Lower Boundary Conditions and Pricing Efficiency Testing of Indian Index Options Market : Empirical Evidence from Nifty 50 Index

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Abstract

This article examined the pricing efficiency of the Nifty 50 index options market by empirically testing the lower boundary conditions (LBCs), a model - free approach. The study covered a period from April 1, 2012 to March 31, 2018. The violations of LBCs indicated that options were underpriced (mispriced). The frequency and magnitude of mispriced signals were examined according to liquidity and maturity of the options contracts. This was done with the view that mere mispricing of options does not indicate inefficiency of the market. It is the opportunity to extract abnormal profit (arbitrage) from these mispriced signals which poses a serious threat to the market efficiency. It was observed that most of the mispriced signals were concentrated at the thinly traded region and options which were going to get expired. The magnitude of mispriced signals at the thinly traded region and options which were going to get expired was significantly larger than the moderately and highly traded levels and options, which were far away from the maturity date. Furthermore, in order to validate whether the differences in the magnitude of violations were statistically significant, the hypotheses were formulated and tested for both the call and put options. The results of the study suggested that the Indian index options market during the period of study was efficient as most of the mispriced signals were not exploitable due to lack of liquidity.

Keywords: abnormal profits, lower boundary conditions, mispriced options, call and put options

JEL Classification: G10, G14, G19

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Options are financial contracts whose values are derived from some underlying asset(s) like stock, index, commodity, interest rate, and they serve as innovative risk management instruments. An index option gives market participants to limit their downward risk without buying or selling a large number of securities. They also help in price discovery mechanism (Pathak, Ranajee, & Kumar, 2014) and allocation of resources to its most fruitful uses (Choksi, 2010 ; Joshipura, 2010 ; Ramanjaneyalu & Hosmani, 2010).

Exchange - traded index options were first introduced at the Chicago Board Options Exchange (CBOE) in 1983. Their simple cash settlement, inexpensive instruments for systematic risk management, high leverage capabilities, and popularity of structured products made them more attractive to the investment world.

Indian financial markets took a longer time to realize the importance of financial derivative instruments. It was

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in June 2000 that the Bombay Stock Exchange (BSE) and National Stock Exchange (NSE) commenced trading on index futures. Soon after, options on individual stocks, index options, futures on a single stock, and long-dated options were permitted to trade in India. At the initial development stage of the Indian options market, there was very low liquidity. However, the scenario changed in April 2008. The traded volume increased by fourfold, that is, 55,366,038 number of index options contracts traded in 2007-08 jumped to 212,088,444 number of index options contracts traded in the year 2008-2009 (NSE). Index options are the most traded instruments in the derivatives market segment of India. Given the importance of efficiency tests of the options market, the correctness of options prices, as defined by Ackert and Tian (2000), is important to academicians, practitioners, as well as to the regulators.

A number of studies have been carried out to test the efficiency of different options market around the globe. However, most of them have been conducted in context of well - developed markets in America and Europe, where options are already employed at their maximum utility. The present paper examines the efficiency of the Indian index options market through the ex - post test of lower boundary conditions (LBCs) on the daily closing prices of the Nifty index options. The LBCs represent the minimum price of an option contract at a given point of time. The price, other than minimum, indicates the existence of arbitrage (abnormal profit).

The frequency and magnitude of mispriced signals observed from the empirical study have been classified as per liquidity and maturity to facilitate a meaningful explanation in examining the efficiency of the options market. This has been done with the view that mere mispricing of options does not indicate inefficiency of the options market. It is the opportunity to extract abnormal profits from the observed mispriced signals which give a serious threat to the market efficiency.

Literature Review

The LBCs is a well - known technique to test the efficiency of the options market (Merton, 1973). Some of the previous studies are Galai (1978) and Bhattacharya (1983) on the Chicago Board Options Exchange (CBOE), Chance (1988) on the S&P 100 index options market for the United States (USA), Puttonen (1993) on the Finnish Options Market, Ackert and Tian (2000, 2001) on S&P 500 index options market for the US.

In the Indian context, few studies have been done (Dixit, Yadav, & Jain, 2009, 2011 ; Mohanti and Priyan, 2013). Since then, there have been notable changes in the Indian financial markets - like regulator rules on the relaxation of shorting, brokerage charged only on the premium amount, reduced contract settlement time and meantime, and so on. Due to these steps, the volume of index options traded has increased tremendously. Efficient working of the options market plays an important role in the development of the economy as such markets help in risk management, price discovery mechanism, and proper allocation of resources. So, testing the efficiency of the Indian index options market is needed. The present study is confined to test the efficiency of Nifty 50 index options market - the European types (which can be exercised only at maturity) and settled by cash.

Theoretical Framework of LBCs

The LBCs for the call and put options are given by equations (1) and (2), respectively. These conditions have to be fulfilled to avoid arbitrage.

$$C_t \geq \max(0, I_t - K e^{-r(T-t)}) \quad (1)$$
$$P_t \geq \max(0, K e^{-r(T-t)} - I_t) \quad (2)$$

In the equations (1) and (2), C_t is the market price of the call options at time t, P_t is the market price of the put options at time t, I_t is the level of the underlying index at time t, K is the strike price of the options contract, T is the expiration time of the options contract, r is the continuously compounded annual risk-free rate of return, and $(T - t)$ is the time to maturity of the options at time t (measured in years).

Equations (1) and (2) do not incorporate the effect of dividends. Assuming the underlying index pays continuously compounded annual dividend yield (δ), equations (1) and (2) are transformed to equations (3) and (4), respectively. This transformation is in line with Chance (1988) and Dixit et al. (2009).

$$C_t \geq \max(0, I_t e^{-\delta(T-t)} - K e^{-r(T-t)}) \quad (3)$$

$$P_t \geq \max(0, K e^{-r(T-t)} - I_t e^{-\delta(T-t)}) \quad (4)$$

From equations (3) and (4), the testable forms of the LBCs are given by equations (5) and (6) as follows :

$$\varepsilon^c_t = \{(I_t e^{-\delta(T-t)} - K e^{-r(T-t)}) - C_t\} \quad (5)$$

$$\varepsilon^p_t = \{(K e^{-r(T-t)} - I_t e^{-\delta(T-t)}) - P_t\} \quad (6)$$

In the above equations (5) and (6), ε^c_t and ε^p_t are the absolute amount of abnormal profits from the call and put index options, respectively. The violations of the LBCs are recorded if $\varepsilon^c_t > 0$ and $\varepsilon^p_t > 0$ in the case of the call and put index options, respectively.

Although the equations (5) and (6) give a positive result, it only indicates mispriced signals. It should not be considered as a conclusive remark on the inefficiency of the market as the study was conducted assuming no transaction costs. Galai (1978) and Bhattacharya (1983) pointed out that the abnormal profits might disappear if the transaction costs are considered.

Objectives of the Study

The main objective of the study is to test the pricing efficiency of Nifty 50 index options market employing LBCs. To get more insight on the behaviours of the mispriced signals obtained from LBCs, frequency and magnitude of the mispriced signals were examined in light of liquidity and maturity of the options contracts. This has been done with the view that mere mispricing of options does not indicate inefficiency of the market. It is the opportunity to extract abnormal profit from these mispriced signals which poses a serious threat to the market efficiency.

Methodology

(1) The Data : The data employed for the study were collected from NSE and Reserve Bank of India (RBI) websites. First, the options contracts were collected from the NSE India website. It consists of daily closing prices of options, deal dates, strike prices, maturity dates, and the number of call and put index options. Only liquid options quotations (contracts that have at least one contract traded in a day) were considered to minimize the bias associated with non - synchronous trading. This process is in line with the methodology obtained by Dixit et al. (2009, 2011). Although there are Near (current month), Next (one month next to current month), Far (two months next to current month), and others long - term options contracts available at a point of time in the Indian options market ; for the study, only Near month options contracts were considered as others lack liquidity (Dixit et al., 2009, 2011 ; Mohanti & Priyan, 2013). The second data sets, Nifty index were also collected from the NSE, India website. It consists of daily closing values of Nifty index and its dividend yields (converted into continuously compounded annual dividend yield). The third data set are the monthly average yield on the 91-day T-bills (converted into a continuously compounded annual rate of return) collected from the RBI website. All these data were collected from April 1, 2012 to March 31, 2018 from the above - stated sources.

(2) Steps for Conducting LBCs

Step 1: The call and put index options were filtered based on liquidity and maturity.

Step 2: The index values were then matched with the corresponding options contracts on the basis of deal date and the maturity date of the options contracts.

Step 3: The matched pairs in Step 2 were fitted to Equations (5) and (6) to check the possibility of arbitrage.

Analysis and Empirical Results

There are 61681 total call index options and 60478 total put index options after filtration based on liquidity and maturity. The total LBCs violated signals for both the call and put index options are reported in the Table 1. The total observed mispriced signals for both the call and put index options have been classified into three specified liquidity levels as: (a) thinly traded options, options that were traded less than 500 contracts per day, (b) moderately traded options, options that were traded more than 500 but less than 1000 contracts per day, (c) highly traded options, options that were traded more than 1000 contracts per day. These classifications were done based on the fact that more the liquidity, higher the opportunity to extract abnormal profits from the mispriced signals, and higher liquidity also ensures execution of trading strategy required to trap the abnormal profits.

It is observed from Table 1 that LBCs are more frequently violated in the case of call index options with 18.30% as compared to put index options with 15.24%. These violations have increased as compared to the previous studies done at the Indian index options market by Dixit et al. (2009) and Mohanti and Priyan (2013). Dixit et al. (2009) reported mispriced signals of about 17.42% for call and about 4.39% for put of the total call (40298) and put (35171) index options considered in their study. Mohanti and Priyan (2013) reported mispriced signals of about 14% for call and 9% for put of the total call (46277) and put (46815) index options considered in their study. This increase in mispriced signals might be due to the fact that the present Indian index options are less efficient or

Table 1. Violations of Lower Boundary Conditions and Liquidity Levels (Number of Observations)

Particulars	Call Options	Put Options
Total number of observations analyzed	61681	60478
Total number of violations observed	14467 (18.30)	10687 (15.24)
Violations with respect to liquidity		
(i) Thinly traded options		
(1-500)	10328 (71.39)	6900 (64.56)
(ii) Moderately traded options		
(501-1000)	1394 (9.64)	1154 (10.80)
(iii) Highly traded options		
(1000 above)	2745 (18.97)	2633 (24.64)
Total	**14467 (100)**	**10687 (100)**

Note. Figures in parentheses indicate percentage.

it might be due to the fact that the present study considers only the current month contracts (Near) while the previous studies considered Near, Next, and Far months contracts. From all these observations, the most important observation is that the frequency of mispriced signals is more at the call compared to the put index options market (both present and previous studies). It is also observed from the Table 1 that the frequency of mispricing is highest in the thinly traded call (71.39%) and put (64.56%) index options. Therefore, the chance of accruing abnormal profit is very low because of high transaction costs associated with it.

The total mispriced signals have been further classified as per the maturity of the options contracts (days left for the options to expire) as 0 - 7, 8 - 14, 15 - 21, and 22 - 30 days as shown in the Table 2. This classification was done based on the fact that most of the arbitrageurs try to unwind their arbitrage positions when the options are going to get expired and there will be more sellers than buyers, which results in increasing the bid - ask spread. Therefore, lesser the days left for the options to expire, lesser will be the opportunity to extract abnormal profits from the observed mispriced signals.

It is observed from the Table 2 that about 32.63% of the total mispriced call and about 39.29% of the total mispriced put index options were concentrated at 0 - 7 days and they lacked abnormal profits. This finding is in resonance with the findings of the previous studies by Dixit et al. (2009, 2011) on Nifty index options, India and Bhattacharya (1983) on the CBOE, USA. To obtain more meaningful information about the frequency of mispriced signals, cross tables across maturity and liquidity levels for both the call and put index options are constructed and shown in Table 3.

The Table 3 reveals that majority of the observed mispriced signals for both the index options are concentrated at the thinly traded region (lack abnormal profits). On the contrary, the mispriced signals at moderately and highly liquid options, which might have the opportunity to extract abnormal profits, belong to the options contracts

Table 2. Mispriced Signals with Respect to Different Maturity Levels (Number of Observations)

Maturity (in day)	Call Options	Put Options
0 - 7	4721 (32.63)	4199 (39.29)
8 - 14	2913 (20.14)	2589 (24.23)
15 - 21	3156 (21.81)	2075 (19.41)
22 - 30	3677 (25.42)	1824 (17.07)
Total	**14467 (100)**	**10687 (100)**

Note. Figures in parentheses indicate percentage.

Table 3. Cross - Table Across Liquidity and Maturity for Mispriced Call and Put Index Options (Number of Observations)

Maturity (in days)	Liquidity					
	Thinly		Moderately		Highly	
	Call	Put	Call	Put	Call	Put
0-7	2417	2152	548	418	1756	1629
8-14	2302	1809	254	267	357	513
15-21	2629	1561	247	229	280	285
22-30	2980	1378	345	240	352	206
Total	**10328**	**6900**	**1394**	**1154**	**2745**	**2633**

Table 4. Descriptive Statistics of the Mispriced Signals with Respect to Liquidity

Liquidity	Mean		*SD*		Q_1		Q_2		Q_3	
	Call	Put	Call	Put	Call	Put	Call	Put	Call	Put
Thinly	17.89	16.83	21.50	18.71	5.63	5.75	12.41	11.81	23.24	20.76
Moderately	11.05	10.78	10.31	8.45	3.75	4.12	8.12	9.35	15.14	15.44
Highly	8.39	9.02	8.59	7.51	2.83	3.50	6.05	7.20	10.95	12.59
Total	15.42	14.25	19.23	16.12	4.53	4.82	10.25	10.20	20.12	17.97

Note. In the table, *SD*, Q_1, Q_2, and Q_3 denote standard deviation, first quartile, second quartile, and third quartile, respectively.

Table 5. Descriptive Statistics of the Mispriced Signals with Respect to Maturity

Maturity	Mean		*SD*		Q_1		Q_2		Q_3	
(in days)	Call	Put	Call	Put	Call	Put	Call	Put	Call	Put
0-7	10.75	12.50	16.26	15.74	3.00	4.15	6.46	8.67	12.58	14.78
8-14	14.35	15.55	19.81	15.83	4.21	5.82	9.46	11.91	18.09	19.87
15-21	16.30	14.93	16.62	15.37	5.93	5.19	12.60	10.43	21.63	19.27
22-30	21.53	15.67	22.38	17.78	8.10	4.84	16.18	11.25	28.66	20.47
Total	15.42	14.25	19.23	16.12	4.53	4.82	10.25	10.20	20.12	17.97

Note. In the table, *SD*, Q_1, Q_2, and Q_3 denote standard deviation, first quartile, second quartile, and third quartile, respectively.

which are going to expire. So, in spite of having high frequent mispriced signals, extracting abnormal profits was not possible due to the fact that a majority of the mispriced signals were concentrated at the thinly traded region and options which are going to expire. All these findings are a good sign for the Indian index options market as it indicates less or no abnormal profits from the observed mispriced signals.

Before giving any conclusion about the efficiency or inefficiency of the Indian index options market, it is important to understand the magnitude of the mispriced signals as it plays an important role to identify the abnormal profits. The magnitudes of mispriced signals are shown in absolute terms with respect to liquidity in Table 4 and with respect to maturity in Table 5.

It is observed from the Table 4 that the mean size and quartile distribution of mispriced signals reduce as the liquidity increases for both the mispriced call and put index options. The abnormal profits in the case of highly and moderately traded options, that is, the mispriced signals, which may have the opportunities to extract abnormal profits as bid-ask spread is assumed to be low, might disappear in the presence of transaction costs as the mean magnitude of mispriced signals seems to be significantly lower than that of thinly traded options. Though the mean magnitude of mispriced signals is quite high for thinly traded options, they may lack abnormal profits due to high bid - ask spread.

From the Table 5, it is observed that for call index options, the mean magnitude of mispriced signals decreases as the options are going to expire, but this kind of observation is not observed at the put index options. This implies that there may be opportunities for abnormal profits as more the days left for maturity, the greater is the increase in the mean magnitude of the mispriced signals. To better understand the behaviour of the observed mispriced signals with respect to maturity, each maturity level has been classified into three specified liquidity levels, and they are reported in the Table 6 for both the call and put index options as liquidity constitutes the basis for extracting the abnormal profits. As higher liquidity ensures lower bid-ask spread and execution of the trading strategy required to trap the abnormal profits, therefore, the magnitude of mispriced signals with respect to maturity has been interpreted in light of the liquidity levels corresponding to their specified levels.

Table 6 clearly reveals that the magnitude of the mispriced signals are more for the options which have more days to expire as reported in Table 5. After the classification of each maturity level into three specified liquidity levels, it becomes clear that extracting abnormal profits will be impossible as mispriced signals show a similar pattern to that of Table 4, that is, the mean magnitude and the quartile distribution of the mispriced signals at thinly traded options are significantly larger than moderately and highly traded liquidity levels. All these signs are good for the market as they all indicate a lack of abnormal profits from the mispriced signals.

Analysis was carried out further to identify whether there exists a significant difference among the mean magnitude across different liquidity and maturity levels as specified in Tables 4 and 5. To validate whether these differences are statistically significant, student's *t* - test and analysis of variance (ANOVA) test were to be applied. Before applying the test statistics on the sampled data, normality test was conducted through one - sample Kolmogorov - Smirnov (KS) statistics. The results are summarized in the Table 7.

From the Table 7, it is observed that the sample data were violating the main assumption of student's *t* - test and ANOVA. So, student's *t* - test and ANOVA couldn't be employed ; instead, their analogous non-parametric statistics, which do not require data to follow any specified distribution, Mann - Whitney *U* test and Kruskal-Wallis (*H* - statistics) were employed for the study. The hypothesis was formulated to test whether there is a

Table 6. Classification of Each Maturity Level Into Three Specified Liquidity Levels for Mispriced Call and Put Index Options (Magnitude of Mispriced Signals)

Maturity (in days)	Liquidity	No. of Violations	Call Options: Magnitude of Violations					No. of Violations	Put Options: Magnitude of Violations				
			Mean	*SD*	Q_1	Q_2	Q_3		Mean	*SD*	Q_1	Q_2	Q_3
0-7	Thinly	2417 (51.20)	14.58	21.18	3.73	8.65	17.62	2152 (51.25)	16.62	20.25	5.50	11.05	19.31
	Moderately	548 (11.61)	7.07	6.50	2.59	5.08	9.97	418 (9.95)	9.78	7.62	4.10	8.39	13.31
	Highly	1756 (37.19)	6.63	6.25	2.58	5.15	9.02	1629 (38.80)	7.74	5.95	3.08	6.37	11.21
	Overall	**4721**	**10.75**	**16.26**	**3.00**	**6.46**	**12.58**	**4199**	**12.50**	**15.74**	**4.15**	**8.67**	**14.78**
8-14	Thinly	2302 (79.03)	15.79	21.71	4.65	10.43	19.87	1809 (69.87)	17.34	17.73	6.64	13.03	20.98
	Moderately	254 (8.72)	9.71	7.59	3.77	7.84	14.12	267 (10.31)	11.65	8.36	4.99	10.24	16.93
	Highly	357 (12.25)	8.37	7.70	2.80	6.45	11.37	513 (19.82)	11.30	9.10	4.65	9.57	15.28
	Overall	**2913**	**14.35**	**19.81**	**4.21**	**9.46**	**18.09**	**2589**	**15.55**	**15.83**	**5.82**	**11.91**	**19.87**
15-21	Thinly	2629 (83.30)	17.31	17.44	6.61	13.30	22.44	1561 (75.23)	16.35	16.82	5.55	10.99	21.20
	Moderately	247 (7.83)	11.50	9.08	4.28	9.50	16.36	229 (11.04)	10.83	8.34	3.90	9.50	15.99
	Highly	280 (8.87)	11.08	11.27	3.55	8.08	15.57	285 (13.73)	10.40	8.38	4.28	8.67	14.01
	Overall	**3156**	**16.30**	**16.62**	**5.93**	**12.60**	**21.63**	**2075**	**14.93**	**15.37**	**5.19**	**10.43**	**19.27**
22-30	Thinly	2980 (81.04)	22.69	23.89	8.42	17.15	30.36	1378 (75.55)	17.01	19.47	5.24	12.25	22.18
	Moderately	345 (9.38)	18.04	13.64	8.07	14.85	25.65	240 (13.16)	11.48	9.80	3.77	9.93	16.35
	Highly	352 (9.58)	15.05	12.46	5.63	11.87	21.41	206 (11.29)	11.56	10.19	4.06	8.60	15.77
	Overall	**3677**	**21.53**	**22.38**	**8.10**	**16.18**	**28.66**	**1824**	**15.67**	**17.78**	**4.84**	**11.25**	**20.47**

Note.

1. Figures in parentheses indicate percentage.
2. In the table *SD*, Q_1, Q_2, and Q_3 denote standard deviation, first quartile, second quartile, and third quartile, respectively.

Table 7. One - Sample Kolmogorov - Smirnov Statistics to Assess Normality

Variables		Call Options	Put Options
Number of Observations		14467	10687
Normal Parameters (a, b)	Mean	15.42	14.25
	Std. Dev	19.23	16.12
Most Extreme Differences	Absolute	0.21	0.19
	Positive	0.16	0.16
	Negative	-0.21	-0.19
Kolmogorov-Smirnov *Z*		25.41	19.47
Asymp. Sig. (2-tailed)		**0.00**	**0.00**

Note.
1. a. Test distribution is Normal. b. Calculated from data.
2. Significant at 5% level of significance.

Table 8. Summary of Mann - Whitney *U* Statistics

Options Types	*N*	Test Statistics	
Call	14467	Mann-Whitney *U*	75843057.50
Put	10687	Wilcoxon *W*	132954385.50
Total	25154	*Z*	-2.57
		Asymp. Sig (2-tailed)	**0.01**

Note. Significant at 5% level of significance.

significant difference between the mean magnitude of the mispriced call and put index options. For this, the Mann-Whitney *U* test was employed. The results of the test are summarized in the Table 8.

↳ **H_{01}:** There is no significant difference between the mean sizes of the mispriced call and put index options.

It is observed from the Table 8 that the test result is significant at the 5% level. Therefore, we reject the null hypothesis (H_{01}) and we conclude that there is a significant difference between the mean magnitudes of mispriced call and put index options.

Further, to validate whether the mean magnitude of mispriced signals at different specified levels of liquidity and maturity are statistically significant from one another, the hypotheses were formulated and tested by a non-parametric test, Kruskal - Wallis test. The test results are summarized in Tables 9 and 11 for liquidity and maturity, respectively. In addition to this, Dunn's multiple comparison tests were employed for the post-hoc analyses of all possible pairs and the tests results are summarized in Tables 10 and 12 for liquidity and maturity, respectively.

The following are the null-hypotheses drawn for the study :

↳ **H_{02}:** There is no significant difference between the mean sizes of different liquidity levels for the mispriced call index options.

↳ **H_{03}:** There is no significant difference between the mean sizes of different liquidity levels for the mispriced put index options.

↳ **H_{04}:** There is no significant difference between the mean sizes of different maturity levels for the mispriced call index options.

Table 9. Kruskal - Wallis Test for the Difference Among the Mispriced Signals Across Different Liquidity Levels of Call and Put Index Options

Liquidity	Call Options					Put Options				
	Ranks		Test Statistic (a, b)			Ranks		Test Statistic (a, b)		
	N	Mean Rank	Chi-Square	*df*	Sig.	*N*	Mean Rank	Chi-Square	*df*	Sig.
Thinly	10328	7907.30				6900	5838.12			
Moderately	1394	6278.04	1001.42	2	**0.00**	1154	4881.65	532.91	2	**0.00**
Highly	2745	5186.20				2633	4251.75			
Total	**14467**					**9215**				

Note.

1.a. Kruskal Wallis Test b. Grouping Variable: Liquidity

2.Significant at 5% level of significance.

Table 10. Dunn's Test for Multiple Comparisons Amongst Different Liquidity Levels of Call and Put Index Options

Dunn's Multiple Comparison	Call Options			Put Options		
Sample 1 Vs Sample 2	Test Statistic	Std. Test Statistic	Adj. Sig. (*p* < 0.05)	Test Statistic	Std. Test Statistic	Adj. Sig.(*p* < 0.05)
Highly Vs Moderately	1091.84	7.95	**Yes**	629.90	5.78	**Yes**
Highly Vs Thinly	2721.10	30.34	**Yes**	1586.37	22.45	**Yes**
Moderately Vs Thinly	1629.26	13.67	**Yes**	956.47	9.75	**Yes**

Note. Each row tests the null hypothesis that Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests).

➯ **H_{05}:** There is no significant difference between the mean sizes of different maturity levels for the mispriced put index options.

From the Table 9, it is observed that the test results for both the call and put index options show statistical significance at the 5% level (H_{02} and H_{03} are rejected), which implies that there is a significant difference between the mean magnitudes of the different liquidity levels for both the call and put index options. The post - hoc test was conducted, and Dunn's multiple comparison tests for all possible pairs of liquidity for both the call and put index options were conducted, and the results are reported in the Table 10.

It is observed from the Table 10 that the test results show statistical significance at the 5% for all the pairs, which implies that all the possible pairs : highly traded vs moderately traded, highly traded vs thinly traded, and moderately traded vs thinly traded for both the call and put index options are significantly different from one another.

From the Table 11, it is observed that the test results for both the call and put index options show statistical significance at the 5% level (H_{04} and H_{05} are rejected), which implies that there is a significant difference between the mean magnitude of the four specified levels of maturity. The post - hoc test was conducted, and Dunn's multiple comparison tests for all possible pairs of maturity was conducted for both the call and put index options, and the results are reported in the Table 12.

From the Table 12, it is observed that the test results for the call index options show statistical significance at 5% for all the possible pairs. For the put index options, 8 -14 vs 22 - 30 and 15 - 21 vs 22 - 30 pairs are not statistically

Table 11. Kruskal-Wallis Test for the Difference Among the Mispriced Signals Across Different Maturity Levels of Call and Put Index Options

Maturity (in days)	Call Options					Put Options				
	Ranks		Test Statistic (a, b)			Ranks		Test Statistic (a, b)		
	N	Mean Rank	Chi-Square	*df*	Sig.	*N*	Mean Rank	Chi-Square	*df*	Sig.
0-7	4721	5647.49				4199	4850.50			
8-14	2913	6915.64	1418.64	3	**0.00**	2589	5809.46	187.65	3	**0.00**
15-21	3156	7853.75				2075	5519.47			
22-30	3677	8991.24				1824	5619.79			
Total	**14467**					**10687**				

Note.
1.a. Kruskal - Wallis Test b. Grouping Variable: Liquidity
2.Significant at 5% level of significance.

Table 12. Dunn's Test for Multiple Comparisons Amongst the Different Maturity Levels of Call and Put Index Options

Dunn's Multiple Comparison	Call Options			Put Options		
Sample 1 Vs Sample 2	Test Statistic	Std. Test Statistic	Adj. Sig. ($p < 0.05$)	Test Statistic	Std. Test Statistic	Adj. Sig. ($p < 0.05$)
0-7 Vs 8-14	-1268.15	-12.89	Yes	-958.96	-12.44	Yes
0-7 Vs 15-21	-2206.27	-22.98	Yes	-668.97	-8.08	Yes
0-7 Vs 22-30	-3343.76	-36.40	Yes	-769.28	-8.89	Yes
8-14 Vs 15-21	-938.11	-8.74	Yes	-289.99	-3.19	Yes
8-14 Vs 22-30	-2075.60	-20.04	Yes	-189.67	-2.01	No
15-21 Vs 22-30	-1137.49	-11.22	Yes	-100.32	-1.01	No

Note. Each row tests the null hypothesis that Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests).

significant at the 5% level. This will not cause major issues while interpreting the results of the analyses as majority of the mispriced put are concentrated at 0 -7 days to maturity and the mean magnitude of 0 -7 days to maturity is significantly different from all the possible pairs.

In operational term, the results show that the mean magnitude of mispriced signals for the thinly traded index options is significantly different from those of moderately and highly traded for both the call and put index options. In the case of the days left for maturity, for call index options, the mean magnitude of the mispriced signals for all the possible pairs are significantly different from each other. However, in the case of the put index options, all the levels pairs of the days left for the maturity are significantly different, except 8 - 14 vs 22 - 30 and 15-21 vs 22-30. All these findings are a good sign for the Indian index options market as it indicates that truly exploitable mispriced signals are significantly different from the non - exploitable mispriced signals. This means that the mispriced signals which are designated to have abnormal profits are significantly different from the mispriced signals which are not designated to have abnormal profits.

Conclusion

The pricing efficiency of the Indian index options market was examined empirically by testing the LBCs. The study finds frequent violations of LBCs both at the call and put index options market. The frequency of violations is more at the call compared to that of the put index options market, a finding which is consistent with the previous studies conducted by Mohanti and Priyan (2013) and Dixit et al. (2009, 2011).

In terms of frequency of mispriced signals, the majority of the mispriced signals are concentrated at the thinly traded level and options which are going to get matured. The cross table between the liquidity and maturity reveals that majority of the mispriced signals are concentrated at the thinly traded level, irrespective of the days left for the options to expire, which lack abnormal profits. On the contrary, a majority of the mispriced signals are concentrated at the highly traded level, which might have abnormal profits that are concentrated at 0 - 7 days left for maturity. In short, extracting abnormal profits from the observed mispriced signals is not possible due to lack of liquidity and less time to maturity.

In terms of magnitude of the mispriced signals, the mean magnitude of mispriced put and call index options is significantly different. The mean magnitude of mispriced signals reduces as the liquidity increases and the magnitude of mispriced signals at the thinly traded levels is much larger than that of the moderately and highly traded levels, which gives no room to extract abnormal profits from the observed mispriced signals. Same patterns are also observed in terms of maturity when each maturity level is classified into three specified liquidity levels.

It becomes clear that in spite of frequent violations of LBCs prevailing in the Indian index options market, extracting abnormal profit is not possible as most of the violations are at the thinly traded level and options which are going to expire. The study concludes that the Indian index options market during the period of the study was efficient as there was no or lack of arbitrage profits from the mispriced signals. This finding is in line with the findings of previous studies such as the studies of Dixit et al. (2009, 2011) and Mohanti and Priyan (2013), who also conducted their studies at the initial development stage of the Nifty index options market.

Policy Implications

The findings of the study will be useful to all types of investors, stock exchanges, policymakers, and other concerned authorities nationally and internationally who are involved in this market. The study is important from the view of academicians, professionals, and the regulators as the index options market plays an important role in price discovery, risk management, and asset allocations, which are vital for the development of an economy. The study also contributes to the literature on market efficiency of the index options, particularly in the case of the Indian index options market.

Limitations of the Study and Scope for Further Research

There are some limitations in the study that can be considered as scope for further research. The data for the index options are daily closing prices and because of this problem of data, non-synchronization may arise and the only solution to overcome it is to employee intraday data. In the meantime, the study was conducted assuming no transaction costs as these are difficult to estimate. Such costs differ for different participants in the market, and with the types of trading strategies employed. So, the scope for further research is to incorporate transaction costs and employee intraday data while testing the LBCs of the Indian index options market.

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