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VIOLATIONS OF PUT-CALL PARITY FOR CNX NIFTY INDEX OPTIONS: A STUDY AT NATIONAL STOCK EXCHANGE

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Abstract: *In the past decade, there has been unprecedented growth in the Indian financial market. Developed markets are characterized by the presence of market efficiency, and also, efficiency in markets facilitates their development. Therefore, smooth functioning of financial markets has gained importance. The derivatives market provides a platform for market participants to hedge their risk, and aid price discovery. Correct pricing of derivatives instruments is imperative in performing these functions. In the present study, an attempt has been made to examine the valuation of extremely popular CNX Nifty Index Options, in terms of Put-Call Parity (PCP) relationship, over a ten-year period. Since PCP is a no-arbitrage based argument, it does not suffer from the limitations that are inevitable while gauging pricing efficiency using model-based approaches. Various error estimates, supported by non-parametric tests have been used to establish the validity of our results. Our findings indicate frequent violations of PCP, though the magnitude of mispricing is small. To gain further insights into the behavior of mispricing, the results are charted across variables like Moneyness, Days-to-Expiry and Liquidity. All of them have a bearing on PCP violation. The present study can be extremely important for all the stakeholders, as violation of PCP leads to risk-free profitable arbitrage, which is an antithesis to efficient markets.*

Key Words: *put-call parity, index options, pricing efficiency, non-parametric tests, moneyness, days to expiry.*

JEL Classification: *G13, C580, G140*

1. INTRODUCTION

In an efficient market, at any point in time the actual price of a security is a good estimate of its intrinsic value (Fama, 1965). When securities are trading away from their intrinsic values, excess profit making opportunities arise, from which market participants can make guaranteed profits. This is a complete antithesis for the theory of efficient markets. Therefore, correct pricing of derivatives instruments gains paramount importance. If these instruments are not priced as per the tenets of efficient markets, then they do not effectively perform their function of price discovery. Also, they prove to be ineffective in hedging price volatility.

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In this background, it becomes necessary to investigate empirically the notions of pricing efficiency in the thriving Indian derivatives market. India's tryst with exchange-traded derivatives commenced in the year 2000, with the introduction of Index futures. Since then there has been a remarkable growth especially in the equity derivatives segment, with Index Options at the forefront. The number of contracts traded in 2001-02 were 175,900. This number rose to 928,565,175 in 2013-14 (www.nseindia.com), representing CAGR of approximately 84%.

In light of the importance of correct pricing coupled with immense growth, the present paper attempts to assess the pricing efficiency for CNX Nifty Index Options. The present study embodies an attempt to examine the put-call parity relationship for these contracts on India's National Stock Exchange, over a ten-year period from 2003 to 2012. The paper consists of six sections including the present one on introduction. This is followed by a survey of past empirical studies in the literature review section. Section 3 lays down the theoretical foundations, on the basis of which the study is undertaken. The subsequent section discusses the methodology of the research in detail along with the description of tools used for research. Section 4 reports the empirical findings. Finally, the paper concludes with section 6 which also lays down direction for future research.

2. LITERATURE REVIEW

Stoll (1969) was the first to identify the PCP relationship. The study by Merton (1973) established the PCP for both European and American Options. Klemkosky & Resnick (1979) were the earliest to study the PCP on the exchange traded US market. The empirical results were found to be consistent with the established put-call parity relationship. A small degree of inefficiency was detected.

Evnine & Rudd (1985) studied the U.S. market and reported that S&P 100 calls were underpriced, whereas the MMI call options were overpriced. This was true when both these options were considered European Options and American Options. There were significant differences between theoretical price and current price based on the binomial model. The research deduced that the inefficiency was largely due to the inability of investors to arbitrage away the profits.

Loudon (1985) examined all the available options in Australian Markets during 1985 and determined that the magnitude of violations were insufficient to account for arbitrage opportunities, considering transaction costs. The lower boundary conditions were violated more frequently. The presence of transaction costs appeared to be most significant for mispricing behavior.

Wagner *et al.* (1996) studied the factors behind deviations in PCP for S&P 100 Index Options from April 1984 to December 1986. The study reported substantial number of violations of PCP even after accounting for transaction costs contrary to Klemkosky & Resnick (1979), but in line with Evnine & Rudd (1985). With respect to days to expiry, the longer the time to maturity, the calls tend to be overpriced. Risk-free interest rate, daily volatility in spot market and option trading volumes did not have any significant impact on the PCP violations.

Berg *et al.* (1996) examined the Oslo Stock Exchange options in the Norwegian market. They reported a large number of PCP violations. The calls were relatively overpriced, when compared with puts.

Fung *et al.* (1997) studied the Hang Seng Index Options and futures market. The sample period was from April 1993 to November 1994. The paper examined the Put-Call futures parity. The mispricing was evident in the markets on account of high number of violations before accounting for transaction costs. However, the majority of violations did not justify arbitrage trading after considering costs.

Ackert & Tian (1999) examined the Standard and Poor's Depository Receipts (SPDRs), using boundary conditions, put-call parity and other spread based relationships. They inferred that there were significant violations, but these diminished after considering the transactions costs and commission. Also, the efficiency improved over the period of time, after the introduction of SPDRs.

Mittnik & Reiken (2000) studied the DAX index options in German market. They opined that put-call parity did not hold. The arbitrage opportunities could not be exploited due to short-selling restrictions. The market exhibited learning behavior in the sense that market efficiency improved in the last years of the sample period.

Blancard & Chaudhury (2001) studied the CAC 40 index options in the French Options market. They studied several no-arbitrage conditions. The study reported that frequency of violation was low indicating, high efficiency of French markets. In some strategies, arbitrageurs are able to make high profits. In the study, the short PCP violations are more common than long PCP violations for the CAC 40 index options.

In the U.K., Draper & Fung (2002) used the put-call futures parity for FTSE 100 futures and FTSE 100 options relationships. The study confirmed the efficiency of the market, since there were relatively fewer arbitrage opportunities for the traders. The study also concluded that ex-post arbitrage profits for traders who have to pay transaction costs are more applicable for at-the-money options.

Ahn et al. (2003) assessed the Korean market and deduced that there existed significant violations of put-call parity conditions. The arbitrage opportunities remained intact even after considering transaction cost and replacing index price with index futures price.

Cassese & Guidolin (2004) examined the Italian Market for MIB 30 Stock Index options. The study indicated significant violations of no-arbitrage conditions including put-call parity at various moneyness levels and different maturities. However, like Mittnik & Reiken (2000), these violations decreased when market frictions were considered.

Ofek *et al.* (2004) examine the put-call parity under the short sales restrictions as measured by the rebate rate. The findings suggested statistically significant violations of PCP. The study reported clear relationship between arbitrage constraints and mispricing. The violations persisted even after accounting for transactions costs. Also, the PCP violations are more for longer maturity options. The paper provided an alternate perspective about the rationale behind violation of PCP. Accordingly, due to the diverse beliefs of investors, the stocks deviate from their fundamental value.

Andreou & Pierides (2004) studied the emerging Greek Index Options Markets during the period January 2001 to March 2003 for PCP and box spread strategy. They concluded that most arbitrage opportunities were available to those market participants who were faced with low transaction costs. Contrary to the findings of other markets, the efficiency did not improve over the sample period.

Misra & Misra (2005) investigated the Nifty options for put-call parity between the period January 2004 and December 2004. The study reported many instances for violations of PCP. There were arbitrage profits for deeply ITM or deeply OTM options. Also, with higher liquidity of options, lesser arbitrage profits could be realised.

Li (2006) investigated the Osaka Securities Exchange (OSE), the largest derivatives exchange in Japan, for the period 2003-2005. The study did not find support for efficiency in the market. The violations of PCP were occasional, but the magnitude of profits led to arbitrage opportunities even after considering transactions costs.

Cremers & Weinbaum (2008) examined the put-call parity deviations to determine whether they contained information about the future stock prices. The stocks with relatively expensive calls outperformed stocks with relatively expensive puts. Since the violations were both positive and negative, the authors deliberated that these could not be attributed to short-sales restrictions alone.

Vipul (2008) tested the put–call–futures (PCF) and put–call–index (PCI) parity conditions for European Style Nifty Index Options, for the period Jan 2002 to Nov 2004. Frequent violations of both PCF and PCI parity were observed. Put options are overpriced more often than call options due to short selling restrictions. The mispricing exhibited specific patterns with respect to time of the day, “moneyness”, volatility, and days to expiry.

Gallo (2009) studied the Italian Index Options Markets and used futures prices instead of spot prices in assessing PCP. The paper investigated the relationship of liquidity as denoted by bid-ask spread with the violations of PCP. The findings indicated that the majority of violations were concentrated around zero. There was no significant correlation between the liquidity and mispricing.

Gupta & Jithendranathan (2010) investigated the Indian market over the period Aug 2001 to Dec 2006. The study indicated that in 24% of the observations, the put-call parity was violated where the arbitrage required short sales.

Hou & Zhao (2011) studied the Swedish OMX Index Options for both model-based conditions and model-free conditions. The paper reported infrequent violations of put-call parity. The magnitude of violations was on the lower side as well.

Nishiotis & Rompolis (2011) studied the PCP in the ban period in the U.S. markets. The analysis documented a significant increase in the magnitude of violations during the ban period relative to both the pre-and post-ban periods. Similar to this study, Grundy *et al.* (2012) investigated the differences in market behavior before, during, and after the ban for stocks for which short sales were prohibited and for all other stock on which options were traded in the US market included in the S&P 500 Index. The PCP violations increased for banned stocks compared to the unbanned ones.

Dixit *et al.* (2012) studied the PCP using spot prices and futures prices for Nifty Index Options. They reported extremely high frequency of violations, which did not disappear to a large extent even after considering transaction costs. The majority of the violations were in the case of underpriced calls.

It can be concluded from the above discussion that the put-call parity relationship has been studied across the globe, in various markets, and over a variety of instruments, in the past. There are mixed results regarding the violations of PCP. However, most of the studies concede that short-sales restraints lead to more violations of PCP. The present study attempts to investigate the PCP relationship for CNX Nifty Index Options. Over a longer time horizon (10 years), the trend in PCP violations has been examined. Also, the explanatory variables of this violation like moneyness, days-to-expiry and liquidity are taken into consideration to gain meaningful insights into the mispricing behavior as denoted by deviations in PCP.

3. THEORETICAL BACKGROUND

Put-call parity was first identified by Stoll (1969). It defines the parity that must exist between European call options and European put options, which have the same expiration, strike price and underlying. This implies that the price of the call options can be determined from the price of the put options and vice-versa.

The Put-Call Parity for European Options can be explained as follows:

If there are two portfolios,

- Portfolio A: European call on the underlying+ PV of the strike price in cash
- Portfolio B: European put on the Index + the underlying

Both are worth max (S_T, K) at the maturity of the options

They must therefore be worth the same today. This means that

$$c + Ke^{-rT} = p + S_0 \qquad \text{Equation 2.2}$$

where,

c = call option price

Ke^{-rT} = Present value of Strike Price K, continuously compounded at the risk free interest rate, r, for the time period T

p = put option price

S_0 = Spot price of the underlying

If the above relationship is violated, there is a possibility of arbitrage. A careful arbitrageur can buy the underpriced portfolio and sell the overpriced portfolio thereby making riskless profits.

Since financial assets yield income in the form of dividends, it is imperative to account for the same while valuation of derivative based on such assets. The dividend adjustment is made for Nifty Index Options by replacing S_0' for S_0 where $S_0' = S_0e^{-dT}$, d denotes the continuously compounded annual dividend yield and T is the time-to-expiry of the option in years. This adjustment removes the present value of the dividends from the underlying's spot price (S_0) (Chance & Brooks, 2013).

For the purpose of the present study, the call option prices are calculated vis-à-vis the put price using the Put-Call Parity relationship. A violation is recorded when there is a difference between the observed market price and the call price so determined. When observed price is more (less) than the theoretical price, it is construed as overpricing (underpricing).

4. DATA & METHODOLOGY

The present study focuses on CNX Nifty Index Options traded on National Stock Exchange (NSE) of India. The main objective of the study is to examine the pricing efficiency of these Index Options using Put-Call Parity. The sample period for the study has been taken from January 2003 to December 2012, a period spanning 10 years.

Wherever deemed necessary, the period has been divided into various sub-periods to discern a meaningful pattern of efficiency/inefficiency as (a) 2003-07, (b) 2008-12 and (c) 2010-12. 'a' and 'b' simply divide the period of study into two five-year periods. The last three years (c) have been studied separately to determine the latest developments in Indian options market.

The results are charted across variables to understand the behavior of mispricing. "Moneyness" has been determined as S-K/K, where S and K are spot price and the strike price respectively. Five levels of moneyness has been studied: Deep-in-the-Money (DITM) as >10%, In-the-Money (ITM) as between 5% and 10%, At-the-Money (ATM) as between -5% to 5%, Out-of-the-Money as between -5% to -10% and Deep-Out-of-the-Money (DOTM) as >-10% of Moneyness.

Liquidity has been defined as a proxy of number of contracts traded for that option. Accordingly, there are three categories of liquidity: less than 100; 100-500, and; more than 500 contracts traded. With respect to maturity of option contracts, the study is taken up for four categories: less than 7 days; 8-14 days; 15-21 days, and; more than 21 days left for expiry.

Only near-term expiry options contracts have been taken up for the study. This conforms to earlier studies like Lung & Marshall (2002).

The present study is based on secondary sources of data. All data like strike price, the transaction date, expiry date and number of contracts traded, option price, underlying price, dividend yield and 30-day MIBOR (as a proxy to risk-free interest rate) have been obtained from the official website of NSE, www.nseindia.com.

Data Screening Procedure

Initially, 108,314 observations were recorded. To obtain high quality database, this sample is subjected to a stringent screening process. When options are not traded, their price is the theoretical one. Therefore, for both call and put options, the zero-trading observations have been taken off. The observations in case of call options are then matched with put options with respect to deal date, expiry date and strike price. Tripathy (2010) suggests that the trading volume on expiry day is significantly different from trading volumes of other days. Therefore, the expiry day data has been taken off from the resultant sample. After this process 47,572 observations are available for the study.

Error Estimates

In most empirical studies, error estimates are used to evaluate the performance of the competing models for forecasting. The following notations are used:

Y_{mod} = The theoretical price of the option as determined by PCP

Y_{obs} = Observed market price of the option

N = Number of observations

(a) Mean Error (ME)

$$ME = \frac{1}{N}\sum_{t=1}^{n}(Y_{obs} - Y_{\text{mod}})$$

(b) Mean Absolute Error

$$MAE = \frac{1}{N}\sum_{t=1}^{n}| Y_{obs} - Y_{\text{mod}} |$$

(c) Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{n}(Y_{obs} - Y_{\text{mod}})^2}$$

(d) Percentage Mean Error (PME)

$$PME = \frac{1}{N}\sum_{t=1}^{n}\left[\frac{(Y_{obs} - Y_{\text{mod}})}{Y_{\text{mod}}}\right]$$

(e) Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{1}{N}\sum_{t=1}^{n}\left|\frac{(Y_{obs} - Y_{\text{mod}})}{Y_{\text{mod}}}\right|$$

(f) Theil's U Statistic

$$Theil's\ U = \sqrt{\frac{\frac{1}{N}\sum_{t=1}^{n}(Y_{obs} - Y_{\text{mod}})^2}{\sqrt{\left[\frac{1}{N}\sum_{t=1}^{n}(Y_{obs})^2\right]} + \sqrt{\left[\frac{1}{N}\sum_{t=1}^{n}(Y_{\text{mod}})^2\right]}}}$$

The PME, MAPE and Theil's U Statistic are scale-independent measures.

Statistical Tools

Financial time series data are known to be non-normal. The Jarque-Bera (JB) Test is used to check the assumption of normality of data. Table 2 demonstrates that the Mean Error series does not follow the normal distribution for any of the year/ sub-period of the study. Therefore, non-parametric tests are applied for further analysis.

Wilcoxon Signed Rank Test is used to find out the significant differences between the medians of two samples. In the present study, this test is used to study whether there is any significant difference between the market price of options and the theoretical price as calculated PCP.

The Kruskal–Wallis (KW) is used in the present study to analyze the behavior of mispricing across various levels of moneyness, days-to-expiry and liquidity. A post-hoc test, Dunn's multiple comparison tests is used to discern differences pairwise amongst the samples. This test is useful, only if *k* independent samples have revealed significant difference using KW Test.

5. EMPIRICAL FINDINGS

It can be observed from Table 1 that using Put-Call Parity (PCP) the market exhibits overall underpricing. When there is underpricing in the market, the arbitrage opportunities cannot be exploited because this process entails short selling of the underlying, which is restricted at Indian bourses. Compared to the period 2003-07 the Mean Error (ME), which stood at Rs. -10.6277, declined in 2008-12 to Rs. -6.4902. This further declined in the last three years (2010-12). The magnitude of violations is not very high in the Nifty Index Options market.

These findings are consistent with the results obtained in Indian markets especially to the findings reported by Vipul (2008) and Dixit et al (2012) in Indian Markets.

The Mean Absolute Error (MAE) values were on the higher side in the years 2006, 2007 and 2008. Compared to the period 2003-07, the MAE rose in the period 2008-12 slightly (Refer Figure 1). There was a correction in the values in the last three years of the study, indicating the higher values in the second-sub period could have been due to the global economic meltdown.

The Percentage Mean Error (PME) is in a consistent bracket as can be observed from Figure 2. The Mean Absolute Percentage Errors (MAPE) rose considerably in the second sub-period 2008-12 and 2010-12 compared to the first sub-period. This was on account of higher values in the year 2008 and 2012. The Root Mean Square Error (RMSE) results depicted high values for the years 2007 and 2008.

With the exception of the year 2008, the Theil's U Statistic continues to be low, indicating higher pricing efficiency. Overall, this statistic shows a declining trend in the 10-year study period indicating increase in efficiency (Refer Figure 3), which can be an extremely encouraging finding for all participants. This also implies the learning behavior and market maturity.

Table 1
Error Estimates for Nifty Index Options using Put-Call Parity

Years	*Average of Mkt Price*	*StdDev of Mkt Price*	*Mean Call Price*	*StdDev Call Price*	*ME*	*PME*	*MAE*	*MAPE*	*RMSE*	*Theil's U*
2003	47.9542	45.4809	49.3691	46.1539	-1.4149	0.0840	5.5281	0.9172	8.2497	0.0617
2004	60.5428	51.9503	66.7224	54.0673	-6.1796	-0.0858	10.1678	1.7527	15.9833	0.0965
2005	75.1820	83.5305	85.5362	85.9003	-10.3542	-1.0712	12.8842	1.7385	18.4315	0.0789
2006	163.2630	163.4244	178.7469	163.4731	-15.4839	-0.5764	20.7942	1.4143	29.7933	0.0630
2007	286.4974	340.5632	304.1227	337.2652	-17.6253	-0.6196	27.3836	1.2737	46.3889	0.0516
2008	149.6391	202.1797	163.1242	207.1363	-13.4851	1.5242	27.1910	13.7772	47.5657	0.0923
2009	457.8650	542.0061	464.4397	541.2239	-6.5747	-0.6291	14.3732	3.4971	26.7890	0.0188
2010	409.5892	483.4170	414.2673	484.5318	-4.6780	1.0704	13.0205	4.5048	17.9969	0.0142
2011	318.4078	496.8989	325.7570	498.1477	-7.3492	-1.0878	14.6267	14.4569	21.8098	0.0184
2012	424.9212	577.3037	425.8881	578.0461	-0.9670	1.4628	12.0950	20.5658	17.2914	0.0121
2003-07	130.5487	201.9867	141.1765	203.4928	-10.6277	-0.4800	15.8270	1.4509	27.8698	0.0571
2008-12	350.5390	494.5175	357.0292	494.6530	-6.4902	0.4641	16.1917	12.0419	28.3494	0.0233
2010-12	382.7789	526.7014	387.0396	527.4842	-4.2607	0.4467	13.2511	13.9701	19.2028	0.0147
2003-12	**258.0610**	**413.1423**	**266.2905**	**413.0152**	**-8.2295**	**0.0672**	**16.0384**	**7.5897**	**28.1487**	**0.0288**

StdDev: Standard Deviation, ME: Mean Error, PME: Percentage Mean Error, MAE: Mean Absolute Error, MAPE: Mean Absolute Percentage Error, RMSE: Root Mean Square Error

Figure 1: Mean Error (ME) and Mean Absolute Error (MAE) for Nifty Index Options using PCP

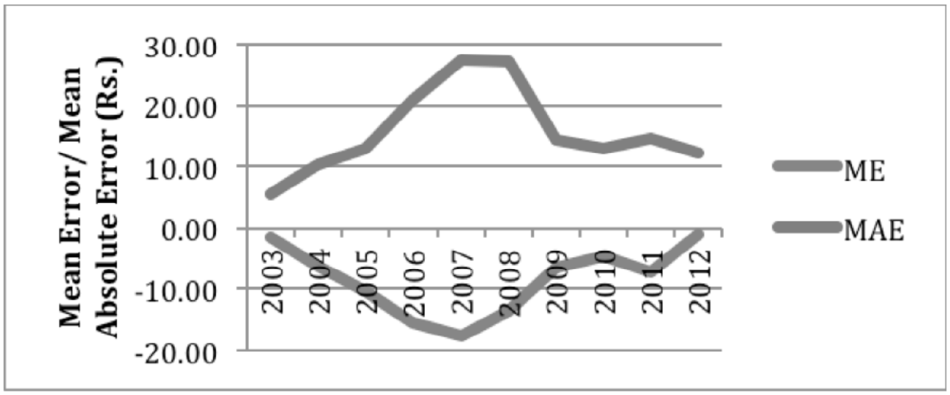


Figure 2: Percentage Mean Error (PME) and Mean Absolute Percentage Error (MAPE) for Nifty Index Options using PCP

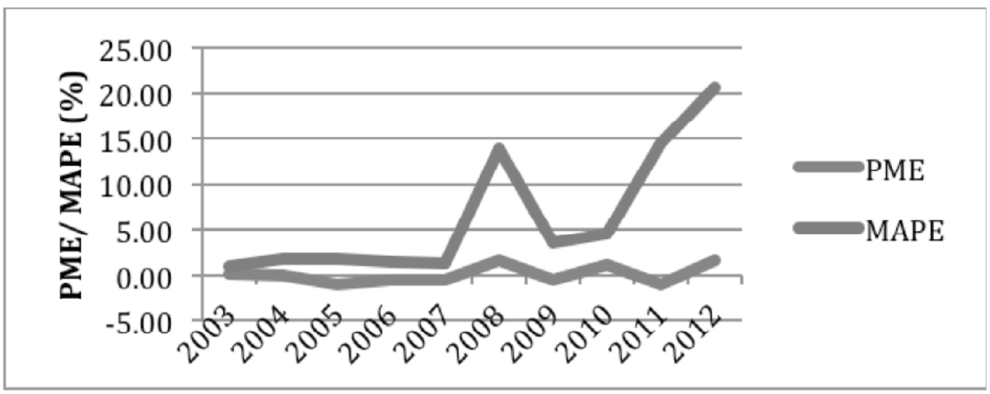
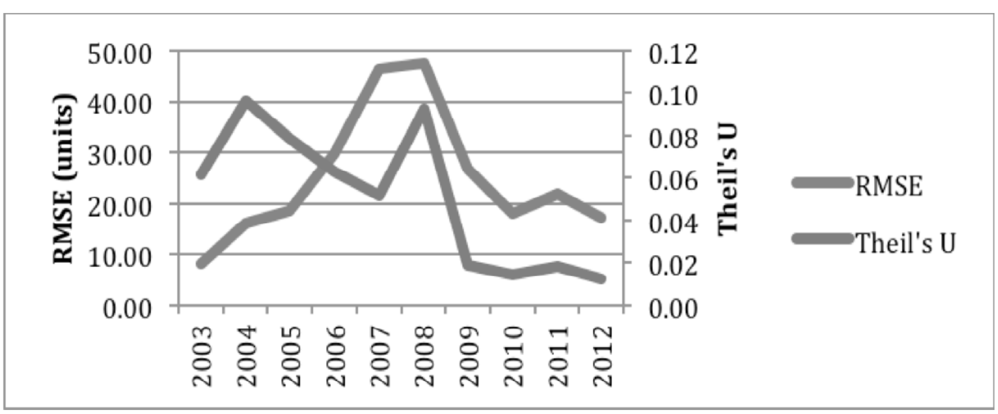


Figure 3: Root Mean Square Error (RMSE) and Theil's U Statistic for Nifty Index Options using PCP



It is important to establish whether these differences in market price and price determined by the PCP are statistically significant. The normality tests are carried out for the Mean Error series using the descriptive statistics and Jarque-Bera Test for all the sub-periods. The results are presented in Table 2.

Table 2
Descriptive Statistics & Jarque-Bera Test for Mean Error for Nifty Index Options with PCP

Years	*Observations*	*Min*	*Max*	*Mean*	*Std dev*	*Skewness*	*Kurtosis*	*JB (Observed value)*
2003-07	19998	-926.2204	666.0206	-10.6277	25.7638	-4.8258	203.7570	34671589.30*
2008-12	27574	-648.2938	468.9959	-6.4902	27.5964	-1.6890	79.0457	7191798.77*
2010-12	17181	-432.5210	389.1335	-4.2607	18.7241	-0.3919	34.7364	864226.36*
2003-12	47572	-926.2204	666.0206	-8.2295	26.9189	-2.8183	122.8527	29979412.17*

*Denotes significant at 5% level

From Table 2, it can be observed that the Mean of Violations show extreme fluctuations. The minimum values of violations stand at Rs. -926.2204 whereas the maximum is at Rs. 666.0206. The excess kurtosis denotes leptokurtic distribution, indicating non-normality of mispricing series. This can be confirmed with the Jarque-Bera Test. For each of the sub-periods, the JB statistic is significant at 5% alpha level indicating non-normality of data. Therefore, non-parametric tests are used to determine whether the mispricing as evidenced by PCP is statistically significant.

The Wilcoxon-Signed Rank Tests depicted in Table 3a and 3b indicate that for all the sub-periods, the departure from Put-Call Parity is significant at 5% level. This means that Put-Call Parity is violated and is statistically significant, thereby confirming pricing inefficiency in CNX Nifty Index Options.

Biases Across Moneyness

From Table 4a, it can be observed that using Put-Call Parity, the In-The-Money (ITM) options are worst priced. The Out-of-The-Money (OTM) options exhibit least underpricing, followed by Deep-In-The-Money (DITM) options. The ATM options are also mispriced to a large extent. This result is consistent with the study of Blancard & Choudhury (2001). The mispricing is statistically significant across all moneyness levels as determined by the Kruskal-Wallis Test, Table 4b. For all moneyness pairs too, there lies significant difference between the Mean Errors as represented in Table 4c. This finding can have a significant impact for traders - they can put arbitrage strategies into place according to moneyness levels, keeping in mind the short-sales restrictions.

Table 3a
Wilcoxon Signed Ranks Test for differences between Market Price and Price determined by Put-Call Parity for the various sub-periods (Compiled)

		Ranks		
		N	*Mean Rank*	*Sum of Ranks*
2003-07	Negative Ranks	14734	11074.86	163177051.00
	Positive Ranks	5254	6964.79	36593015.00
	Ties	10		
	Total	19998		
2008-12	Negative Ranks	17418	14882.70	259226884.00
	Positive Ranks	10150	11899.92	120784212.00
	Ties	6		
	Total	27574		
2010-12	Negative Ranks	10311	9195.91	94818980.50
	Positive Ranks	6865	7676.20	52697095.50
	Ties	5		
	Total	17181		
2003-12	Negative Ranks	32152	25971.44	835033836.00
	Positive Ranks	15404	19201.28	295776510.00
	Ties	16		
	Total	47572		

Negative Ranks: When Market Price < PCP Price
Positive Ranks: When Market Price > PCP Price
Ties: When Market Price = PCP Price

Table 3b
Test Statistics

	Test Statistics[a]			
	2003-07	*2008-12*	*2010-12*	*2003-12*
Z	-77.583[b]	-52.385[b]	-32.409[b]	-90.062[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Table 4a
Mean Error across various moneyness levels for Index options using PCP for the period 2003-12

Variable	*Observations*	*Mean*
DITM	10480	-8.046
ITM	5981	-10.360
ATM	19365	-8.858
OTM	4664	-5.453
DOTM	7082	-6.812

Table 4b
Kruskal-Wallis Test

K (Observed value)	-302086.717
K (Critical value)	9.488
DF	4
Alpha	0.05

Table 4c
Table of pairwise differences using Dunn's Multiple Comparisons

	DITM	*ITM*	*ATM*	*OTM*	*DOTM*
DITM	0	2168.421*	989.077*	-1927.818*	-1089.605*
ITM	-2168.421*	0	-1179.344*	-4096.239*	-3258.026*
ATM	-989.077*	1179.344*	0	-2916.895*	-2078.682*
OTM	1927.818*	4096.239*	2916.895*	0	838.213*
DOTM	1089.605*	3258.026*	2078.682*	-838.213*	0

*Denotes Significant at 5% level

Biases across Liquidity

The liquidity levels do not give out a consistent pattern of mispricing using Put-Call Parity as can be observed from Table 5a. The highest Mean Error is at lower liquidity levels, when the number of contracts traded is Less than 100. When contracts traded is in between 100 to 500 then the mispricing (underpricing) level is least. This may not be an agreeable argument in the favor of pricing efficiency since mispricing at higher liquidity levels leads to exploitable arbitrage opportunities. The Kruskal-Wallis Test (Table 5b) confirms that there is significant difference between the trends in mispricing at different liquidity levels. Dunn's Multiple Comparison also indicates that there is statistically significant difference between all possible pairs of liquidity levels with respect to mispricing as can be observed from Table 5c. This indicates that with growth in the volumes in Nifty Index Options market, there could be a possibility of reduction in mispricing leading to better pricing efficiency.

Table 5a
Mean Error across various liquidity levels for Index options using PCP for the period 2003-12

Variable	*Observations*	*Mean*
Less than 100	15873	-9.841
100 to 500	9576	-6.747
More than 500	22123	-7.715

Table 5b
Kruskal-Wallis Test:

K (Observed value)	-301817.873
K (Critical value)	5.991
DF	2
Alpha	0.05

Table 5c
Table of pairwise differences using Dunn's Multiple Comparison

	Less than 100	*100 to 500*	*More than 500*
Less than 100	0	-1716.271*	-1276.020*
100 to 500	1716.271*	0	440.251*
More than 500	1276.020*	-440.251*	0

*Denotes significant at 5% level

Biases with respect to Days to Expiry

It can be noted from Table 6a that there exists a clear trend in mispricing with respect to Days-To-Expiry (DTE). The quantum of mispricing increases when expiry date approaches. The Kruskal-Wallis Test (Table 6b) confirms statistically significant difference between all maturity groups. The multiple comparisons as observed from Table 6c yields that for all the pairs of maturity levels, there were significant differences in the Mean Error trend.

The arbitragers can benefit in this scenario. When maturity is away, they can take advantage of the high mispricing and make risk-free profits. However, the direction of the Mean Error necessitates short selling of the underlying. This can be possible only intra-day at the National Stock Exchange (NSE) therefore, arbitrage opportunities, though plenty, will be time bound.

Table 6a
Mean Error across various maturity levels for Index options using PCP for the period 2003-12

Variable	*Observations*	*Mean*
1 to 7	12192	-0.996
8 to 14	11808	-5.289
15 to 21	11193	-10.754
More than 21	12379	-15.876

Table 6b
Kruskal-Wallis Test

K (Observed value)	-307248.267
K (Critical value)	7.815
DF	3
Alpha	0.05

Table 6c
Table of pairwise differences using Dunn's Multiple Comparisons

	1 to 7	*8 to 14*	*15 to 21*	*More than 21*
1 to 7	0	4685.537*	8836.325*	11655.965*
8 to 14	-4685.537*	0	4150.788*	6970.428*
15 to 21	-8836.325*	-4150.788*	0	2819.640*
More than 21	-11655.965*	-6970.428*	-2819.640*	0

*Denotes significant at 5% level

CONCLUSION

This paper is an attempt to assess the pricing efficiency of CNX Nifty Index Options using the put-call parity relationship. The study has been taken up for a 10-year study period from 2003 to 2012. Statistically significant differences between the observed prices and PCP prices are found to exist. There is underpricing in the market for all the years of the study, confirming market inefficiency. This underpricing could largely be due to profit not being arbitraged away due to restrictions on short selling.

The most encouraging result from the study is the decline in magnitude of mispricing in all the sub-periods, from 2003-2007 to 2008-12 and further from 2010-12. From this it can be inferred that Indian derivatives markets are showing signs of maturity and better understanding by market participants.

With respect to moneyness, the findings indicate that ITM options are severely mispriced and OTM options are most efficiently priced. In terms of liquidity, the findings seem to be counter-intuitive since at lesser liquidity levels (100-500 contracts), there is lesser degree of violation compared to higher liquidity levels (More than 500 contracts). This denotes that even though there is high liquidity, the profit opportunities are not being arbitraged away. Regarding maturity, it is evident that more mispricing ensues when expiry is distant. This implies that traders start winding up their positions as the contracts near expiry and therefore drive the prices to their fair valuations.

The implications of the study are manifold. The Indian derivatives market exhibit encouraging prospects. The improving efficiency in the markets can be an enhancement in investor interest, and can encourage participation in this segment. The informational efficiency of the instruments can aid price discovery. Hedging can be carried out more effectively, with increasing the market efficiency evidenced by the study.

The present study can be extended in many possible ways. Similar research can be taken up, with equity options. A comparative study can be made using different approaches of assessing pricing efficiency like, Black-Scholes Model (1973), Box-Spreads, Butterfly Spreads etc.

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