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Testing Market Efficiency Using Lower Boundary Conditions of Indian Options Market

Atul Kumar[1] and T V Raman[2]

[1] *Pursuing Ph. D from Amity Business School*
[2] *Associate Professor in Amity Business School, Amity University*

Abstract: This paper is an empirical study on the Indian options market from the period 1st January, 2010 to 31st December 2015. The Nifty futures index and Nifty options index data is considered to test the efficiency of options market. This method is moreover a test of joint market efficiency as we test the efficiency of futures and options market simultaneously. Violations or mispricing in the options market has been calculated by taking the lower boundary conditions of a contract. The number of violations in the call and put options are taken as the basis of efficiency and imply a possibility of arbitrage. The percentage violations in put options was found to be less than the call options, thereby implying that the put options contracts are relatively more efficient than the call options. The analysis has been done for different level of maturity and liquidity. It was found that more than 90 percent of the violations happen in the level where the liquidity is of less than 500 contracts traded per day.

Keywords: Call options, Put options, Lower Boundary conditions, Violations, Joint market efficiency, Arbitrage

INTRODUCTION

The options contracts in the Indian capital market were introduced from 4th June, 2001. The primary purpose of the options market is to provide hedging to the investors for their investment in the real market, equity market etc. The options market is assumed to be more complicated than the equity market and therefore the participation of informed investors is high and therefore should be used for the price discovery of an asset. The options market would also help the investors to allocate their capital in a more efficient manner (Ackert and Tian, 2000).

The price of an options contract depends on the spot price of the underlying asset. The efficiency of the options market can be analyzed taking the spot price or the futures price of the underlying asset.

In this research paper the futures price is considered for testing the efficiency of options market. As we are testing two markets simultaneously, so it is basically a test for joint market efficiency.

The violation in the options market is defined as when there is an opportunity for an arbitrageur to make risk free absolute abnormal profits. The mispricing can be exploited by taking opposite position in the futures and options market. Let's say that the price of a call option is lower than price as calculated by the lower boundary condition. In such situation riskless profit can be made by purchasing a call and selling the futures contract on the same underlying asset. The number of violations is a measure of efficiency of the options market. Data analysis shows that 46 percent and 52 percent of mispricing in call and put options occur in less than "30 days" category. The abnormal profit that can be made by arbitrageur by exploiting the mispricing could not be achieved due to lack of liquidity as shown by the data analysis.

The efficiency of the options market has been studied by researcher through various methods. Conceptually the efficiency can be between the (i) spot and options market (ii) futures and options market. The efficiency can be analyzed using put-call parity or violations of lower boundary conditions.

The objective of this paper is to test the efficiency of options and futures market. In the paper the efficiency has been analyzed between futures and options market and using lower boundary conditions in call and put options.

REVIEW OF LITERATURE

The futures and options market participants are assumed to be more informed. The efficiency of the options market indicate that the market is fulfilling the purpose of price discovery, allocation of capital and risk hedging (Ackert and Tian, 2000).

Analyzing the Index futures and Index options for mispricing is also an indicator of inter-relationship of futures and options market. This method is moreover a test of joint market efficiency. The use of futures contract for mispricing is also advantageous as it removes the constraint of short selling, which is present in the spot market (Fung, Cheng and Chan, 1997). The smoothness at which the violations can be exploited also shows the efficiency of the market and sophistication of participants (Lee and Nayar, 1993).

The percentage of violations should reduce along the years to prove that the market participants are moving along the learning curve process. The intraday data was analyzed for the German stock index options by Mittnik and Rieken (2000).

The rational pricing of options contract using lower boundary conditions was first attempted by Merton (1973). The inter-relationship of futures and options market and the arbitrage profits that can be made by the investor by exploiting the violations was studied by Galai (1978). Similar studies to test the options market efficiency was done by Bhattacharya (1983), Halpern and Turnbull (1985), Shastri and Tandon (1985), Chance (1988), Puttonen (1993a), Berg, Brevik and Saettem, (1996), Mittnik and Rieken (2000), Ackert and Tian (2001), Dixit (2009), Mohanti (2013)

Put-call parity condition has been used to test the options efficiency using the futures price for the same underlying asset by Lee and Nayar (1993), Fung and Chan (1994), Fung, Cheng and Chan (1997), Fung and Fung (1997), Fung and Mok (2001).

In this paper the condition tested is the lower boundary condition rather than the put-call parity violations. This study in terms of conducting the analysis is similar to the work done by Halpern and Turnbull (1985).

Violations in the options market can be *ex-ante* exploited by adopting a trading strategy as given by Trippi (1977), Chiras and Manaster (1978). In this study no trading strategy has been adopted and the analysis is *ex-post* in nature.

DATA AND METHODOLOGY

The data required for the research paper can be divided into three categories (i) Nifty Index futures data (ii) Nifty Index options contract data and (iii) Annualized returns on 91 Day T-Bills. The first and the second category of data has been taken from NSE website and the third category of data has been taken from RBI website.

The data for the period from 1st January 2010 to 31st December 2015 is taken from the mentioned sources. On NSE the daily trade for Nifty index futures contract has three expiry periods. The three expiry periods are referred as near to the month, next to the month and far to the month periods. On each trading day the closing price of three expiry periods of Nifty futures index is taken and mapped with the Nifty index options contract data. In the options market, on each day for each expiry period there may be dozens of contracts at different strike place. The pairing of futures and options contract data is done on day to day basis to analyze the violation of lower boundary condition.

Theoretically, the premium for options contract should not be lower than a certain limit. The equations for the lower boundary condition for the premium of call and the put options are:

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

$$P_t \geq \max\{0, e^{-r(T-t)}(K - F_t)\};$$

Where:

C_t: Call premium at time period ‘t’

P_t: Put premium at time period ‘t’

r: Annual risk free returns

K: Strike price of the options contract

F_t: Futures price of the Nifty contract with the same expiration period at time period ‘t’

T: Expiration time for the options contract

(T-t): Time to maturity for the option contract expressed in years

The minimum premium should be as per the equations and if incase the premium on the contracts is lower than what is arrived by the equations then there is a scope of arbitrage. For the actual absolute profit that can be made through arbitrage the transaction costs and the bid-ask spread data are to be considered. The bid-ask spread data is not available on the NSE website and therefore, it is assumed that the spread is minimal and does not impact the calculations of absolute profits. The above equations have been converted to test the efficiency of options market. The testable forms of equations are:

$$\varepsilon_t^c \geq \max\{0, e^{-r(T-t)}(F_t - K)\} - C_t;$$

$$\varepsilon_t^p \geq \max\{0, e^{-r(T-t)}(K - F_t)\} - P_t;$$

If $\varepsilon_t^c > 0$, and $\varepsilon_t^p > 0$, then there is a possibility of arbitrage after considering the transaction costs due to the violation of lower boundary condition. The amount of absolute profit which an arbitrageur can make by exploiting the opportunity will be ε_t^c minus the transaction costs

Transaction Costs

The transaction cost is the cost incurred by the investor while taking a position in the options and the futures market. The transaction cost comprises brokerage charges, service tax, security transaction tax, SEBI turnover charges and stamp duty. The latest charges under each category have been taken from NSE website. The service tax is 15 percent on the brokerage charges. The security transaction tax (STT) on options contract is 0.017 percent and 0.010 percent on futures contract. The stamp duty differs from state to state and is approximately 0.002 percent on non-delivery trade derivatives contracts. The SEBI turnover charge is 0.0002 percent. The brokerage charges depends upon the type of brokerage plan availed by the retail investors from the brokerage house. The average brokerage charge is around 0.05 percent of the strike price plus price of call premium or put premium. Similarly, the brokerage charge for the futures contract when expressed as a percentage strike price plus the premium for call or put options is around 0.046 percent (Dixit, Yadav and Jain, 2011).

The arbitrage process will incur the transaction cost of the options contract and the transaction cost of the futures contract. The total transaction cost for the retail investors is taken as 0.20 percent for the analysis. The total transaction cost for the institutional investors is around 0.12 percent (Mohanti and Priyan, 2013). The transaction cost is expressed as a percentage of normalized profits as the violations are recorded in terms of normalized profits.

Normalized Profits

The absolute profit made from the arbitrage process is normalized by dividing the abnormal profit by strike price plus the premium for call or put options. For call options it will be $\varepsilon_t^c/(K+C_t)$ and $\varepsilon_t^p/(K+P_t)$ for put options. The purpose of normalizing the profit is for convenience in the calculation of violations as the transaction cost is also expressed in terms of normalized profits. The normalizing method is as per the technique by Nilsson (2008).

DATA ANALYSIS AND EMPIRICAL RESULTS

The violations analysis has been classified on the basis of maturity and liquidity. The maturity level has been divided into four categories (i) "0-7" Days to maturity; (ii) "8-30" Days to maturity; (iii) "31-60" Days to maturity; and (iv) "61-90" Days to maturity. The liquidity refers to number of contracts traded and it has been divided into three levels (i) less than 500 contracts traded per day; (ii) more than 500 and less than 2000 contracts traded per day; and (iii) more than 2000 contracts traded per day.

The number of violations in the call and the put options are given in Table-1. The percentage of violations in the call options and put options is 4.90 and 2.33 respectively. This implies that the put options are relatively more efficient than the call options.

Table 1
Data regarding the number of violations including transaction costs in the call options

	Call Options		
Year	*No. of observations*	*No. of violations*	*Percentage*
2010	12878	378	2.94
2011	16398	501	3.06
2012	17556	790	4.50
2013	18248	1185	6.49
2014	23337	1620	6.94
2015	21972	935	4.26
Total	**110389**	**5409**	**4.90**

Table 2
Data regarding the number of violations including transaction costs in the put options

	Put Options		
Year	*No. of observations*	*No. of violations*	*Percentage*
2010	13444	228	1.70
2011	15271	483	3.16
2012	17597	534	3.03
2013	17595	414	2.35
2014	21936	334	1.52
2015	22790	535	2.35
Total	**108633**	**2528**	2.33

The trend analysis of percentage violations from 2010 to 2015 is shown in Figure-1. The trend line shows that the efficiency in the put options is more as compared to the efficiency in the call options.

The liquidity in the call and put options is high for the same month expiration period and very low in the following months. Figure-2, shows that out of the total number of contracts traded 92 percent of the call options contracts are of the same month expiration period. The liquidity in the options market is very low as the expiration time increases.

The analysis on the number and magnitude of violations is shown in Table 3 and Table 4. The violations have been calculated after considering the transaction costs. The transaction cost has been taken as 0.2 percent of strike price plus premium on the call options. About 98 percent of violations are in the thinly traded and moderately traded level in all the category of maturity level as depicted in Table-3. Similar results are also depicted in Table 4. Most of the violations are in the thinly trade level and that can be conceptually understood also. As in the thinly traded level the number of contracts

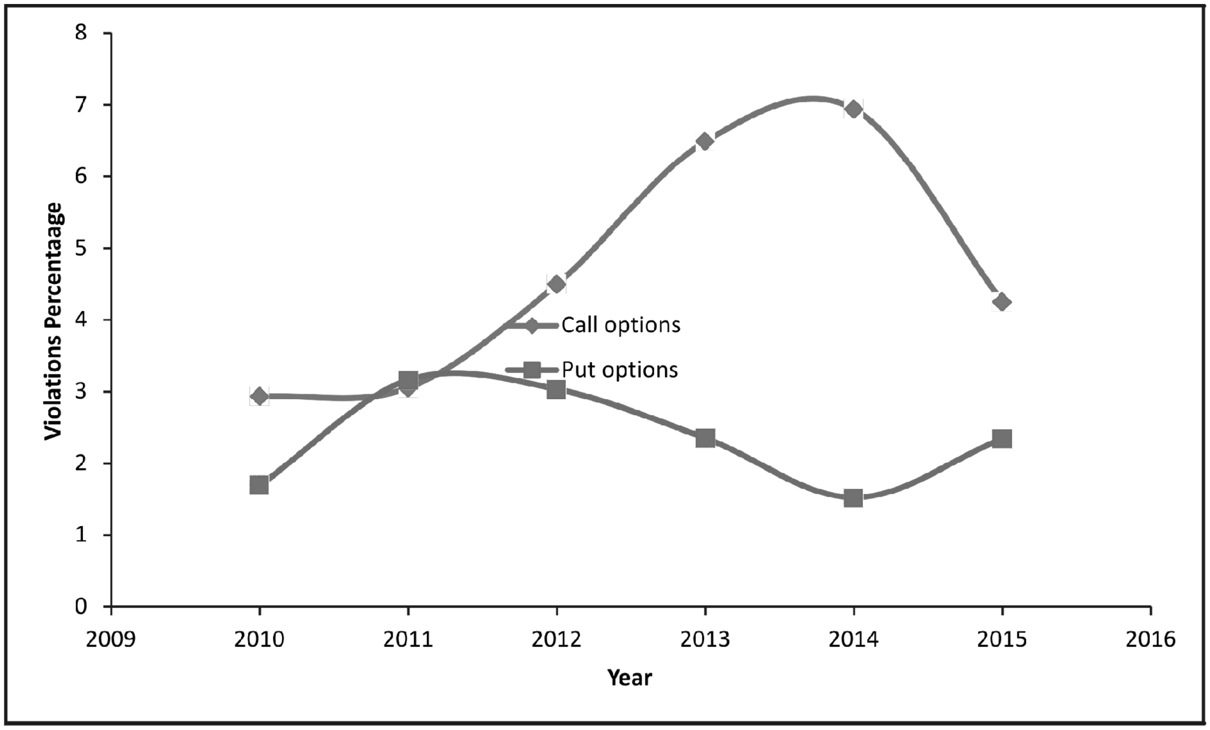

Figure 1: Shows the change in percentage of violations in call and put options from 2010 to 2015

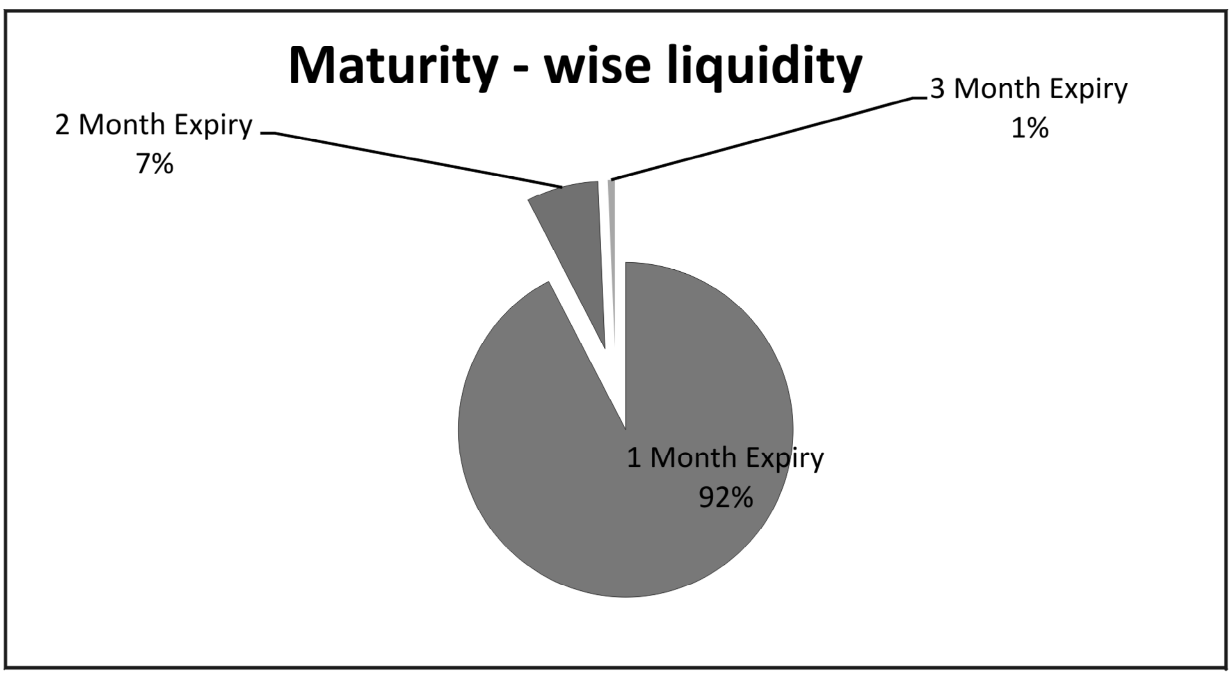

Figure 2 : Shows the percentage of call options contracts having one month, two months and three months expiry

trade in the market is less than 500 and therefore, there is liquidity problem in the market. The mispricing or the violations are not exploitable in the market as there would be wide gap between the bid-ask spread. On the other hand there are hardly 2 percent of violations in the highly traded level. As the liquidity is high in the market so the mispricing in the market is exploitable by the retail investor and financial Institutions. The Table-2 also shows that 46 percent of the violations in the call options and 52 percent of violations in the put options take place in "0-7" Days and "8-30" Days categories. One of the reasons cited for the above percentage is the unwinding of open position by arbitrageur and speculators, the liquidity is less in the market and the violations are not exploitable by the investors.

In the "31-60" Days category, the total percentage of violations in the call options and put options is 35 percent and 32 percent respectively. Around 96 percent and 98 percent of violations are concentrated in the thinly traded level. For this category also the reason for the mispricing not being exploited is lack of liquidity.

In the "61-90" Days category, the total percentage of violations in the call options and put options is 17 percent and 14 percent respectively. In the put options around 99 percent of mispricing is in the thinly traded segment and zero percent violations in the highly traded segment. The number of contracts traded is less and less participation of investors in the market leads to high bid-ask spread.

Table 3
Shows the number and magnitude of violations with respect to time to maturity in call options after including the transaction costs

Days to Maturity	*Liquidity*	*Call Options*					
		No. of Violations	*Mean*	*SD*	*Q1*	*Q2*	*Q3*
"0-7" Days	Thinly traded	475 (81.06)	0.5310	0.5913	0.2604	0.3689	0.5754
	Moderately traded	99 (16.89)	0.6280	0.7029	0.2586	0.3717	0.6934
	Highly traded	12 (2.05)	0.4925	0.3605	0.2096	0.3607	0.6165
	Total	586	0.5465	0.6080	0.2595	0.3678	0.5896
"8-30" Days	Thinly traded	1668 (86.07)	0.4845	0.4526	0.2489	0.3422	0.5422
	Moderately traded	256 (13.21)	0.4618	0.5471	0.2475	0.3237	0.4844
	Highly traded	14 (0.72)	0.2531	0.0724	0.2068	0.2214	0.2732
	Total	1938	0.4798	0.4649	0.4649	0.4661	0.4683
"31-60" Days	Thinly traded	1684 (87.66)	0.4697	0.4149	0.2550	0.3392	0.5348
	Moderately traded	210 (10.93)	0.6327	0.7169	0.2465	0.3582	0.7211
	Highly traded	27 (1.41)	0.5290	0.5982	0.2456	0.2747	0.4504
	Total	1921	0.4883	0.4629	0.2542	0.3414	0.5462
"61-90" Days	Thinly traded	894 (92.64)	0.6378	0.7292	0.3060	0.4412	0.6904
	Moderately traded	44 (4.56)	0.9152	1.0191	0.3520	0.7273	1.0423
	Highly traded	27 (2.80)	1.4104	1.1811	0.5116	0.9879	2.0303
	Total	965	0.6720	0.7717	0.3093	0.4556	0.7540

Note: 1. Figure in the parenthesis shows percentage

2. SD stands for standard deviation and Q1, Q2 and Q3 are the first, second and third Quartile

Table 4
Shows the number and magnitude of violations with respect to time to maturity in put options after including the transaction costs.

Days to Maturity	*Liquidity*	*Put Options*					
		No. of Violations	*Mean*	*SD*	*Q1*	*Q2*	*Q3*
"0-7" Days	Thinly traded	371 (94.88)	0.4612	0.3104	0.2580	0.3601	0.5370
	Moderately traded	16 (4.09)	0.3067	0.1046	0.2414	0.2663	0.3431
	Highly traded	4 (1.02)	0.2169	0.0064	0.2118	0.2171	0.2222
	Total	391	0.4524	0.3055	0.2515	0.3543	0.5209
"8-30" Days	Thinly traded	916 (96.52)	0.4587	0.3092	0.2558	0.3390	0.5521
	Moderately traded	26 (2.74)	0.2688	0.0703	0.2245	0.2522	0.2840
	Highly traded	7 (0.74)	0.2336	0.0358	0.2154	0.2194	0.2344
	Total	949	0.4518	0.3062	0.2531	0.3310	0.5332
"31-60" Days	Thinly traded	819 (98.44)	0.4867	0.3804	0.2579	0.3438	0.5451
	Moderately traded	11 (1.32)	0.3750	0.3649	0.2387	0.2674	0.3061
	Highly traded	2 (0.24)	0.2103	0.0043	0.2088	0.2103	0.2118
	Total	832	0.4846	0.3800	0.2569	0.3425	0.5417
"61-90" Days	Thinly traded	356 (99.44)	0.5822	0.6036	0.2925	0.3969	0.6386
	Moderately traded	2 (0.56)	0.3290	0.0246	0.3203	0.3290	0.3377
	Highly traded	0 (0.00)	0.0000	0.0000	0.0000	0.0000	0.0000
	Total	358	0.5808	0.6022	0.2932	0.3947	0.6379

Note : 1. Figure in the parenthesis shows percentage

2. SD stands for standard deviation and Q1, Q2 and Q3 are the first, second and third Quartile

The number of violations in different categories was tested for statistical significance. Analysis of Variance (ANOVA) is a statistical tool to analyze the significant difference in means across the various groups. ANOVA assumes that the data has been taken from a sample of normal distribution population. Table-3 shows the result of Kolmogorov-Smirnov test of normality on the violations in the call and put options. As the '*p*' value is less than 0.05, so we fail to accept the null hypothesis. The data is not normally distributed and therefore ANOVA cannot be applied for statistical testing. A non-parametric test "kruskal-Wallis" test can be applied when the condition of normality is not met.

Table 5
Shows the result of Kolmogorov-Smirnov Test for Normality

Parameter	*Call Options* *Normalized violations*	*Put Options* *Normalized violations*
Number of observations	5409	2528
Mean	.524328	.481048
Median	.360675	.348973
Variance	.305	.150
Std. Deviation	.5519727	.3874440
Minimum	.2000	.2001
Maximum	13.5784	5.7082
Kolmogorov-Smirnov[a (Statistic)]	0.2780	.234
Sig.	0.000	0.000

The kruskal-Wallis test was applied on the level of maturity category. Table 6 shows that there is statistical significant difference in the number of violations between the various maturity levels in the call options. The Table does not specifically indicate that in which specific pair of maturity level the number of violations are significantly different.

The null hypothesis is rejected for the put options. Table 7 shows that there is statistical significant difference in the number of violations between the various maturity levels in the put options. The Table does not specifically indicate that in which specific pair of maturity level the number of violations are significantly different.

Table 6
Shows the output of Kruskal-Wallis test for the call options

		Call Options			
Maturity	*Number of Violations*	*Mean Rank*	*Chi-Square*	*df*	*Asymp. Sig.*
0-7 Days	585	2745.57	147.962	3	.000
"8-30" Days	1938	2540.64			
"31-60" Days	1921	2587.41			
"61-90" Days	965	3244.56			
Total	5409				

Table 7
Shows the output of Kruskal-Wallis test for the put options

		Put Options			
Maturity	*Number of Violations*	*Mean Rank*	*Chi-Square*	*Df*	*Asymp. Sig.*
0-7 Days	391	1238.77	25.426	3	.000s
"8-30" Days	949	1219.33			
"31-60" Days	832	1252.14			
"61-90" Days	356	1442.06			
Total	2528				

There are six possible groups combination from four levels of maturity category. Table-8, shows that between "8-30" Days and "31-60" Days categories there is no significant difference in the number of violation. In all the remaining categories there is a statistical significant difference as the '*P*' value is less than 0.05.

The analysis of put options in Table-9 shows that between "0-7" Days and "8-30" Days, "0-7" Days and "31-60" Days, "8-30" Days and "31-60" Day groups there is no significant difference in the number of violations as the '*P*' value is greater than 0.05.

Table 8
Shows the level of significance between the various maturity categories in call options

Call Options			
Maturity category	*Chi-Square*	*Df*	*Asymp. Sig.*
“0-7” Days and “8-30” Days	7.566	1	.006
“0-7” Days and “31-60” Days	4.620	1	.032
“0-7” Days and “61-90” Days	36.604	1	.000
“8-30” Days and “31-60” Days	.947	1	.330
“8-30” Days and “61-90” Days	129.791	1	.000
“31-60” Days and “61-90” Days	115.167	1	.000

Table 9
Shows the level of significance between the various maturity category in put options

Put Options			
Maturity category	*Chi-Square*	*Df*	*Asymp. Sig.*
“0-7” Days and “8-30” Days	.170	1	.680
“0-7” Days and “31-60” Days	.065	1	.799
“0-7” Days and “61-90” Days	14.582	1	.000
“8-30” Days and “31-60” Days	.873	1	.350
“8-30” Days and “61-90” Days	24.629	1	.000
“31-60” Days and “61-90” Days	16.298	1	.000

CONCLUSION

The percentage of violations in the call options is more than the put options during the time period 2010 to 2015. On the basis of trend analysis for the call and put options for the mentioned period it can be concluded that the put market is relatively more efficient than the call options. The trend analysis also depicts the cyclical trend of call options thereby showing the irrational behavior of the investors. Around 92 percent of the contacts traded in options market have a maturity of less than 30 days. This shows that the liquidity is low in the contracts of high maturity period. Impact of liquidity was analyzed by sub-dividing it into thinly, moderately and highly traded categories. It was seen that around 90 percent and 95 percent of mispricing in call and put options respectively occur in thinly traded category. Therefore, it can be concluded that the mispricing is not exploitable by the arbitrageurs due to lack of liquidity in the market.

Around 46 percent of the violations in the call options and 52 percent of violations in the put options take place in “0-7” Days and “8-30” Days categories. It shows that the violations are concentrated where the maturity period is low. The reason for clustering of mispricing could be the unwinding of open positions by the arbitrageur and lack of liquidity on the buy and sell side of the trade. The results are similar to study done by Bhattacharya (1983), Dixit (2011) and Mohanti (2013).

The percentage of violations in the options market suggest that the Indian capital market in derivative segment is yet to achieve the stage, where it can be used to perfectly price the underlying asset and allocation of resources. As long as inefficiency exists in the options market the price discovery objective of derivative market will remain questionable.

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