Nifty Futures Rollover Strategies

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Abstract

As expiration dates for Nifty stock index futures approach, trading volume in calendar spreads rises at times to over 50% of the total daily volume, making this transaction particularly important to execute efficiently for investors rolling over sizable positions into deferred month contracts. In this study, futures data covering 12 recent Nifty futures expirations was used for rollover strategy construction, analysis, and testing. We reported here on the comparison of findings for three different strategies: optimally rolling an amount that minimized average calendar spread volatility subject to practical trading constraints, rolling an equal number of Nifty futures daily, and rolling all contracts on a single day. We found, in all cases, that the optimal strategy outperformed the other two commonly employed rollover strategies. Practical guidelines for rolling Nifty futures positions were also discussed.

Key words : rollover strategy, calendar spreads, stock index futures, Nifty futures

JEL Classification : G10, G11, G13, G14, G15

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Strategies using stock index futures contracts to create and sustain investment products and hedging tactics over a sustained period of time require that expiring contracts be replaced regularly with new ones expiring at a later date. Typically, the contract in current use is closed out, and a new contract is opened, thereby maintaining strategy integrity. While execution of the two contracts can be accomplished separately, it is normal in most futures markets to accomplish these transactions simultaneously by placing a single order called a calendar spread. That the order level is placed as the difference (spread) between the prices of the two contracts makes this a spread order. That the two contracts in question have calendar months differing in expiration accounts for the transaction being named a calendar spread. Replacement of the currently expiring or front month contract with another future is termed a rollover.

Calendar spreads play three important roles in capital markets. First, they limit the market risk arising from two independent transactions that replace one contract with another by requiring execution at an investor-controlled arithmetic difference between the two futures prices. Trading contracts simultaneously removes uncertainty in the final spread, resulting in a cost reduction for rollovers. Next, the ability of market participants to control the rollover risk, in turn, encourages rising transaction volume with related liquidity as expiring front month contracts are rolled into new ones. Finally, governments in both developed and developing countries intentionally

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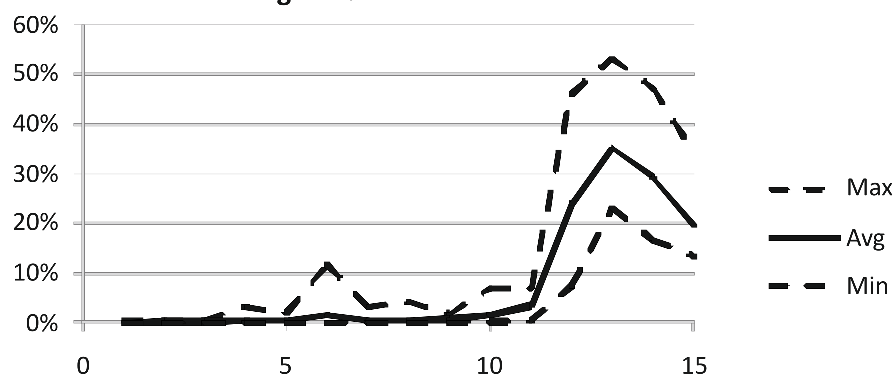
encourage the growth of domestic futures markets to support a broader, vital strategic goal of attracting and sustaining foreign investment in their capital markets. By reducing market risk and enhancing liquidity, calendar spreads help create an appealing market for foreign and domestic institutional investing. In this paper, we compare two common institutional rollover strategies with a new, potentially optimal means for conducting rolls that may add to overall market efficiency. Data used for testing and comparing these three strategies covers all monthly expirations for 2016. The results add new and practical information to the sparse literature on futures calendar spreads.

Literature Review

The three primary futures market participants in calendar spreads are arbitrageurs, hedge funds, and institutional investors. Separately, these participants pursue long or short futures strategies that require maintenance of positions spanning multiple expiration dates. Together, as seen in the Figure 1, these participants in India's Nifty futures market create calendar spread volumes that can rise to over 50% of daily futures trading volume, thereby making this an essential transaction of considerable significance and worthy of study. Literature on this topic, however, is extremely sparse.

Figure 1. Nifty Futures Daily Average Spread Volume and Range as % of Total Futures Volume



The vast literature of statistical arbitrage and pairs trading includes selected studies of calendar spreads specifically related to their arbitrage potential (Gatev, Goetzmann, & Rouwenhorst, 2006 ; Girma & Paulson, 1999 ; Jones, 1981 ; Miao, 2014 ; Monroe & Cohn, 1986 ; Peterson, 1977 ; Rentzler, 1986 ; Schrock, 1971). However, these studies dealt with establishing efficient arbitrage positions and have not addressed practical strategies for rolling futures already in place.

A second group of studies analyzed pricing, volume, and volatility characteristics of calendar spreads in stock and commodity markets, but once again, did not address rollover strategies (Billingsley & Chance, 1988 ; Castelino & Vora, 1984 ; Frino & McKenzie, 2002 ; Holmes & Rougier, 2005).

A third group of studies addressed rolling futures arising from existing long and short investment strategies and these form a very small subset of literature in which arbitrage has not been a primary objective and arbitrage theory played a minor role. Attention in these studies was on the simple necessity of replacing one contract with another. Such work on this practical topic has mostly been published outside of academic journals (Mouakhar & Roberge, 2010 ; Taylor, 2015 ; Tsui & Dash, 2011 ; Slivka, Li, & Zhang, 2011).

Despite the recognized value in adding to capital market efficiency, published studies of rolling futures hedges remain rare and incomplete. In India, the use of futures to implement investing and hedging strategies is well known (Auxilia, Vishwanath, & Panneerselvam, 2013 ; Verma & Chauhan, 2008), but to our knowledge, no known studies exist of futures rolling strategies.

There are many forms of inter - and intra - market futures calendar spreads, but the most frequently occurring type is one within the same market (intramarket) in which a contract approaching its month of expiration is closed out and simultaneously replaced by a contract in the same market having a month with a longer time to expiration. Because market orders to execute these transactions are governed only by the price difference (spread) between the two contracts, they help to control transaction risk when rolling over contracts. Between 80% and 90% of average open interest in the Nifty futures front month contract is typically rolled monthly by market participants prior to expiration. In the three weeks preceding expiration, calendar spread volume rose in our study to between 25% and over 50% of daily trading volume, yet this most commonly occurring transaction near expiration dates is little studied in developed markets and studied almost not at all in developing markets.

Data and Methodology

Using Bloomberg daily transaction data on Nifty contracts, answers to the following four central questions are sought in this study.

(1) Is there a characteristic time period prior to contract expiration during which rolling contracts is most favorable ?

(2) Are some days more favorable than others for executing rollovers ?

(3) Do calendar spread transactions nearing expiration dates have defining characteristics among the important variables of price, volume, and volatility ?

(4) Is it possible to define a rollover strategy that is superior to the common alternatives of executing all spreads on a single day or an equal number of spreads on every day ?

To answer these primary questions, the following steps were taken. Daily historical price, volume, open interest, and data for computing single Nifty futures and calendar spread fair values were downloaded from Bloomberg covering rolls for all 12 2016 futures expirations (Table 1). Each study period covered the last 15 trading days for the spread.

Table 1. Daily Data Captured (2016)

Nifty Index Levels
MIBOR (1 - 60 days)
Dividends in index points
Single Futures Prices, Volumes, Open Interest
Calendar Spread Prices, Volumes

Calendar spread pricing behavior was analyzed to determine if an optimal time period existed during which market participants should best consider executing spread transactions. Historical profiles nearing expiration dates were constructed for calendar spread volume and for the percentage of total open interest appearing in deferred contracts. These profiles provided an important guide to establishing the critical timing for proposed roll strategies.

Correlation analysis was used on each set of expiration dates data to identify possible relationships between three critical calendar spread variables measured daily : settlement price, volume, and volatility. The results were used to improve an understanding of how calendar spreads are affected by other variables.

Daily calculations of an "implied financing rate" and the Parkinson volatility (Parkinson, 1980) for calendar spreads were made for trades covering three weeks prior to each expiration date. Numerical results for these calendar spread characteristics were studied for value - added interpretations and then used, where appropriate, to construct a new trading strategy to compare with executing all rolls on a single one day or rolling an equal number of contracts per day.

Analysis, Results, and Discussion

(1) Rollover Definitions and Terminology : Efficient communication about futures transactions requires a common understanding of definitions and terminology. To avoid confusion, we begin analysis with a carefully defined set of terms and helpful abbreviations used throughout this paper.

(i) Calendar Spread, Front, Back, and Deferred Month Contracts : In a calendar spread transaction, one contract is closed and a second, with a different expiration month, is opened. In this paper, we use the term calendar spread to describe the typical closing of a stock index futures contract having the shortest current time to expiration (front month or near term contract) and the simultaneous opening of a second contract with either the next longest time to expiration (back month contract) or a third (deferred month) contract having an expiration immediately following the back month. The total open interest for Nifty contracts is the sum of front, back, and deferred month open interests since only these three contracts trade at any moment in time.

(ii) Roll Analysis Period (RAP) : In our study, we define the roll analysis period (RAP) to be 15 sequential trading days prior to and including expiration day of the front month contract. Excluding holidays, this period normally covers the three calendar weeks leading to front month expiration.

(iii) Roll Plan : A roll plan is simply the number of contracts planned for roll trading each day of the RAP. Such plans are often set in advance of a RAP and modified as new information is available about market conditions.

(iv) Futures Maturity Curve, Contango, and Backwardation Markets : The curve connecting all contract prices, when plotted against contract expiration dates, is called the futures maturity curve and reflects the term structure of futures prices. When the curve is downward (upward) sloping, the futures market is said to be in backwardation (contango).

(v) Implied Financing Rate and Implied Forward Rate : Calendar spread price quotations *(CS)* contain an implied forward interest rate, rf^*. That rate may differ from the forward rate rf obtained directly from the current yield curve (Slivka et al., 2011). The value of rf^* can be computed using market values of price quotations for the calendar spread and futures contracts.

$$\textit{Calendar Spread Fair Value} = CSFV = FV2 - FV1 \qquad (1)$$

where,

$FV1$ = fair value of front month contract,
$FV2$ = fair value of back month contract.

The fair value for the front month contract is given by :

$$FV1 = Io \times [1 + (r1 - d1) \times n1/360] \quad (2)$$

where,

Io = level of the stock index stated in index points,
$r1$ = interest rate for borrowing matched to the expiration date of the front month contract,
$d1$ = dividend yield on the index calculated to the expiration date of the front month contract,
$n1$ = number of days to the expiration date of the front month contract.

Similarly, the fair value equation for the next term contract is $FV2$ with related definitions.
So, the calendar spread fair value is :

$$CSFV = (Io / 360) [(n1\, d1 - n2\, d2) + (n2\, r2 - n1\, r1)] \quad (3)$$

Rewrite this as :

$$CSFV = (Io/360) \quad [(n1\, d1 - n2\, d2) + rf^* \times nf \times (1 + r1 \times n1)] \quad (4)$$

where,
rf = yield curve forward rate for a forward period $nf = (n2 - n1)$ in length
and substituting the market price CS for $CSFV$ and $F1$ for $FV1$, we have :

$$CS = (Io/360) [(n1\, d1 - n2\, d2) + rf \times nf \times (1 + r1 \times n1)] \quad (5)$$

which is solved for an implied forward rate rf^* as :

$$rf^* = (360/nf) [CS + (D2 - D1)] / (F1 + D1) \quad (6)$$

$D1 = (Io/360)\, n1\, d1$ = dividend in index points to expiration of the front month,
$D2 = (Io/360)\, n2\, d2$ = dividend in index points to expiration of the back month,
$F1$ = Quoted futures price for the front month contract,
$F2$ = Quoted futures price for the back month contract,
Fk = Quoted futures prices for deferred month contracts $(k = 2, 3, ...)$,

Separately, the Chicago Mercantile Exchange (CME) defines the implied financing rate *(IFR)* as :

$$IFR = (360/Days\ between) [(Roll + Div\ Between) / (F1 + Div\ to\ Nearby)] \quad (7)$$

where,

$Roll = Roll\ Value = CS = F2 - F1$,
Days between is equivalent to $(n2 - n1) = nf$,
Dividends Between $= D2 - D1 = (Io/360)\, [n2\, d2 - n1\, d1]$,
Dividends to Nearby $= D1$,
So, $IFR = (360/nf) [CS + (D2 - D1)] / (F1 + D1)$
which is equivalent to equation (6)

(vi) Cheap and Rich Rolls / Negative and Positive Carry : When rf^* is less than (more than) rf, the calendar spread quote, CS, is less than (more than) fair value and the roll is said to be "cheap" ("rich").

The concept of being cheap or rich is an artificial one and can be understood by reference to the calendar spread quotation convention. $CS = F2 - F1$ can be thought of as the "cost" to purchase $F2$ and sell $F1$ but only if we assume that there is a real investment to our calendar spread. Of course, with futures, there is no exchange of principal and so no gross or net investment. In a calendar spread, there is only the replacement of one future for another. The only cash flow upon execution is a final mark to market of the front month as it is closed and that cash flow has nothing to do with the numerical difference between the front and back month contracts. Nevertheless, assuming an actual investment equal to CS then : If $F2 > (<) F1$, the market is in contango (backwardation) and receipts from dividends will be less than (greater than) from interest so there is a (an implied) positive (negative) cost to finance, or carry, so the position and the calendar spread is said to have negative (positive) carry. The magnitude of carry is defined as the dividends received less the interest due for financing the spread.

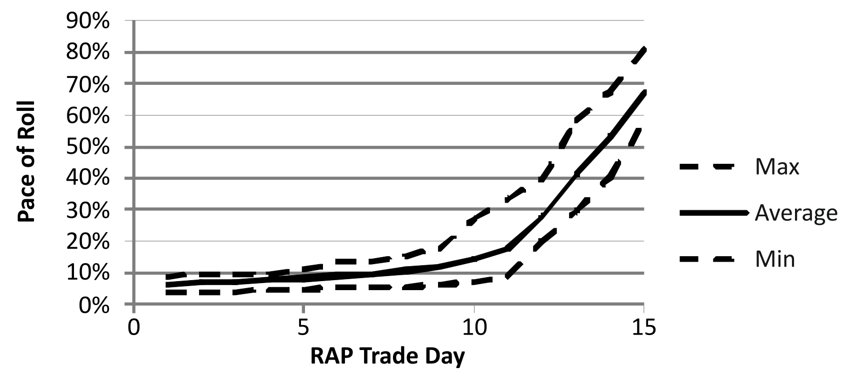
(vii) Pace of Roll : The CME - defined pace of roll ratio is a measure of the degree to which the back month open interest rises relative to the aggregate total open interest of front, back, and deferred contracts. On any single trading day in the RAP, it is the ratio of the back month open interest to the total open interest. The pace of roll profile typically follows a curve that rises steadily as the expiration date approaches.

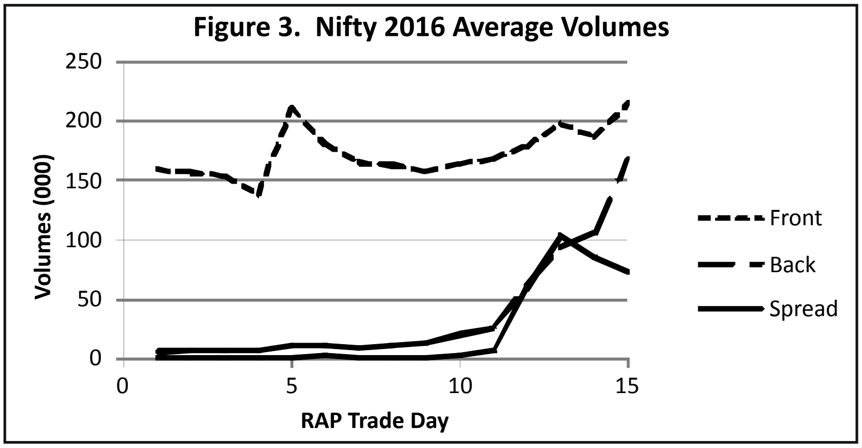
(2) Analysis of Price, Volume, and Volatility : While the National Stock Exchange of India does not officially calculate a pace of roll, the data to construct one is readily available. The Figure 2 displays the average Nifty pace of roll for 2016 expirations in this study. The horizontal axis in this figure is the trade day during the RAP where trade day 15 is the expiration day. This definition of RAP trade day facilitates comparisons between pace of roll profiles for different expirations. Related curves in the UK and U.S. markets are remarkably similar to the Nifty.

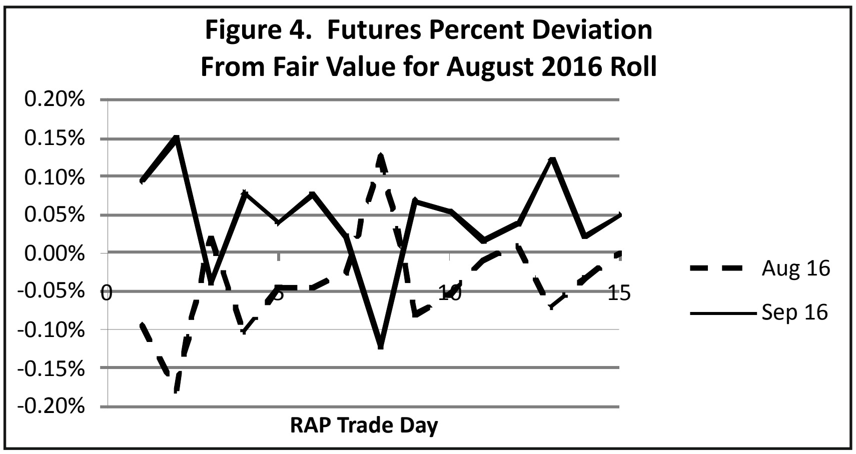
The average percentage of front, back, and spread volumes traded during these 12 RAPs appears in the Figure 3. The spread volume begins a rapid increase on RAP trade day 10 as the back month volume begins its own rise, driving the shape of the spread volume.

The convergence property of stock index futures requires the front month contract price to converge to the index at expiration. If during the approach to expiration, a futures price is typically within its zero arbitrage band (ZAB), then no profitable arbitrage is feasible (Slivka, Zhang, & Zhang, 2012) and the contract can be operationally considered to be efficiently priced. In developed markets, the ZAB is typically plus or minus 0.5% of fair value. Being so close to expiration, it is not surprising that we found Nifty front and back month pricing consistently inside a ZAB of 0.5%, leaving us to conclude that the calendar spread also remained efficiently priced

Figure 2. Nifty 2016 Average and Range for Pace of Roll







throughout the RAPs. The Figure 4 provides an example of futures percentage deviation from fair value during the August 2016 roll.

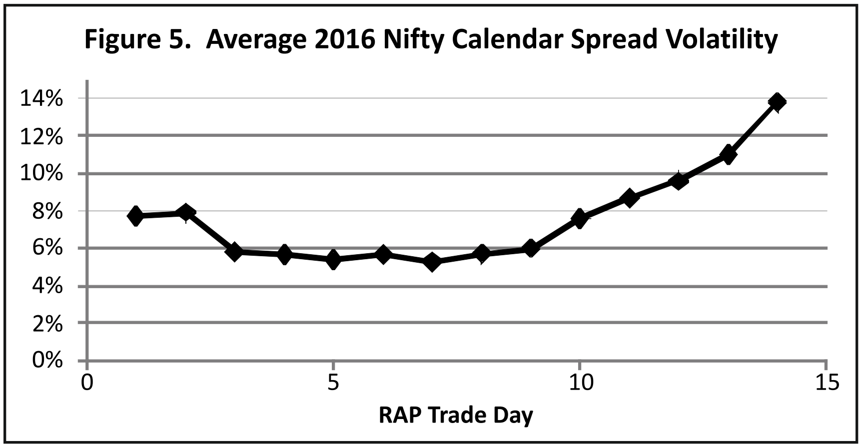
In general, the most common method for calculating volatility is to compute the standard deviation of closing prices. However, there are other advanced volatility measures, which give a statistically stronger estimate compared to the simple closing price standard deviation. In our research, we adopted the Parkinson volatility to measure the volatility of calendar spread prices.

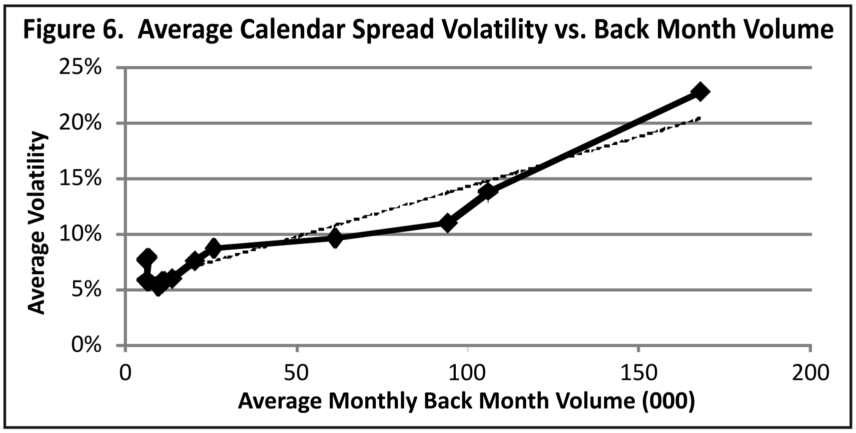
The Parkinson volatility method was created by Michael Parkinson in 1980 and is especially useful for estimating the volatility for trading activities where samples of data are small such as we have. This method uses daily high and low prices instead of only closing prices as given in equation (9).

$$\textit{Parkinson Volatility} = V_p = \sqrt{\frac{1}{N}}\sqrt{\frac{1}{4Ln(2)}\sum_{j=1}^{N}\left[Ln\left(\frac{H_j}{L_j}\right)\right]^2} \qquad (9)$$

Hj = High price on RAP trade day j,
Lj = Low price on RAP trade day j.

An alternative choice of volatility measure is that developed by Yang - Zhang (Yang & Zhang, 2000). While this measure has a rather low error of estimation compared with close - to - close and Parkinson volatility, it requires daily high and low data on calendar spreads, which is not always readily available.





The Figure 5 shows the rise in Parkinson volatility *(Vp)* for 2016 rolls as expiration date approaches. This rise in volatility, especially in the last 7-8 trade days, was regularly observed in all Nifty - analyzed rolls and a linear fit was found to be statistically significant at the 95% confidence level. The rise is also consistent with the observations by practitioners executing futures rollovers who claim volatility rises as expiration nears. A possible source of this result is that the declining front month open interest and volume (liquidity) make the spread increasingly less liquid, and so, subject to more volatility at the same time that rising volume of the back month adds to trading volatility (Figure 6).

(3) Correlation Analysis : For each Nifty RAP, a correlation matrix was calculated and inspected to identify possible patterns in the roll data. Daily values of the following quantities were included :

- trade day,
- Parkinson volatility,
- back volume,
- spread volume,
- front volume,
- spread settle price.

Variables with absolute correlations at or above 0.9 are generally considered to be strong ; between 0.70 and 0.9 are considered moderate, and below 0.7 are taken to be weak. Using this classification of correlation strength, the

Table 2. Correlation Matrix for 2016 Nifty Rolls

	Trade Day	Volatility	Back Volume	Spread Volume	Front Volume
Trade Day	1.00		0.81	0.77	
Volatility		1.00	0.95	0.73	
Back Volume	0.81	0.95	1.00	0.88	0.70
Spread Volume	0.77	0.73	0.88	1.00	
Front Volume			0.70		1.00

correlation matrix was simplified by eliminating weak values, leaving the balance to be examined for potentially useful relationships. The matrix in the Table 2 covers all 12 rolls for 2016 and suggests affiliations among test variables.

Five of the correlations are simply understood with reference to the Figure 3. Front (back) month volume rises gently (rapidly) with trade day as reflected in the weak (moderate) correlation. Back to front (back to spread) volume is seen to be border line weak (border line strong). During the first 13 trade days of the RAP, the back to spread volume correlation rises to 0.98 and is degraded only as spread volume declines on two days before expiring. That correlation suggests that rising spread volume during the RAP may result in rising spread volatility, a normal result in most traded markets. Futures traders frequently observe such behavior and use this common knowledge to plan their transaction timing by rolling as early in the RAP as spread liquidity allows.

This leaves for explanation only the strong correlation (0.95) between volatility and back month volume, which is best understood by reference to the practical execution of calendar spreads. For spread volume to rise, back volume must first rise to facilitate spreading by increasing spread liquidity. Back month trading volume begins to build on RAP trading day 10 from a small base, increasing rapidly thereafter. This growth, in turn, drives the volume of rolls and the rise in spread volatility quickly follows.

(4) Roll Trading Strategies : In this section, we first describe two strategies commonly used by investors (Strategies 2 and 3) before comparing them with a minimum volatility strategy (Strategy 1).

(i) Even Roll Strategy 2 : An investor's total front month open position is divided by the number of days remaining in the RAP period and if liquidity allows, an equal number of contracts are rolled each day. There are small variations of this strategy that are also used in the market, such as selecting only the last 5 days during the RAP for an equal number of contracts to roll daily. To avoid incurring unwanted costs by adversely moving spread price or by widening the bid/ask spread, the planned daily transaction volume is chosen by traders to be limited to a specific percentage, w (often 5% - 20%), of the historical daily traded spread volume depending upon market conditions.

(ii) Stack Roll Strategy 3 : All front month contracts are rolled on a consistently fixed RAP trade day. For example, once back month volume begins to rise rapidly, there is likely to be sufficient liquidity to consider rolling an entire front month position (stack). To avoid incurring unwanted costs by adversely moving spread price or by widening the bid/ask spread, the planned daily transaction volume is once again chosen by traders to be limited to w percent.

(iii) Minimum Volatility Strategy 1 : The prominence of the volatility vs back month volume relationship taken together with the historical calendar spread volume profile suggests a third, optimal trading strategy for minimizing the average volatility experienced while rolling contracts during a RAP. A proxy for this experienced volatility is the daily Parkinson volatility weighted by the number of contracts traded and then averaged.

Minimizing this aggregate volatility measure is again made subject to the practical constraints of limiting volume at w% of its historical value.

In their pure form, Strategies 2 and 3 make no assumptions about information content in historical pace of roll or calendar spread volume profiles, but as we have learned, these profiles suggest varying liquidity during the RAP. We also know from our analysis that spread volatility rises as expiration approaches. It is normally the case in markets that investors prefer less volatility since stable prices for their transactions are relied upon to result in lower uncertainty about final execution costs, especially bid/ask costs.

Let,

N = number of front month contracts to roll during the *RAP*,
NT = total of all spread contracts traded during the *RAP*,
Nj = number of contracts designated to roll on day j,
j = trade day (j = 1 - 15) during the *RAP*,
Φj = Historical percentage of calendar spreads traded on trade day j,
$Pj = w \times \Phi j$ = Adjusted percentage of calendar spreads traded on trade day j,
w = 5% to 20% chosen by the investor depending upon market conditions,
Vpj = Historical Parkinson volatility on trade day j,
$NMAXj$ = maximum spread volume allowed to trade on trade day $j = w \times \Phi j \times NT$,
$Aj = Nj \times Vpj$ = Aggregate volatility measure experienced on trade day j.

For the 12 rolls analyzed in 2016, the average Vpj, j, and Φj values appear in the Table 3.

Strategy 1 then becomes the set of Nj that satisfy the following objective function and constraints.

Minimize $\overline{Vp} = \Sigma^{15}_{1} (\frac{Nj}{N})\, Vpj$

Subject to $\Sigma^{15}_{1} Nj = N$

$$Nj <= w\,\Phi j \;\; NT = NMAXj \tag{10}$$

Table 3. Average Parkinson Volatility *(Vp)* and Percent of Calendar Spread Traded Volume (Φ)

Trade Day *j*	*Vpj*	Φ*j*
1	7.7%	0.0%
2	7.9%	0.1%
3	5.8%	0.1%
4	5.6%	0.2%
5	5.4%	0.2%
6	5.7%	0.9%
7	5.3%	0.3%
8	5.7%	0.4%
9	6.0%	0.4%
10	7.6%	0.8%
11	8.7%	1.8%
12	9.6%	16.8%
13	11.0%	30.1%
14	13.8%	25.8%
15	22.8%	22.2%

Table 4. January 2016 Roll Strategy Solutions for 1000 Contracts

Trade Day, *j*	Optimal Roll			Even Roll			Stack Roll		
w --->	5%	10%	20%	5%	10%	20%	5%	10%	20%
1	3	6	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	14	28	56	0	0	0	0	0	0
4	17	34	0	0	0	0	0	0	0
5	89	178	0	0	91	91	0	0	0
6	478	24	0	0	91	91	0	0	*
7	310	619	944	0	91	91	0	0	*
8	56	111	0	0	91	91	0	0	0
9	34	0	0	143	91	91	0	0	0
10	0	0	0	143	91	91	0	0	*
11	0	0	0	143	91	91	0	*	*
12	0	0	0	143	91	91	0	*	*
13	0	0	0	143	91	91	*	*	*
14	0	0	0	143	91	91	*	*	*
15	0	0	0	143	91	91	*	*	*
	1000	1000	1000	1000	1000	1000			

* RAP Days on which all 1000 contracts might be rolled

Table 5. Average Volatility for January 2016 Roll

w	Optimal Roll	Even Roll	Stack Roll
5%	5.98%	26.17%	45.21%
10%	5.71%	18.32%	33.39%
20%	5.57%	18.32%	23.54%

The resulting values of Nj define a roll plan containing the number of contracts to roll on trade day j. Should all Nj be traded in the RAP, then $\overline{Vp}$ is the weighted average volatility measure expected in Strategy 1 for a choice of w. For combinations of w and Φj resulting in N less than all $NMAXj$, N will simply concentrate at the lowest volatility trade day which, for our 2016 Nifty profile, is trade day 7. If N is greater than the largest $NMAXj$, Nj will concentrate first at the smallest value of Φj and then populate the balance of trade days in increasing order of Φj consistent with the constraints.

To illustrate this, consider an investor position with $N = 1000$ and variable w. The Tables 4 and 5 display roll plans and average volatility for the January - February 2016 roll, assuming the historical January volatility profile. As w rises, the optimal roll strategy increasingly concentrates trades on RAP days with smaller volatility at the earliest possible opportunity (trade days 3 and 7 for the January roll, not shown).

The equal roll strategy, on the other hand, is forced by its construction to use many later RAP days with higher volatility so that the sum of all daily trades will equal the initial position of 1000 contracts.

For the stack roll, single permissible days on which all contracts can be rolled are identified in the Table 4, and the average volatility measure for this strategy in the Table 5 is taken to be the average of over permitted days. Even when the first permissible stack roll day was chosen, the average volatility exceeded that for the optimal roll. The Table 6 displays the average roll strategy performance for all 2016 RAPs for three levels of w. The optimal roll strategy is seen to provide superior performance to even and stack roll strategies for the entire chosen range of w.

Table 6. Average Volatility for all 2016 RAPs

w	Optimal Roll	Even Roll	Stack Roll
5%	7.04%	11.82%	13.73%
10%	6.15%	10.75%	12.59%
20%	5.25%	9.74%	11.67%

Summary and Conclusion

The four central questions posed in this study have been answered.

We have confirmed that for the Nifty market, there is indeed a characteristic time period (roll analysis period) before index futures expirations during which rolling contracts is most favorable if spread volume (liquidity) is used as a preferred measure. That period consistently begins approximately three weeks prior to expiration (15 trading days) during which calendar spread transaction volume rises, reaches a peak, and then declines rapidly, and eventually falls to zero. Maximum volume occurs within five trading days of expiration, so if liquidity is critical to an investor, this window of time should receive the most attention.

Calendar spread price does not appear related to other key variables in this study. The most significant relationship among study variables is between rising back month volume and rising volatility. That rising back month volume facilitates rising spread volume (liquidity) makes market sense.

Calendar spread volatility appears in our sample to generally rise throughout the roll analysis period to a maximum near expiration date, a behavior often anecdotally noted by traders. If minimizing average volatility is desired, then the optimal strategy is to shift roll volume to earlier in the RAP, but with constraints reflecting a historic liquidity profile.

The strategy of rolling a fixed percentage of held contracts each RAP day (even roll) proved sub - optimal as it took no advantage of the volatility profile. The even roll strategy underperformed an optimal strategy but performed better than the stack roll strategy. As the RAP day on which volatility will be lowest is unknowable, the strategy of rolling consistently on a fixed single RAP day (stack roll) is not likely an optimal one. In our study, the stack roll significantly underperformed other two strategies.

However, we have shown for 2016 futures expirations that it is consistently possible to determine an optimal number of contracts to trade daily by minimizing the average volatility subject to practical trading volume constraints. This strategy proved superior to both an even and stack roll strategy by generous margins.

The findings here so far suggest the following practical guidelines for rolling calendar spreads :

(i) To minimize daily calendar spread price volatility, concentrate on rolling earlier rather than later during the RAP.

(ii) For maximum liquidity, however, concentrate on rollover transactions when possible to RAP trade days typically three to five trading days before expiration.

(iii) To minimize average roll volatility subject to transacting during more liquid RAP days, use an optimization approach similar to the one described in this study.

Implications, Limitations of the Study, and Opportunities for Further Research

The findings in this study have several practical strategy implications. If minimizing volatility risk during the RAP is the investor's objective, then rolling earlier rather than later in the RAP should be considered since volatility rises as expiration approaches. However, to avoid incurring unwanted transaction costs, care should be taken not to exceed a chosen percentage, *w,* of daily traded spread volume. The value of *w* will depend upon market conditions and is set by the investor based upon experience.

Since it is not possible to predict the exact RAP trade day with minimum volatility, rolling consistently on the same RAP date (stack roll strategy) is not likely to be the most effective strategy. On the other hand, rolling an equal number of contracts each RAP trade day (even roll strategy) ignores the information content in the volatility and pace of roll profiles and proves to be suboptimal if minimizing volatility is the objective. For the even roll strategy, low calendar spread volumes also made infeasible the execution of large fixed volumes on early days of the RAP, thereby requiring transaction deferral to later days, exhibiting higher volatility.

Minimizing average volatility throughout the RAP subject to a simple liquidity constraint (minimum volatility strategy) produces an original optimal rolling strategy that incorporates important relationships between calendar spread price, volume, and volatility. This roll strategy outperforms the stack and even roll strategies for all tested values of *w.*

As the present study does not address real time implementation of optimal strategy, further testing would be useful to assess the benefits of optimization in constructing roll plans. The present study is also limited to 2016 expirations, so it is not clear if rising volatility during the RAP is consistent over longer periods.

Further research opportunities can both broaden and deepen the study presented here. For the three strategies studied here, exploring performance differences between developed and developing futures markets would contribute to the literature of how index futures markets evolve following market introduction. Separately, relative performance results might guide investors' transacting in global futures to better strategy construction. As the present study does not address real time implementation of optimal strategy, further testing would be useful to assess the benefits of optimization in constructing roll plans. A further extension of this work could also be to examine rollover strategies for index options, a more challenging topic due to additional variables required for option pricing and valuation.

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