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CME Group Volatility Index (CVOL^{tm}) Benchmark Methodology

CME Group Benchmark Administration Limited

Version 1.1

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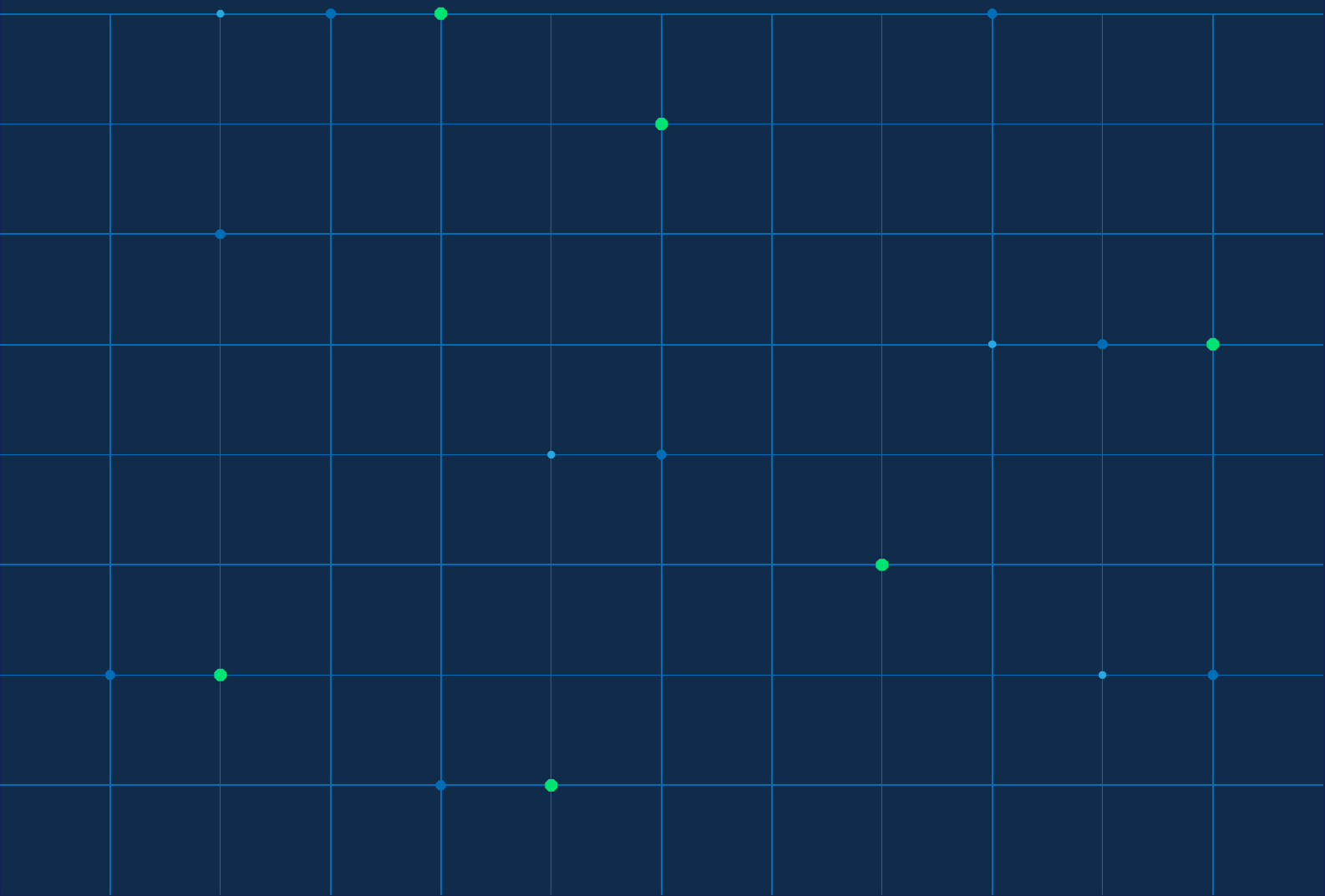

Version Control

VERSION	KEY CHANGES	APPROVAL DATE
1.0.0	Initial version	3 November 2020
1.0.1	Added: • Tenor Selection Process • Up Var and Down Var Yield Conversion	8 December 2020
1.1	Added: • New Indices • New Indices Derivative Indicators (ATM and Convexity) • Indices Classification criteria	9 February 2021

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Contents

1. Introduction

This document describes the calculation methodology of the CME Group Volatility Index (CVOL™) family of indices and includes their related derivative indicators. The underlying methodology can be used to create single product indices, that can also be combined to create broad-based indices, described herein.

The components of the CVOL family include:

- Volatility Index value
- Up Variance (Up Var) – Implied volatility of call options
- Down Variance (Down Var) – Implied volatility of put options
- Skew – Difference of Up Var and Down Var
- At the Money Vol (ATM Vol) - Premium of the theoretical at-the-money (ATM) volatility
- Convexity – The degree of curvature of the volatility curve as indicated by the ratio of the Volatility Index value and the ATM Vol.

The table below in CVOL details the mapping between the Derivative Indicators and underlying indices.

Variants of the basic calculation methodology are introduced to calculate CVOL in interest rate yield numeraire, when the underlying options are struck against the price of debt instruments, such as US Treasury Futures. The modified construction of these is described in Yield-Volatility Methodology.

CME Group and CME Group Benchmark Administration Limited

As the world's leading and most diverse derivatives marketplace, CME Group is where the world comes to manage risk. Through its four exchanges, CME, CBOT, NYMEX and COMEX, CME Group offers the widest range of global benchmark products across all major asset classes, including futures and options based on interest rates, equity indices, foreign exchange, energy, agricultural products and metals.

CME Group Benchmark Administration Limited (CBA) is authorized and supervised, as a Benchmark Administrator, by the UK Financial Conduct Authority (FCA). CBA is the Benchmark Administrator of the CME Group Volatility (CVOL) Family of Benchmarks, with Chicago Mercantile Exchange Group Inc. providing calculation agent and distribution services.

Bantix Technologies, LLC, operate a suite of products under the QuikStrike name, offering options software applications as well as a set of custom reporting, data retrieval, market collaboration and historical volatility tools and will provide calculation services on behalf of CME Group Inc.

Regulatory and IOSCO Compliance

CVOL is a family of benchmarks, designed on the basis of industry best practices and the IOSCO Principles for Financial Benchmarks. This will include but not be limited to the creation of an oversight committee and a published methodology. The Index will also be subject to an audit process. Material changes to the methodology will be announced via public consultation and any changes such as a re-balancing of the constituent components would be announced with a notice period of at least one (1) month.

2. CME Group Volatility Index (CVOL)

CVOL measures the volatility of the following option contracts, traded on CME Designated Contract Markets (DCMs).

Foreign Exchange							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
EUR/USD (EUU)	Tenor Selection 3	EUVL	EUUP	EUDN	EUSK	EUAM	EUCV
GBP/USD (GBU)	Tenor Selection 3	GBVL	GBUP	GBDN	GBSK	GBAM	GBCV
JPY/USD (JPU)	Tenor Selection 3	JPVL	JPUP	JPDN	JPSK	JPAM	JPCV
AUD/USD (AUU)	Tenor Selection 3	ADVL	ADUP	ADDN	ADSK	ADAM	ADCV
CAD/USD (CAU)	Tenor Selection 3	CAVL	CAUP	CADN	CASK	CAAM	CACV

Sovereign Debt							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
US 5-year T-Note (OZF) - Price	Tenor Selection 3	FVVL	FVUP	FVDN	FVSK	FVAM	FVCV
US 5-year T-Note (OZF) - Yield	Tenor Selection 3	FVVY	FVUY	FVDY	FVSY	FVAY	FVCY
US 10-year T-Note (OZN) - Price	Tenor Selection 3	TYVL	TYUP	TYDN	TYSK	TYAM	TYCV
US 10-year T-Note (OZN) - Yield	Tenor Selection 3	TYVY	TYUY	TYDY	TYSY	TYAY	TYCY
US 30-year T-Bond (OZB) - Price	Tenor Selection 3	USVL	USUP	USDN	USSK	USAM	USCV
US 30-year T-Bond (OZB) - Price	Tenor Selection 3	USVY	USUY	USDY	USSY	USAY	USCY

Metals							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Silver (SO)	Tenor Selection 3	SIVL	SIUP	SIDN	SISK	SIAM	SICV
Gold (OG)	Tenor Selection 3	GCVL	GCUP	GCDN	GCSK	GCAM	GCCV

Agriculture							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Wheat (OZW)	Tenor Selection 2	WVL	WUP	WDN	WSK	WAM	WCV
Corn (OZC)	Tenor Selection 2	CVL	CUP	CDN	CSK	CAM	CCV
Soybean (OZS)	Tenor Selection 2	SVL	SUP	SDN	SSK	SAM	SCV

Energy							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
WTI Crude Oil (LO)	Tenor Selection 1	CLVL	CLUP	CLDN	CLSK	CLAM	CLCV
Henry Hub Natural Gas (LN)	Tenor Selection 1	NGVL	NGUP	NGDN	NGSK	NGAM	NGCV

Furthermore, single product indices are aggregated to form broad-based indices.

Broad-based Indices					
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**Constituents**
FX G5 Volatility Index	FXVL	FXUP	FXDN	FXSK	EUVL, GBVL, JPVL, ADVL, CAVL

Designated Contract Markets

A wide range of options on various asset classes, including agriculture, energy, equity, FX, interest rates and metals are actively traded on CME Group Designated Contract Markets (DCMs). Details of the most traded options contracts are available on the CME Group page: CME Group Options.

The entirety of options contracts traded on CME Group DCMs are available on: CME Group All Products – Codes and Slate.

Input data

The calculation of CVOL is based on the respective option settlement prices, as published by CME Group. Settlement Prices calculation methodologies for each option series are available on CME, CBOT, NYMEX, COMEX Daily Option Settlement Procedures.

For a given product the following input data are required:

- Selected Option Expiration(s) $T_1, T_2, \ldots T_N$
- For Selected Option Expiration, T_N, the vector of all listed strikes, K_i
- For each strike, K_i, settlement prices for both the call and the put at that strike, C_{K_i}, P_{K_i}, respectively
- Discounting SOFR interest rate corresponding to selected expiration, R_N. The Discount Factors used by the model represent the present value of 1 USD at each future date leveraging SOFR rates as the daily prevailing rate of interest and are generated for each settlement day by CME Clearing.
- Futures contract settlement price for selected expiration, F_N

For Yield Volatility Variant:

- DV01 value corresponding to the Treasury Future that underlies a particular vector of Treasury Future Options.

For Agricultural CVOL Indices (Wheat, Corn, Soybean):

The futures contract settlement price for the Agricultural CVOL indices is determined as follows:

1. A synthetic future using the strike where the put and call premiums are closest but nonzero is calculated using Put-Call Parity (in the instance where there are two strikes with equally distant premium, the lower strike is chosen):

- The strike K is determined as the strike for $Min\left(\left|C_{K_i} - P_{K_i}\right|\right)$
- The synthetic future F_S is calculated as $F_S = K + C_K - P_K$

2. The synthetic future calculated F_S is compared to the published settled futures price F_N; if the absolute difference between the two is greater than two times the minimum option price tick z, the synthetic price F_S is used instead of F_N:

- If $|F_S - F_N| > 2z$:
    - F_S is used as the contract settlement price.
- Otherwise:
    - F_N is used as the contract settlement price.

For Broad-Based Index Calculations:

- Total Open Interest Dollar Vega for selected product or complex as calculated and provided by Bantix-QuikStrike
- The contract multiplier for each product included in the Broad-Based Index

Use of Expert Judgement

The CME Group Volatility Index Methodology is structured with the intent of minimising the need for Expert Judgement or discretion.

Input data are sourced from CME Group Designated Contract Markets and are automatically applied to the calculation algorithm; Indices values are subject to stringent validation as in section Pre-publication reliability checks.

CBA may utilise expert judgement in the classification review of CVOL indices into tenor selection groups. As part of the CVOL control framework and governance arrangements, proposed tenor selection classifications will be presented to the CVOL Oversight Committee.

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3. CME Group Volatility Index (CVOL) Methodology for Single Product, Single Expiration

Single Tenor formula:

$$Single\ Tenor\ Index = \sigma_N = 100 * \sqrt{\frac{2}{T}\sum_{i=m}^{n}\frac{\Delta K_i}{F_N^2}e^{R_N T_N}Q(O_{K_i})}$$

Determining the discount rate

Because CME Group options are fully funded at the time of purchase, their values are a "present value" of a future contingent cashflow. This means that the option prices collectively will understate the expected variance and will need to be adjusted to represent the contingent cashflow at the time of expiry. Each option price will need to be multiplied by $e^{R_N T_N}$ with T_N representing the expiry of the option and R_N being a rate appropriate for T_N and $R_N T_N$ will represent the product of the appropriate rate for the appropriate time.

Each date's discount factor (Df_N) is drawn from a CME discounting curve and converted into a growth factor, as described in the Input Data section. The discount factors will be inverted to represent the corresponding growth factor; $\frac{1}{Df_N} = e^{R_N T_N}$

Determining Delta K

If the option is the highest struck Call:	$\Delta K = K_i - K_{i-1}$
If the option is the lowest struck Put:	$\Delta K = K_{i+1} - K_i$
If the option is the K_0 struck Call:	$\Delta K = K_1 - K_0$
If the option is the K_0 struck Put:	$\Delta K = K_0 - K_{-1}$
Otherwise:	$\Delta K = (K_{i+1} - K_{i-1})/2$

Where:

- $K_0 = F$

Determining the Set of Options Included in the Calculation

The forward price determined in many implied volatility calculations requires a Put and a Call of the same tenor with the same strike. Because CME Group options deliver an actual future at expiry, the implied forward does not need to be calculated because the price of the Future itself serves this purpose and will be designated as F.

When determining a constant forward-looking implied volatility measure using more than one tenor of options strips, then F will be designated with subscripting such as F_1 and F_2, even if the two tenors of options are both predicated on the same underlying future; in which case F_1 and F_2 will be equal to one another.

Options to be included:

- Any Call Option with a Strike that is equal to or greater than the underlying Future's price and having a settlement price greater than zero.
- Any Put Option with a Strike that is less than the underlying Future's price and having a settlement price greater than zero.

CVOL Index Classification

Each CVOL index will be assessed at launch and classified into a Tenor Selection Group based on the following criteria:

- Availability of contract tenors
- Seasonality impacts on the instruments and related markets
- Consistency with other CVOL indices of the same asset class
- Liquidity and availability of settlement data

Please refer to CME Group Volatility Index (CVOL) section for the current classification of CVOL instruments.

The Tenor Selection Groups are used to determine the tenor selection applied to each CVOL calculation. The classification of each CVOL index will be reviewed at least annually by the Administrator and the Oversight Committee, with ad-hoc reviews performed as necessary.

In circumstances where, based on a review of the criteria, a CVOL index is determined to be classified into a different Tenor Selection Group, the Administrator will provide stakeholders with at least 1 (one) month notice.

Tenor Selection Groups

Tenor Selection 1

If there is a Monthly where DTE = 30, that single component expiration is used for index calculation.

Otherwise contracts will be selected as follows:

Far contract selection

- The Monthly expiration > 30 DTE and greater than the DTE of the Near contract (if the Near expiry is > 30 DTE) and is the closest monthly to 30 DTE.

Near contract selection

- The Monthly expiration closest to 30 DTE and < 30 DTE and > 10 DTE.
- If there is no contract 10 DTE < Monthly < 30 DTE, then select the closest expiration to 30 DTE.

Tenor Selection 2

If there is a Monthly where DTE = 30, that single component expiration is used for index calculation.

Otherwise contracts will be selected as follows:

Far contract selection

- The Monthly contract expiration > 30 DTE and closest to 30 DTE.

Near contract selection

- The Monthly contract expiration 14 ≤ DTE < 30 and closest to 30 DTE.
- If the shorted dated monthly contract(s) expiration is/are DTE < 14 OR DTE > 30, then Friday Weekly 14 ≤ DTE ≤ 21 and closest to 30 DTE is selected.
- If a Friday Weekly contract is selected and there are no settlement values present to generate a CVOL value, that contract is ignored. The next Friday Weekly contract with 14 ≤ DTE and the shortest expiry is chosen.
- If the next Friday Weekly selected as above has no settlement values, the longest dated Monthly or Friday Weekly contract 10 ≤ DTE with settlement values available, is taken as the front tenor.

Tenor Selection 3

If there is a Monthly where DTE = 30, that single component expiration is used for index calculation.

Otherwise contracts will be selected as follows:

Far contract selection

- The Monthly contract expiration > 30 DTE and closest to 30 DTE.

Near contract selection

- The Monthly contract expiration 14 ≤ DTE < 30 and closest to 30 DTE.
- If the shorted dated monthly contract(s) expiration is/are DTE < 14 OR DTE > 30, then Friday Weekly 14 ≤ DTE ≤ 21 and closest to 30 DTE is selected.

Tenor Selection 4

If there is a Monthly, Weekly or EOM where DTE = 30, that single component expiration is used for index calculation.

Otherwise contracts will be selected as follows:

Far contract selection

- The Monthly, Weekly or End-of-Month (EOM) expiration > 30 DTE and closest to 30 DTE.

Near contract selection

- The Monthly, Weekly or EOM expiration < 30 DTE and closest to 30 DTE.

Tapering

In order to establish option inclusion boundaries, the calculation methodology looks for three consecutive options that are priced at the smallest pricing increment for that product. In the event that this occurs, prices will be adjusted or tapered. The tapering process attributes decreasing weight to the second and third option prices of the three consecutive prices at such increment and does not incorporate any prices beyond these.

The price of the second option at the smallest pricing increment is weighted 50% of its settlement price and the price of the third option is weighted 25% of its settlement price.

Determining Time

The time T for each strip of options is the amount of time as a fraction of a year (365 days) from the current time until the expiry of those options.

$$T_1 = \text{expiry}_1 - t$$

When determining a constant forward-looking implied volatility measure using more than one tenor of options strips, then T will be designated with subscripting such as T_1 and T_2

Each tenor of options will have its own variance metric, and these two-variance metrics will be time-weighted to a specific time horizon, for example 30 days (T_H, where $H = 30$ DTE in this case). The time weighting applied is defined as follows:

$$\sigma_H = \sqrt{\frac{(T_2 - T_H) * (\sigma_1^2) + (T_H - T_1) * (\sigma_2^2)}{(T_2 - T_1)}}$$

Where:

- T_1 is the time to expiry of the front tenor
- T_2 is the time to expiry of the back tenor
- σ_1 is the variance of the front tenor
- σ_2 is the variance of the back tenor
- $\sigma_H$is the time-weighted variance

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4. Broad-based Index Construction (Vega)

The calculation of broad-based indices uses a combination of the CVOL calculations, Open Interest of the associated contracts, and the Vega of the options within the strips. The Vega is calculated by Bantix-QuikStrike, in line with industry standards. The first component (i.e. Implied Volatility calculation) uses current day data while the other two components (i.e. Open Interest and Vega) are provided by End-of-Day (EOD) data from the most recent five days prior to today.

The broad-based index currently produced, measures the volatility of a basket of currencies:

Index Symbol	Name	Constituents
FXVL	FX G5 Volatility Index	EUCV, GBCV, JPCV, AUCV, CACV

The FX Volatility Index is calculated as the sum of their respective Implied Volatility Calculations, weighted by the Dollar Vega Open Interest ($\$VOI$). The dollar Vega Open Interest for a single day can be defined as follows:

$$\$VOI = M \sum_{t=0}^{i} \sum_{k=0}^{j} v_{t,k} * OI_{t,k}$$

We then use five days of $\$VOI$ to arrive at a five-day moving average as defined below:

$$MA_{T=0} = \frac{\sum_{T=-1}^{-5} \$VOI_T}{5}$$

Where:

- t is tenor of a given option.
- T is the day of a given $\$VOI$, where T_{-5} is five settlement days prior to the current calculation day.
- k is the strike of a given option.
- $v_{t,k}$ is the Vega of the option at time t with strike k (both calls and puts).
- $OI_{t,k}$ is the Open Interest of the option at time t with strike k (both calls and puts).
- M is the contract multiplier associated with the particular option product.

Summing the product of the above components as shown in the definition will produce the Dollar Vega Open Interest for a given option product. It is important to note that because EOD data is being used for this portion of the calculation, all outstanding contracts will be used in the calculation from the most recent five EOD data files.

The weighting is used to capture the overall risk profile in volatility terms for each product represented through the product of Vega and Open Interest. This is then normalized using the product multiplier M.

Using the Dollar Vega Open Interest, we formulate the weighting for each product using the following definition:

$$W_n = \frac{MA_n}{\sum_{n=0}^{q} MA_n}$$

Where q is the number of products being combined into the index.

With the weightings calculated, we take the final step and calculate the index by combining the weightings and Implied Volatility values for each respective product in the following manner:

$$\sigma_{index} = \sum_{n=0}^{q} \sigma_n * W_n$$

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5. Derivative Indicators

In addition to the Index Value a set of derivative indicators as described in the Introduction section, is calculated and published.

Derivative Indicators Calculation Methodology

Up Variance (Up Var)

Up Var is the Implied Volatility on the calls and can be defined as follows:

$$xxUP = 100 * \sqrt{2 * \frac{2}{T} \sum_{i=m}^{n} \frac{\Delta K_i}{F_N^2} e^{R_N T_N} Q(C_{K_i}) + \frac{1}{F_N^2} e^{R_N T_N} * (adjVA_{\mp 1N})}$$

Where “xx” represents the first two letters of the Index Symbol.

This follows the definition provided previously with the exception that the entirety of the option strip O is replaced with C which refers solely to the call strip.

Down Variance (Down Var)

Down Var is the Implied Volatility on the puts and can be defined as follows:

$$xxDN = 100 * \sqrt{2 * \frac{2}{T} \sum_{i=m}^{n} \frac{\Delta K_i}{F_N^2} e^{R_N T_N} Q(P_{K_i}) + \frac{1}{F_N^2} e^{R_N T_N} * (adjVA_{\pm 1N})}$$

This follows the definition provided previously with the exception that the entirety of the option strip O is replaced with P which refers solely to the put strip.

Skew

Skew refers to the difference of Up Var and Down Var to serve as an indication of the direction of volatility relative to the put or call wings. Skew is therefore defined as:

$$xxSK = xxUP - xxDN$$

ATM Volatility (ATM Vol)

The theoretical ATM option price is used to estimate the ATM Vol (Brenner and Subrahmanyam - 1988):

$$\sigma_{atm} \approx 100 * \sqrt{\frac{2\pi}{T}} * \frac{O_0}{F}$$

Where:

- σ_{atm} is the ATM Vol
- T is the time to expiry in terms of years (365 days)
- O_0 is the synthetic ATM option price (as defined in Derivative Indicators Input Data)

Convexity

Convexity refers to the degree of curvature of the volatility curve as indicated by the ratio of the Volatility Index value and the ATM Vol .The expression to calculate the convexity is as follows:

$$Convexity = \frac{\sigma_n}{\sigma_{atm}}$$

Where:

- σ_n refers to the Volatility Index value of a given product
- σ_{atm} refers to the ATM Vol as specified by the ATM Vol calculation above.

Derivative Indicators Input Data

Synthetic ATM Option Price

In order to determine the ATM Price and Volatility, the following are considered.

- When there is a strike that is exactly ATM.
- When there is a strike that is closer to the strike of the first out-of-the-money (OTM) Put in the option strip.
- When there is a strike that is closer to the strike of the first OTM Call in the option strip.
- When there is a strike exactly half-way between the closest OTM Call and OTM put.

If there is no exact ATM option, a synthetic ATM option price is generated using an assumed delta and a nearby existing option price, according the following four scenarios:

ATM: the Call and Put prices at the strike are averaged as follows:

If the Call and Put prices are non 0 then:

$$O_0 = \frac{O_{c_0} + O_{p_0}}{2}$$

If the Put price is 0 then:

$$O_0 = O_{c_0}$$

If the Call price is 0 then:

$$O_0 = O_{p_0}$$

Put: where the closest strike to ATM is below the Future, we define O_0 as follows:

$$O_0 = O_{K-1} + 0.50 * (F - K_{-1})$$

Call: where the closest strike to ATM is above the Future, we define O_0 as follows:

$$O_0 = O_{K+1} + 0.50 * (K_1 - F)$$

Mid-price: where F is a mid-price between K_{-1} and K_1, we define O_0 as follows:

$$O_0 = \frac{\left(O_{K-1} + 0.50 * (F - K_{-1})\right) + \left(O_{K+1} + 0.50 * (K_1 - F)\right)}{2}$$

Since $(F - K_{-1}) = (K_1 - F)$, the expression is simplified as follows:

$$O_0 = \frac{O_{K-1} + 0.50 * (K_1 - K_{-1}) + O_{K+1}}{2}$$

$K_0 = F$ is the theoretical ATM strike; the value of ΔK_0 for the ATM option is defined as follows:

ATM ΔK: where there is a strike that is exactly ATM, the ΔK_0 is already known.

Put ΔK: where the closest strike to ATM is below the Future, ΔK_0 is defined as follows.

$$\Delta K_0 = \left(\frac{K_{-1} + K_1}{2}\right) - F$$

Call ΔK: where the closest strike to ATM is above the Future, ΔK_0 is defined as follows.

$$\Delta K_0 = F - \left(\frac{K_{-1} + K_1}{2}\right)$$

Mid-price: where F is a mid-point between K_{-1} and K_1, no adjustment is needed as ΔK would be zero in the two instances above.

Where:

- K_{-1} is the nearest to-the-money Put strike and K_1 is the nearest to-the-money Call strike
- Δ_K is assumed to be 0.5
- K_{-1} or K_1, depending on which strike is used
- ΔK_{-1} is the delta K for the nearest to-the-money Put (as defined in 'Determining Delta K')
- ΔK_1 is the delta K for the nearest to-the-money Call (as defined in 'Determining Delta K')
- O_K is the option premium at either strike K_{-1} or K_1, depending on which strike is used
- O_{c_0} is the option premium for the ATM Call
- O_{p_0} is the option premium for the ATM Put

Time Weighting

Derivative indicators are time weighted; the two specific tenors of options each produce its own variance estimate up to the expiry of those options. These two variance estimates are time weighted with a 30-day horizon.

$$\sigma_H = \sqrt{\frac{(T_2 - T_H) * (\sigma_1^2) + (T_H - T_1) * (\sigma_2^2)}{(T_2 - T_1)}}$$

Each of the derivative indicators are appropriately time weighted, as described above.

ATM Variance Adjustment

To correctly attribute variances, adjustments are applied to the following scenarios.

The Variance Area is defined as follows:

$$VA_i = \Delta K_i * O_i$$

The ATM Variance Area is specified as follows:

$$VA_0 = \Delta K_0 * O_0$$

The following notation is assigned to the Adjusted Variance Area:

$$\text{Adjusted Variance Area} = adjVA_i$$

In the instance where the closest strike to ATM is below the Future, the calculated ATM variance from the Put wing is added to the Call wing. This is defined as follows:

$$adjVA_{-1} = VA_{-1} - VA_0$$
$$adjVA_1 = VA_1 + VA_0$$

In the instance where the closest strike to ATM is above the Future, the calculated ATM variance from the Call wing is subtracted and added to the Put wing. This is defined as follows:

$$adjVA_1 = VA_1 - VA_0$$
$$adjVA_{-1} = VA_{-1} + VA_0$$

In the previous section, we represent the permutations described above as they apply to either the Call or Put wings using the following notation:

(1) $adjVA_{\mp 1}$
(2) $adjVA_{\pm 1}$

Where (1) indicates the Adjusted Variance Area being either subtracted or added to the Call wing and (2) indicates the Adjusted Variance Area being either subtracted or added to the Put wing.

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6. Yield-Volatility Methodology

In order to render the price-based volatility as an annualized basis point (BP) volatility the DV01 is used; DV01 is the change of a bond price for a 1 basis change of the rate associated with that bond.

To convert a futures price volatility into a BP volatility, the transformation happens at the variance level.

$$\sigma_{bp}^2 = \frac{F_T^2}{DV01_T^2} * \sigma_T^2$$

Where σ_T^2 is the variance calculation of the single tenor T.

From the prior calculation

$$\sigma_H = \sqrt{\frac{(T_2 - T_H) * (\sigma_1^2) + (T_H - T_1) * (\sigma_2^2)}{(T_2 - T_1)}}$$

Substituting the DV01 formula

$$\sigma_{Hbp} = \sqrt{\frac{(T_2 - T_H) * \left(\frac{F_1^2}{DV01_1^2}\right) * (\sigma_1^2) + (T_H - T_1) * \left(\frac{F_2^2}{DV01_2^2}\right) * (\sigma_2^2)}{(T_2 - T_1)}}$$

Up Var and Down Var Yield Conversion

When calculating the Up Var and Down Var for a yield volatility, the derivative metrics are inverted relative to the price volatility.

Call options on the price will behave like Put options on the yield, and vice versa. An Up Var calculation on the price (which uses Call options on said Future) is equivalent to the Down Var calculation on the yield.

This also affects the calculation of skew for yield volatilities. So, when skew is positive (or above one) for the price volatility, the equivalent yield skew would be negative (or below one).

7. Publication and Error Policy

Publication

The CVOL and related Derivative Indicators are generated from CME Group options settlement prices, as published according to CME, CBOT, NYMEX, COMEX Daily Option Settlement Procedures.

Settlement prices will be available by 07:00pm ET; in the event that SOFR or DV01 input values are unavailable, the previous day values will be applied.

The CVOL and derivative indicators are calculated as soon as the input data are available and are subject to rigorous reliability checks before publication.

Once the pre-publication reliability checks are fully satisfied, Indices are published by 09:00pm ET same day. Indices are published to CME Group DataMine and CME Group QuikStrike, where historical values for the last two years are available subject to a license agreement. Daily values are also published to the CME Group website.

Pre-publication reliability checks

Indices are validated for publication if the following conditions are met in full:

- Each fixing value for each product or broad-based index (Index fixing, UpVar fixing, DownVar fixing, Skew fixing) must be a non-zero value;
- Each fixing value must be a double-precision floating point format value, i.e. not an integer;
- For each of the following values, a tolerance check will be performed:
    - CVOL Index: the value must be within +/- 30% of the same day's closing CM_30[1] Implied Volatility level for that product as calculated by QuikStrike
        - For the US Treasury Yield Volatility version, this same check will apply by using the US Treasury Yield Volatility CM_30 value as calculated by QuikStrike
    - UpVar – DownVar (i.e. Skew): (0.5)*(UpVar^2) + (0.5)*(DownVar^2) must be within +/- 30% of CVOL Index^2

In the event that any of the above conditions are not met, the Calculation Agent will check the integrity of the input data and re-run the calculation. If the error persists, the index value will be the previous day published value.

If the input data (settlement prices) for that day are unavailable, the previous day index value will be published.

The published values include a timestamp; instances where the prior day's calculation is re-published will be indicated in an additional field.

[1] The QuikStrike CM_30 value is the result of the interpolation of ATM volatilities derived from widely adopted option pricing models.

If the previous day value is used for more than three consecutive business days, the Administrator must promptly convene the Oversight Committee to assess available remedial actions.

Error policy

If a calculation error in an Index is identified post publication and prior to the publication of next day values, the Administrator will investigate and re-run the calculation where necessary. Re-calculation, reliability checks and re-publication, follow the same rules stated in Publication and Error Policy. Where the difference between re-calculated index and the original calculation is greater than 5% the index will be re-published.

If an error is identified after next day Index value has been published, no re-publication will occur.

8. Governance

The Administrator operates under a comprehensive Risk and Control Framework, providing clear policies on Governance, Oversight, Benchmark Design and Calculation, Outsourcing, Operations, Reporting of Infringements and Business Continuity.

CBA has in place a "Three Lines of Defence" model, enabling close cross-monitoring of the governance process - this being business, compliance and audit who all have a key role in ensuring that CBA meets its regulatory requirements.

The over-arching governance is ensured by the Oversight Committee, formed and operating under the CBA Terms of Reference for Oversight Committees. The Oversight Committees can escalate to the CBA Board if required.

Oversight Committee

An Oversight Committee is appointed by the Administrator to review the integrity of the benchmark, in accordance with the Oversight Committee Terms of Reference.

The Oversight Committee will provide independent oversight of, and challenge to the Administrator on all aspects of the Benchmark determination process. The Oversight Committee approves proposed changes to the Calculation Methodology including, but not limited to, the structure of the Benchmark, input data used and all aspects of the Calculation Methodology.

The minutes of the Oversight Committee are made available on the Administrator's website.

Review of the Methodology

The Administrator constantly monitors the Benchmark Methodology and its consistency with the stated objectives. All changes to the Methodology are reviewed by the Oversight Committee including, but not limited to, changes in input data and calculation parameters used in the calculation of the benchmark.

The Oversight Committee may direct the Administrator to consult on any changes to the methodology with Stakeholders and the wider market.

Review of the Methodology - Consultation Process

The Administrator will engage relevant stakeholders and end users on material changes to the benchmark, or where the Oversight Committee requests such consultation.

The Administrator will publish notice of the consultation on its website, inviting feedback from stakeholders and the wider market. Notice of a consultation will be posted at least 1 (one) month prior to the deadline for responses. The notice will include the details of the proposed material change, the timeline and the rationale for the change.

Findings of the consultation process and proposed changes to the Benchmark Methodology, recommended as a result of the consultation, will be presented by the Administrator to the Oversight Committee for its consideration.

Feedback to a consultation is considered confidential, however the Administrator will publish an anonymized summary with its conclusions, as soon as is practical, but before implementation of any changes.

Cessation

The Administrator constantly monitors the representativeness of the Benchmark. If the Benchmark is deemed to be unrepresentative of the underlying economic reality due to paucity of input data or systemic changes in the related markets, the Administrator will engage the Oversight Committee at the earliest opportunity. These cessation arrangements are designed to mitigate cessation and transition risks.

The Oversight Committee may direct the Administrator to consult with Stakeholders as in Review of the Methodology - Consultation Process.

As a last resort, if no alternative arrangements are feasible, the Oversight Committee may instruct the Administrator to discontinue the Benchmark, providing Stakeholders at least 6 (six) months' notice and assistance to explore alternative reference instruments.

The Administrator will endeavour to identify alternative benchmarks; however, this might not always be possible due to Regulations, market conditions or suitable alternatives and users of the benchmark are recommended to ensure that they have adequate fallback policies and procedures in the event of the Benchmark becoming unrepresentative of its economic interest.

Records Retention

The Administrator has in place policies for the retention of any relevant evidence and documentation related to the determination and dissemination of the Benchmark, either in paper or in electronic format, for at least the mandatory term of 5 (five) years.

Auditing

An internal audit process is undertaken regularly, to ensure adherence to the stated Methodology, the IOSCO principles and regulatory requirements.

External audits can be requested at any time by the Administrator's board, the Oversight Committee or the internal audit function (including if it is dissatisfied with any aspects of its conduct).

Data Licensing and Distribution

The Benchmark is made available subject to execution of an Information License Agreement (ILA) together with the appropriate Schedules. Market participants that intend to subscribe to the benchmark should contact the Administrator at the following email address: benchmark@cmegroup.com

Complaints Procedures

CME Group has publicly available Complaints Procedures, applicable to the Administrator, that sets out the procedure according to which a complaint will be dealt with by a senior member of staff not directly involved with the benchmark calculation and dissemination. Information related to complaints will be stored in a restricted access area and kept for a period of up to 5 (five) years following the date when the complaint was first lodged. Complaints can be submitted at internationalcompliance@cmegroup.com

9. Appendix I – Key Terms & Definitions

TERM	DESCRIPTION
Administrator	CME Group Benchmark Administration Limited
ATM	At-the-Money
ATM Vol	At-the-Money Volatility
BMR	Benchmark Regulation
BP	Basis Point (0.01%)
CBA	CME Group Benchmark Administration Limited
Convexity	The degree of curvature of the volatility curve
CVOL^{tm}	CME Group Volatility Index
DCM	Designated Contract Market
Down Var	Implied volatility of put options
DTE	Days to Expiry
DV01	Dollar Value of a Basis Point
EOD	End of Day
EOM	End of Month
FCA UK	Financial Conduct Authority (UK)
FED	Federal Reserve System
IOSCO	International Organization of Securities Commissions
NY FED	Federal Reserve Bank of New York
OC	Oversight Committee
OTC	Over the Counter
Skew	Difference of Up Var and Down Var
SLA	Service Level Agreement
SOFR	Secured Overnight Financing Rate
Up Var	Implied volatility of call options
VWAP	Volume Weighted Average Price