The Bats-T3 SPY Volatility Index

Introducing the SPYIX ("Spikes")

INTRODUCTION

The Bats-T3 SPY Volatility Index (SPYIX – the "Spikes") is a measure of expected 30-day volatility in the SPDR S&P 500 ETF (SPY), the largest exchange traded fund in the world that tracks the most widely-followed stock index in the United States. With nearly $24 billion in daily notional value traded in the third quarter of 2015, the SPY is the world's most actively traded security.

A by-product of the SPY's popularity is a highly liquid market for its associated options, accounting for nearly half of the $110 billion in notional value traded per day across all U.S. equity options.[1] Therein, the SPYIX Volatility Index is calculated using live prices on options linked to the SPY and represents the market's expectation of price movements in the SPY over the next 30 days.

To best align to the way the trading community models risk and hedges exposure, the SPYIX is constructed using the well known variance swap methodology using actual options prices to calculate volatility. The SPYIX can be physically replicated with a strip of options, and can easily be incorporated into the existing ecosystem of volatility-based products, including options, futures, and ETPs.

In addition, the SPYIX incorporates material enhancements in its calculation to help improve index stability – namely its proprietary "price dragging" technique, which is designed to reduce erratic movements in the index during periods of low liquidity in the broader market. Moreover, to calculate the index, the SPYIX uses highly-active, electronically-traded multiply SPY options over slower, manually traded floor-based S&P 500 index options. This better reflects the nature of today's high-velocity, and principally electronic, options market.

As a global exchange leader operating at the forefront of electronic markets around the globe, with proven expertise in trading U.S. and European equities and ETFs and U.S. options, Bats is proud to partner with T3 Index to offer the SPYIX as an alternative measure of equity benchmark volatility.

$24 BILLION

With nearly $24 billion in daily notional value traded in the third quarter of 2015, the SPY is the world's most actively traded security

47.6%

47.6% of the daily notional value of all equity option volume is linked to the SPY

[1] "That Giant Sucking Sound You Hear Is the ETF Options Markets", Bloomberg Business, January 8th, 2016, http://tinyurl.com/jfwppwh

THE SPYIX FORMULA

Like most indices, the SPYIX has a defined rules-based approach to selecting components – a series of options on the SPY – and weighting them to derive a single price for the index.

Therefore, the formula for expected T-term variance is as follows:

$$\sigma^2 = \frac{1}{T}\left[2e^{RT}\sum_i \frac{\Delta K_i p_i}{K_i^2} - \left(\frac{e^{RT}\left(p_{ATM}^{c} - p_{ATM}^{p}\right)}{K_{ATM}}\right)^2\right]$$

WHERE:

T — Time to options expiration (in years, with 1-second precision)

K_i, p_i — A list of unique options strikes, ordered from lowest to highest, and corresponding options prices; of a call if $K_i > K_{ATM}$; and of a put if $K_i < K_{ATM}$; if $K_i = K_{ATM}$ then an average between the ATM put and call prices

ΔK_i — Half the difference between the strikes on either side of K_i;

$$\Delta K_i = \frac{(K_{i+1} - K_{i-1})}{2}$$

For the last (highest and lowest) selected strikes, ΔK_i is simply the absolute difference between K_i and the nearest selected option's strike

R — Risk-free interest rate to option's expiration

p_{ATM}^{c} — Price of the at-the-money (ATM) call option

p_{ATM}^{p} — Price of the ATM put option

K_{ATM} — Strike closest to the point where linearly interpolated call and put prices intersect

CALCULATION METHODOLOGY

The SPYIX is calculated using only standard options on the SPY that expire on the Friday following the third Thursday of each calendar month. Although weekly options on the SPY are available, these are not used in the calculation of the SPYIX Index.

The calculation linearly interpolates between the variances of two monthly expirations – near-term (the closest expiration more than two full days into the future) and next-term (the monthly expiration following the near-term). This expiration selection method is used to avoid using highly irregular option prices close to the options settlement date.

The 30-day point is typically in between these two expirations and the index interpolated between the volatilities of these two terms. When the closest expiration is too close to expiry (less than two full days), rolling to the third-closest expiration occurs. This rolling rule serves to reduce spurious variability in the index by means of minimizing the period of "extrapolation" between the two expirations. The switch from closest to third-closest expiry rarely has any noticeable impact on the actual index value, as the weight of the switched term is close to zero.

1. Determine Option Prices

SPYIX uses a proprietary "price dragging" technique to capture live options prices to calculate the index, as follows:

- Initially set all prices to 0;
- On the opening quote, the opening bid is used as the current price;
- When there is a trade, the price of the option is set to trade price;
- For newly-placed ask (bid) quotes, if the ask (bid) is lower (higher) than the current price, the option price is set to ask (bid).

This method should materially reduce erratic movements of the index value as quotations on out-of-the-money (OTM) options are rapidly altered during times of low liquidity.

2. Select the Options

For each of the expirations, the securities to be used in the calculation are then selected by removing in-the-money and OTM options.

- To determine the ATM strike, find the intersection of the put and call linearly interpolated price curves. Select the strike closest to the value of the intersection of the curves – this becomes the ATM strike.

  If the intersection falls exactly in the middle of two strikes, or in case if the whole segments overlap (i.e., when four neighboring calls and puts have the same price), use the lower strike. In case of more than one intersection points (in rare cases of highly irregular market prices), use the one closest to the current value of the SPY.
- Use all listed puts below the ATM strike and all listed calls above the ATM strike, and both the ATM call and put. When 2 consecutive option prices of 5 cents or less are encountered when moving away from the ATM, exclude all the strikes beyond that level, from both put and call side.

3. Weight the Options and Estimate Volatility

For each term, the volatility is estimated using the variance swap approximation, with the selected options' prices weighted according to the SPYIX formula:

$$\sigma^2 = \frac{1}{T}\left[2e^{RT}\sum_i \frac{\Delta K_i p_i}{K_i^2} - \left(\frac{e^{RT}\left(p^c_{ATM} - p^p_{ATM}\right)}{K_{ATM}}\right)^2\right]$$

4. Calculate the Index

Compute the 30-day weighted average of the near- and next-term variances, take the square root, and multiply by 100, as follows:

$$SPYIX = 100 \times \sqrt{\left(\frac{t_1}{t_M}\frac{t_2 - t_M}{t_2 - t_1}\sigma_1^2 + \frac{t_2}{t_M}\frac{t_M - t_1}{t_2 - t_1}\sigma_2^2\right)}$$

t_1	Time (in seconds) to near-term expiration
σ_1	Estimated volatility computed by variance swap approximation, near-term
t_2	Time (in seconds) to next-term expiration
σ_2	Estimated volatility computed by variance swap approximation, next-term
t_M	Number of seconds in 30 days (30 x 86,400 = 2,592,000)

SAMPLE CALCULATION

Some examples of "price dragging" and options selection using real prices are included below to help illustrate how the SPYIX is calculated. Since the full calculation is very repetitive, only a select sample of the full calculation method is included.

A fully worked up example of the full calculation with formulas in Excel is available for download at Bats.com.

Price Dragging

Options are often quoted in bulk by market makers, which in some cases causes a divergence from orthodox supply-demand dynamics as quotes are constantly updated across a series of strikes throughout the day. As a result, there can be more notable movements within the bid/ask spread that impact the calculation of an index based on mid-point prices. SPYIX's proprietary price dragging technique has been designed to mitigate this effect, producing a more stable index value.

Time	Update	Price Update	Comment
9:30:00	Market Open	0	Initially set at zero
9:31:12	2.35 bid	Set to 2.35	Opening price is the bid
9:33:01	2.31 bid	Unchanged	Bid updates but is not above current price
9:33:48	2.37 ask	Unchanged	Ask is not below the last eligible price of 2.35
9:36:41	Trade at 2.37	Set to 2.37	Trade triggers price update to 2.37
9:38:34	2.38 ask	Unchanged	Ask is updated but is not below the last price
9:39:00	2.36 ask	Set to 2.36	Ask moves below the latest price, becomes the new price

Note: Block trades and out of sequence prints are ignored.

Options Selection

The following sample uses use actual SPY option prices (determined by using the price dragging technique) sampled on February 13th, 2015. Based on the SPYIX rules, the two closest eligible expirations are February 20th, 2015 and March 20th, 2015. Both are more than two days away from the current date of February 13th so are selected as near-and next-term.

The intersections of put and call prices are observed in between the orange highlighted strikes. For the near-term, the absolute difference between the 209.50 strike call and put price is 29 cents, whereas for 210 it is 21 cents.

Since the intersection of the price curves is closer to 210, the ATM strike is 210. Using the same logic, the next-term ATM strike would be 209.

Once the ATM strike is determined, the series is truncated from the point where two consecutive prices (of calls if above ATM, of puts if below ATM) are 5 cents or less. For the near-term, all strikes at 199 and below and 217 and above are removed as the puts encounter two consecutive prices below or equal to 5 cents at 200 and 199.50 and the calls at 215 and 216. Similarly, for the next-term expiration, strikes at 148 and below and 240 and above are truncated.

Near-Term (February 20th)

Strike	Call Price	Put Price
197	12.82	0.04
197.5	12.32	0.03
198	11.83	0.04
198.5	10.62	0.03
199	10.86	0.05
199.5	10.35	0.04
200	9.87	0.05
200.5	9.36	0.06
201	8.85	0.06
201.5	8.36	0.07
202	7.86	0.08
202.5	7.42	0.09
203	6.91	0.1
203.5	6.44	0.11
204	5.96	0.13
204.5	5.48	0.15
205	5.01	0.19
205.5	4.54	0.23
206	4.11	0.28
206.5	3.64	0.33
207	3.22	0.41
207.5	2.8	0.5
208	2.41	0.6
208.5	2.04	0.71
209	1.68	0.88
209.5	1.35	1.07
210	**1.09**	**1.29**
210.5	0.82	1.53
211	0.6	1.8
212	0.3	2.51
212.5	0.21	2.92
213	0.15	3.32
214	0.07	4.24
215	0.04	5.82
216	0.03	6.21
217	0.02	6.74
217.5	0.02	6.9
218	0.01	8.22
219	0.01	8.76
220	0.01	10.19
221	0.01	11.2

Next-Term (March 20th)

Strike	Call Price	Put Price
144	65.85	0.03
145	64.87	0.04
146	63.85	0.03
147	62.87	0.04
148	61.87	0.04
149	60.57	0.04
150	59.84	0.04
151	58.88	0.06
152	57.88	0.06
153	56.58	0.06
154	55.86	0.06
155	54.7	0.07
156	53.59	0.06
157	52.9	0.07
158	51.87	0.06
159	50.86	0.06
160	49.6	0.07
161	48.93	0.07
162	47.92	0.08
163	46.92	0.08
164	45.62	0.08
165	44.95	0.09
166	43.94	0.09
167	42.63	0.1
168	41.64	0.11
169	40.95	0.11
170	39.65	0.12
171	38.98	0.12
172	37.83	0.13
173	36.66	0.13
174	35.97	0.14
175	34.68	0.16
176	33.69	0.17
177	32.7	0.18
178	31.72	0.19
179	31.18	0.2
180	30.07	0.22
181	29.47	0.23
182	28.04	0.26
183	27.08	0.27
184	26.04	0.3
185	24.97	0.32
186	24.12	0.33
187	23.02	0.36
188	22.61	0.39

Strike	Call Price	Put Price
189	21.2	0.43
190	20.22	0.46
191	19.26	0.51
192	18.29	0.55
193	16.59	0.6
194	15.76	0.67
195	15.44	0.73
196	14.51	0.82
197	13.56	0.9
198	12.67	1
199	11.76	1.11
200	10.83	1.25
201	9.99	1.38
202	9.11	1.54
203	8.27	1.71
204	7.42	1.92
205	6.67	2.14
206	5.82	2.39
207	5.09	2.68
208	4.38	3
209	**3.7**	**3.37**
210	3.09	3.8
211	2.53	4.26
212	1.98	4.79
213	1.53	5.38
214	1.18	6.03
215	0.88	6.77
216	0.6	7.56
217	0.42	8.41
218	0.3	9.32
219	0.22	10.27
220	0.17	11.21
221	0.13	12.34
2 22	0.1	13.16
223	0.09	13.85
224	0.08	15.15
225	0.06	16.14
230	0.04	21.12
235	0.03	25.81
240	0.02	31.11
245	0.01	36.09
250	0.01	41.08
255	0.01	46.08
260	0.01	51.08

Contacts

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