Guide to the CBOE / CBOT 10 Year Treasury Note Volatility Index (TYVIX® Index)

Part II: VXTY Futures Primer
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I. Introduction

This is the second module of CBOE’s Handbook to futures on the CBOE/CBOT 10-Year U.S. Treasury Note Volatility Index (TYVIX® Index), which focuses on the futures. The first module, called “Introduction to the TYVIX Index”, is a guide to the TYVIX Index, and the third module, called “Compendium of Empirical Findings”, is a compilation of additional empirical facts about the index and the futures. Here, we highlight basic features of VXTY futures that are relevant to futures traders, such as contract design, fair value, term structure, volatility, and applications to portfolio management, whether for hedging or yield enhancement purposes.

II. Contract Design of VXTY Futures

On Thursday, November 13, 2014, CBOE Futures Exchange, LLC (CFE®) launched trading in futures on the CBOE/CBOT 10-Year U.S. Treasury Note Volatility Index (tickers: VXTY (index) and VXTY (futures)).

**Index Description:** The TYVIX Index is based on real-time mid-quotes of options on 10-Year Treasury Note futures listed by CME Group (CME) which trade on the Chicago Board of Trade (CBOT) (OZN options), and is designed to reflect investor’s consensus view of the expected volatility of CBOT 10-Year Treasury Note futures (TY futures) over the next 30 calendar days.

**Contract Size:** $1,000

**Trading Hours:** 7:00 a.m. to 3:15 p.m. Chicago time, except that on the Final Settlement Date trading in the expiring VXTY futures will terminate at 2:00 p.m. Chicago time. Non-expiring VXTY futures will continue to trade until 3:15 p.m. on that date.

**Minimum Tick:** 0.01 index point for single and multiple leg trades and net prices of spread trades, equal to $10.00 per contract.

**Listed Months:** CFE may list for trading up to twelve contract months for the VXTY futures contract.
Termination of Trading: 2:00 p.m. Chicago time on the Final Settlement Date in expiring VXTY futures.

Final Settlement Date: The Wednesday that is thirty days prior to the last Friday of the calendar month immediately following the month in which the VXTY contract expires that precedes the last business day of that month by at least two business days (“Final Settlement Date”).

Final Settlement Value: The final settlement value for VXTY futures (Ticker: VXTYS) is a Special Quotation (“SQ”) of VXTY futures calculated using the indicative daily settlement prices (“IDS”) published by CME Group for the OZN options used to calculate the final settlement value for expiring VXTY futures on their Final Settlement Date. CME Group’s settlement price calculation methodology is described at www.cmegroup.com/market-data/cme-groupsettlement-procedures.html.

OZN options expire in the calendar month that precedes their designated contract month (e.g., February OZN options expire in January). For example, a January VXTY futures contract would be calculated using March OZN options and a February VXTY futures contract would be calculated using April OZN options.

CBOT publishes indicative daily settlement prices for OZN options at approximately 2:00 p.m. (IDS Prices) and may subsequently update the IDS Prices after 2:00 p.m. The prices for OZN options that will be used to calculate the final settlement value for expiring VXTY futures will be the most current IDS Prices received by Chicago Board Options Exchange, Incorporated (CBOE®) at the time when CBOE commences the final settlement value calculation process at approximately 3:45 p.m. CBOE could determine to commence this process earlier or as late as 4:20 p.m. These prices are the final and only prices that CBOE will use to calculate the final settlement value for expiring VXTY futures. The final settlement value used to settle expiring VXTY futures will not be adjusted in the event that CBOT updates the IDS Prices for OZN options after CBOE commences the final settlement value calculation process.

The OZN option series used to calculate the final settlement value for expiring VXTY futures shall include:

(i) all at- and out-of-the-money put options beginning with the highest-strike put option with an IDS Price equal to or greater than the minimum tick size for OZN options (1/64th of a point or $15.625) of one (1) tick and ending with the put option with a strike price equal to at-the-money strike K0; and
(ii) all at- and out-of-the-money call options beginning with the call option with a strike price equal to the at-the-money strike $K_0$ and ending with the lowest-strike call option with an IDS Price equal to or greater than the minimum tick size for OZN options (1/64th of a point or $15.625$);

provided that the IDS Prices of put series below the lowest strike put and of call series greater than the highest strike call are no greater than one tick.

For example, if the IDS Prices of at- and out-of-the-money OZN options are: 1, 1, 2, 3, 5, 8, 10, 7, 6, 3, 3, 1, 1, 1, the range of strikes would be truncated as 1, 2, 3, 5, 8, 10, 7, 6, 3, 3, 1. If the daily indicative settlement prices of at- and out-of-the-money OZN options are: 1, 1, 2, 1, 2, 3, 5, 8, 10, 7, 6, 3, 3, 1, 1, 1, 2, 1, 1 the range of strikes would be truncated as 1, 2, 1, 2, 3, 5, 8, 10, 7, 6, 3, 3, 1, 1, 1, 2, 1.

### III. Fair Value of VXTY Futures

A fair value of VXTY futures based on option prices gives the market a point of reference for traded futures prices$^1$. On any date $t$, the fair value of VXTY futures that expire at date $T$ is driven by the forward variance from $T$ to $T+30$. Bruno Dupire$^2$ offers an explicit formula for the fair value of VIX futures that provides a good approximation to the fair value of VXTY futures:

$$E_0[F_T] = \sqrt{\text{var}_0[T, T+30] - \text{var}_0[F_T]}$$

$E_0[F_T]$ is the expected value of the price of VXTY futures that expire at date $T$ and the term under the square root is the forward variance of 10-Year U.S. Treasury Note futures (TY) from $T$ to $T+30$ adjusted by a convexity term equal to the variance of the price of VXTY futures at expiration.

Example (Figure 1): Suppose today is February 4, 2014 and you wish to estimate the fair value of a hypothetical March 2014 VXTY futures.

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$^1$ Theoretical prices may also be generated from a model as done in “Government Bond Volatility Futures”, February 2014 Draft, Antonio Mele and Yoshiki Obayashi, Swiss Finance Institute and CEPR Applied Academics LLC).

$^2$ Dupire 2006 – “Model free results on volatility derivatives”
Figure 1. Data to Calculate Fair Value of VXTY Futures

The first step is to determine the forward 30-day variance from March 26, 2014 when the futures expire to April 25, 2014, 30 days later.

- The first term under the square root of Dupire’s formula is a 30-day forward variance. It is approximated by a calendar spread of the following “VXTY portfolios” (portfolios of options on TY futures) used to calculate VXTY futures:

a. The long portfolio holds May 2014 TY options that expire on April 25, 2014. This long leg of the calendar spread replicates variance from February 4 to April 25, 2014. In Figure 1, the total price of the May options is labeled “Twice Sum (option …)” and is equal to 0.000651132. We calculate its forward value using the effective rate of interest to the option expiration and based on the three-month CMT Treasury rate. The forward value is then corrected by the adjustment factor that compensates for the deviation...
between the forward strike (124.28) and the listed strike closest below (124). The effective variance shaded in orange is 0.000653222

b. The short portfolio holds a short position in April TY options that expire on March 21, 2014. The price of that portfolio is 0.00042138. After finding the forward value and adding the adjustment factor, the effective variance is 0.00046544, shaded in orange. Holding this leg only provides variance to March 21, 5 days short of March 26 when VXY futures expire. To compensate, we scale it up by a factor of 50/453. An alternative would be to interpolate the variance to March 26, 2014 from April and May 2014 TY options. If the same scheme is followed throughout, then past March 21, 2014, April TY options are no longer available, and May and June 2014 TY options would be used to extrapolate the variance to March 26, 2014. Extrapolation using distant option expirations can generate significant estimation errors.

The effective forward variance is the difference between the effective variances of May and April options, multiplied by an annualization factor:

\[
10^4 \times (365/30) \times (0.000653222 - 0.00046544) = 22.84724186
\]

The second term under the square root is the variance of the futures price at expiration, which can be estimated from historical VXY futures prices or other alternative methods. For the sake of simplicity, let's assume that the variance of the futures price is equal to .32. Thus, the estimate of fair value is equal to the square root of the difference between the forward variance from March 26 to April 25, 2014 and the hypothetical variance of the futures price, (22.84724186 - 0.32), or 4.75.

\[\text{\footnotesize 3 An alternative would be to interpolate the variance to March 26, 2014 from April and May 2014 TY options. If the same scheme is followed throughout, then past March 21, 2014, April TY options are no longer available, and May and June 2014 TY options would be used to extrapolate the variance to March 26, 2014. Extrapolation using distant option expirations can generate significant estimation errors.}\]
A short-cut to the calculation is to ignore the second term under the square root because, based on the empirical evidence from VIX futures, it is likely to be very small relative to the forward variance. We take this short-cut to calculate the fair values of VXTY futures that are analyzed in the following sections.

IV. Empirical Features of VXTY Futures

1. The Toggle between Backwardation and Contango

The term structure of VXTY futures reflects market expectations of Treasury volatility at future dates. It also helps to gauge the cost of rolling between nearby futures to establish a constant maturity exposure to forward values of VXTY futures, similar to the exposures of exchange-traded funds that are based on VIX futures.

In commodity markets, a term structure of futures prices that slopes upwards is said to be in contango, while a downward sloping term structure is said to be in backwardation. The slopes of different sections of the term structure can differ. For example, there can be backwardation at the front end, and contango at the back end. Two factors determine the slope between the prices of two successive futures: (1) expected changes in VXTY futures between future dates, and (2) differences between risk premia at future dates. Ignoring risk premia for a moment, futures are in contango when the market expects VXTY futures to increase over time, and they are in backwardation when the market expects VXTY futures to decrease. Risk premia can muddle the picture if they are sufficiently significant. Risk premia shape the term structure when the market does not expect major changes in VXTY futures.
Contango translates to a positive spread between futures, and backwardation to a negative spread. The spreads of VXTY futures in Figure 2 reveal that the term structure of VXTY futures is strikingly different from the term structure of VIX futures. Whereas VIX futures are usually in contango, VXTY futures alternate between backwardation and contango over time, as well as across different segments of the term structure. The conjunction of these patterns sometimes leads to contango or backwardation straight across the term structure, and sometimes to V or inverted V shapes. Figure 3 shows the frequencies of these patterns from 2003 to 2014. A value of -2 means straight backwardation, a value of -1 is a V shape, a value of 1 is an inverted V shape, and a 2 is straight contango. From 2003 to 2014, the term structure was in straight backwardation 24% of the time, and in straight contango 26% of the time. It had a V shape 23% of the time and an inverted V shape 27% of the time. Straight backwardation and V shapes were more prevalent between 2003 and 2008; straight contango and inverted V shapes were more frequent between 2008 and 2014.

Source: CBOE
2. Volatility of VXTY Futures

As for VIX futures, fair value estimates of VXTY futures prices are less volatile than the index itself. This is illustrated in Figure 4, a graph of the average annual absolute daily variations of VXTY index and of 30-day forward VXTY futures.

Figure 4: Volatility of TYVIX Index & 30-Day Forward VXTY Futures

The behavior of the volatility of VXTY futures as they approach expiration provides a different perspective. Figure 5 shows the absolute daily variation of nearby VXTY futures and of the TYVIX index. Nearby VXTY futures become more volatile as they get close to expiration.
Figure 5. Daily Volatility of VXTY Futures by Days to Expiration

Volatility of VXTY Futures by Time to Expiration

Source: CBOE

V. Integrating VXTY Futures in Portfolio Management

1. Hedging

Strong downturns in the values of fixed income assets are often accompanied by increases in volatility. This is illustrated in Figure 6 where hypothetical 30-day VXTY futures ⁴ are overlaid on a selection of fixed income benchmarks. Treasuries are proxied by Citigroup’s 10 year Treasury benchmark (SBTSY10), mortgage-backed securities by Bloomberg’s Mortgage-Backed Security index (BMBS), and corporates by PIMCO’s Investment Grade Corporate Bond Fund Institutional Class (PIGIX). Since there is no readily available benchmark for interest rate swap exposures, the proxy is the USD 10 year swap rate.

⁴ The prices of 30-day futures are interpolated from first nearby and second nearby VXTYN futures.
The red dots in each chart identify periods during which a fixed income benchmark had a steep downturn, and show the concurrent increase in 30-day VXTY futures. From this historical behavior, it appears that buying VXTY futures may hedge drawdowns in the value of a variety of fixed income sectors. To explore this, Figure 7 shows an overlay of 30-day VXTY futures on the BMBS index held from 2010 to 2014. The daily number of futures is set to have a notional value of the futures equal to 5% of the BMBS\(^5\).

\(^5\) There are many alternative hedges. For example the hedging ratio can be selected to minimize variance of the return of the hedged portfolio.
2. Directional Trades

Since nearby VXTY futures track the TYVIX index, a position long futures can approximate a position in TYVIX index. Figure 8 is the cumulative P&L of rolling daily into a 30-day position by buying a portfolio of the first and second nearby VXTY futures. The fortunes of an investor consistently buying this 30-day exposure from 2003 to 2014 follow the tribulations of VXTY futures. A more nimble investor could alternate between long and short depending on the current behavior of VXTY futures.
3. Calendar Trades

Calendar trades in futures are a perennial favorite of traders who put on spreads to profit from a steepening or flattening term structure. The back and forth of the term structure of VXTY futures between backwardation and contango provides interesting opportunities to spread between futures. For example, we saw earlier that the backwardation between the first two nearby VXTY futures deepens during very volatile periods and veers more to contango once volatility fades. A calendar spread long the second nearby and short the first nearby would be poised to take advantage of this pattern.

Source: CBOE
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