An Empirical Test of Efficiency of Exchange-traded Currency Options in India

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Abstract

The objective of this paper is to examine efficiency of the exchange-traded currency options market in India. Put-call-futures parity for the USD-INR currency options is studied by analyzing daily closing prices of options and futures for thirty two months on the National Stock Exchange. The study reveals frequent violations of the put-call-futures parity creating significant arbitrage opportunities. The pattern of mispricing varies when examined for time to maturity, moneyness of strike, liquidity and volatility of the underlying. These observations are consistent with those of studies of other young markets.

Keywords: put-call parity, efficient markets, currency options

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Integrated and well-functioning financial markets are known to have a number of benefits such as efficient allocation of capital, better price discovery and better risk-sharing. An integrated financial market would imply that identical assets with the same risk would have the same expected return. This is embodied in the theoretical principle of Law of One Price. Integration between domestic spot and derivatives markets is of prime importance. This is captured in the principle of put-call parity which states that when there are no arbitrage opportunities one can replicate a derivative instrument in terms of the spot price of the underlying asset and by borrowing or lending as appropriate. A violation of the put-call parity condition would therefore imply that the spot and derivatives markets are not integrated or efficient. Option markets form a very important component of the derivatives markets. A number of studies in finance theory have tested the efficiency of option markets in different countries either by applying specific option-pricing models or by conducting model-independent tests. The latter can be further categorized into tests of cross-market efficiency such as the put-call parity and lower boundary tests and tests of internal efficiency such as call-put spreads and box-spreads. This paper attempts to determine whether the market for exchange-traded currency options in India is efficient.

Exchange-traded derivatives were introduced in India only in the year 2000 when the Securities and Exchange Board of India (SEBI) permitted stock exchanges to introduce trading of index futures contracts based on the Nifty and Sensex. Trading of index options and futures and options on individual securities was allowed soon after. While trading of equity futures and options quickly gathered momentum currency derivatives continued to be traded in the over-the-counter market dominated by banks. A joint RBI-SEBI committee permitted the trading of futures contracts on the USD-INR pair on the National Stock Exchange (NSE) from August 2008. The success of these contracts led to the introduction of futures contracts on three other currency pairs. Trading of options on the USD-INR was allowed on the NSE from October 29, 2010. The number of currency option contracts traded on the NSE has grown exponentially from 3,74,20,147 during 2010-11 to 27,50,84,185 during the year 2012-13 while the notional turnover increased from Rs.1.71 crore to Rs.15.09 crore over the same period. The average daily turnover in the currency derivatives segment of the NSE increased from Rs.13854.57 crore in 2010-11 to Rs.21705.62 crore in 2012-13. While average daily turnover in the currency derivatives segment is much smaller than that of the equity derivatives segment of the NSE which was Rs.1,26,639 crore during 2012-13, it is significant considering the relative newness of the currency derivatives segment. The FIA 2012 Annual Volume Survey of the Futures Industry ranked the USD-INR currency futures contract traded on the NSE as the top foreign exchange futures contract traded globally during the calendar year 2012 according to number of contracts traded. Similarly the USD-INR currency options contract traded on the NSE was ranked at number four during the same period. In view of the rising global significance of the Indian exchange-traded currency derivatives segment it is imperative to examine the efficiency of this market. We test the efficiency by examining if put call parity holds for currency options and futures on the USD-INR traded on the NSE. While testing for parity we use currency futures instead of the spot exchange rate because it would be practically easier to arbitrage between the currency options and futures instead of the currency options and the spot rupee. This is because the rupee is not a liquid and fully convertible currency and hence it is not possible for retail investors or even exchange non-bank members to take large long or short positions in the rupee in order to exploit the arbitrage opportunity.

The rest of the paper is organized as follows. Section II describes the specifications of the USD-INR option contract traded on the NSE which is the subject of this study. Section III reviews the existing literature on efficiency of the options market. Section IV discusses the put-call parity condition. Section V explains the data and methodology adopted and the results of the analysis are discussed in Section VI. Section VII compares the results with those of other similar studies and concludes.

II: The USD-INR option contract

The USD-INR option contract is a European style contract with the underlying being the exchange rate in Indian rupees for one US Dollar. Each contract is for a notional value of 1000 USD but the premium for the contract is quoted in Indian rupees. The tick size of the contract is 0.25 paise. The exchange introduces for trading three serial monthly contracts followed by one quarterly contract of the cycle March/June/September/December at any given time. It makes available at a point of time twelve in-the-money, twelve out-of-the money and one near-the-money contracts for both calls and puts with strike prices at an interval of 25 paise. The contract is traded between 9.00 am and 5.00 pm from Monday to Friday so as to coincide with the trading hours of the inter-bank forex market in India. The contract expires at 12 noon two business days prior to the last business day of the expiry month. The final settlement takes place on the last working day (excluding Saturdays) of the expiry month and the last working day is the same as that for inter-bank settlements in Mumbai. The RBI reference rate for the USD-INR on the date of expiry is the final settlement price of the option contract. The contract is settled in cash in Indian rupees. The regulators have specified separate limits for gross open positions for various market participants such as trading members who are banks, non-bank trading members and clients. The margins to be charged and the mode of margin computation have also been specified by the regulator.

III: Literature Review

Two distinct strands can be observed in the existing literature on option market efficiency. One approach is a model-based one in that a specific model such as the Black-Scholes model or the Binomial model is used for deriving the theoretical option price which is then compared with the market price to identify the mispricing. The extent of mispricing is then tested for its statistical significance. A problem with the model-based approach is that it involves testing of two hypotheses simultaneously – first that the model itself is valid and the second, that the market is efficient; and the test is not able to distinguish between the two hypotheses (Galai, 1977). The second approach involves (a) testing for violation of no-arbitrage relationships between option and spot or futures prices (put-call parity or lower boundary conditions) which is known as test of cross-market efficiency or (b) testing for violation of no-arbitrage relationships between option prices alone (call-put spreads, box spreads etc) which is known as test of internal market efficiency. The second approach is less restrictive than the first because it is not based upon specific assumptions regarding the distribution of the price of the underlying and estimation of its volatility. As such it has been adopted by many researchers in different option markets. Klemkowski and Resnick (1979, 1980), Evnine and Rudd (1985), Chance (1988), Fung and Chan (1994), Kamara and Miller (1995), Lee and Nayar (1993) all study the arbitrage-free relationships between options and futures in the US market. While Evnine and Rudd find frequent violations of put call parity, Chance, Fung and Chan, Kamara and Miller and Lee and Nayar find less frequent violations and hold that the market is generally efficient. Capelle-Blancard and Chaudhury test violation of put-call parity in the French CAC40 index options market and find reduced violations after accounting for transaction costs. Zhang and Lai (2006) examine put-call parity in the Hong Kong derivatives market during the period 2002-2004 and find that though parity is violated the arbitrage is not exploitable in a number of cases. They therefore conclude that the markets are priced efficiently, Brunetti and Torricelli (2007) study the Italian Index options market and find very few arbitrage violations but higher average profits than in the US market. Vipul (2008) studies put-call-index parity and put-call-futures parity for Nifty options and finds frequent violations of both conditions. Most of the earlier research is focused on equity options and futures. To the best of our knowledge there has been no study so far in India about arbitrage between currency options and futures given the novelty of these instruments in India.

IV: Put-Call parity explained:

The put-call parity principle was first expounded by Stoll (1969) and later generalized by Tucker (1991) to put-call-futures parity. The principle states that the put, call and the underlying security are inter-related so that any two of these can be combined so as to yield the pay-off of the third instrument. The relationship between a call and a put option on a foreign currency and the spot value of the foreign currency can be stated as:

$$c + Xe^{-r(T-t)} = p + Se^{-q(T-t)} \qquad (1)$$

Where

c = European call option price expressed in domestic currency for a given strike price

p = European put option price expressed in domestic currency for the same strike as the call

X = strike price of the call and the put

S = spot price in domestic currency for one unit of foreign currency

r = domestic risk-free interest rate

q = foreign risk-free interest rate

T-t = time to expiry of the option

Since the spot price can be expressed as the discounted futures price we have

$$c + Xe^{-r(T-t)} = p + Fe^{-(r-q)(T-t)}e^{-q(T-t)}$$

Where F = the currency futures price

Or

$$c + Xe^{-r(T-t)} = p + Fe^{-r(T-t)} \quad (2)$$

From the above we can derive the theoretical or fair price of a call option as:

$$c = p + (F - X)e^{-r(T-t)} \quad (3)$$

Or

$$c - p - (F - X)e^{-r(T-t)} = \acute{\varepsilon} \quad (4)$$

The left-hand side of equation (4) above is the pricing error which we denote as έ and should ideally be equal to zero. If έ is greater than zero then the call is overpriced (put underpriced and futures underpriced). A trader can then enter into a long-futures arbitrage by shorting the call, taking a long position in the futures and the put and borrow an amount equal to present value of the strike price at the risk-free rate and hold these positions till expiry. If έ is less than zero, then the call is underpriced (put overpriced and futures overpriced). A trader can then enter into a short futures arbitrage by shorting the futures and the put, taking a long position in the call and investing an amount equal to the present value of the strike price at the risk-free rate and hold the positions till expiry. For any arbitrage to be profitable the pricing error should exceed the explicit and implicit costs of trading.

V: Data and Methodology adopted

The data for testing includes daily closing prices of options and futures on the USD-INR exchange rate traded on the NSE from October 29, 2010 till June 30, 2013. We first match a call option with a specific strike and expiry date with a put option of the same strike and expiry date and then match this pair with a futures contract with the same expiry date. We thus have 11,481 triplets of calls, puts and futures for the above period. Owing to the short trading history of USD-INR options we have considered the entire data set without omitting the early days of trading. We have also not excluded observations from the week prior to expiry as we intend to study the effect of time to maturity on the magnitude and frequency of mispricing. Using daily closing prices instead of time-stamped transaction data exposes us to the problem of non-synchronicity of data. Hence our results should be treated with caution. Similar studies based on transaction data use ex-ante tests to examine market efficiency. According to Galai (1977), ex-ante tests are the true test of market efficiency as they involve testing whether an opportunity can be practically exploited by the market participant after a time lag. We have not been able to conduct ex-ante tests in the absence of intra-day data and our results are based purely on ex-post tests.

We use the yields of Treasury Bills with the maturity closest to the maturity of the option as the risk-free rate of return. The yields have been retrieved from publications of the RBI and have been converted to continuously compounded rates by the formula:

$r_{cc} = \ln(1 + r)$

While incorporating transaction costs in the study we consider two scenarios; the first is a frictionless world without any trading costs and the second is a scenario with explicit trading costs. We ignore implicit trading costs in the form of the bid-ask spread because the data set of closing prices does not include the closing bid-ask quotes. Moreover it would be simplistic to assume a common bid-ask spread for all strikes because there is a wide variation in the spread according to the strike price and the expiry month. However the bid-ask spread is given due weight when we examine the mispricing from the point of view of liquidity and maturity of the options. We ignore the opportunity cost for margin deposits as it is possible for members to post collateral in the form of securities for the purpose of margin. Some brokerages also allow retail investors to place specified securities as collateral for margin. We also ignore daily mark-to-market of the futures and short option position for the sake of simplicity.

For the purpose of computing explicit trading costs, we classify the market participants into two broad categories: members of the exchange and non-members (retail investors). We ignore institutional investors as their trading cost would be largely based on their relationship with the brokers and hence difficult to estimate for all institutional investors in general.

Transaction costs for Members of the Exchange

Members do not have to pay any brokerage on their proprietary trades. The main components of explicit costs for members are as follows:

a) Transaction charges of the Exchange: The NSE collects transaction charges from its members at the rate of Rs.1.15 per lakh rupees based on the turnover in case of futures and at the rate of Rs.40 per lakh rupees of premium in case of options. The Exchange started collecting these charges only from August 22, 2011 and hence these charges have been deducted only for the period from this date.

b) SEBI turnover fees and Stamp Duty: These are charged on the turnover in case of futures and the sum of premium and the strike price in case of options. The SEBI turnover fees are charged at Rs.10 per crore. Since stamp duty is levied by individual state governments we have considered the duty levied by the Government of Maharashtra which is Rs.200 per crore.

Transaction costs for Non-Members (Retail Investors)

a) Brokerage: Retail investors trade through members of the exchange and hence pay brokerage. There has been a marked shift in the manner of charging brokerage as investors became more risk-averse after the credit crisis and slowdown of 2008. A number of discount-brokerages sprang up with brokerages as low as Rs. 9 per lot. Even existing full-price brokerages started offering schemes whereby a client could pay a fixed amount for a month or a year and a low brokerage would be charged per lot traded. For the purpose of this study we have not assumed any fixed amount of brokerage for the retail investor but a percentage cost per trade. Specifically we have assumed a brokerage of 0.01% for futures and 0.006% for options as charged by leading discount brokers.

b) Transaction charges of the Exchange: We have assumed transaction charges of Rs.160 per Rs. crore for futures transactions and Rs.7000 per crore of premium in case of options trades in line with that followed by many discount brokerages. Again these have been considered only for the period from August 22, 2011.

c) SEBI turnover fees and Stamp Duty: SEBI turnover fees have been considered at Rs.10 per crore. Stamp duty has been reckoned at 0.002% and 0.01% for futures and options respectively.

If there is a mispricing a trader would execute three trades simultaneously, take a long (short) position in a futures contract and a put and a short (long) position in the call. We compute the costs for these three trades and assume that these positions are held till expiry so that there are no costs attached to the second leg of the strategy.

Computation of the arbitrage gain

The gain from mispricing arrived as per equation (4) above is converted into an annualised rate of return so as to arrive at the gross percentage of mispricing. The explicit trading costs are computed for each triplet of futures and options separately for members and non-members. The net amount of mispricing is then annualized to arrive at the actual arbitrage gain that can be exploited by members and non-members.

VI: Results

All results are detailed in Tables 1 to 9 after the section on References. Of the 11,481 triplets analysed, the call option is correctly priced only in three cases. The call is overpriced (put underpriced) in 5471 cases while the call is underpriced (put overpriced) in 6007 cases. The mean amount of mispricing is Rs.0.06 for both cases of mispricing. The mean annualized return before trading costs is 4.54%. However the mean gross annualized return is 4.66% which is slightly higher for positive mispricing or overvalued calls and long futures arbitrage than the gross annualized return of 4.44% for overvalued puts or short futures arbitrage. This result is in line with that of Fung et al (1997) and Cheng et al (1998) who find that long futures arbitrage is more profitable. Despite the very large number of instances of mispricing (99.97%) the instances of profitable arbitrage (after accounting for explicit costs) are 9,268 (80.75%) for members of the exchange and only 5,147 (44.84%) for retail investors. As may be expected members are in a better position to exploit the arbitrage due to their lower trading costs. The mean annualized return on the arbitrage after accounting for explicit costs is 5.25% for members and 7.93% for retail investors. The higher net return for non-members is contrary to expectations because non-members always face higher trading costs. However in case of non-members the marginal trades get removed and only the profitable ones remain. It is possible to earn a net return of 1.5% to 2% in a single day which translates to an annualized return of more than 500%.

Insert Table 1 here

Insert Table 2 here

Insert Table 3 here

We analyze the absolute mispricing with respect to five parameters: the type of option, moneyness of the option, time to maturity, traded volume and underlying volatility. Parametric tests such as ANOVA can be used for this purpose if the distribution of the series of mispricing is normal. As the descriptive statistics for the mispricing data exhibit a high skewness and kurtosis we use the Jarque-Bera test to test for normality of the mispricing series. The JB test-statistic is very high (816194.7) and the p-value is zero leading us to reject the null hypothesis of normality. Since the probability distribution of the mispricing is not normal we have to resort to non-parametric tests which do not assume any specific form for the distribution. Two such tests are the Wilcoxon Rank Sum Test (for two independent samples) and the Kruskal-Wallis test (for several independent samples).

We first examine whether absolute mispricing is higher in case of calls than for puts. We therefore test the null hypothesis that there is no significant difference between the mispricing of call options and put options. The alternate hypothesis is that positive mispricing (or mispricing for calls) is higher than negative mispricing (mispricing for puts). We use the Wilcoxon Rank Sum test for two independent samples to test the hypothesis. The Wilcoxon test statistic is -0.84974 which corresponds to a p-value of Pr(Z>-0.84974), i.e. 0.802264. Hence we cannot reject the null hypothesis and conclude that there is no significant difference between the absolute mispricing for calls and puts.

For the purpose of analyzing the gross mispricing with respect to moneyness we define moneyness of call options as S/X and use the following classification: (a) S/X > 1.15: Deep-in-the-money (b) S/X >1.05 and <=1.15: In-the-money (c) S/X >0.95 and <=1.05: At-the-money (d) S/X >0.85 and <=0.95: Out-of-the-money and (e) S/X <0.85: Deep-out-of-the-money. The analysis reveals that about 89% of the cases of mispricing are at-the-money options. However the magnitude of absolute mispricing for at-the-money options is Rs.0.05 as compared to Rs.0.49 for deep in-the-money and Rs.0.20 for out-of-the-money options. Thus there is an inverse relation between the number of instances of mispricing and the average magnitude of mispricing. This result is in line with the study of put-call parity for Nifty futures and options (Vipul, 2008).

Insert Table 4 here

We test whether there is a significant difference in absolute mispricing with respect to moneyness of the option. We use the Kruskal-Wallis test for many independent samples for this purpose. The Kruskal-Wallis test-statistic H is 785.39 which is high and the p-value is zero. We therefore reject the null hypothesis and conclude that the differences in mispricing according to option moneyness are statistically significant.

We next analyse gross mispricing with respect to traded volumes. Traded volume up to 400 contracts is classified as thin, between 400 and 35000 contracts is termed ‘moderate’ and greater than 35000 contracts is termed as ‘high’. The analysis shows that roughly 50% of the instances of mispricing are in respect of moderately traded options with a mean magnitude of mispricing of Rs.0.06. The frequency of mispricing is lower (25%) for thinly traded options but the mean magnitude of mispricing is higher (Rs.0.13).

Insert Table 5 here

We test for significance in the difference of mispricing according to traded volume. The Kruskal-Wallis test statistic is a high 2696.64 and the p-value is zero leading us to reject the null hypothesis of no significant difference. We conclude that the differences in mispricing because of differences in traded volume are statistically significant.

Analysis of the gross mispricing with respect to time to maturity reveals that 73% of the instances of mispricing are in respect of options maturing in the range of 0 to 30 days. The remaining 27% of the cases are options maturing beyond 30 days. There are just 65 cases (0.57% of cases) of mispricing in respect of options with time to maturity beyond 90 days. The mean magnitude of mispricing is higher (Rs.0.08) in case of options with maturity beyond 30 days than in case of options with up to 30 days maturity (Rs.0.06). Thus we can conclude that while the frequency of mispricing is higher for shorter-dated options the magnitude of mispricing is higher for longer-dated options. Analysing the options with respect to time to maturity and traded volume we find that within all maturity buckets the frequency of mispricing is lowest and mean mispricing is highest in case of thinly traded options.

Insert Table 6 here

The Kruskal-Wallis test statistic for differences in mispricing across maturity comes to a high 306.98 and the p-value is very low (2.1823E-67) leading us to reject the null hypothesis of no significant difference in mispricing across maturities. We therefore conclude that the differences in absolute mispricing because of difference in time to maturity are statistically significant.

We analyze the gross mispricing with respect to volatility of the underlying USD-INR rate. We measure volatility using a simple 10-day moving average of the standard deviation of daily logarithmic return of the closing exchange rate observed in the Mumbai inter-bank market. During the period under study the annualized volatility of the USD-INR ranged from 3.06% to 24.29%, the average being 9.78%. We classify the data set into periods of low volatility (volatility less than 6%), moderate volatility (between 6% and 15%) and high volatility (greater than 15%). We report higher average mispricing (Rs.0.08) for the high volatility period as against Rs. 0.03 for the low and Rs.0.06 for the moderate volatility period.

Insert Table 7 here

We test whether the mispricing is significantly different in periods with different volatility. The KW test statistic H is 271.7194 with a p-value of zero thus leading us to reject the null hypothesis of no significant difference. We conclude that there is a significant difference in the mispricing in periods of different underlying volatility.

Lastly we examine whether the behaviour of the market participants has changed over the period since trading of options started. The frequency of mispricing is expected to decline over a period as market participants become more familiar with the new instrument. We divide the total period of thirty two months into four eight-month periods and examine the magnitude and instances of mispricing in each period. The number of instances of mispricing shows an increase in all four periods which is contrary to expectations. The average magnitude of mispricing increased from Rs.0.04 in the first period to Rs.0.076 in the third period and then declined to Rs.0.0529 in the fourth period.

Insert Table 8 here

Following Mittnik and Rieken (2000) we test the pattern of mispricing over the four eight-month periods by running an Ordinary Least Squares regression for equation (3) which we rewrite as:

$$c - p = \alpha + \beta * (F - X)e^{-r(T-t)} + \acute{\omega}$$

If put-call parity holds, the intercept α should not be statistically different from zero and the coefficient β should not be statistically different from 1. The results of regression show that the p-value of the intercept term is greater than 0.05 in three of the four periods and in one of the periods it is 0.045. Thus we can conclude that overall the intercept is not statistically different from zero as we cannot reject the null hypothesis. The intercept is positive in the three of the periods indicating that at-the-money calls in these periods were on an average overpriced relative to at-the-money puts. A negative intercept in the last period suggests underpricing of at-the-money calls in this period. The β values are close to one but the p-values are all equal to zero and hence we reject the null hypothesis that β is statistically not different from 1. We therefore conclude that even though the mispricing is very small as evidenced by the α which is not statistically different from zero, put-call parity does not hold because the β values are statistically different from 1.

Insert Table 9 here

VII: Conclusion

Our study of put-call parity in respect of USD-INR options and futures shows the following:

a. In general put-call parity does not hold as the regression shows that β values are statistically different from 1.

b. A positive intercept for the regression in three of the four sub-periods examined suggests relative overpricing of at-the-money call options during those periods.

c. Despite the large number of instances of mispricing the number of profitable opportunities are smaller, 80.75% for members of the exchange and 44.84% for retail investors

d. The frequency of mispricing is higher for at-the-money options but the magnitude of mispricing is larger for in-the-money and out-of-the-money options

e. The frequency of mispricing is smaller but the magnitude of mispricing is larger for thinly traded options

f. The frequency of mispricing is higher for options with maturity up to 30 days but the magnitude of mispricing is larger for options maturing beyond 30 days

g. The mean amount of mispricing is higher for periods of high volatility than for periods of low and moderate volatility

h. The instances of mispricing have continued to grow since the inception of trading in currency options which is contrary to expectations of the learning behaviour.

Our findings regarding the frequency of violations are consistent with those of Evnine and Rudd (1985) who also found frequent violations in the S&P100 index options when the market was young. The number of profitable opportunities also points to an inefficient market. Members could make a net annualized return of more than 50% in 177 cases (1.91% of the sample) and in excess of 100% in 73 cases (0.79%). Retail investors with no special edge in the market in terms of trading costs could also have made net annualized return in excess of 50% in 159 cases (3.09% of the sample) and in excess of 100% in 67 cases (1.3% of the sample). Again these results are in line with those of Vipul (2008) who studied the violations of PCP in early stages of the Nifty options market. The result that mispricing is more severe for less liquid, deep in-the-money and out-of-the money options and during periods of higher volatility is consistent with those of Kamara and Miller (1995), Ackert and Tian (1999) and Draper and Fung (2002) for the US and UK markets. Our finding that the average magnitude of mispricing declines as options approach maturity is similar to that of Klemkosky and Lee (1991). The high execution risk in all these cases leads to higher mispricing. Contrary to the finding of Vipul (2008) that put options are more frequently overpriced than call options we report relative overpricing of calls in three sub-periods of our data set. Relative overpricing of puts in many studies by Chesney et al, (1994), Mittnik and Rieken (2000), Vipul (2008) has been attributed to short-sale restrictions which make it difficult for investors to short the index and thus exploit the mispricing. Since our study is based upon futures which can be shorted easily the question of short sale restrictions does not arise. The findings regarding learning behaviour or improvement in market efficiency are similar to those of Ackert and Tian (2000) who study spread relationships in the S&P 500 index options during the period 1986-1996 and find no marked improvement in market efficiency over that period. Mittnik and Rieken (2000) also conclude that put-call parity does not hold on the basis of their testing of the sample data from 1992-1995. They find consistent overpricing of puts throughout the sample period.

On the basis of the sample data set we conclude that there are frequent violations of put-call parity in the USD-INR currency options market and ex-post tests show profitable arbitrage opportunities. We therefore conclude that the market is not efficient. However since our study is based upon closing prices of options and futures it is exposed to the problem of non-synchronous data. Moreover our results are based on ex-post tests as ex-ante tests could not be conducted due to lack of intra-day data. There is scope for further research in this area using transaction data.

References

Ackert, L. F., & Tian,Y. S. (1999). Efficiency in index options markets and trading in stock baskets (Working Paper 99–5). Atlanta, US: Federal Reserve Bank of Atlanta.

Brunetti, M., & Torricelli, C. (2005). Put–call parity and cross-markets efficiency in the index options markets: Evidence from the Italian market. International Review of Financial Analysis, 14, 508–532.

Capelle-Blancard, G., & Chaudhury, M. (2001). Efficiency tests of the French Index (CAC 40) options market (working paper). Montréal, Canada: McGill Finance Research Center.

Chance, Don M., (1986) Empirical Tests of the Pricing of Index Call options, Advances in Futures and Options research, Vol. 1, Greenwich, Conn, JAI Press

Chesney, M., Gibson, R., & Louberge, H. (1994). Arbitrage trading and index option pricing at SOFFEX: An empirical study using daily and intradaily data. Cahiers du Department d'Economique, Faculte des Sciences Economiques, Universite de Geneve.

Draper, P., & Fung, J. K. W. (2002). A study of arbitrage efficiency between the FTSE-100 Index futures and options contracts. Journal of Futures Markets, 22, 31–58.

Evnine, J., & Rudd, A. (1985). Index options: The early evidence. Journal of Finance, 40, 743–756.

Fung, J. K. W., & Chan, K. C. (1994). On the arbitrage free pricing relationship between index futures and index options: A note. Journal of Futures Markets, 14, 957–962.

Fung, J. K. W., Cheng, L. T. W., & Chan, K. C. (1997). The intraday pricing efficiency of Hang Seng Index options and futures markets. Journal of Futures Markets, 17, 327–331.

Galai, D. (1977), Tests of market efficiency of the Chicago Board of Options Exchange, The Journal of Business, 50, 167–97

Kamara, A., & Miller, T. W. (1995). Daily and intradaily tests of European put–call parity. Journal of Financial and Quantitative Analysis, 30, 519–539.

Klemkosky, R. C., & Resnick, B. G. (1979). Put–call parity and market efficiency. The Journal of Finance, 34, 1141–1155.

Lee, J. H., & Nayar, N. (1993). A transactions data analysis of arbitrage between index options and index futures. Journal of Futures Markets, 13, 889–902.

Mittnik, S., & Rieken, S. (2000). put–call parity and the information efficiency of the German DAX Index options market. International Review of Financial Analysis, 9,259–279.

Stoll, H.R. (1969) The Relationship between Put and Call Option Prices, Journal of Finance,24, 801-24

Tucker, A. L. (1991) Financial Futures, Options, and Swaps, 1st Edn, West Publishing Company, St. Paul, MN.

Vipul (2008) Cross-Market Efficiency in the Indian Derivatives Market: A Test of Put-Call Parity, The Journal of Futures Markets, Vol.28, No.9, 889-910

Zhang,Z. & Lai, R.N. (2006) Pricing Efficiency and Arbitrage: Hong Kong derivatives markets revisited, Applied Financial Economics,16, 1185-1198

Table 1
Descriptive Statistics of absolute mispricing

Mean	0.064356
Standard Error	0.001462
Median	0.015866
Mode	0.005000
Standard Deviation	0.156622
Sample Variance	0.024531
Kurtosis	42.693231
Skewness	5.695963
Range	2.177249
Minimum	0.000004
Maximum	2.177253
Sum	738.674918
Count	11478

Table 2
Absolute mispricing before trading cost

	Instances of mispricing	**Mean (Rs.)**	**Median (Rs.)**	**Standard Deviation**
Absolute mispricing	11478	0.0644	0.0159	0.1566
Positive mispricing	5471	0.0639	0.0158	0.1637
Negative mispricing	6007	-0.0648	-0.0160	0.1499

Table 3
Mispricing net of trading costs

	Instances of mispricing	**Mean (Rs.)**	**Median (Rs.)**	**Standard Deviation**	**Percentage of total mispricing**
Members	9268	0.0748	0.0190	0.1708	80.75%
Non-members	5147	0.1144	0.0363	0.2137	44.84%

Table 4
Mispricing as per moneyness of strike

Moneyness	S/X	Type of mispricing	Instances of mispricing	Mean (Rs.)	Median (Rs.)	Standard Deviation	Percentage of mispricing instances
Deep ITM	>1.15	Positive	10	0.1417	0.1692	0.0824	
		Negative	20	-0.6777	-0.8198	0.4581	
		Absolute	**30**	**0.4991**	**0.2397**	**0.4535**	**0.26%**
ITM	1.05-1.15	Positive	454	0.1333	0.0501	0.2300	
		Negative	508	-0.2076	-0.0711	0.3128	
		Absolute	**962**	**0.1726**	**0.0589**	**0.2792**	**8.38%**
ATM	0.95-1.05	Positive	4886	0.0517	0.0139	0.1346	
		Negative	5375	-0.0482	-0.0136	0.1043	
		Absolute	**10261**	**0.0498**	**0.0138**	**0.1197**	**89.40%**
OTM	0.85-0.95	Positive	121	0.2875	0.0765	0.4565	
		Negative	104	-0.1097	-0.0381	0.1790	
		Absolute	**225**	**0.2053**	**0.0518**	**0.3664**	**1.96%**
Total			**11478**				

Table 5
Mispricing as per traded volume

Traded contract volume	Traded number of contracts	Instances of Absolute mispricing	Mean (Rs.)	Median (Rs.)	Standard Deviation	Percentage of mispricing instances
Thin	Upto 400	2915	0.1296	0.0516	0.2125	25.40%
Moderate	400-35000	5762	0.0568	0.0162	0.1488	50.20%
High	> 35000	2801	0.0120	0.0057	0.0266	24.40%
Total		**11478**				

Table 6

Mispricing as per time to maturity

Time to maturity	**Traded Volumes**	**Instances of Absolute mispricing**	**Mean (Rs.)**	**Median (Rs.)**	**Standard Deviation**	**Percentage of mispricing instances**
Less than 7 days	Thin	440	0.1398	0.0490	0.2333	
	Moderate	1027	0.0510	0.0164	0.1280	
	High	566	0.0125	0.0055	0.0300	
	Total	**2033**	**0.0595**	**0.0147**	**0.1494**	**17.71%**
8-30 days	Thin	1312	0.1360	0.0528	0.2312	
	Moderate	3030	0.0565	0.0142	0.1634	
	High	1971	0.0117	0.0056	0.0254	
	Total	**6313**	**0.0590**	**0.0129**	**0.1614**	**55.00%**
Greater than 30 days	Thin	1163	0.1185	0.0514	0.1794	
	Moderate	1705	0.0610	0.0205	0.1324	
	High	264	0.0130	0.0063	0.0274	
	Total	**3132**	**0.0783**	**0.0255**	**0.1506**	**27.29%**

Table 7

Mispricing as per volatility of the underlying

Annualized volatility	**Instances of mispricing**	**Mean (Rs.)**	**Median (Rs.)**	**Standard Deviation**
<0.06	593	0.0322	0.0063	0.1005
>0.06 < 0.15	8636	0.0616	0.0152	0.1533
> 0.15	2249	0.0834	0.0241	0.1777

Table 8

Mispricing according to the four sub-periods

	Instances of mispricing	**Mean (Rs.)**	**Median (Rs.)**	**Standard Deviation**
Oct2010-June2011	1648	0.0409	0.0088	0.1261
Jul2011-Feb2012	2928	0.0774	0.0204	0.1709
Mar2012-Oct2012	3357	0.0766	0.0194	0.1816
Nov2012-June2013	3545	0.0529	0.0136	0.1267

Table 9
Regression results for sub-periods of the data set

Period	Intercept	p-value	Beta	p-value	F	Significance	R squared
Oct2010-June2011	0.0044	0.1775	0.9868	0.0000	37340.87	0.0000	0.9578
Jul2011-Feb2012	0.0060	0.0880	0.9722	0.0000	248792.26	0.0000	0.9884
Mar2012-Oct2012	0.0070	0.0456	0.9811	0.0000	296495.41	0.0000	0.9888
Nov2012-June2013	-0.0015	0.5544	0.9978	0.0000	469910.39	0.0000	0.9925