outperform the forecasts based on the historical returns. In view of this, majority of the studies have compared IVs as a future estimate of volatility with forecasts based on select conditional volatility models, namely Generalized Autoregressive Conditional Heteroscedasticity (GARCH) and Exponential GARCH or EGARCH models.

In literature, some of the studies have supported the hypothesis that IVs are informational efficient, i.e. these can be used as a predictor of future volatility, whereas some of the studies have rejected this hypothesis. In this respect, Day and Lewis (1992), a pioneering study on informational efficiency of IVs of Standard & Poor's 100 index options market of USA, found that the IVs could not impound all the information available in the past returns and, therefore, concluded that the IVs were not better forecasts of futures volatility compared with those based on select conditional volatility models, namely, GARCH(1, 1) and EGARCH(1, 1). The inability of implied volatility to forecast future volatility is indicative of informational inefficiency of options market. Lamoureux and Lastrapes (1993), who investigated this issue using stochastic volatility model, for the very first time, on several individual stocks traded on Chicago Board Options Exchange (CBOE), and Canina and Figlewski (1993) also rejected the IVs as a predictor of future volatility in S&P 100 index options market.

In contrast, a number of empirical studies found support for the hypothesis that the IVs can be used as a predictor for future volatility and historical returns do not contain any information beyond the IVs (Latane and Rendleman, 1976; Chiras and Manaster, 1978; Gemmill, 1986; Shastri and Tandon, 1986; Scott and Tucker, 1989). Also, some recent studies on the informational efficiency of options market, e.g. Blair *et al*. (2001) and Claessen and Mittnik (2002), supported the hypothesis and concluded that IVs impound all the information available in past returns data. In addition, Xu and Taylor (1995) and Guo (1996) found support for the hypothesis in PHLX currency options market.

In this study, the informational efficiency of IVs, calculated from daily closing premium of S&P CNX Nifty index options, is tested vis-à-vis the forecasts from select conditional volatility models, namely GARCH(1,1) and EGARCH(1,1). For the purpose, the methodology proposed by Day and Lewis (1992) constitutes the basis for the study. In the study, in-the-sample as well as out-of-the-sample forecast abilities of IVs have been tested by regressing volatility forecasts (estimated using the select conditional volatility models on historical returns of S&P CNX Nifty index) on IVs. In addition to this, the study attempts at a comparative analysis of informational efficiency of IVs of call and put options unlike majority of studies, which have focused on the call options only, and draws its relationship with the present market microstructure in India.

The rest of the chapter is organized in five sections. Characteristics of volatility and conditional volatility models have been discussed in Section 6.2. Section 6.3 contains data and calculation of implied volatility. Theoretical framework for examining informational efficiency of IVs has been discussed in Section 6.4. Analysis and results are presented in Section 6.5. The chapter ends with concluding observation in Section 6.6.

6.2 CHARACTERISTICS OF VOLATILITY AND CONDITIONAL VOLATILITY MODELS

6.2.1 Characteristics of Volatility

In literature, a number of features of financial time series and stock market volatility have been identified across the globe. Some of the select features of volatility of time series data that have been found commonly across the world are *volatility clustering, mean-reversion, fat-tailed or leptokurtic distribution of returns and the leverage effect*.

1. **Volatility clustering:** Volatility clustering refers to the tendency of large changes in asset prices (of either sign) to follow large changes and small changes (of either sign) to follow small changes (Brooks, 2005. In another study, Mandelbrot (1963) noted that the periods of large returns were clustered and distinct from periods of small returns, which were also clustered. This indicates that the current level of volatility is positively correlated with that of the immediately preceding period(s).

   Therefore, it would be appropriate to infer that volatility changes over time (i.e. heteroscedastic in nature) and exhibits clusters of large and small changes. Also, this characteristic has been reported by numerous other studies, e.g. Fama (1965), Chou (1988), Schwert (1989) and Baillie *et al*. (1996). In short, it signifies that the volatility today is expected to influence the level of volatility in future.

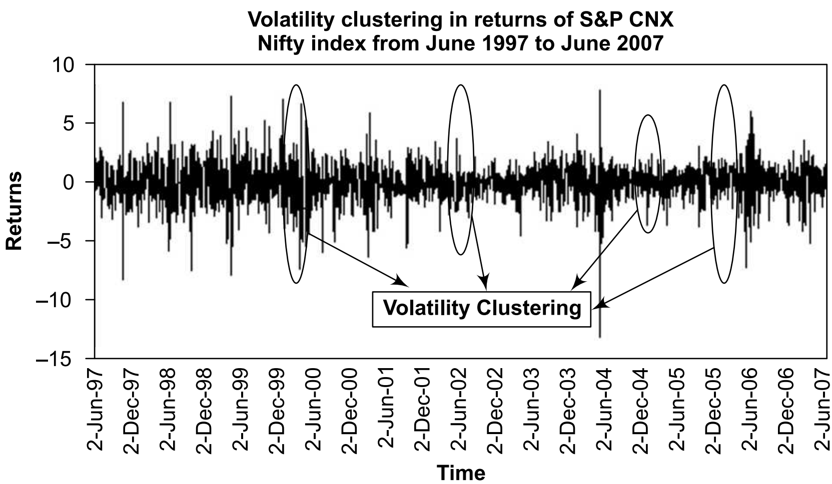

Figure 6.1 Volatility clustering in daily returns of S&P CNX Nifty index, June 1997–2006

   For clustering, data consisting of NSE Nifty index values has been analysed for the period of 10 years from June 2, 1997 to June 30, 2006. Figure 6.1 shows the daily returns of S&P CNX Nifty index and the typical pattern of clustering. The returns are expressed in percentage terms and are continuously compounded [$\ln(I_t/I_{t-1})$; where I_t and I_{t-1} represent the value of index at day t and the previous day, $t - 1$, respectively]. The figure clearly indicates that there are different phases of high as well as low volatility. In the present study, this tendency in index returns has been confirmed by using Ljung-Box statistics.

2. **Fat-tailed distribution of asset returns**: The fat-tailed distribution property of asset returns is also known as leptokurtic (highly peaked) distribution of returns. This represents the tendency of returns to cluster

excessively near the mean value (i.e. more peaked around the mean) and higher probability of returns at tails of the distribution compared with expected returns in case of a mesokurtic (normal) distribution. In earlier studies, it is documented in Mandelbrot (1963) and Fama (1965). Nattenberg (1994) concludes that stock returns exhibit non-normal skewness and kurtosis. These findings were also supported by the work of Corrado and Su (1997), Clark (1973) and Blattberg and Gonedes (1974). In this respect, Ghysels *et al*. (1996) contend that volatility clustering and fat tails of asset returns are intimately related. The distributional assumption of returns/innovations becomes important as it needs to be specified for the estimation of variance equation in conditional volatility models, e.g. GARCH and EGARCH.

3. **Mean reversion**: Mean reversion in volatilities indicates the tendency of volatility to return to its normal level (i.e. the long-run level of volatility) in long-run. It signifies that irrespective of the magnitude and sign of fluctuations, the series reverts to its mean. Such a series in time-series statistics is refereed to as a covariance stationary series, i.e. a series which has a constant mean, variance and autocovariance (at different lags), regardless of the point of time at which the measurement is made. Though the property of mean reversion is accepted by most of the practitioners, they may differ in the magnitude of the normal volatility level and changes in it over a period of time (Engle and Patton, 2001). The mean reversion in IVs has been examined empirically by Dixit *et al*. (2007), a study on Indian options market.
4. **Leverage effect:** It is designated as the main reason for the asymmetrical contribution of innovations (having different sign) to the volatility of returns of a financial time series. In financial markets, it has been observed that a negative shock contributes more to the volatility of returns compared with a positive shock. That is, the volatility is high when the market falls and is found to be relatively lower in times of upward trends. This is explained by leverage effect. The financial leverage or debt-equity ratio of the company increases as the value of equity shares goes down in the market. This causes increase in the risk the investor's perceive as the futures streams of the cash flows from the company become more uncertain. Therefore, a down movement in the stock prices is expected to cause more volatility compared with appositive movement. This effect was first noted by Black (1976) and later supported by Christie (1982), Schwert (1989), Nelson (1991), Glosten *et al*. (1993) and Engle and Ng (1993). They observe that the changes in stock prices tend to be negatively correlated with the changes in stock return volatility, and changes in stock return volatility are too large in response to the changes in returns direction.

These typical characteristics of the financial time series data have helped financial econometricians to engineer more sophisticated models for measurement and forecasting of volatility and led to the conditional volatility models for more precise measurement and estimation of volatility.

6.2.2 Conditional Volatility Models

6.2.2.1 GARCH model

Generalized ARCH (GARCH) models of volatility, introduced by Bollerslev (1986), came into existence in order to overcome the problems of ARCH model of Engle (1982). This model estimates variance as the weighted average of past squared residuals but has declining weights that never go completely to zero (Engle, 2002). GARCH is a parsimonious version of the ARCH model, which is achieved by adding moving average term(s) or GARCH component(s) and, essentially, can be written as an ARCH model with infinite lag structure. In this respect, Brooks (2005) opined that these models are more parsimonious than ARCH model and avoid over-fitting. In addition, non-negativity constraints[1] are less likely to be violated, as GARCH provides a parsimonious model. The GARCH(1, 1) models with AR(1) mean equation is given in Eqs (6.1) and (6.2).

$$r_t = c + \phi r_{t-1} + \varepsilon_t \quad \varepsilon_t \sim N(0, \sigma_t^2) \qquad \text{[Mean equation]} \qquad (6.1)$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2) \qquad \text{[Variance equation]} \qquad (6.2)$$

where,

c is a constant term, ϕ is the first-order autoregression coefficient, ε_t is the normally distributed error term/innovations with zero mean and time varying (heteroscedastic) variance. $\omega = \lambda * V_L$, where V_L is the long-run/unconditional variance of the series and $\lambda = 1 - \alpha - \beta$. σ_t^2 and σ_{t-1}^2 are the GARCH estimates of variance for the period t and $t-1$, respectively. α and β are the ARCH and GARCH parameters, respectively.

This model represents variance for the current period as a weighted average of three sources of variance, namely (a) long-run or unconditional variance (V_L); (b) new information about volatility or innovations during the previous period (ε_{t-1}^2), i.e. the ARCH component; and (c) the conditional variance for the last period (σ_{t-1}^2) or the GARCH component estimated at point of time $t-2$.

The most widely used GARCH specification, i.e. GARCH(1,1), asserts that the best predictor of the variance in next period is a weighted average of the long-run average variance, the variance predicted for this period and the new information in this period that is captured by the most recent residual (Engle, 2002). This model can be extended to a GARCH(p, q) specification, where current conditional variance is parameterized to depend upon q lags of the squared error and p lags of the conditional variance. The GARCH(p, q) model is summarized in Eq. (6.3.)

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 \tag{6.3}$$

Diagnostics of GARCH models

In order to ascertain the effectiveness of the specified model, a number of diagnostic tests have been specified. To test the mean equation, one can test the series ofet ε_t, Engle (2002). The test of mean equation attempts to test whether $\{\varepsilon_t\}$ is a white noise or not, i.e. whether it has a constant mean and variance. For this purpose, in general, correlograms, i.e. Autocorrelation Functions (ACFs) and Partial Autocorrelation Functions (PACFs) along with Ljung-Box (Q) test, are used up to a specified lag length to find how successfully the specified mean equation has modelled the data. In general, 15 lags can be used to diagnose the problems in specification, if any (Engle, 2002). For a correctly specified mean equation, the ACFs and PACFs along with the Ljung-Box (Q) statistics should turn out to be insignificant up to the specified lags. Similarly, squared innovations $\{\varepsilon_t^2\}$ are used to test the correct specification of the variance equation in the model. In addition, ARCH LM test up to a specified lag—1 for a GARCH(1,1) variance equation—is carried out to diagnose the remaining ARCH effect in the data that could not be captured/explained by the model. For a correctly specified variance equation, the ACFs, PACFs, Q statistics along with the ARCH LM test should turn out to be insignificant (up to the specified lag length).

Limitations of GARCH models

In spite of numerous attractive qualities that the GARCH models possess, these are subject to certain limitations as well. Harvey (1981) reported a few limitations of GARCH models. Some of these limitations are: (a) GARCH models do not account for leverage effect as the conditional variance incorporates the same impact of innovations (ε_t) irrespective of the sign they possess, and (b) these models might result in violation of non-negativity constraints on parameters.

6.2.2.2 EGARCH model

In order to overcome the above-mentioned limitations, Nelson (1991) introduced EGARCH model, where conditional variance is constrained to be non-negative by specifying the logarithm of σ_t^2 to be a function of the past εs$(\varepsilon_{t-1}, \varepsilon_{t-2} ..., \varepsilon_{t-n})$. In EGARCH specification, the conditional variance depends upon the magnitude as well as sign of the lagged residual. The conditional variance equation for the EGARCH(1,1) model is given in Eq. (6.4).

$$\text{In } \sigma_t^2 = \omega + \beta \ln(\sigma_{t-1}^2) + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \tag{6.4}$$

In the Eq, (6.4), coefficient γ represents the leverage effect. Empirically, γ should possess a negative sign and be statistically significant to corroborate the leverage effect of innovations on volatility. From Eq. (6.4), it can be inferred that a positive ε_{t-1} contributes less to the volatility compared with a negative ε_{t-1} as γ is expected to possess a negative sign if the leverage effect is present in the series being analysed. Notably, this specification enables σ_t^2 to respond asymmetrically to rises and falls in the error term and has several advantages over GARCH model, viz. (a) σ_t^2 will always be positive even if the parameters are negative, as the log specification is used in this model, thus avoiding the need to impose the non-negativity constraints, and (b) this model accounts for the asymmetries as γ becomes negative in case the relationship between volatility and return is negative.

Besides, there are other models that respond to the asymmetrical contribution of innovations to the variance equation. These include Threshold GARCH (TGARCH) introduced by Zakoian (1991), Quadratic GARCH (QGARCH) proposed by Sentana (1995), Semi-parametric ARCH model of Engle and Gonzalez-Rivera (1991), and Log GARCH models of Pantula (1986) and Geweke (1986), among others. In addition, Engle and Ng (1993) gave the concept of *News Impact Curve* that depicts the impact of new information on the next period variance. The standard GARCH model has this curve symmetrical; it implies that positive and negative surprises of the same magnitude would produce the same amount of volatility. However, a negative innovation causes more volatility than a positive innovation of the same size, and thus, a GARCH model results in under-prediction of volatility following bad news and over-prediction following good news.

6.3 DATA AND IMPLIED VOLATILITY

6.3.1 Data

The data considered for the analysis can consist of (i) data related to S&P CNX Nifty index options contracts, (ii) data related to the underlying asset, i.e. the S&P CNX Nifty index, and (iii) data on the risk-free rate of return. The data on the options consist of daily closing prices of options, strike prices, deal dates, maturity dates and number of contracts of call as well as put options. In order to minimize the bias associated with *nonsynchonous trading,* only liquid option quotations (i.e. contracts which are having at least 100 contracts traded) have been considered for the analysis. The second data set is regarding the underlying asset. It includes daily closing prices of S&P CNX Nifty index. The third data set consists of monthly average yield on 91-days Treasury-bills with maturity date most close to the expiry of the options contracts.

The details pertaining to data collection and conversion of discrete yields into continuous one have been provided in Chapter 3.

6.3.2 Implied Volatilities

The volatilities implied by the options prices (IVs) have been calculated using the adjusted version of Black-Scholes (BS) model, also known as Black-Scholes-Merton model (1973). The Black-Scholes formula and other details on IVs have been provided in Chapter 3.

As the BS model has been used to estimate the IVs, it might give rise to a problem of systematic bias in the estimates of implied volatility because of its inherent assumptions. It assumes volatility to be constant over time. On the contrary, time varying behaviour of volatility is well documented in literature. In addition, the ARCH models (used in analysis) are based on the empirical premise of time varying volatility. Therefore, *per-se*, the use of BS model might result into systematic bias in the estimates of IVs. Fortunately, the problem of systematic bias in the estimates of implied volatility is less likely to occur, as the data on option price quotations that have been used essentially pertain to the near-the-money options. And, Hull and White (1987) demonstrated empirically that BS model performs equally well in the case of at-the-money options as the prices of such option quotations are almost linear in volatilities across all the maturities.

Feinstein (1989) and Takezaba and Shiraishi (1998) made a similar observation that the implied volatility, estimated from BS model, can be used as an unbiased approximation of the expected average volatility for at-the-money options. Takezaba and Shiraishi (1998) further carried out the analysis by extending it to the near-the-money options. In addition, Day and Lewis (1988, 1992) also concluded, considering both Black–Scholes (1973) and Hull and White (1987) model, that the specification error can be minimized by focusing on at-the-money options because Hull–White and BS models are linear in average volatility for such options. In view of the above, the present study has used near-the-money options in order to minimize the noise in estimating IVs using BS model. Following Claessen and Mittnik (2002), near-the-money options have been defined as the options that are up to 10% in/out of-the-money.

Moreover, the shortest maturity options, having maturity time of 8–30 days, have been chosen in order to reduce the possibility of maturity mismatch. The options having minimum 8 days to maturity have been chosen in view of the fact that the possibility of the week-end effect on IVs could be ruled out. The maturity period chosen is similar to various studies conducted in this area, e.g. Xu and Taylor (1995) and Claessen and Mittnik (2002).

Besides, efforts have been made to reduce the bias due to non-synchronous trading, which is likely to distort the quality of implied volatility estimates derived from the options prices. For this purpose, following Day and Lewis (1992), all the contracts having at least 100 contracts traded per day have been chosen for the analysis. The bias due to non-synchronous trading emerges from the fact that closing prices for the thinly traded contracts are more likely to represent transactions that occur before the close of the trading (Day and Lewis, 1988). For further details refer to Chapter 5.

6.4 INFORMATIONAL EFFICIENCY OF IMPLIED VOLATILITY VIS-À-VIS VOLATILITIES ESTIMATED USING ARCH VOLATILITY MODELS

In the study, an attempt has been made to test the informational efficiency of IVs of call as well as put options. The IVs are said to be informational efficient when no other model of volatility estimation is able to capture any information (based on the historical returns) beyond the informational contents of IVs. In other words, the IVs shall contain all the information available in historical returns if the options market is informational efficient.

To this end, the informational efficiency of IVs has been tested vis-à-vis the two popular conditional volatility models, namely GARCH and EGARCH. The conditional volatility models have been chosen as the forecasts from such models have less variance compared with those from unconditional models (Enders, 2005. Moreover, the ARCH models become a natural choice for the purpose because (i) these are able to capture much of the volatility clustering and serial correlation, well documented in the literature on financial time series, and (ii) the estimation of ARCH model within the maximum likelihood framework is straightforward. In this respect, commenting upon the functional utility of ARCH models amongst other studies in the literature, Busch (2005) opines that the GARCH model has become an extremely popular tool for modelling conditional variance amongst academics and practitioners.

In view of the above, the efficiency tests of the IVs have been conducted based on the two models, namely GARCH(1,1)-IV and EGARCH(1,1)-IV. That is to say, the scope of the present study is confined to testing the IVs vis-à-vis GARCH(1,1) and EGARCH(1,1) models only.

6.4.1 GARCH(1,1)-IV and EGARCH(1,1)-IV Models

The *GARCH(1,1)-IV* model attempts to test the informational efficiency of IVs vis-à-vis the GARCH(1,1) model. The model incorporates daily implied volatility/variance from the options contracts as an additional explanatory variable in the variance equation. The proposed model, i.e. *AR(1)-GARCH(1,1)-IV*, which has been used for *in-the-sample* analysis, is summarized in Eqs (6.5) and (6.6). Though the model mentioned in Eqs (6.5) and (6.6) is based on the literature reviewed, it has been validated empirically for the data used in the present study for *in-the-sample* as well as *out-of-the-sample* analysis.

$$r_t = c + \phi r_{t-1} + \varepsilon_t;\ \ \varepsilon_t \sim GED\ (0, \sigma_t)^2 \tag{6.5}$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 + \delta IV_{t-1}^2 \tag{6.6}$$

In Eqs (6.5) and (6.6), all the elements are the same as in Eqs (6.1) and (6.2) except the distributional assumption of innovations/error terms, i.e. generalized error distribution (GED). Notably, Eq. (6.6) includes another exogenous variable, i.e. implied volatility, in addition to those included in Eq. (6.2). In other words, the model given in Eq. (6.2) represents a constrained version of the model given in Eq. (6.6), with the constraint $\delta = 0$.

As discussed earlier, for an options market to be informational efficient, all the information available in historical returns should be reflected in IVs, or in this case, forecasts from the GARCH model should not reflect or contain any information beyond the IVs. Therefore, in operational terms, the ARCH and GARCH parameters (α and β, respectively) should become zero in presence of implied volatility as an exogenous variable in the GARCH variance equation, if the options market has to be informational efficient. In short, in the GARCH (1, 1)-IV model, the null hypothesis tested is that the ARCH and GARCH coefficients are zero (H_0: α and $\beta = 0$).

In addition, the EGARCH model has been used to test whether the IVs incorporate the leverage effect or not. In other words, the EGARCH-IV model has been proposed to test if the IVs respond asymmetrically to the innovations with different sign (+ve and –ve) or not. The informational efficiency (particularly the presence of leverage effect) of IVs vis-à-vis volatility estimates using EGARCH models has been analysed for in-the-sample data using the model summarized in Eq. (6.6). For the model, the innovations (ε_t) have been derived from the model for mean equation, summarized in Eq. (6.5).

$$\ln(\sigma_t^2) = \omega + \beta\ln(\sigma_{t-1}^2) + \alpha\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \delta\ln(IV_{t-1}^2) \tag{6.7}$$

Equation (6.7) can be seen as an extension of Eq. (6.4) by adding implied volatility as an additional exogenous variable. In the model, it has been hypothesized that all the three parameters α, β and $\gamma = 0$, if the options market is informational efficient. The EGARCH-IV model tests the null hypothesis that $\gamma = 0$, which is additional to the GARCH-IV model (α and $\beta = 0$). This hypothesis addresses to the leverage effect, i.e. the IVs incorporate the asymmetrical effect of negative and positive shocks in the returns of the underlying asset.

The methodology adopted, i.e. the introduction of implied volatility as an exogenous variable in the GARCH and EGARCH variance equation, is in line with a number of studies carried out across the globe, including the pioneering one by Day and Levis (1992) on S&P 100 index options in the context of the US market. Some other studies which adopted similar methodology include Lamoureux and Lastrapes (1993), Canina and Figlewski (1993), Xu and Taylor (1995), Fleming (1998), Claessen and Mittnik (2002), Pong *et al.* (2004).

Though the above-mentioned methodology has been used extensively for assessing the informational efficiency of IVs, one major problem of this methodology has been the maturity mismatch as documented by some studies, e.g. Xu and Taylor (1995), Claessen and Mittinik (2002).

The problem of maturity mismatch emanates from the fact that the two forecasts to be compared, viz. the forecasts from ARCH models and implied volatility based forecasts, represent different maturities. The forecast from the IVs represent average forecast of volatility for the rest of the life of the options, whereas the ARCH models generate forecasts for the next period (one day, in our case, for in-the-sample analysis and one-week for out-of-the-sample analysis). Xu and Taylor (1995), in their study on currency options market, empirically examined the effect of maturity mismatch on the performance of mixed models (ARCH-IV models). They concluded that the maturity of implied volatility does not affect the performance of the ARCH-IV models.

6.5 ANALYSIS AND EMPIRICAL RESULTS

6.5.1 Behavior of Stock Returns and ARCH Effect

The estimation of an ARCH model requires three basic specifications—(i) the order of the mean equation, (ii) distributional assumption for innovations and (iii) specification of the ARCH variance equation. In this section, an attempt has been made to diagnose the correct specification for the innovations to be used in the ARCH variance equation. For the purpose, all the six years' data (i.e. from June 04, 2001 to June 30, 2007) have been analysed to arrive at the correct distributional assumption for the innovations.

Table 6.1 Summary Statistics of the Daily Returns of S&P CNX Nifty Index and the Diagnosis for ARCH Effect, June 04, 2001, to June 30, 2006

	Summary statistics of returns					
No. of observations	*Mean*	*Std. Dev.*	*Skewness*	*Kurtosis*	*Jarque–Bera*	*Probability*
2772	*0.0490 (0.1060)*	*1.5975*	*−0.3892*	*7.7817*	*2710.82*	*0.000*

Lag	*Ljung–Box Statistics* r_t	$\lvert r_t \rvert$	r_t^2	*ARCH LM test* TR^2
4	20.29 (0.000)	344.40 (0.000)	381.03 (0.000)	317.17 (0.000)
8	29.36 (0.000)	549.79 (0.000)	449.02 (0.000)	336.82 (0.000)
12	48.44 (0.000)	666.43 (0.000)	483.76 (0.000)	342.41 (0.000)
16	56.13 (0.000)	741.11 (0.000)	509.09 (0.000)	345.52 (0.000)
32	79.04 (0.000)	946.59 (0.000)	565.52 (0.000)	364.50 (0.000)

The most commonly used specification for the innovations is the normal distribution. However, in practice, the GED has been found to be a more correct specification for the financial time serieshaving fat-tails. In order to arrive at the correct specification for the innovations, the assumption of normal distribution has been tested empirically, and the results are summarized in Table 6.1.

Skewness and kurtosis of the returns data provide initial evidences that the distribution of returns departs from normality, as the observed values of skewness and kustosis are different from the desired values of 0 and 3, respectively, required for a normal distribution. The departure from normality further gets corroborated by the *Jarque and Bera test* (summarized in Table 6.1), as it indicates severe departure from the normality. In addition, the kurtosis of 7.7817 is indicative of leptokurtic distribution of returns, i.e. high peakedness of the data and a relatively higher likelihood of observations on the tails (fat-tails) compared with a normal (mesokurtic) distribution. The high peakedness and fat-tails for the returns data are clearly depicted in Fig. 6.2, which compares the empirical distribution of returns with the normal distribution for such data set.

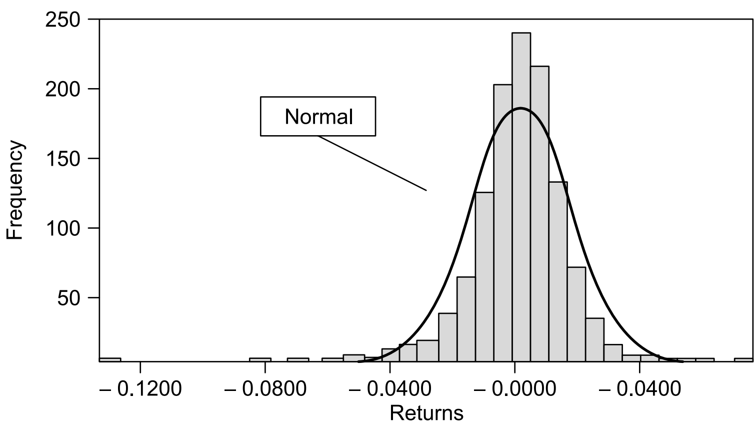

Figure 6.2 Histogram of returns and normal distribution

These findings clearly indicate that the assumption of normal distribution for the returns/innovations would not be appropriate. And, some other distributional assumption should be specified to respond to the behaviour of the data. For the purpose, it is imperative to assume that the returns/innovations follow the GED, which is the most suited distribution for the data having high peakedness and fat-tails. This assumption has further been validated while estimating the coefficient of variance equation for the ARCH models.

6.5.1.1 Testing the ARCH effect

Moreover, another very popular characteristic of the financial time series data, i.e. the presence of ARCH, has been validated using Ljung–Box (Q) statistics and the Engle's ARCH-LM test statistics. The results are summarized in Table 6.1. The results of the Q statistics (for the returns, absolute returns and squared returns data series) and ARCH test have been found to be highly significant at the all specified lags, viz. 4, 8, 12, 16 and 32. The high significance levels for Q statistics at all specified lags for returns and absolute returns series indicate the presence of serial correlation in the data. The high significance of Q statistics for the squared returns, *prima-facie*, suggests the presence of conditional heteroscedaticity. The presence of ARCH effect in the data further gets validated by the high significance levels for Engle's ARCH-LM test.

In short, the financial time series under consideration demonstrates the typical characteristics which suggest an *ARCH model with GED innovations*, an obvious choice for forecasting the volatility of NSE CNX Nifty index returns.

6.5.2 In-The-Sample Results

The results regarding in-the-sample analysis of the informational efficiency of IVs of call as well as put options vis-à-vis the volatility estimates from the select ARCH models are summarized in Tables 6.2 and 6.3. Table 6.2 contains the results using GARCH(1,1) model, and Table 6.3 presents results using EGARCH(1,1) model.

6.5.2.1 ARCH & GARCH effect and informational efficiency of implied volatility

The results summarized in Table 6.2 reveal that the IVs could not capture all the information available in GARCH forecasts for call as well as put options. It is evident from the fact that the GARCH coefficient (β) in GARCH-IV model turned out to be significant at 5% level of significance for both call and put options. In addition, notwithstanding the IVs of call options, the IVs of put options failed to capture the ARCH effect as the coefficient representing ARCH effect (α) turned out to be statistically significant at 5% level of significance in the GARCH-IV model for put options. The findings, *prima-facie*, are indicative of informational inefficiency of the IVs for both call and put options.

Despites being informational inefficient, IVs seem to have incorporated some relevant information contained in GARCH forecasts as the persistence of volatility, i.e. ($\alpha + \beta$), has reduced from 0.8357 (in the constrained model, i.e. GARCH model) to 0.5175 (in the unconstrained model, i.e. GARCH-IV model) along with the statistically significant coefficient of implied volatility, 0.4354. Likewise, the persistence of volatility in the case of put options has reduced from 0.9606 to 0.7526 and implied volatility turned out to be a significant predictor, however, with relatively lower coefficient, i.e. 0.1107.

Moreover, the incremental informational contents of IVs have been examined by comparing the two models, i.e. the *unconstrained model*[3] and the *constrained model*[4]. For the purpose, Likelihood Ratio (LR) test has been carried out. The results of LR test are summarized in Table 6.2. The results clearly

Table 6.2 In-The-Sample Test of Informational Efficiency of Implied Volatilities of Call as well as Put Options vis-à-vis Volatility Estimates Using GARCH(1,1) Model, June 04, 2001, to June 30, 2006 (Unconstrained Model: $\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 + \delta IV_{t-1}^2$)

Options type	*Model*	*Coefficients* ω	α	β	δ	*GED parameter*	*Log likelihood*	*Likelihood Ratio (LR) test*
Call Options	**Unconstrained model** *(GARCH-IV model)*	0.000040 (0.043)	0.0762 (0.055)	0.4413 (0.049)	0.4354 (0.046)	1.2160 (0.000)	2644.44	21.86 ($P < 0.01$)
	Constrained model *(GARCH-IV model with the constraint $\delta = 0$)*	0.000038 (.007)	0.1314 (.000)	0.7045 (.000)	**Constrained to zero**	**1.1884** **(0.000)**	2633.51	
Put Options	**Unconstrained model** *(GARCH-IV model)*	0.000034 (0.035)	0.1318 (0.000)	0.6208 (0.000)	0.1107 (0.030)	1.1676 (0.000)	2353.05	5.02 ($P < 0.05$)
	Constrained model *(GARCH-IV model with the constraint $\delta = 0$)*	0.000010 (0.050)	0.0584 (0.050)	0.9022 (0.050)	**Constrained to zero**	**1.1550** **(0.000)**	2350.54	

(i) The figures given in parentheses denote level of significance (p-values).

(ii) To estimate the coefficient of the ARCH variance equation, the conditional mean equation which has been found adequate is $r_t = c + \phi_1 r_{t-1} + \varepsilon_t$, where $\varepsilon_t \sim GED(0, h_t)$.

indicate that the IVs do have some relevant information. This is borne out by the fact that the introduction of IVs as an exogenous variable in the GARCH variance equation resulted in an increase in the value of log likelihood functions (LLF), and the increase was found to be statistically significant.

Notably, the IVs of call options seem to be less inefficient compared with those of put options, as the latter failed to capture ARCH as well as GARCH effect present in the GARCH forecasts compared with the former which failed to include only the GARCH effect. This finding further gets corroborated by the fact that the coefficient of IVs in GARCH-IV models for call options turns out to be higher compared with that in the case of put options, i.e. 0.4354 and 0.1107 for call and put options, respectively.

Besides, the incremental information of IVs in the case of put options seem to be relatively less since its introduction as an exogenous variable in the GARCH variance equation has increased the LLF just by 5.02 compared with an increase of 21.86 in the case of call options. Also, the increase in LLF has been found to be significant at 5% level of significance compared with the call options, where it is significant even at 1% level of significance. In sum, 'in-the-sample' analysis using GARCH model reveals that the IVs of call options have been informationally superior to those of put options.

6.5.2.2 Leverage effect and informational efficiency of implied volatility

This study has also attempted to diagnose the leverage effect in the IVs, as the informational efficiency requires that IVs should impound all the information contained in historical returns. For the purpose, EGARCH-IV model has been used. The results of EGARCH(1,1) model, summarized in Table 6.3, clearly demonstrate that Indian securities market exhibits leverage effect in volatility of returns, as the parameter addressing the leverage effect (γ) turns out to be statistical significant and has a negative sign attached to it. That is, the Indian market, in line with its international counterparts, corroborates that a negative shock adds more to the volatility of returns compared with a positive shock.

The informational inefficiency of IVs is reaffirmed by the results of the EGARCH-IV model, as all the coefficients of the EGARCH model (in conformity with the results using GARCH model) remained statistically significant even after the inclusion of IVs as an exogenous variable in the EGARCH variance equation for call as well as put options; however, the ARCH coefficient (α) was found to be statistically insignificant at 5% level of significance for call options. The results of the model reject the null hypothesis of informational efficiency of the IVs, i.e. α, β and $\gamma = 0$.

The most crucial finding from the EGARCH-IV model is that the IVs have failed to incorporate the leverage effect as well (in addition to the ARCH and GARCH effect). This is borne out by the fact that the coefficient γ remains negative and statistically significant in the unconstrained model for both call and put options. These findings, *prima-facie,* lead to the conclusion that the IVs are informational inefficient. In sum, it would be reasonable to conclude that the IVs have failed to incorporate all the typical characteristics of the returns series under consideration, for in-the-sample analysis.

However, the informational inefficiency of IVs does not necessarily mean that these do not include any information contained in EGARCH forecasts. It is evident from the fact that the persistence of volatility for call options has reduced from 0.8410 to 0.6649 on account of inclusion of implied volatility as an exogenous variable in the variance equation. A reduction in persistence of volatility was also observed in the case of put options, as it has reduced from 0.8785 to 0.7841. Besides, the statistical significance of the coefficient associated with IVs denotes that these do have incremental information. The finding that the IVs, in spite of their informational inefficiency, contain some useful information has further been corroborated by the significant values of the LR tests. Notably, the coefficients of IVs are statistically significant; however, the magnitude is very low compared with those in the case of GARCH model. This could be attributed to the inability of IVs to capture the leverage effect.

Moreover, as far as comparative efficiency of IVs of call and put options is concerned, the results are in line with the GARCH-IV model. The poor performance of IVs of put options is indicated by comparatively lower magnitude of coefficient of IVs of put options in EGARCH-IV variance equation. Also, the increase in LLF on account of introduction of implied volatility as an exogenous variable is 5.80 for put options compared with an increase of 15.18 for call options. Therefore, it would be reasonable to conclude that put options market is more inefficient compared with call options market in India.

6.5.3 Out-Of-The-Sample Forecast

In addition to 'in-the-sample' examination of IVs, it would be appropriate to look at their 'out-of-the-sample' performance to have a complete assessment of the informational efficiency. For the purpose, the *ex-ante* forecasting ability of IVs has been examined vis-à-vis *ex-ante* forecasts from GARCH(1,1) and EGARCH(1,1) models. In the study, a sample period of 1 year, i.e. from July 03, 2006 to June 29, 2007, has been used to assess the out-of-sample forecast ability of all the volatility models. The period of 1 year has been chosen from the total data of 6 years as the correct estimation of ARCH models requires a larger sample. Therefore, the data for the first 5 years have been used to estimate the coefficients of ARCH model(s) required for forecasting *ex-ante* volatility for the very first week. Thereafter, a rolling sample for 5 years data has been used for *ex-ante* forecast of subsequent weeks. The approach is similar to Xu and Taylor (1995), which used 5 years data from the total data

Table 6.3 In-The-Sample Test of Informational Efficiency of Implied Volatilities of Call as well as Put Options vis-à-vis Volatility Estimates Using EGARCH (1,1) Model, June 04, 2001 to June 30, 2006 [Unconstrained Model: $\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \delta \ln(IV_{t-1}^2)$]

Options type	*Model*	*Coefficients*					*GED parameter*	*Log likelihood*	*Likelihood Ratio (LR) test*
		ω	α	γ	β	δ			
Call Options	Unconstrained model *(EGARCH-IV model)*	−1.4615 (0.002)	0.1277 (0.052)	−0.1878 (0.000)	0.6649 (0.000)	0.1654 (0.013)	1.2239 (0.000)	2648.18	15.18 ($P < 0.01$)
	Constrained model *(EGARCH-IV model with the constraint $\delta = 0$)*	−1.49795 (.002)	0.1978 (.001)	−0.1513 (.000)	0.8410 (.000)	**Constrained to zero**	1.2103 (0.000)	2640.59	
Put Options	Unconstrained model *(EGARCH-IV model)*	−1.2099 (0.001)	0.1899 (0.000)	−0.1813 (0.000)	0.7841 (0.000)	0.0890 (0.013)	1.1839 (0.000)	2358.64	5.80 ($P < 0.05$)
	Constrained model *(EGARCH-IV model with the constraint $\delta = 0$)*	−1.1809 (0.001)	0.2076 (0.000)	−0.1265 (0.001)	0.8785 (0.000)	**Constrained to zero**	1.1810 (0.000)	2355.74	

(i) The figures given in parentheses denote level of significance (p-values).

(ii) To estimate the coefficient of the ARCH variance equation, the conditional mean equation which has been found adequate is $r_t = c + \phi_1 r_{t-1} + \varepsilon_t$, where $\varepsilon_t \sim GED(0, h_t)$.

of 7 years to estimate the ARCH coefficients for forecasting *ex-ante* volatility for the rest of the period.

A total of 53 non-overlapping one-week ahead *ex-ante* forecasts of volatility have been examined, as the forecasting horizon chosen is one-week. The weekly forecasts from ARCH models have been carried out on rolling basis with 5-years daily data. The rolling data set included most recent daily data available just before the week for which forecast is to be made. For example, if the forecast is to be made for the week 't', the data set includes all the most recent daily observations for a period of 5 years up to the last trading day of week '$t - 1$'. Similarly, for the forecast for week '$t + 1$', the data set has been revised by including all the daily observations for the most recent week, i.e. 't', and the data pertaining to the oldest week has been excluded so that the sample size remains intact. The coefficients of the 53 weekly revised ARCH models (based on these rolling data samples) estimated for forecasting the *ex-ante one-week ahead forecast* are summarized in Table 6.4.

Table 6.4 Coefficients of ARCH Models Estimated on the Basis of Weekly Revised Rolling Samples Having 5 Years Daily Data

S. no.	Estimation date	Coefficients						
		$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$			$\ln(\sigma_t^2) = \omega + \alpha\left\|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right\| + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta\ln(\sigma_{t-1}^2)$			
		ω	α	β	ω	α	γ	β
1	30-Jun-06	0.000013*	0.1559*	0.7746*	−1.0473*	0.2706*	−0.1369*	0.9054*
2	7-Jul-06	0.000012*	0.1530*	0.7780*	−1.0333*	0.2707*	−0.1340*	0.9071*
3	14-Jul-06	0.000012*	0.1546*	0.7771*	−1.0274*	0.2739*	−0.1318*	0.9080*
4	21-Jul-06	0.000012*	0.1546*	0.7820*	−0.9915*	0.2736*	−0.1316*	0.9119*
5	28-Jul-06	0.000012*	0.1548*	0.7811*	−0.9911*	0.2707*	−0.1330*	0.9117*
6	4-Aug-06	0.000013*	0.1588*	0.7714*	−1.0294*	0.2668*	−0.1515*	0.9070*
7	11-Aug-06	0.000012*	0.1575*	0.7741*	−1.0279*	0.2707*	−0.1384*	0.9076*
8	18-Aug-06	0.000013*	0.1581*	0.7719*	−1.0359*	0.2685*	−0.1419*	0.9065*
9	25-Aug-06	0.000013*	0.1658*	0.7636*	−1.0435*	0.2688*	−0.1471*	0.9054*
10	1-Sep-06	0.000013*	0.1608*	0.7690*	−1.0515*	0.2695*	−0.1436*	0.9049*
11	8-Sep-06	0.000013*	0.1594*	0.7719*	−1.0777*	0.2642*	−0.1556*	0.9013*
12	15-Sep-06	0.000014*	0.1583*	0.7639*	−1.1392*	0.2619*	−0.1537*	0.8940*
13	22-Sep-06	0.000013*	0.1528*	0.7740*	−1.1256*	0.2600*	−0.1506*	0.8955*
14	30-Sep-06	0.000012*	0.1429*	0.7896*	−1.0417*	0.2543*	−0.1381*	0.9048*
15	6-Oct-06	0.000013*	0.1472*	0.7743*	−1.0719*	0.2543*	−0.1345*	0.9015*
16	13-Oct-06	0.000012*	0.1414*	0.7880*	−1.0649*	0.2557*	−0.1319*	0.9024*
17	20-Oct-06	0.000012*	0.1400*	0.7912*	−1.0582*	0.2545*	−0.1337*	0.9031*
18	27-Oct-06	0.000012*	0.1401*	0.7912*	−1.0532*	0.2550*	−0.1325*	0.9037*
19	3-Nov-06	0.000012*	0.1418*	0.7896*	−1.0518*	0.2573*	−0.1312*	0.9041*
20	10-Nov-06	0.000012*	0.1442*	0.7872*	−1.0635*	0.2601*	−0.1348*	0.9031*

S. no.	Estimation date	Coefficients						
		$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$			$\ln(\sigma_t^2) = \omega + \alpha\left\|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right\| + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta\ln(\sigma_{t-1}^2)$			
		ω	α	β	ω	α	γ	β
21	17-Nov-06	0.000011*	0.1434*	0.7920*	−1.0254*	0.2611*	−0.1308*	0.9076*
22	24-Nov-06	0.000011*	0.1469*	0.7860*	−1.0857*	0.2683*	−0.1320*	0.9014*
23	1-Dec-06	0.000011*	0.1436*	0.7919*	−1.0252*	0.2605*	−0.1286*	0.9076*
24	8-Dec-06	0.000011*	0.1424*	0.7938*	−1.0453*	0.2569*	−0.1388*	0.9051*
25	15-Dec-06	0.000012*	0.1506*	0.7818*	−1.1328*	0.2631*	−0.1515*	0.8956*
26	22-Dec-06	0.000012*	0.1506*	0.7822*	−1.1150*	0.2627*	−0.1502*	0.8975*
27	29-Dec-06	0.000012*	0.1540*	0.7752*	−1.1371*	0.2647*	−0.1512*	0.8952*
28	5-Jan-07	0.000012*	0.1538*	0.7760*	−1.1685*	0.2716*	−0.1486*	0.8924*
29	12-Jan-07	0.000012*	0.1572*	0.7724*	−1.1588*	0.2689*	−0.1540*	0.8932*
30	19-Jan-07	0.000012*	0.1565*	0.7716*	−1.1881*	0.2703*	−0.1537*	0.8901*
31	26-Jan-07	0.000012*	0.1570*	0.7707*	−1.1824*	0.2699*	−0.1546*	0.8907*
32	2-Feb-07	0.000012*	0.1564*	0.7715*	−1.1669*	0.2680*	−0.1541*	0.8923*
33	9-Feb-07	0.000012*	0.1565*	0.7719*	−1.1570*	0.2660*	−0.1575*	0.8932*
34	16-Feb-07	0.000013*	0.1555*	0.7714*	−1.1941*	0.2640*	−0.1638*	0.8887*
35	23-Feb-07	0.000012*	0.1542*	0.7780*	−1.1653*	0.2638*	−0.1622*	0.8920*
36	2-Mar-07	0.000012*	0.1650*	0.7668*	−1.1869*	0.2727*	−0.1634*	0.8902*
37	9-Mar-07	0.000012*	0.1658*	0.7694*	−1.1409*	0.2688*	−0.1640*	0.8950*
38	16-Mar-07	0.000011*	0.1594*	0.7782*	−1.1406*	0.2719*	−0.1575*	0.8955*
39	23-Mar-07	0.000011*	0.1603*	0.7777*	−1.0829*	0.2643*	−0.1608*	0.9013*
40	30-Mar-07	0.000011*	0.1597*	0.7770*	−1.0881*	0.2634*	−0.1612*	0.9006*
41	6-Apr-07	0.000010*	0.1522*	0.7930*	−1.0185*	0.2576*	−0.1551*	0.9078*
42	13-Apr-07	0.000010*	0.1533*	0.7914*	−1.0269*	0.2583*	−0.1581*	0.9069*
43	20-Apr-07	0.000011*	0.1583*	0.7848*	−1.0724*	0.2680*	−0.1563*	0.9027*
44	27-Apr-07	0.000010*	0.1529*	0.7914*	−1.0153*	0.2553*	−0.1579*	0.9078*
45	4-May-07	0.000010*	0.1519*	0.7931*	−1.0151*	0.2564*	−0.1546*	0.9080*
46	11-May-07	0.000011*	0.1585*	0.7838*	−1.0505*	0.2661*	−0.1518*	0.9050*
47	18-May-07	0.000011*	0.1584*	0.7844*	−1.0490*	0.2647*	−0.1539*	0.9051*
48	25-May-07	0.000011*	0.1590*	0.7834*	−1.0473*	0.2638*	−0.1551*	0.9051*
49	1-Jun-07	0.000011*	0.1577*	0.7853*	−1.0385*	0.2620*	−0.1567*	0.9059*
50	8-Jun-07	0.000010*	0.1497*	0.7949*	−1.0125*	0.2584*	−0.1514*	0.9086*
51	15-Jun-07	0.000010*	0.1494*	0.7929*	−1.0514*	0.2623*	−0.1456*	0.9046*
52	22-Jun-07	0.000010*	0.1484*	0.7956*	−1.0289*	0.2614*	−0.1429*	0.9071*
53	29-Jun-07	0.000010*	0.1500*	0.7946*	−1.0267*	0.2637*	−0.1436*	0.9076*

* represents that the associated coefficient is significant at 1% level of significance.

Note: (1) To estimate the coefficient of the ARCH variance equation, the conditional mean equation which has been found adequate is $r_1 = c + \phi_1 r_{t-1} + \phi_4 r_{t-4} + \varepsilon_t$, where $\varepsilon_t \sim GED\ (0.\ h_t)$.

On the basis of the estimated ARCH coefficients, the *ex-ante* forecasts of volatility for a total number of 53 weeks have been determined. The weekly forecast represents the average volatility for the week. That is, it is the average of the daily forecasted volatilities for all trading days available in that week. Equation (6.8) represents the formula for calculating the weekly average variance.

$$\hat{h}^{W}_{F,t} = \left[\frac{1}{n}\sum_{i=1}^{n}\hat{h}^{D}_{F,t+i}\right] \tag{6.8}$$

where, $\hat{h}^{W}_{F,t}$ is the average *ex-ante* forecast of conditional variance for the week at time t; $\hat{h}^{D}_{F,t+1}$ is the daily *ex-ante* forecast of conditional variance for the i^{th} day of the week at time t estimated from GARCH(1,1) or EGARCH(1,1) model and n represents the number of trading days in that week. All such forecasts of volatility have been annualized multiplying by 252 (number of trading days in the year).

Likewise, the IVs of the options with shortest maturity (ranging between '8–30 days to maturity') have been used as an *ex-ante* forecast of volatility (V^{1}_{t}). The options having shortest maturity have been chosen in order to minimize the noise caused by maturity mismatch, as these forecasts are to be used as one-week ahead *ex-ante* forecast of volatility. Notably, the IVs (as an *ex-ante* forecast for the next week) have been calculated at the close of trading on the Friday, which, at the same time, marks the end of the rolling samples for the estimation of ARCH models. From the options data, a series of 49 implied volatility forecasts of *one-week-ahead* volatility could be examined for call as well as put option unlike the total number of 53 forecasts from ARCH models, as four contracts were lost in filtering the data on specified moneyness and liquidity criteria. This approach is similar to that adopted by Day and Lewis (1992) and most of the other studies carried out later on (e.g. Claessen and Mittinik, 2002).

Having estimated the *ex-ante* one-week ahead forecasts of volatility from select ARCH and implied volatility models, the *ex-post* calculation of realized volatility for the forecasted weeks has been carried out. Also, like ARCH models, a total number of 53 *one-week ahead* realized volatilities were calculated *ex-post*. The realized volatilities so calculated have been used as a benchmark for assessing the forecasting ability of different volatility models under consideration. The realized volatility for one week represents the average of daily volatilities for all the trading days of the week. The formula used for calculation of the realized volatility is given in Eq. (6.9).

$$V^{R}_{t} = \left[\frac{1}{n}\sum_{i=1}^{n}r^{2}_{t+i}\right] \tag{6.9}$$

where, V_t^R is the realized average variance for the week at time 't', r_{t+i}^2 is the squared return for the i^{th} day calculated *ex-post* and n represents the number of trading days in the week. The volatility so arrived has been annualized multiplying by 252 (i.e. number of trading days in a year).

Further, mean error (ME), mean absolute error (MAE) and mean squared error (MSE), the most commonly used criteria for assessing the forecasting ability of different models, have been used to examine the forecasts from the four models (i.e. 'GARCH', 'EGARCH', 'Implied volatility of call options' and 'Implied volatility of put options') vis-à-vis the realized volatility for the week. The ME, MAE and MSE are given in Eqs (6.10), (6.11) and (6.12), respectively.

$$\mathrm{ME} = \frac{1}{n}\sum_{t=1}^{n}\left(V_t^F - V_t^R\right) \tag{6.10}$$

$$\mathrm{MAE} = \frac{1}{n}\sum_{t=1}^{n}\left|V_t^F - V_t^R\right| \tag{6.11}$$

$$\mathrm{MSE} = \frac{1}{n}\sum_{t=1}^{n}\left(V_t^F - V_t^R\right)^2 \tag{6.12}$$

where, V_t^F is *one-week ahead ex-ante* forecast from one of the select volatility models under consideration, specifically, $\hat{h}_{F,t}^{W}$ in the case of ARCH models and V_t^I in the case of implied volatility models; n denotes the number of forecasts made using each method, i.e. 53 in the case of ARCH models and 49 in the case of implied volatility models; and V_t^R is the *ex-post* estimation of one-week ahead realized volatility.

The results pertaining to the *ex-ante* forecasting performance of all the volatility models under consideration are summarized in Table 6.5. The findings clearly indicate that forecasts from the EGARCH model are the best amongst all other competing models used to forecast the *ex-ante* volatility. Also, the forecast from the GARCH model have shown better results compared with those based on IVs of call as well as put options as indicated by MAE and MSE. To sum up, the measures of forecast efficiency in terms of overall MAE and MSE indicate that IVs have failed to generate considerably good forecasts compared with those from the ARCH models both in the cases of call and put options.

Notwithstanding the overall MAE and MSE, the overall ME designates IVs from the call options as the best *ex-ante* forecast of future volatility because it turns out to be the least. However, the conceptual superiority of the other two measures, namely MAE and MSE, lessens the importance and reliability of this finding, as the ME is sensitive to the sign of deviation. That is, positive and negative deviations are neutralized in calculation of ME.

The forecasts based on IVs seem to have failed in impounding the ARCH as well as leverage effect, which probably be assigned as a major reason for relatively high forecast error compared with ARCH model. This finding, *prima-facie*, rejects the hypothesis that the IVs have subsumed all the information contained in ARCH forecasts, which are based on historical returns data. And, therefore, the IVs can be designated as informational inefficient as these do not seem to have impounded relevant information about the future forecasts compared with ARCH models.

Since the above-mentioned findings are based on the overall measures of forecast performance, there is always a possibility that such measures might present a distorted picture on account of the presence of a few outliers in the data. Therefore, it would be useful to further analyse the data for more reliable results using different percentiles to test the consistency in forecasting efficiency of different models under consideration. The percentiles are reported in Table 6.5.

The results in terms of percentiles corroborate the above finding that forecasts from the EGARCH model are the best as the first three quartiles (25th, 50th and 75th percentiles) turn out to be the least for this model compared with all the other three competing models. That is, in 75% cases, the forecasts from the EGARCH models have outperformed the forecasts from the other models and, therefore, reflects the consistency of EGARCH *ex-ante* forecasts.

Moreover, if we look at all the percentiles calculated, the forecasts from the EGARCH model have outperformed the forecasts from the implied volatility in a total number of 85% cases, i.e. first 75% cases plus 10% cases from 85th to 95th percentiles. In other words, the forecasts from the IVs of call options (the next best model) have outperformed the EGARCH forecast only in 15% of the total cases analysed. Likewise, the forecasts from the GARCH model have outperformed the forecasts from the IVs of call options in a total number of 65% of the cases analysed, i.e. first 50% cases plus 15% cases from 85th to 100th percentiles. Thus, the forecasts from implied volatility of call options have outperformed the GARCH forecasts in 35%s of cases analysed.

In contrast, the forecasts from ARCH models have outperformed the forecasts from the IVs of put options in a total number of 90% cases. That is, the forecasts based on IVs of put options could outperform the forecasts from the ARCH models only in 10% of the cases.

In view of the above findings, it would be appropriate to conclude that IVs do not have much information about the futures volatility. These findings corroborate the earlier finding (based on the overall ME, MAE and MSE) that the IVs are informational inefficient. However, one of the plausible arguments in favour of implied volatility could be the maturity mismatch. That is, IVs of the options having 8–30 days to maturity have been used to forecast one-week ahead volatility. Therefore, it would be appropriate to analyse the options that

Table 6.5 Comparative Forecasting Performance of Implied Volatility Models for Call as well as Put Options Having 8–30 Days to Maturity vis-à-vis Select Conditional Volatility Models in Forecasting One-Week-Ahead Volatility, July 2006 to June 2006

Performance measurement	*Forecasting models*											
	GARCH(1,1)			*EGARCH(1,1)*			*Implied variance call options*			*Implied variance put options*		
	ME	*MAE*	*MSE*	*ME*	*MAE*	*MSE*	*ME*	*MAE*	*MSE*	*ME*	*MAE*	*MSE*
Overall	0.00380	0.03083	0.00188	**–0.00256**	0.02700	0.00172	0.00156	0.03208	0.00199	0.03646	0.04953	0.00320
Percentiles												
25	0.00229	0.01065	0.00012	–0.00311	0.00859	0.00007	–0.00750	0.01501	0.00023	0.02104	0.03332	0.00111
50	0.01530	0.02024	0.00041	0.00964	0.01658	0.00027	0.01567	0.02469	0.00061	0.04053	0.04508	0.00203
75	0.02484	0.03977	0.00159	0.01875	0.02851	**0.00082**	0.03054	0.03541	0.00126	0.05925	0.06447	0.00416
80	0.02667	0.04830	0.00234	0.02131	0.03654	0.00135	0.03339	0.03635	0.00132	0.06465	0.06679	0.00446
85	0.03492	0.06916	0.00480	0.02505	0.04998	0.00250	0.03482	0.03860	0.00149	0.07036	0.08225	0.00677
90	0.03981	0.07563	0.00573	0.02890	0.07250	0.00525	0.03606	0.08018	0.00643	0.08242	0.09462	0.00895
95	0.05658	0.10436	0.01096	0.03752	0.11309	0.01281	0.03860	0.12754	0.01644	0.10205	0.10204	0.01041
100	0.07065	0.13849	0.01918	0.05057	0.14231	0.02025	0.04214	0.14248	0.02030	0.12827	0.12827	0.01645

Note: In the table, ME, MAE and MSE denote mean error, mean absolute error and mean squared error, respectively.

are close to the one-week forecast horizon (in terms of maturity) to assess the true informational efficiency of IVs in forecasting the future volatility. For the purpose, the IVs of the options having 8 days to maturity have been used to compare the *ex-ante* one-week ahead forecasting ability of different volatility models under consideration. The results in this regard are summarized in Table 6.6.

The results clearly indicate that the forecasts from the IVs of call options turn out to the best, as the overall ME, MAE and MSE are the least amongst all the competing models. However, the percentiles corroborate that the forecasts from the EGARCH model still remain the best forecasts, as the MAE and MSE for the first three quartiles (for 75% of the cases) are the least among all the models. That is, the percentage of forecasts from EGARCH that outperformed the implied volatility forecasts from the call options has reduced from 85% to 75% and can be attributed to the correction of maturity mismatch.

At the same time, the forecasts from the IVs have shown considerable improvement vis-à-vis GARCH forecasts when corrected for maturity mismatch. The forecasts from the IVs of call options have outperformed all the forecasts from the GARCH model; the percentage of GARCH forecasts outperforming the forecasts based on the IVs of call options has reduced from 65% to 0. In view of these findings, it would be appropriate to infer that the informational inefficiency in the IVs of call options can, to a marked extent, be attributed to the maturity mismatch.

In sum, it can be concluded that the forecasts from the IVs of the call options impound all the information contained in the GARCH forecast. In other words, the IVs of call options do contain relevant information about the future volatility; however, these failed to capture the leverage effect as the forecasts from the EGARCH models still outperformed implied volatility in 75% of the cases.

Unlike the IVs of call options, those of put options have shown no improvement in their forecasting ability. It is evident from the fact that the forecasts of put options from the ARCH models have outperformed the forecasts based on IVs in 95% of the cases. This finding corroborates the earlier finding that the IVs of put options are clearly informational inefficient and do not contain much relevant information for forecasting the future volatility.

6.5.4 Comparison of Call and Put Options

The 'in-the-sample' analysis has revealed that the IVs of call as well as put options are informational inefficient. However, a comparative examination of IVs demonstrates that IVs of call options have impounded higher amount of information available in the historical returns compared with those of put options. It is evident from the fact that the coefficient of IVs in the GARCH variance equation is 0.4354 and 0.1107 for call and put options, respectively.

Table 6.6 Comparative Forecasting Performance of Implied Volatility Models for Call as well as Put Options Having 8 Days to Maturity vis-à-vis Select Conditional Volatility Models in Forecasting One-Week-Ahead Volatility, July 2006 to June 2006

Performance measurement	*Forecasting models*											
	GARCH(1,1)			*EGARCH(1,1)*			*Implied variance call options*			*Implied variance put options*		
	ME	*MAE*	*MSE*	*ME*	*MAE*	*MSE*	*ME*	*MAE*	*MSE*	*ME*	*MAE*	*MSE*
Average	0.00380	0.03083	0.00188	**–0.00256**	0.02700	0.00172	0.01964	0.01964	0.00053	0.04958	0.04958	0.00356
Percentiles												
25	0.00229	0.01065	0.00012	–0.00311	0.00859	0.00007	0.00947	0.00947	0.00009	0.02378	0.02378	**0.00061**
50	0.01530	0.02024	0.00041	0.00964	0.01658	0.00027	0.01673	0.01673	0.00029	0.04263	0.04263	0.00182
75	0.02484	0.03977	0.00159	0.01875	0.02851	**0.00082**	0.03495	0.03495	**0.00123**	0.06157	0.06157	**0.00381**
80	0.02667	0.04830	0.00234	0.02131	0.03654	0.00135	0.03536	0.03536	0.00125	0.07882	0.07882	0.00653
85	0.03492	0.06916	0.00480	0.02505	0.04998	0.00250	0.03569	0.03568	0.00127	0.10199	0.10199	0.01044
90	0.03981	0.07563	0.00573	0.02890	0.07250	0.00525	0.03614	0.03614	0.00131	0.11997	0.11997	0.01455
95	0.05658	0.10436	0.01096	0.03752	0.11309	0.01281	0.03635	0.03635	0.00132	0.12827	0.12827	0.01645
100	0.07065	0.13849	0.01918	0.05057	0.14231	0.02025	0.03635	0.03635	0.00132	0.12827	0.12827	0.01645

Note: In the table, ME, MAE and MSE signify mean error, mean absolute error and mean squared error.

Similarly, the respective coefficients turn out to be 0.1654 and 0.0890 for the EGARCH variance equation. These findings denote that the IVs of call options are more informational efficient compared with those of put options.

Further, the forecasts based on IVs of put options have been outperformed by the forecast of all the other models under consideration (Tables 6.5 and 6.6). Notably, the forecasts based on IVs of put options have consistently been outperformed by those based on the IVs of call options, as manifested in ME, MAE and MSE on aggregate as well as disaggregate basis (in terms of percentiles). Moreover, the MEs in the case of forecasts from the IVs of put options have consistently been higher (nearly more than double) compared with those in the case of call options. This finding (along with the MAE and MSE), *per-se*, reveals that the IVs of put options are consistently overstating the forecasts of future volatility compared with those of call options and signifies that the IVs of put options are overpriced. The relative overpricing of IVs of put options can be attributed to the overpricing of the put options, as the call and put options used for out-of-the-sample analysis have the same characteristics, viz. trading date, maturity date and strike price. The overpricing of put options in relation to the corresponding call options is, apparently, indicative of violation of the put–call parity relationship.

Therefore, the poor performance of IVs of put options vis-à-vis those of call options, as revealed by in-the-sample as well as out-of the-sample analysis, can be attributed to the overpricing of put options. Also, it would be appropriate to conclude that the IVs of put options are more informational inefficient compared with those of call options. However, such anomalies in an efficient market should be corrected by arbitrage mechanism, provided the market microstructure facilitates the arbitrage processes required to correct such anomalies.

Given the state of market microstructure of Indian securities market during the period under reference, the relative overpricing of put options can possibly be attributed to the *short-selling constraint.* This has been assigned as one of the major reasons in view of the fact that to exploit such an arbitrage opportunity, the three courses of action, namely (i) sell the overpriced put, (ii) buy a corresponding call with the same contract specifications and (iii) *sell the underlying asset(s) short*, are required to be taken. In short, relatively lower informational efficiency of the IVs of put options could be traced to the existing market microstructure in India during the period under reference.

The major finding of the study that the IVs do not incorporate all the information available in the historical returns, which signifies the informational inefficiency of IVs vis-à-vis the volatility estimates from select ARCH models, is in line with Day and Lewis (1992), Canina and Figlewski (1993), Lamoureux and Lastrapes (1993) and Pong *et al*. (2004) for the forecast horizon of one day and one-week. However, at the same time, the results of the study are opposite to some studies that found IVs to be informational efficient. These include Latane and Rendleman (1976), Chiras and Manaster (1978), Gemmill (1986), Shastri and Tandon (1986), Scott and Tucker (1989), Xu and Taylor (1995), Fleming, J. (1998) and Claessen and Mittnik (2002).

6.6 CONCLUDING OBSERVATIONS

The present study has attempted to assess the informational efficiency of IVs vis-à-vis volatility estimates from select conditional volatility models, namely GARCH(1,1) and EGARCH(1,1). In the study, the IVs have been analysed for 'in-the-sample' as well as 'out-of-the-sample' data. The results of the analysis reveal that the IVs have failed to capture all the information available in the historical returns, and the forecasts based on the IVs are inferior to those based on the ARCH models. Though the IVs have been found to be informational inefficient for both call and put options, the IVs of call options, when corrected for maturity mismatch, have shown marked improvement in the quality of forecasts. This is borne out by the fact that these successfully impounded all the information available in the forecasts based on GARCH model in case of 'out-of-the-sample' analysis, though it failed to incorporate the leverage effect, which remained the basic reason for the best quality forecasts from EGARCH model. In contrast, the put options market has shown comparatively higher inefficiency both for in-the-sample and out-of-the-sample analysis.

In short, the implied volatility of call options does have relevant information about the future volatility; however, it fails to capture all the information available in the historical returns (especially in terms of leverage effect). On the contrary, the implied volatility of put options does not show any improvement in the quality of its forecasts of future volatility even when corrected for maturity mismatch. Therefore, the implied volatility of put options has remained more informational inefficient compared with call options.

The relative overpricing of implied volatility of put options compared with call options can be attributed to the short-selling constraint in Indian securities market under reference, as the arbitrage mechanisms that corrects such anomalies requires the underlying assets to be sold short. Notwithstanding the constraints in terms of market microstructure of Indian securities market, such anomalies are expected to hinder the performance of options on its well identified functions, namely risk hedging, price discovery and the resultant of these two, i.e. the efficient allocation of funds.

The informational inefficiency of IVs is indicative of mispricing of options contracts in Indian securities market and puts a question mark on performance of the options market.

END NOTES

1. The non-negativity constraints on the coefficients of an ARCH variance equation rule out the possibility of negative coefficients, as the values of the coefficients are restricted to zero or a positive value (may or may not be specified explicitly). This, in turn, does away with the possibility of a negative variance estimate.
2. Generalized Error Distribution (GED) is a theoretical distribution, which is suitable for the data which have fat-tails and high peakedness.
3. It represents a model where no constraint has been imposed on the value of coefficients in the model.
4. It represents a model where one or more coefficients have been constrained to some value, e.g. zero.

CHAPTER 7

Survey Analysis and Findings

7.1 INTRODUCTION

This survey attempts to gauge viewpoint of trading member organizations/brokers on the state of pricing of options contracts in Indian derivatives market and reforms in terms of regulation and educational initiatives for the betterment of the market. For the purpose, a questionnaire has been prepared to seek responses/perception of trading member organizations on the issue. The survey was conducted amongst the branch managers and research analysts of brokerage firms based at Delhi and Mumbai. The survey is expected to provide a useful insight primarily for two reasons: (i) the brokerage firms play a central role in capital creation in an economy as they facilitate trading of financial securities/assets (including derivatives securities), and (ii) derivatives markets is new in India as it took off in June 2000 only, and therefore, the understanding of the market amongst such intermediaries needs to be assessed.

In the survey, the viewpoint of the respondents has been captured on five major aspects. These are: (i) level of participation and usage of the options market, (ii) awareness and use of models for options valuation, (iii) understanding of put–call parity relationship, (iv) correctness of options pricing, its impact and existence and exploitability of arbitrage opportunities and (v) need of regulations and educational initiatives for the betterment of the market.

The rest of the chapter has been organized in four sections. The Section 7.2 enumerates survey methodology. Profile of respondents has been summarized in Section 7.3. Section 7.4 contains analysis and empirical evidences. The chapter ends with concluding observations in Section 7.5.

7.2 SURVEY METHODOLOGY

7.2.1 Questionnaire Development, Scales Used in the Questionnaire and Identification of the Target Population

In the survey, questionnaire has been used as a major tool for collecting required information from the respondents. The questionnaire was developed based on the experts' opinion and an earlier survey on derivatives in Indian securities market by Srivastava *et al*. (2008). Expert opinion was sought from five eminent academician (including the head of the Committee on Development of Derivatives Market in India) and five branch managers of different trading member organizations in Delhi, actively dealing with the derivatives segment. The questionnaire is based on two measurement scales, namely nominal and interval scales, for the measurement of the responses.

Since the purpose of the survey has been to gauge the perception of the market participants of the pricing of options, the questionnaire has been administered amongst the trading member organizations. The trading member organizations play a crucial role in the financial markets, as they not only facilitate trading in the market but also participate actively in the trading. The understanding of derivatives market is crucial amongst such organizations, as they facilitate trading for retail (including high net worth individuals) and institutional investors (through proprietary trading). Moreover, the investors seek the advice of such organizations regarding their investment decisions from time to time. Therefore, based on the active participation and crucial advisory role, we have selected trading member organizations as the target population for the purpose of the survey to gauge the market perception on the pricing of options contract in Indian derivatives market. For the purpose, a list of total number of trading member organizations active in derivatives market as on September 2007 was retrieved from the website of Securities and Exchange Board of India (SEBI).

7.2.2 Pre-Testing of Questionnaire (Reliability and Validity)

The questionnaire was firmed up after incorporating suggestions and improvements from various practitioners and academics, and the validity and reliability of the instrument have been tested. For the purpose, it has been pre-tested on five branch managers from different trading member organizations based at Delhi and five eminent academics.

Reliability and validity refer to the ability of the instrument to measure consistently what it proposes to measure. The face and/or content validity of the questionnaire have been ensured by discussing the responses with experts on the subject. In addition to this, the reliability of the instrument was tested for the related questions, which have been measured on interval scale. The reliability of the related questions that constitute a construct has been tested using Chronbach's alpha. The coefficient, i.e. the Chronbach's alpha, turned out to be more than 0.66 for all related questions. This reasonably good value of Cronbach's alpha for all related questions confirms reliability of the questionnaire.

7.2.3 Sample Size Determination

Moreover, based on the responses from the pilot survey, an attempt has been made to statistically determine the sample size. The statistical approach adopted to determine the sample size is based on traditional statistical inference as mentioned in Malhotra (2005). In this approach, the desired precision level is specified in advance. The approach is based on creating confidence intervals around the mean.

The sample size determination under this approach requires five steps as mentioned in Malhotra (2005). These steps are:

(i) Specifying the level of precision—it represents the maximum permissible difference between the sample and population mean of the characteristics of interest. The level of precision can be specified in absolute terms as well as in relative terms (in per cent). In the study, it has been set at the commonly used level of 5%.

(ii) Specifying the level of confidence—The level of confidence in the present study has been set at 95%.

(iii) Determining the z value associated with the specified level of confidence.

(iv) Estimation of the sample mean and standard deviation of the characteristics of interest in case the population mean and standard deviation are unknown and

(v) Determining the sample size using the formula given in Eq. (7.1).

$$n = \frac{C^2 z^2}{R^2} \tag{7.1}$$

where, C is the coefficient of variation, (σ/μ), z is the value of the standardized normal variate at 95% level of confidence and R represents the precision level/maximum permissible difference in percentage terms.

Based on the 10 responses from the pilot survey, the mean and standard deviation for all the characteristics of interest was estimated and an average of mean of all the characteristics of interest along with the average variance was determined. The aggregate mean and standard deviation for the pilot data have been 3.62 and 0.7575, respectively. Finally, we arrived at the sample size of 67 for the 95% confidence level and 5% level of precision, based on the aggregate mean and standard deviation determined from the data.

7.2.4 Sample Selection/Sampling Technique Used

We have used a two-stage cluster sampling technique as we are required to gauge the perception of market participants/trading member organizations based at Delhi and Mumbai. The geographical cluster/area sampling has been applied in view of the fact that the population to be surveyed fits the requirement for such a sampling technique, i.e. externally homogenous and internally heterogeneous groups/clusters. The respondents of the survey form *'externally homogeneous' geographical clusters* in terms of the cities they are located at and are *'internally heterogeneous'* based on their different trading volumes within a given city.

The two stages of the sampling technique are (i) choosing clusters of the populations to be surveyed and (ii) choosing sampling units from within the selected clusters. Amongst all the clusters of the target population, we have chosen to study the two selected clusters (Delhi and Mumbai). The survey has been focused on the trading member organization situated at Delhi and Mumbai only, as the majority of trading member organizations are located at these two places. In addition, an earlier survey on derivatives by Srivastava *et al*. (2008) revealed that majority of responses, i.e. 78% of the total responses, were from these two cities. This then constitutes the rationale of limiting the survey to the trading member organizations of Delhi and Mumbai only.

Further, *simple random sampling* has been used at the second stage of sampling in order to select the sampling units from within each cluster. This has been done in view of the fact that it was not feasible to survey the whole population of select clusters owing to the *budgetary constraints*. For the purpose, we have generated 100 random numbers within the range of 1–172 for Delhi. Likewise, 250 random numbers have been generated within the range of 1–345 for the selection of trading member organizations in Mumbai. Based on these numbers, a total number of 350 respondents have been surveyed; 100 from Delhi and 250 from Mumbai.

7.2.5 Questionnaire Administration and Data Collection

The pilot-tested questionnaire was sent to a total number of 100 and 250 trading organizations out of the total population of 172 and 345 trading member organizations based at Delhi and Mumbai, respectively. Subsequently, a reminder was sent through email after one week of the date the questionnaire was mailed though postal mail. In total, 350 questionnaires were mailed to the randomly selected trading member organizations based at Delhi and Mumbai, out of the total population of 517 organizations. Moreover, all such trading member organizations were also sent a questionnaire through email.

The initial response was very poor as only 10 trading members responded. Two reminders were sent to the remaining respondents through email mode with the interval of one month and two months, respectively, from the date of the first reminder. In addition, a total number of 20 trading member organizations were surveyed by personally visiting to the offices of organizations based at Delhi. For the purpose, the researcher sought appointments through email and phone calls. As a result, in the time span of approximately 5 months from March 2008 to August 2008, a total number of 64 responses were received. The responses include 31 responses from Delhi and 33 from Mumbai. Out of all the 31 responses from Delhi, 19 were collected through personal visits and rest of the responses were received though postal mail (9) and email (3). Similarly, all the 33 responses from Mumbai were received through postal mail (26) and email (7). This amounts to 12.38% of the total population of trading members active in derivatives segments.

Though the response rate is less than one-fifth (18.29%, i.e. 64 out of 350), it should not be considered as low/poor response in view of the busy schedule of executives of trading member organizations. Another reason for such a response rate is that business organizations normally consider information related to financial matters very sensitive and confidential. However, the response level should be borne in mind while interpreting the results/findings of the survey.

7.3 PROFILE OF RESPONDENTS IN TERMS OF THEIR BACKGROUND AND TRADING VOLUME

As mentioned earlier in the methodology section, the respondents of the survey belong to the two major clusters/ hubs of trading for derivatives securities, namely Delhi and Mumbai. The number of respondents from Delhi and Mumbai were 31 and 33, which account for 48% and 52%, respectively, of the total number of respondents. Almost equal percentages of respondents from the two clusters represent a balanced sample, which assigns equal importance to the opinion of the respondents from both Delhi and Mumbai. The geographical background of the respondents has been presented in Fig. 7.1.

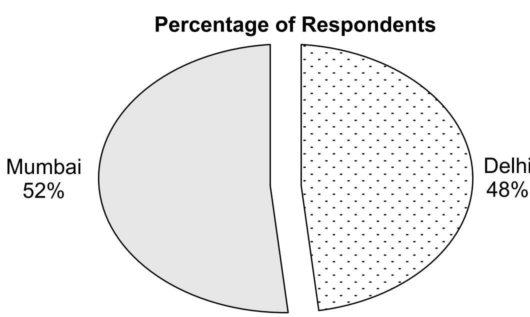

Figure 7.1 Geographical location of the respondents

In addition, profile of the respondents based on their trading volume (based on the notional value of contracts) in derivatives (F&O) segment has been depicted in Fig. 7.2. The results enumerate that majority of the traders, i.e.

51% of total respondents had average daily turnover (notional value) between ₹ 25 and 100 crore, one-fourth of the respondents had daily trading volume of more than ₹ 100 crore, and nearly one-fourth (24%) of the respondents belongs to the category having a daily turnover of less than ₹ 25 crore.

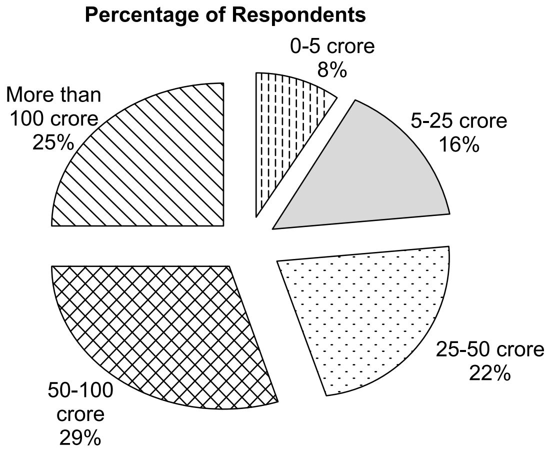

Figure 7.2 Average daily turnover (in ₹) of the respondents in Futures & Options (F&O) segment

7.4 ANALYSIS AND EMPIRICAL RESULTS

The analysis of the responses has been classified into five subsections relating to the viewpoint of trading member organizations on pricing of options contracts in Indian derivatives market and need of regulation and educational initiatives for the betterment of the market. These subsections represent the five dimensions proposed to be measured by the survey.

7.4.1 Participation in Options Market and Its Usage

In order to examine the popularity of options vis-à-vis other derivative products in Indian securities market, the respondents were asked on the share of options in their total trading volume relating to derivatives. The results in this respect have been depicted in Fig. 7.3. The results of the survey reveal that the vast majority of participants (79%) have been found to have a relatively meagre share (up to 20%) in the options compared with other derivative products in the portfolio.

The finding is corroborated by the fact that more than one-third (35%) of the respondents had less than 10% of their trading volume in options; majority of which were the respondents having less than 5% proportion in derivatives trading devoted to options. In addition, a major segment of respondents representing 44% of the participants have invested on an average 10–20% in options of their trading volume relating to derivatives segment.

Only 16% of the respondents have included a reasonably good proportion of options in their trading volume from derivatives segment by assigning 20–50% weightage to the options contracts in their portfolio of derivatives securities; just 5% of total respondents have shown very high interest in options as they have more than 50% of their activity in derivatives market through options market.

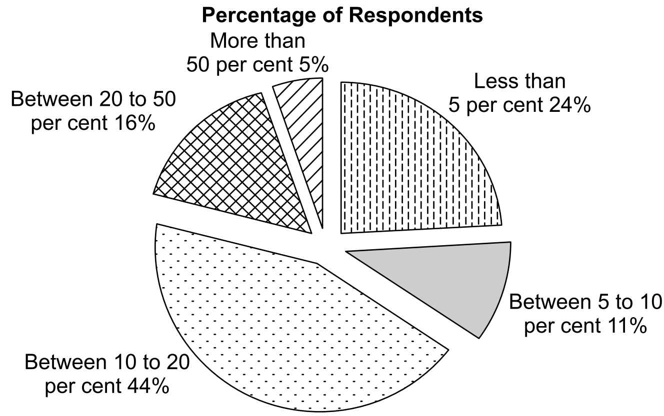

Figure 7.3 Proportion of options trading in the total trading volume relating to derivatives

It would be reasonable to infer from the above findings that the respondents of the survey have accorded relatively less weightage to options; their major interest seems to be in futures contracts. The finding for marked preference to the futures is in conformity with an earlier survey in the Indian derivatives market by Srivastava *et al*. (2008).

It was also of interest to ascertain the purpose of taking a position in options market. The results have been presented in Fig. 7.4. An overwhelming majority

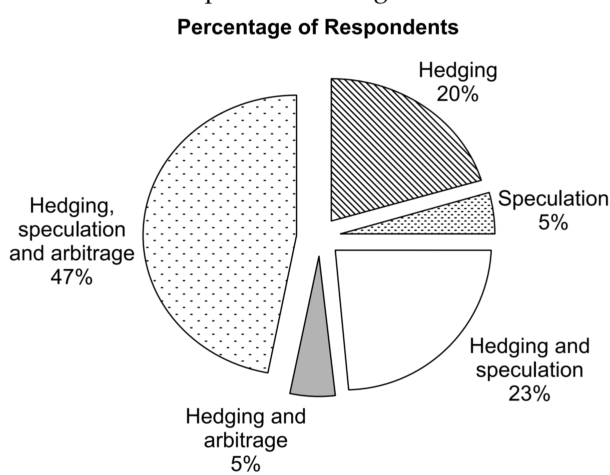

Figure 7.4 Purpose of taking a position in options market

(95%) of the respondents have been using this market primarily for hedging, in conjunction with other objectives, e.g. speculation and arbitrage. Speculation (75% of respondents), along with other purposes, has been the second most preferred objective; however, arbitrage emerged as the least preferred objective for entering the market. The findings of survey, to a marked extent, are in line with the report of the L.C. Gupta Committee (1998) on derivatives market. The Committee reported that majority of the respondents (70%) aspired to have a derivatives market to get a proper hedging mechanism for the equity portfolios.

7.4.2 Awareness and Use of Models for Options Valuation

The survey, amongst other objectives, has attempted to gauge the level of understanding amongst respondents on the important aspects of options valuation. For the purpose, the respondents of the survey have been asked on difficulty in valuing options contracts, factors that need to be considered while valuing options and the valuation models. The results relating to the difficulty in valuation of options in terms of their comparison with futures, difficulty in estimating volatility for valuing options and use of implied volatility for valuing option have been summarized in Table 7.1. The results demonstrate that the respondents have shown their strong agreement on the difficulty in valuation of options compared with futures, difficulty in estimating the volatility and using volatility for valuing options. The results have been found to be highly significant. The agreement on these aspect of options valuation, *prima-facie,* indicate that the respondents are familiar with the major difficulty in valuing an options contract.

Further, the study has attempted to assess the level of awareness amongst respondents on options valuations models and their propensity to use such models for the valuation of options. The results on awareness of valuation models are depicted in Fig. 7.5.

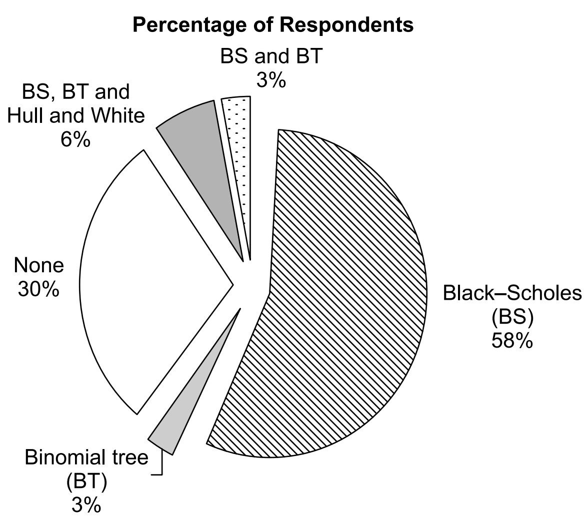

Figure 7.5 Awareness of options valuation models amongst respondents of the survey

Table 7.1 One-Sample '*T*' Test for The Statistical Validation of Agreement/Disagreement of Respondents on the Some Aspects Relating to Valuation of Options

Statement	*Number*	$\bar{X}$	σ	*Test value = 03*					
				t	*df*	*Sig.*	*Mean difference*	*95% confidence interval of the difference*	
								Lower	*Upper*
Valuation of options is more difficult than that of futures	64	4.19	0.687	**13.83**	63	**0.000**	1.188	1.02	1.36
Volatility is most difficult to be estimated	64	3.69	0.990	**5.56**	63	**0.000**	0.688	0.44	0.93
Implied volatility can be used to value the options	64	3.89	0.620	**11.49**	63	**0.000**	0.891	0.74	1.05

The results on awareness of valuation models clearly indicate that the Black–Scholes (BS) model has been found to be the most popular amongst the respondents compared with the other two models, namely Binomial-Tree (BT) model and Hull and White (HW) model. It is corroborated by the fact that two-third (67%) of the respondents have been found to be aware of the BS model; the figure has been much lower for other models. For instance, while nearly one-tenth of the respondents were aware of BT model, HW model was known to just 6% of the respondents.

It is pertinent and revealing to note that 30% of the respondents were not aware of any model. Equally notable finding is that nearly one-half of the total respondents have not been using any model despite the fact that 70% of the respondents are aware of the valuation models.

It was of interest to know from the respondents which model/models of valuation (amongst the three mentioned earlier) have been used to value the options. The results on the use of specific model are summarized in Table 7.2; it is interesting to note that the BS model is popular amongst the respondents as nearly half of the respondents (49%) have been found to be using the BS model. In sharp contrast, just 3% of the respondents have been using BT model and no respondent used HW model for valuing options. In addition to this, the consistency of awareness and use of models has been examined using cross tabulation of awareness and use of the specific models. The results are summarized in Table 7.2.

The results reveal that the 49% of the respondents who are aware of the BS model are actually using it. At the same time, 3% of the respondents who were aware of the BT model have been valuing options using this model. However, 6% of the respondents were those who claimed to be aware of all the models but actually have not been using any model.

Table 7.2 Cross Tabulation of the Responses on Awareness and Use of Options Valuation Models

			Which of the model do you use			*Total*
			BS	*BT*	*None of the above*	
Awareness of the valuation models	BS model	Count	29	0	8	37
		% of Total	45.3%	0.0%	12.5%	57.8%
	BT model	Count	0	2	0	2
		% of Total	0.0%	3.1%	0.0%	3.1%
	None of the above	Count	0	0	19	19
		% of Total	0.0%	0.0%	29.7%	29.7%
	BS, BT and HW	Count	0	0	4	4
		% of Total	0.0%	0.0%	6.3%	6.3%
	BS and BT	Count	2	0	0	2
		% of Total	3.1%	0.0%	0.0%	3.1%
Total		Count	31	2	31	64
		% of Total	48.4%	3.1%	48.4%	100.0%

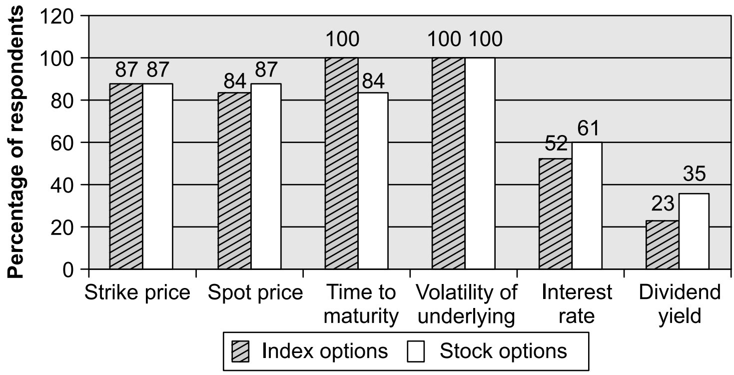

Figure 7.6 Percentage of respondents considering important factors for valuing index and stock options

Figure 7.6 contains the factors considered by those respondents who have been using BS and BT models in valuing options. The results depicted in the figure are revealing, as the respondents who are using BS and BT models in pricings options have not considered all the factors reckoned by these models in valuing options. These models, in general, include six variables, namelystrike price, spot price, time to maturity, volatility of underlying asset, interest rate and dividend yield/absolute amount of dividends, to arrive at the correct price for the options.

The vast majority of respondents (80%) have considered the first four factors in valuing index or stock options; it is surprising to note that the last two factors, namely interest rate and dividend yield, have not been used widely in valuing the options. Amongst the four most considered factors, volatility of underlying asset has been indicated as the most important factor, as all the respondents considered it in valuing the options. As far as interest rate is concerned, only 52% and 61% of the respondents have used it in valuing index and stock options, respectively; the figure is much lower at 23% and 35%, respectively, pertaining to the use of dividend yields for valuation purpose. The finding that interest rate is one of the two least considered factors for valuing options amongst respondent is in line with Srivastava *et al*. (2008). It may be noted that the consideration of dividend yield in valuation would not affect the correct prices much; however, the valuation using these models is not possible without considering the interest rate, as it is a necessary input required to determine options price.

In sum, it would be reasonable to conclude that the 'true' percentage of the respondents who are actually using the 'correct' valuation models is lower than that noted earlier (52%). The actual percentage represents the respondents who reckoned interest rate also (along with other variables) as an important factor for valuing options. Based on such a correct measure, nearly one-fourth of the respondents are actually using valuation models (BS and BT) for valuing index options. Likewise, a marginally higher percentage of respondents have been found to be actually using valuation models for pricing options.

As far as the method used for estimating volatility is concerned, half of the respondents have been found to be using standard deviation method (Fig. 7.7). In contrast, only 16% of the respondents have been using moving average models; surprisingly, the remaining one-third (34%) of the respondents were not using any model to estimate the volatility.

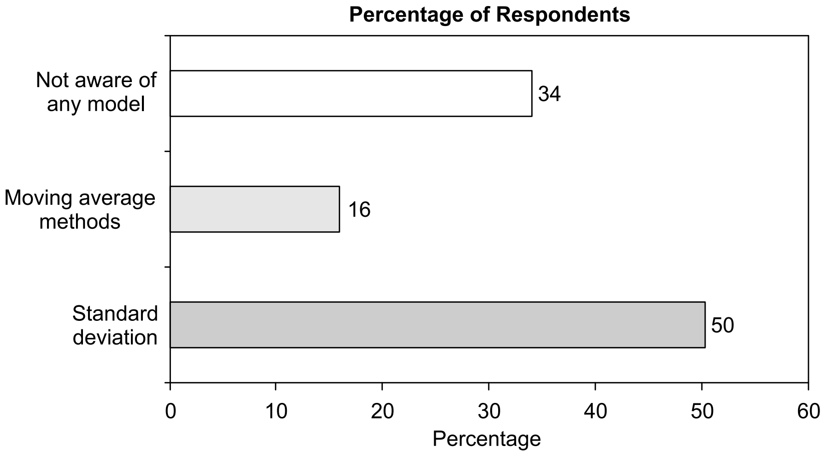

Figure 7.7 Percentage of respondents using specific model for estimating volatility

7.4.3 Understanding of Put–Call Parity Relationship

This section addresses the issue relating to the level of understanding of put-call parity (PCP) relationship amongst the respondents of the survey. The PCP condition denotes relationship between the price of a call and a corresponding put option with the same contract specification. The understanding of PCP relationship is important as it helps to identify the arbitrage opportunities (mispricing signals), which exist on account of the violation of this relationship. In other words, it helps to spot the arbitrage opportunities in terms of underpricing/overpricing of a call (put) option relative to a put (call) option with same contract specifications.

For the purpose, the questionnaire included three questions on the understanding of PCP relationship. The first is a straight question asking the participants whether they are aware of PCP; the next two questions have been asked to confirm whether they know the concept well.

The responses to the first question on PCP relationship are depicted in Fig. 7.7. The results indicate that nearly two-thirds of the respondents are aware of the PCP relationship. It is a matter of concern that nearly one-third of the respondents has shown lack of understanding of PCP relationship. However, there is a possibility that the participants might have good understanding of the concept; they might not be aware of the terminology, i.e. PCP relationship. In order to gauge the true level of awareness of the PCP relationship amongst the participants, we need to analyse these results in light of the responses to the other two questions on the parity relationship.

The responses on the next two questions have first been analysed using '*one-sample t-test*' in order to identify if the mean responses indicate a statistically significant agreement, disagreement or neutral opinion of the respondents on the PCP relationship. For the purpose, the null hypotheses tested are that the mean score $\mu = 0$ against the alternative $\mu > 3$ and $\mu < 3$ in the first and second question, respectively. The results on next two questions on PCP are summarized in Table 7.3.

The results indicate that the null hypothesis is rejected at 5% level of significance in the case of second (first in Table 7.3) question on PCP; the associated empirical value of t statistics is 3.347, which indicates that the agreement on the statement has been found to be statistically significant. In contrast, the null hypothesis could not be rejected at 5% level of significance in the case of the third (second in Table 7.3) question on PCP. It indicates that the respondents had a mixed opinion on the third question, where a disagreement was expected if they knew the concept well. The results of the third question are in contradiction with those in the case of second question. Thus, it is apparent that there is lack of proper understanding of the PCP relationship amongst the participants of the survey.

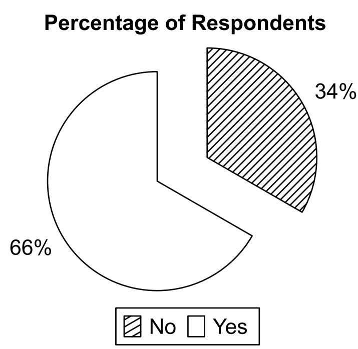

Figure 7.8 Percentage of responses on the understanding of PCP relationship

Since the first direct question has revealed that nearly one-third (34%) of the participants are not aware of the PCP relationship and the next two questions have shown contradictory results on the PCP relationship, it would be reasonable to conclude that a significant proportion of the total respondents lack correct understanding of the concept.

This issue has further been examined by using cross tabulation of responses to all the three questions on PCP relationship. The results are summarized in Table 7.4. It is pertinent to note that nearly one-third (32%) of the

Table 7.3 One-Sample *t*-test for the Responses on the PCP Relationship

Statement	*Number*	$\bar{X}$	σ	*Test value = 03*					
				t	*Df*	*Sig.*	*Mean difference*	*95% confidence interval of the difference*	
								Lower	*Upper*
Price of a European call (put) can be calculated from put (call) option with same contract specifications.	64	3.50	1.195	3.347	63	**0.001**	0.500	0.20	0.80
There is a need to calculate price of a European call and put (with same contract specifications) separately.	64	3.25	1.195	1.673	63	**0.099**	0.250	–0.05	0.55

Note: In the table, $\bar{X}$, σ and df denote mean, standard deviation and degree of freedom, respectively.

Table 7.4 Cross Tabulation of the Responses on all the Three Questions Asked on PCP Relationship

Question/Statement No. 1	*Question/Statement no. 2*			*Question/Statement no. 3*					*Total*
Awareness of put call parity				*There is a need to calculate price of call and put (with same contract specifications) separately*					
				1	*2*	*3*	*4*	*5*	
No	Price of a call(put) can be calculated from put(call) option with same contract specifications	0*	Count		0	0	2		**2**
			% of Total		.0%	.0%	9.1%		**9.1%**
		2	Count		0	0	5		**5**
			% of Total		.0%	.0%	22.7%		**22.7%**
		3	Count		0	1	4		**5**
			% of Total		.0%	4.5%	18.2%		**22.7%**
		4	Count		7	0	3		**10**
			% of Total		31.8%	.0%	13.6%		**45.5%**
	Total		**Count**		**7**	**1**	**14**		**22**
			% of Total		**31.8%**	**4.5%**	**63.6%**		**100.0%**
Yes	Price of a call(put) can be calculated from put(call) option with same contract specifications	1	Count	0	0	0	0	2	**2**
			% of Total	.0%	.0%	.0%	.0%	4.8%	**4.8%**
		2	Count	0	0	0	1	3	**4**
			% of Total	.0%	.0%	.0%	2.4%	7.1%	**9.5%**
		3	Count	0	0	1	4	0	**5**
			% of Total	.0%	.0%	2.4%	9.5%	.0%	**11.9%**
		4	Count	0	9	0	9	3	**21**
			% of Total	.0%	21.4%	.0%	21.4%	7.1%	**50.0%**
		5	Count	3	6	1	0	0	**10**
			% of Total	7.1%	14.3%	2.4%	.0%	.0%	**23.8%**
	Total		**Count**	**3**	**15**	**2**	**14**	**8**	**42**
			% of Total	**7.1%**	**35.7%**	**4.8%**	**33.3%**	**19.0%**	**100.0%**

* represents those respondents who responded to the question/statement no. 1 and 3 but did not respond to question/statement no. 2.

participants who responded negatively to the very first question (of understanding PCP relationship) have answered correctly to the next two questions. The finding is revealing and indicates that such respondents actually knew the parity relationship; perhaps, they responded to the first question negatively as they were not aware of the terminology (PCP) used for the relationship.

In addition, an equally revealing finding of the survey is that only 45% (inclusive of 2.4% of participants responded positive to the first question and had no opinion on the second question) of the participants who responded positively to the very first question on PCP relationship could respond consistently to the next two questions relating to the parity relationship. However, a major segment of such respondents (i.e. 55%) has been inconsistent in responding to the other two questions. In short, nearly one-third ($55\% \times 66\% = 36\%$) of such respondents do not have a correct understanding of the relationship.

The finding is notable as it seems that a major chunk of respondents did not understand the concept well. This finding has serious implications for the pricing efficiency of options in India, as the PCP relationship helps to identify the pricing anomalies/arbitrage opportunities relating to the relative price of call and put options and, in turn, helps to restore equilibrium in the market.

7.4.4 Correctness of Options Pricing, Its Impact and Existence and Exploitability of Arbitrage Opportunities

Another important objective of the survey has been to gauge the opinion of the respondents on correctness of options pricing, its possible impact on the core functions that the options market is expected to perform and the existence and exploitability of arbitrage opportunities. The results regarding viewpoint of the respondents on the state of options pricing and its direction (i.e. underpricing or overpricing) have been depicted in Figs 7.9 and 7.10.

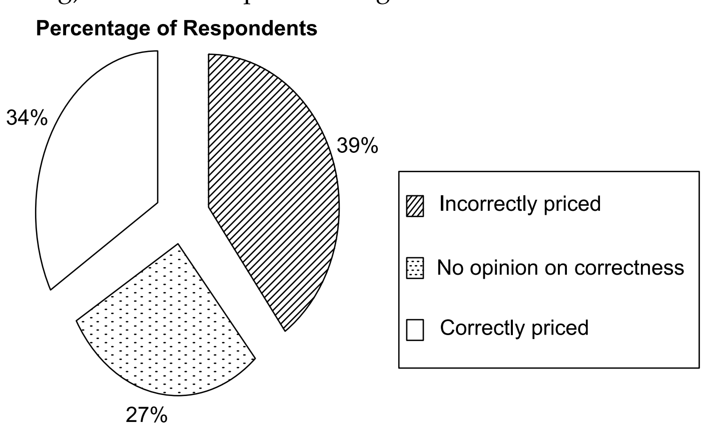

Figure 7.9 Opinion of respondents on correctness of options prices

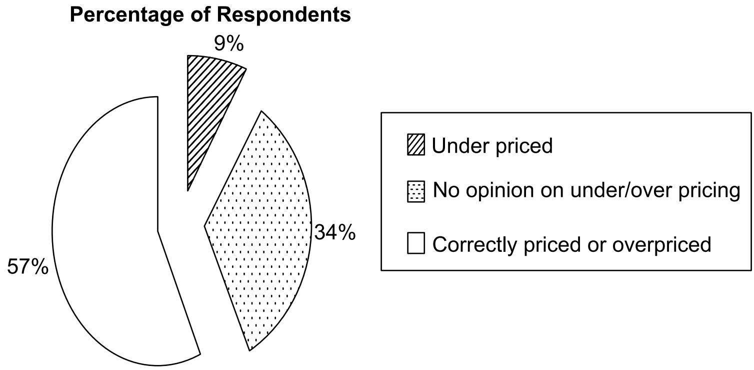

Figure 7.10 Opinion of respondents on underpricing/overpricing of options

The results depicted in Figs 7.9 and 7.10 clearly demonstrate that nearly two-fifth (39%) of the respondents have felt that the options in Indian securities market are incorrectly priced, whereas more than one-third (34%) of the respondents have believed that these are correctly priced. The remaining one-fourth (27%) of the respondents showed their inability to judge the state of options pricing in the market.

On the direction of mispricing of options contracts, only 9% of the respondents opined that options in Indian securities market are underpriced when asked for the direction of mispricing. At the same time, a major segment, i.e. 34% of the respondents, could not say anything on the issue. Majority of the respondents, who represents 57% of the participants, were of the opinion that options are not underpriced, i.e. these could either be correctly priced or overpriced. In order to deduce the percentage of respondents who have believed that options are overpriced, the responses on these two dimensions of options pricing (namely viewpoint on the state of pricing and direction of mispricing, if any) have been cross tabulated. The results are demonstrated in Table 7.5 and Fig. 7.11.

Table 7.5 Correctness of Options Pricing in Indian Market: Trading Members' Perspective

Category of respondents	*Percentage*
Incorrectly priced and overpriced	24
Incorrectly priced and underpriced	9
Incorrectly priced and no opinion on under/overpricing	11
No opinion on correctness and under/overpricing	22
Correctly priced	34
Total	100

In addition to the findings mentioned earlier in this respect, it follows from the cross-tabulation that nearly one-fourth (24%) of the respondents have believed that options were overpriced. Notably, an important segment (33%)

of the respondents had no opinion on the state of pricing in the market. In sum, it can be inferred from the results that more than two-fifth (44%) of the respondents felt that options in Indian securities market are priced incorrectly and, therefore, indicates pricing inefficiency in Indian options market.

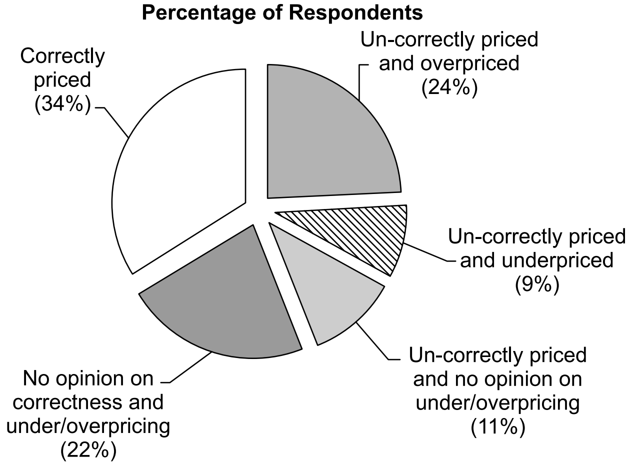

Figure 7.11 Cross tabulation of respondents on correctness and under/overpricing of options

Also, the survey has attempted to gauge perception of the respondents regarding the impact of incorrect pricing on the core functions of the options market, namely risk hedging and price discovery. For the purpose, the respondents have been asked on the probable impact of mispricing on price discovery in underlying's market and hedging efficiency. The majority of the respondents agreed on the likely impact of such pricing anomalies, as a significant segment (78%) of the participants perceived that correct pricing leads to correct price discovery in underlying's market; an approximately equal percentage of respondents (80%) felt that incorrect options pricing lessens the hedging efficiency of such instruments.

The results of *t*-test corroborate the above findings, as the opinion of respondents on the impact of mispricing on price discovery and risk hedging has been found to be highly significant (Table 7.6). The high level of significance along with the positive value of the *t*-test statistic confirm the agreement on these issues, viz. incorrect options pricing results in incorrect price discovery and decreases the hedging efficiency of options.

Further, we attempted to gauge the viewpoint of respondents on existence and exploitability of arbitrage opportunities in Indian options market. A whooping number of respondents (94%) agreed that the arbitrage opportunities do exist in Indian options market. As far as attempting to gain from the arbitrage opportunities is concerned, the results (summarized in

Table 7.6 One-Sample '*t*' Test for the Statistical Validation of Agreement/Disagreement of Respondents on the Impact of Incorrect Pricing of Options on Price Discovery and Hedging Efficiency

Statement	*Number*	$\bar{X}$	σ	*Test value = 03*					
				t	*df*	*Sig.*	*Mean difference*	*95% confidence interval of the difference*	
								Lower	*Upper*
Correct options pricing ensures pricing discovery	64	3.69	1.082	5.083	63	0.000	0.688	0.42	0.96
Incorrect options pricing lessens hedging efficiency	64	4.05	0.881	9.510	63	0.000	1.047	0.83	1.27

Fig. 7.12) indicate that more than 80% of the respondents had actually tried for the arbitrage in the options market. However, amongst these respondents, more than one-fourth (27%) of the respondents have attempted to gain from arbitrage quite frequently, majority of respondents (i.e. 65%) have not attempted frequently, and a meager 8% of such respondents rarely tried such strategies.

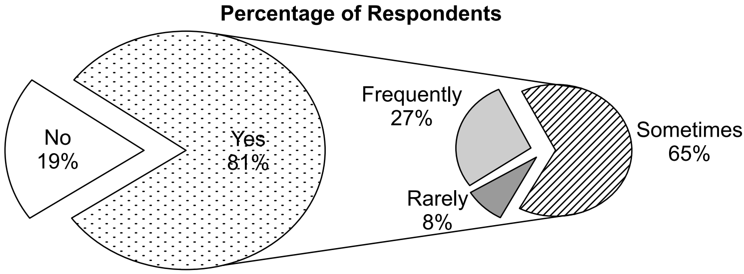

Figure 7.12 Percentage of respondents who attempted to gain from arbitrage opportunities along with their frequency of such attempts

In an equally important finding, responding to the ease of exploiting arbitrage opportunities in Indian options market, less than one-third (31%) of the respondents feels that the opportunities can be easily exploited, as summarized in Fig. 7.13. In sharp contrast to this, a major segment of the respondents opine that such opportunities are either difficult to exploit or cannot be exploited at all.

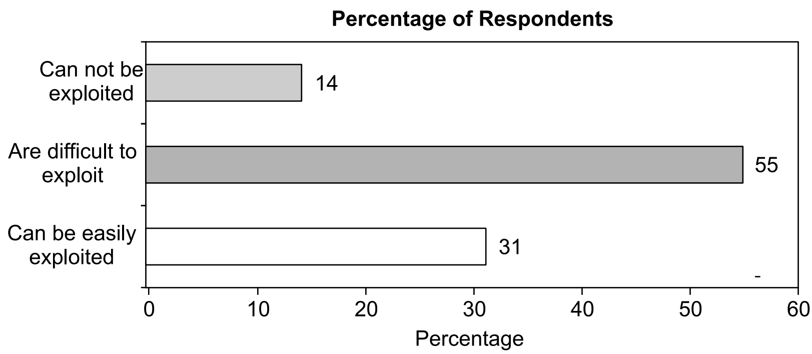

Figure 7.13 Opinion of respondents on exploitability of arbitrage opportunities

Further, the responses on ease to exploit arbitrage opportunities have been examined in terms of the frequency of attempts that the respondents make to exploit such profit opportunities. The results are summarized in Table 7.7. The findings reveal that approximately 5% of the respondents who never attempted to gain from such opportunities have opined that the opportunities can easily be exploited. This may be attributed to the fact that such respondents, perhaps, do not understand the arbitrage mechanism very well. At the same time, in a natural response, nearly one-sixth (14%) of the respondents who never attempted to gain from such opportunities assigned difficulty in exploiting it as the major reason. Similarly, more than two-fifth (41%) of the total respondents who have attempted to gain from such arbitrage opportunities feel that these have been difficult to exploit whereas 6% of such respondents believed that such opportunities have been unexploitable.

Table 7.7 Cross Tabulation of Frequency of Exploiting Arbitrage and Opinion on Exploitability of Such Opportunities

			Ease of exploiting arbitrage opportunities			*Total*
			Can be easily exploited	*Are difficult to exploit*	*Can't be exploited*	
If yes, How frequently	Never	Count	3	9	0	12
		% of Total	4.7%	14.1%	.0%	18.8%
	Frequently	Count	4	7	3	14
		% of Total	6.3%	10.9%	4.7%	21.9%
	Sometimes	Count	12	17	5	34
		% of Total	18.8%	26.6%	7.8%	53.1%
	Rarely	Count	1	2	1	4
		% of Total	1.60%	3.10%	1.60%	6.3%
Total		Count	20	35	9	64
		% of Total	31.3%	54.7%	14.1%	100.0%

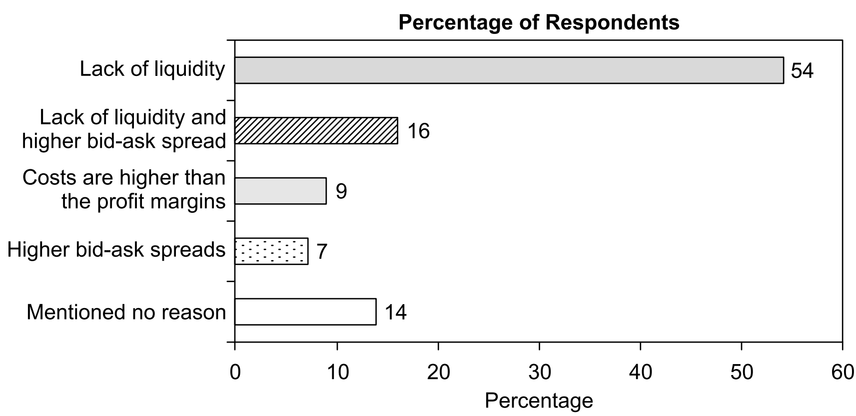

Figure 7.14 Perceived reasons for inability to exploiting arbitrage opportunities

The majority of the respondents (64%) who felt that the arbitrage opportunities had been difficult to exploit or not exploitable at all were of the opinion that dearth of liquidity in the options market was the major reason for their inability to exploiting such opportunities. Higher bid–ask spread had been cited as the second major reason for this. Notably, higher bid-ask spreads essentially can be traced to the dearth of liquidity. In operational terms, the investors who feel this as the reason for inability to exploiting arbitrage indirectly signal liquidity as the main reason.

In sum, therefore, it would be appropriate to conclude that a vast majority (79%) of such respondents perceived dearth of liquidity as the major reason for inability to exploiting arbitrage opportunities. This apart, nearly one-tenth (9%) of such respondents felt that cost associated with such opportunities had been higher than the profit margins expected from such opportunities.

It is surprising to note that none of the respondents mentioned any of the market frictions, e.g. short-selling constraint in the market, as a reason for their inability to exploiting from arbitrage opportunities. The finding suggests that respondents are either using futures market to overcome the short-selling constraint or they are not using the arbitrage strategies which require use of short-sell. However, the latter seems to be the more probable reason as in the absence of short-selling mechanism, the futures market cannot be expected to be correctly priced and, therefore, would not be able to identify the arbitrage in all the cases even if the options market is inefficient. In sum, it would be reasonable to conclude that the respondents do not seem to be aware of arbitrage opportunities that require short-selling mechanism in place.

7.4.5 Need of Regulations and Educational Initiatives for the Betterment of the Options Market

It was also of interest to gauge the opinion of the respondents on aspects related to regulations and educational initiatives needed for the betterment of the options market in India. While a sizable majority (70%) of the respondents felt that a self regulatory mechanism would be preferable to the imposed regulations, one-fourth of the respondents supported need of regulations to restore equilibrium in the options market. Another notable finding of the survey is that the proposal to introduce a price band in order to ensure the correct pricing of options has been rejected by the majority (53%) of the respondents. One-sample *t*-test has been used to statistically validate the agreement or disagreement on the proposed regulations for the betterment of the market. The results are summarized in Table 7.8.

The results of the test regarding the regulations as an initiative for the betterment of the market has been rejected at 5% level of significance. This validates disagreement of the respondents on the possibility of further regulations for the development of the market. However, it is surprising to note that the hypothesis on the proposal of a price band could not be rejected at 5% level of significance. In other words, while a majority of respondents rejected the proposal of launching a pricing band for regulating options prices in the market, the statistical validation of disagreement could not be achieved. In sum, it would be reasonable to infer that the respondents have a negative view on regulations for the betterment of the market.

Table 7.8 One-Sample *t*-Test for the Statistical Validation of Agreement/Disagreement of Respondents on Regulations for the Betterment of the Options Market

Statement	*Number*	$\bar{X}$	σ	*Test value = 03*					
				t	*df*	*Sig.*	*Mean difference*	*95% confidence interval of the difference*	
								Lower	*Upper*
Options prices need to be regulated	64	2.61	1.40	**– 2.23**	63	0.029	– 0.391	– 0.74	– 0.04
A price band should be put in place	64	3.03	1.32	**0.19**	63	**0.851**	0.031	–0.30	0.36

Besides, the opinion of respondents was also sought on the need of educational initiatives for the development of the market. For the purpose, the survey has attempted to gauge the awareness and sufficiency of educational initiatives from SEBI, NSE and BSE. Further, the respondents were asked on need of more education on derivatives to the investors, creating a separate body for the same and the ownership pattern for such an organization.

The results on level of awareness amongst respondents on existing educational initiatives of SEBI, NSE and BSE along with their opinion on the adequacy of such measures have been depicted in Fig. 7.15. The results demonstrate that a significant segment (74%) of the respondents have been found to be aware of such initiative; however, one-fourth (26%) of respondents revealed their ignorance on such educational initiatives. A notable finding of the survey is that amongst those who were aware of educational initiatives, a majority (70%) of such respondents felt that the existing initiatives are not sufficient. In short, the survey indicates that the existing educational initiatives are not adequate; some more educational initiatives are needed for increasing participation of investors in the options market.

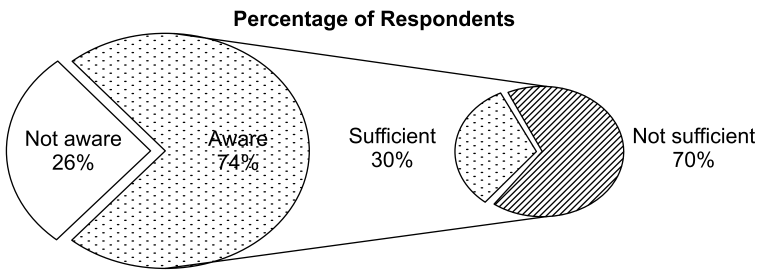

Figure 7.15 Level of awareness on existing educational initiatives amongst respondents and their opinion on sufficiency of these initiatives

On the educational initiatives for the investors, the respondents were asked on three aspects—(i) the need of educating investors more on the derivatives, (ii) opinion on creating a separate body for the purpose and (iii) the acceptable ownership pattern for the proposed educational body. The results regarding the first two aspects have been summarized in Table 7.9 and the responses to the third aspect have been depicted in Fig. 7.16.

In an overwhelming response to the need of more educational initiatives, a vast majority (94%) of the respondents felt that enhanced educational initiatives for investors' education need to be put in place. As a solution to the warranted increase in educational initiatives, more than four-fifth (84%) of the respondents agreed that a separate non-profit organization should be created to carry out this task. The agreement on these two proposals so observed has been supported statistically as well (Table 7.9). With respect to the ownership of the proposed educational organization, a major segment of the respondents has given first priority to the Public Private Partnership (PPP).

Table 7.9 One-Sample *t*-Test for the Statistical Validation of Agreement/Disagreement of Respondents on the Enhanced Educational Initiatives

Statement	*Number*	$\bar{X}$	σ	*Test value = 03*					
				T	*df*	*Sig.*	*Mean difference*	*95% confidence interval of the difference*	
								Lower	*Upper*
Need of more education on derivatives	64	4.55	0.75	16.40	63	0.000	1.547	1.36	1.74
Need of a separate body for educating investors on derivatives	64	3.89	0.86	8.31	63	0.000	0.891	0.68	1.10

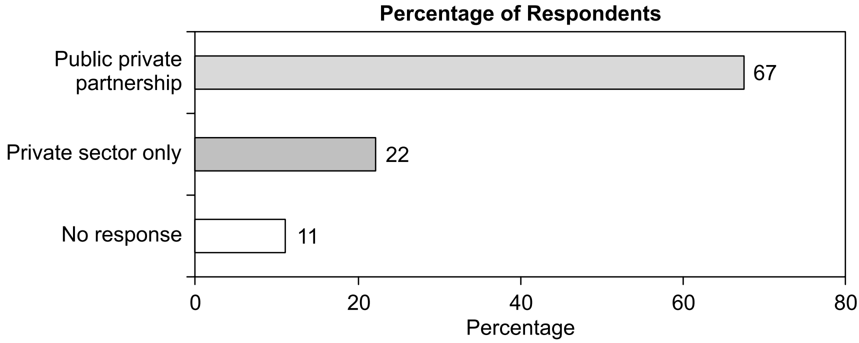

Figure 7.16 Respondents' view point on the ownership pattern of the proposed educational entity

In short, the respondents of the survey showed a clear agreement on enhanced education for investors' on derivatives and strongly felt a need for a separate educational body with the PPP ownership pattern.

7.5 CONCLUDING OBSERVATIONS

This study attempts to gauge the opinion of trading member organizations on the state of options pricing in Indian derivatives market. For the purpose, a survey has been carried out amongst the trading member organizations based at Delhi and Mumbai. The survey has dealt with five major aspects, namely (i) level of participation and usage of the options market, (ii) awareness and use of models for options valuation, (iii) understanding of PCP relationship, (iv) correctness of options pricing, its impact and existence and exploitability of arbitrage opportunities and (v) need of regulations and educational initiatives for the betterment of the market.

With respect to the participation and usage of options market, a vast majority of participants has been found to be involved in trading in futures market as nearly 80% of the respondents had less than 20% of their trading volume relating to derivatives from the options market. The finding clearly demonstrates that futures are preferred by respondents of the survey; options carry lower weight in their derivatives portfolio.

It is satisfying to note that the usage of options market in terms of risk hedging, speculation and arbitrage has been, to a greater extent, in line with the findings of the L.C. Gupta committee (1998).

In addition, the survey attempted to gauge the level of awareness and use of valuation models for valuing options. In this respect, it is surprising to note that only nearly one-fourth (27%) of the respondents have been found to be actually using the valuation models for the purpose of valuing index options; nearly one-third (32%) of the respondents have been using such models in the case of option on individual stock. Another notable finding of the survey is that a major segment of respondents did not understand the concept of PCP relationship well. It is eloquently corroborated by the fact that nearly three-fifth (59%) of the respondents was not aware of the relationship. This might have serious implications for the pricing efficiency of options in India, as the PCP relationship helps to identify the pricing anomalies/arbitrage opportunities relating to the relative price of call and put options and, in turn, helps to restore equilibrium in the market. These findings indicate that the level of understanding of valuation concepts amongst the market participant has been considerably low.

Besides, majority of the respondents perceived that options in Indian securities market are not correctly priced, causing arbitrage opportunities to exist in the market. However, it is pertinent to note that the dearth of liquidity has been the major constraint to arbitrageurs to gain from such opportunities. An equally revealing finding of the survey is that no respondent felt that the short-selling has been one of the major constraints to exploiting arbitrage in the market.

As far as the response for the educational initiatives for the betterment of the market are concerned, the vast majority of respondents strongly feel the need of enhanced investors' education on derivatives and recommend for a separate educational body with the PPP kind of ownership pattern.

In view of the above findings, it would be reasonable to suggest that a separate educational body should be put in place for educating investors more on derivatives. Such an organization, in Indian context, could be proposed in line with its developed counterpart, the USA, where a fully independent organization known as Options Industry Council (OIC) is devoted to enhancing investors' knowledge on options contracts. Such an organization may be financially supported by the stock exchanges facilitating derivatives trading in India, e.g. NSE, BSE and MCX along with the market regulator SEBI and Clearing Corporations in India. Moreover, such an organization should not only be disseminating education amongst investors, all the employees of the trading member organization who are actively managing the derivatives segment should be trained regularly on the derivatives (especially options), as lack of adequate understanding of the options market amongst participants could not be ruled out. Such an organization would, to a marked extent, enhance participation in derivatives market and help the market to operate closer to the equilibrium, as the liquidity has been the biggest constraint to the arbitrageurs.

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Glossary

American option An option contract that can be exercised on or up to the expiration date of the contract.

AR Autoregressive models are those models that include lag(s) of the dependent variable as explanatory variables for modeling the dependent variable.

ARCH Autoregressive Conditional Heteroscedasticity—A time-series model used to deal with the financial time-series data exhibiting variance that is not constant over time. These models use past observations of variance to forecast future variance.

ARIMA Autoregressive Integrated Moving Average models are used to model the time-series data that exhibit a trend along with the 'autoregressive' and 'moving average' characteristics.

ACF Autocorrelation Function represents the correlation sequence of a random time series with itself. This is used to test the autoregressive and moving average tendency of a time series data.

Bid The price at which market participants are willing to buy an asset.

Brokerage firm A firm or person engaged in executing orders to buy or sell futures contracts for customers. A full service broker offers market information and advice to assist the customer in trading. A discount broker simply executes orders for customers.

Call option An option contract that gives a right, but not an obligation, to its holder to buy the underlying asset at a specified price.

Cash price Also called spot price and represents the current market price of an asset.

Cash settlement Final disposition of open positions on the last trading day of a contract month. Such settlement occurs in the market where there is no physical delivery or for

	the assets where physical delivery is not possible (e.g. index).
Clearing house	A market intermediary associated with the stock exchange, responsible for the settlement of trading accounts, clearing trades, collecting, regulating delivery and reporting trading data.
Conditional models	Time-series techniques with explicitly specified dependence on the past sequence of observations.
EGARCH	Exponential Generalized Autoregressive Conditional Heteroscedasticity is one of the time-series models used to estimate the variance of a time series where innovations contribute asymmetrically, depending on their sign, to the variance of the series.
European options	Options that can be exercised only at the expiration date of the contract.
Exercise price (also known as strike price)	The price at which the holder (buyer) can purchase or sell the underlying asset.
Expiration date	The date beyond which the contract has no value.
Forward contract	A private agreement between buyer and seller for the future delivery of an asset at an agreed price.
Futures contract	A standardized form of forward contract. The futures, unlike forwards, are traded on an exchange. These contracts typically include mark-to-market feature to contain the risk that emanates from daily movement in the value of the underlying asset.
GARCH	Generalized Autoregressive Conditional Heteroscedasticity is a time-series model used to estimate the variance of a time series where innovations contribute symmetrically, irrespective of their sign, to the variance of the series.
Hedging	The process of protecting the value of an asset against the unfavourable movement in the market. This typically aims at reducing variations in the value of an asset.
Heteroscedasticity	It refers to the time-dependent variance of time-series data.
Homoscedasticity	It refers to the time-independent nature of volatility (constant volatility over time) of time-series data.
Long position	When a market participant purchases an asset or a contract to purchase the underlying asset, he is said to have taken a long position.

MA model	Moving average models include past observations of the innovations (noise) in the forecast of future observations of the dependent variable of interest.
Mark-to-market	The daily adjustment of a futures account in response to changes in the price of a futures contact to reflect profits and losses. This represents the risk containment measures in the futures market.
MSE	Mean square of error–A statistical measure used to examine the forecasting ability of different models under consideration by looking at the deviation of the model generated forecasts from the realised values.
Non-simultaneity	This refers to the phenomenon of different timings of closing transactions in the two markets (e.g. the options market and the underlying's cash market).
Open interest	Total number of futures or options that have not yet been settled.
Option contract	A contract which gives a right, but not an obligation, to its holder to buy or sell the underlying asset at a specified price within a specified time period.
Option buyer	One who purchases an option and pays a premium.
Option seller or Option writer	One who writes an option and receives a premium.
Put option	An option contract which gives a right, but not an obligation, to its holder to sell the underlying asset at a specified price.
Settlement price	A figure determined by the closing range of prices after a trading session that is used to calculate gains and losses in futures market accounts.
Short position	This refers to selling of an asset without actually having it. The process of short-selling is generally executed through a borrowing and lending mechanism, which allows this process to take place in a legal way.
Speculator	A market participant who attempts to make profit from the anticipated changes in the price of an asset.
Trading volume	The number of contracts traded during a specified period of time, e.g. daily.
Volatility	An annualized measure of the fluctuation in the price of an asset.

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