



Cboe Global Indices

Cboe S&P 500 Left Tail Volatility Index

METHODOLOGY

Contents

- 1 Introduction2
 - 1.1 Index Objective2
 - 1.2 Supporting Documentation2
- 2 Index Construction2
 - 2.1 Pricing3
- 3 Index Calculations3
 - 3.1 Identifying Series and Data Filtering4
 - 3.2 Calculating Time to Expiration4
 - 3.3 Excluding Illiquid Strikes4
 - 3.4 Forward Calculation.....4
 - 3.5 Determination of IVM5
 - 3.6 Selecting Deep-OTM Strikes5
- 4 Calculation and Dissemination6
- 5 Index Information6
- Appendix 1 – Changes6
- Appendix 2 – Document Information.....6

1 Introduction

This document provides a transparent and easily accessible view of the methodology used to calculate the Cboe S&P 500 Left Tail Volatility Index (LTV), referred to in this document as “the Index”.

This methodology was developed by Torben G. Andersen and Viktor Todorov.

1.1 Index Objective

The Cboe S&P 500 Left Tail Volatility Index (LTV) aims to provide market participants with access to a robust tail risk measure estimating the expected (risk-neutral) return volatility stemming from large negative price moves over short horizons. Specifically, the Index measures the expected volatility due to a ten-standard deviation, or larger, down move in the S&P 500 Index over one week.

1.2 Supporting Documentation

This Methodology should be read in conjunction with the following document:

[Cboe_Index_Policies_Practices](#)

2 Index Construction

The construction of the Index is based on the research outlined in the paper “Tail risk premia and return predictability” (Bollerslev, Todorov and Xu, *Journal of Financial Economics*, 2015)¹ and “Tail risk and return predictability for the Japanese equity market” (Andersen, Todorov and Ubukata, *Journal of Econometrics*, 2021)². The methodology is used to calculate a left tail volatility measure assuming a Fréchet Extreme Value Distribution (EVT) and uses short-expiry deep out-of-the-money (OTM) put S&P 500 (SPX) options.

The identification of short-term tail risk is best achieved by using short-dated options. To balance this observation against the potentially excessive measurement and microstructure biases associated with shorter-term options, expirations between 6 – 31 business days are selected. The Index is derived from securities priced under the risk-neutral measure, with tail risk defined in terms of the number of standard deviation down moves. Therefore, the Index embeds (large) risk premiums associated with downward market moves along with the expectations regarding the actual likelihood of such events occurring. Consequently, these tail measures are more suitable as indicators of market risk pricing rather than of the likelihood that such adverse price moves will materialize.

¹ Bollerslev, Tim & Todorov, Viktor & Xu, Lai, 2015. “Tail risk premia and return predictability,” *Journal of Financial Economics*, Elsevier, vol. 118(1), pages 113-134.

² Andersen, Torben G. & Todorov, Viktor & Ubukata, Masato, 2021. “Tail risk and return predictability for the Japanese equity market,” *Journal of Econometrics*, Elsevier, vol. 222(1), pages 344-363.

2.1 Pricing

The market data for the S&P 500 Index option quotes are sourced from the Cboe Options Exchange via the Options Price Reporting Authority (OPRA) feed.

3 Index Calculations

The following describes the methodology for calculating the Index, including applicable formulas and input data.

The Index exploits the fact that the density characterizing the return tails very generally take the form associated with the Fréchet Extreme Value Distribution (assuming fatter left tails relative to the standard normal distribution). To calculate the index, the shape parameter a_t^- , the level shift parameter ϕ_t^- , and jump threshold parameter θ_t must be obtained using the formulas below:

$$a_t = \text{median}_{2 \leq i \leq N} \left| 1 - \frac{\log\left(\frac{O_{t,T}(K_i)}{O_{t,T}(K_{i-1})}\right)}{\log\left(\frac{K_i}{K_{i-1}}\right)} \right|$$

$$\phi_t = \text{median}_{1 \leq i \leq N} \left(\frac{e^{rT} O_{t,T}(K_i)}{T * F_{t,T}} \left(\frac{K_i}{F_{t,T}} \right)^{-(1+a_t)} (a_t + 1)(a_t) \right)$$

$$\theta_t = 10 * IVM_{1M,50 \text{ Delta}} * \sqrt{5/252}$$

$$LTV_t = 100 \sqrt{\phi_t e^{-a_t |\theta_t|} * \frac{a_t |\theta_t| (a_t \theta_t + 2) + 2}{(a_t)^3}}$$

where:

- N refers to the number of valid option quotes;
- K_i refers to the i^{th} option strike (ascending strike);
- $O_{t,T}(K_i)$ refers to the midprice of the i^{th} option expiring in T business days;
- $F_{t,T}$ refers to the implied forward calculated using put-call-parity (refer to section 3.4);
- r refers to the 3 Month T-Bill Rate;
- $IVM_{1M,50 \text{ Delta}}$ refers to the one month implied volatility at the implied forward theoretical 50 delta strike (please refer to section 3.5); and
- T refers to the business day time to maturity in years (please refer to section 3.2).

3.1 Identifying Series and Data Filtering

The Index calculation requires the selection of a basket of deep-OTM SPX put option expirations between 6 and 31 business days that satisfy both strike and series level quote quality data requirements. The basket includes weekly options. Refer to section 3.6 for information on the selection of deep-OTM strikes.

Only Monday, Wednesday, and Friday SPX expirations are used in the calculation to reduce the impact of higher strike increments observed during Tuesday and Thursday SPX expirations.

3.2 Calculating Time to Expiration

The time to expiry is calculated by finding the minutes of expiry and annualizing it by the number of minutes in 252 days.

$$T = \frac{(M_{Current\ Day} + M_{Settlement\ Day} + M_{Other\ Days})}{362880}$$

where:

- $M_{Current\ Day}$ refers to the minutes remaining until midnight of the current day;
- $M_{Settlement\ Day}$ refers to the minutes from midnight until 9:30 a.m. ET for standard SPX expirations and 4:00 p.m. for weekly SPX expirations; and
- $M_{Other\ Days}$ refers to the minutes in the business days between the current and expiration day.

3.3 Excluding Illiquid Strikes

Deep OTM put options can have wide bid-ask spreads. Therefore, for each expiration in the initial universe, the methodology excludes strikes with zero bids or an ask-bid ratio greater than 10. The ask-bid ratio is used as an indicator of option chain liquidity as it represents the size of the bid-ask spread a trader must cross.

In addition, to avoid violations of no-arbitrage, the methodology excludes strikes with mid prices that violate the monotonic valuation rule: if a put option with a lower strike price has a higher or equal value to a preceding one with higher strike price, the former is excluded from our computation. In other words, moving from higher to lower strike prices, we ensure a strictly decreasing sequence of option valuations.

3.4 Forward Calculation

The Index is calculated using deep OTM Put options. These options are identified by calculating the synthetic implied forward using put-call parity. Three near-the-money put call pairs are selected with a minimum absolute put-call price difference to calculate synthetic forwards using put-call parity. Using the median provides robustness in terms of identifying the implied forward level. The absolute put-call difference will only be calculated for strikes with non-excluded put and call quotes.

The following formula outlines the Synthetic Forward Calculation for Strike K:

$$F_{t,T} = K + e^{rT} * [C_{t,T}(K) - P_{t,T}(K)]$$

Where:

- K refers the strike price with the minimum absolute put-call difference;
- $C_{t,T}$ refers to the call option midprice with strike price K and expiry T ;
- $P_{t,T}$ refers to the put option midprice with strike price K and expiry T ;
- r refers to the 3-month T-bill Rate; and
- T refers to the annualized time to expiry.

The implied forward is calculated by taking the median of three synthetic forward levels. The at-the-money (ATM) strike is then identified by taking the strike price directly below the implied forward.

3.5 Determination of IVM

$IVM_{t,T}$ represents the business day implied volatility at the implied forward theoretical strike. It is estimated by taking the weighted average of the implied volatility of the largest strike OTM put option and the lowest strike OTM call option.

$$IVM_{t,T} = \frac{F_{t,T} - K_p}{K_C - K_p} * \sigma_{t,T}^C(K_C) + \frac{K_C - F_{t,T}}{K_C - K_p} * \sigma_{t,T}^P(K_P)$$

where:

- K_C refers to the nearest-ATM call option strike;
- K_P refers to the nearest-ATM put option strike;
- $\sigma_{t,T}^C(K_C)$ refers to the business day call option implied volatility with strike K_C and expiry T ; and
- $\sigma_{t,T}^P(K_P)$ refers to the business day put option implied volatility with strike K_P and expiry T .

The nearest-ATM put, and call option implied volatilities are calculated by inverting the Black Scholes.

3.6 Selecting Deep-OTM Strikes

Out-of-the-money series for each expiration are identified using the ATM strike, and expirations with fewer than three OTM put series are excluded. These exclusions are made to meet sufficient data requirements and incorporate deep OTM premiums in the calculation. Expirations where either the put or call option quote has been excluded at the ATM strike are not considered.

For each expiration in the initial universe, only deep-OTM put options are selected which have a maturity-adjusted log-moneyness less than or equal to -2.5.

The maturity-adjusted log-moneyness is calculated using the following formula:

$$\frac{\log\left(\frac{K_i}{F_{t,T}}\right)}{IVM_{t,T}\sqrt{T}} \leq -2.5$$

4 Calculation and Dissemination

The Index is calculated and disseminated as follows on each Business Day. A Business Day is defined as a day when the Cboe Options Exchange is open for the Cboe Regular Trading Hours (RTH) session. The Index follows the Cboe Options Exchange holiday schedule.

Index Name	Index Ticker	Dissemination Frequency	Dissemination Hours
Cboe S&P 500 Left Tail Volatility Index	LTV	15 Seconds	Between 9:30 a.m. and 4:15 p.m. ET

5 Index Information

Index Name	Index Ticker	Base Date	Launch Date	Base Value	Currency
Cboe S&P 500 Left Tail Volatility Index	LTV	January 3, 2006	March 14, 2024	n/a	USD

Appendix 1 – Changes

Major changes described in this document since March 14, 2024 are as follows:

Change Summary	Effective Date	Previous Language	Updated Language
-	-	-	-

Appendix 2 – Document Information

Version Number	1.2
Last Revised Date	April 10, 2026

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