IvyDB GI

Reference Manual

Version 1.1
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Revision Summary

Date	Revision History	Revision Class	Comments
06/28/2012	1.0.0	Major	Initial Availability.
04/06/2015	1.0.1	Minor	Added VIX and VSTOXX to the daily feed.
10/01/2015	1.1.0	Major	Changed the nightly, patch and archive file name and the name of the text files within each zipped folder by adding <REGION>. Added CalculationPrice and ReferenceExchange fields to Option_Price file (GI.<REGION>.IVYOPPRC.yyyymmdd.txt). Added Distribution file (GI.<REGION>.IVYDISTR.yyyymmdd.txt) to accommodate discrete dividends information for ETFs. Added Future_Price file (GI.<REGION>.IVYFUTPRC.yyyymmdd.txt) to accommodate indices with future contracts as the underlying. Removed index dividend rates for VIX, VSTOXX, IBEX and TAIEX. Discontinued Tick files.

Introduction

IvyDB Global Indices is a comprehensive database of historical price, implied volatility, and sensitivity information for the listed index options markets worldwide. It combines the depth and quality of IvyDB products and the width of US and international exchanges coverage.

The product has been designed to provide data of the highest obtainable quality, suitable for empirical and/or econometric studies of the options markets, development and testing of option trading strategies, and options research support. IvyDB GI data files are updated nightly to reflect new closing prices, dividend yields, and option contract expirations, or other changes.

OptionMetrics compiles the IvyDB GI data from raw end-of-day pricing information. These raw data are edited and organized to facilitate their use in the options market research. The interest rate curves and option implied volatilities and sensitivities are calculated by OptionMetrics using our proprietary algorithms, which are based on the standard market conventions.

File Formats

The data within IvyDB GI is organized in several files:

- **Security_Name** file (GI.<REGION>.IVYSECNM.yyyymmdd.txt)
- **Security_Price** file (GI.<REGION>.IVYSECPR.yyyymmdd.txt)
- **Future_Price** file (GI.<REGION>.IVYFUTPRC.yyyymmdd.txt)
- **Option_Price** file (GI.<REGION>.IVYOPPRC.yyyymmdd.txt)
- **Index_Dividend** file (GI.<REGION>.IVYIDXDV.yyyymmdd.txt)
- **Distribution** file (GI.<REGION>.DISTR.yyyymm.txt)
- **Volatility_Surface** file (GI.<REGION>.IVYVSURF.yyyymmdd.txt)
- **Std_Option_Price** file (GI.<REGION>.IVYSTDOP.yyyymmdd.txt)
- **Historical_Volatility** file (GI.<REGION>.IVYHISTVOL.yyyymmdd.txt)
- **Zero_Curve** file (GI.<REGION>.IVYZEROC.yyyymmdd.txt)
- **Currency** file (GI.<REGION>.IVYCURRENCY.yyyymmdd.txt)
- **Exchange** file (GI.<REGION>.IVYEXCHNG.yyyymmdd.txt)

Files are produced nightly in a tab-delimited format. In the descriptions below, the layout of each file is shown, giving the data type, maximum field length (for character fields) and the field name. All dates are given in YYYYMMDD format.

The <REGION> part of the file name denotes a particular region included in the file (North America, Asia or Europe). If you subscribed to the entire product, the <REGION> will appear as ALL in your file name.

The primary key (unique fields) for each file is shown in **bold**.

Security_Name File

The Security_Name file contains a historical record of changes to the issuer, and international security identifiers such as ISIN, SEDOL, etc.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Effective Date**
char	12	CUSIP
char	12	Ticker
char	255	Issuer
char	12	ISIN
integer	-	Valor
char	12	SEDOL

Field descriptions

Security ID

The Security ID for the security

Effective Date

The effective date of the change

CUSIP

The first 8 digits of the security's CUSIP as of the effective date

Ticker

The base portion of the security's ticker on the effective date

Issuer

A description of the issuing company or entity

ISIN

An International Securities Identifying Number (ISIN) uniquely identifies a security. Its structure is defined in ISO 6166. Securities for which ISINs are issued include bonds, commercial paper, equities and warrants. The ISIN code is a 12-character alpha-numeric code.

VALOR

Swiss Security Number that is used for identifying securities and options.

SEDOL

SEDOL stands for Stock Exchange Daily Official List. SEDOL numbers are assigned to securities for trading/pricing purposes. It is an identification number for the London Stock Exchange. This identification number consists of 7 alphanumeric digits. The SEDOL serves as an NSIN for all securities issued in the United Kingdom.

Security_Price File

The Security_Price file contains the price history for the security.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Date**
integer	-	**Exchange**
integer	-	Currency
real	-	Bid
real	-	Ask
real	-	Open price
real	-	Close price
bigint	-	Volume
real	-	Total return
real	-	Adjustment factor
real	-	Cumulative total return factor

Field descriptions

Security ID

The Security ID for the security

Date

The date for this price record

Exchange

The exchange code where security is traded, see Appendix A

Currency

The code for currency of the security price, see Appendix B or Currency file

Bid

If there was no trading on this date, the closing bid price for the security.[1]

Ask

If there was no trading on this date, the closing ask price for the security.[2]

Open price

If this field is positive, then it is the opening price for the security on this date.

Close price

If this field is positive, then it is the closing price for the security on this date.

Volume

The volume on the exchange where the security traded on this date

Total return

The holding period return for this security, from the last good pricing date to this date. The holding period return is calculated as the total price appreciation for the security over the holding period (adjusted for splits and other price factor changes) plus the cash value of any distributions which go ex-dividend during the holding period, divided by the security's last available closing price (or bid-ask midpoint).
Total return is calculated per security traded on certain exchange. Thus, total return for same instrument traded on different exchanges on the same date might be different.

Total return is calculated as: $\frac{S_t * F_t + A_t}{S_{t-1}} - 1$, where

S – Security price
F – Adjustment factor from Distribution on ExDate t
A – Dividend amount from Distribution on ExDate t

Adjustment factor

The cumulative product of all the adjustment factors for this security as of this date. When a security is first listed, its Cumulative Adjustment factor is set to 1.0. For all subsequent dates, the Cumulative Adjustment Factor is the product of all non-zero Adjustment Factors from the Distribution file having ex-date prior or equal to the date of

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[1] For US securities: If bid is positive, then it is the low price for the security on this date. If it is negative, there was no trading on this date, and the field represents the closing bid price for the security.

[2] For US securities: If ask is positive, then it is the high price for the security on this date. If it is negative, there was no trading on this date, and the field represents the closing ask price for the security.

this price. To calculate an adjusted close price for a security, multiply the Close Price by the Cumulative Adjustment Factor and divide by the value of the Cumulative Adjustment Factor for this security as of today (i.e., the last date in the Security Price file for this security).

Cumulative total return factor (AdjustmentFactor2)

Similar to the Cumulative Adjustment Factor, but includes the effect of dividends.

$$CF = \prod_{i \in \{exDates\}} \frac{A_i}{S_i} + AF_i \text{ , where}$$

A – Dividend amount on ExDate i
S – Security price on ExDate i
AF – Adjustment Factor on ExDate i

When a security is first listed, its Cumulative Total Return factor is set to 1.0. To calculate an adjusted close price for a security including dividends, multiply the Close Price by the Cumulative Total Return Factor and divide by the value of the Cumulative Total Return Factor for this security as of today (i.e., the last date in the Security Price file for this security).

Future_Price File

The Future_Price file contains the future prices history. The future prices are used in implied volatility calculations for certain indices (VIX, VSTOXX, IBEX, TAIEX).

File layout

Data type	Length	Field Name
integer	-	SecurityID
date	-	**Date**
char	255	**Symbol**
integer	-	**Exchange**
integer	-	Currency
date	-	Expiration
float	-	Open Price
float	-	High Price
float	-	Low Price
float	-	Close Price
float	-	Settlement Price
bigint	-	Volume
bigint	-	Open Interest

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of the future price record

Symbol

The future contract symbol

Exchange

Exchange code where the future is traded, see Appendix A or Exchange file.

Currency

The future contract currency code, see Appendix B or Currency file

Expiration

The future contract expiration date

High Price

The future contract high price on this date

Low Price

The future contract low price on this date

Open Price

The future contract open price on this date

Close Price

The future contract close price on this date

Settlement Price

The future contract settlement price on this date

Volume

The future contract volume on this date

Open Interest

The future contract open interest on this date

Option_Price File

The Option_Price file contains the historical price, implied volatility, and sensitivity information for the options on an underlying security.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Date**
integer	-	**OptionID**
integer	-	Exchange
integer	-	Currency
date	-	Expiration
int	-	Strike
char	1	CallPut
char	21	**Symbol**
real	-	Bid
real	-	Ask
real	-	Last
bigint	-	Volume
integer	-	Open Interest
integer	-	Special Settlement
real	-	Implied Volatility
real	-	Delta
real	-	Gamma
real	-	Vega
real	-	Theta
real	-	Adjustment Factor
char	1	Exercise Style
char	1	Symbol Flag
char	1	Calculation Price
integer	-	Reference Exchange

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of the option price record

Option ID

A unique integer identifier for the option contract, can be used to track specific option contracts over time.

Exchange

Exchange code where the option is traded, see Appendix A or Exchange file

Currency

The currency code, see Appendix B or Currency file

Expiration

The expiration date of the option

Strike

The strike price of the option times 1000

CallPut

C – Call
P – Put

Symbol

Option symbol, provided in two formats:
(a) <Root>.<Suffix> – old format or
(b) Options Symbol Initiative format – new format

Bid

The best, or highest, closing bid price across all exchanges on which the option trades

Ask

The best, or lowest, closing ask price across all exchanges on which the option trades

Last

The closing trade price of the option, or the settlement price published by the exchange

Volume

The option contract volume on this date

Open Interest

The option contract open interest on this date

Special Settlement

0 – The option has a standard settlement. (Number of shares of underlying security specified in contract size is to be delivered at the exercise.)
1 – The option has a non-standard settlement. The number of shares to be delivered may be different from standard contract size for an option, additional securities and/or cash may be required. Implied volatility is not calculated for these option records, and it's set to -99.99, although the option may have price.

Implied volatility

The calculated implied volatility of the option

Delta

The delta of the option

Gamma

The gamma of the option

Vega/Kappa

The vega/kappa of the option

Theta

The theta of the option

Adjustment Factor

The cumulative product of all the adjustment factors for this option as of this date. When an option is first listed, its adjustment factor is set to 1.0. For all subsequent dates, the Adjustment Factor is the product of all non-zero Adjustment Factors from the Distribution file having ex-date prior or equal to the date of this price which result in an adjustment in the number of option contracts held.

Exercise style

`A` – American
`E` – European
`B` – Bermudan
`?` – Unknown or not yet classified

Symbol Flag

`0` – The option symbol is in old format[3]
`1` – The option symbol is in new format

Calculation Price

Indicates the method for calculating security price used in option pricing model.

`S` – Settlement
`M` – Midpoint between bid and ask
`A` – Ask
`B` – Bid
`L` – Last
`Y` – Suspect Tick Price*
`Z` – Suspect Settlement Price*

*Suspect prices are excluded from volatility surfaces to maintain surface integrity.

Reference Exchange

The ID of the exchange where the underlying price is taken for implied volatility calculation for a particular option contract on a given day. If the underlying security wasn't

[3] For options on US indices the old format is the root/suffix notation; the new format is the 21-characters option symbol that took place after OSI conversion.

traded on the particular reference exchange, the average underlying price across available exchanges was taken, and the column contains -99.

Index_Dividend file

The Index_Dividend file contains the current dividend yield used for implied volatility calculations on index options.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Date**
date	-	**Expiration**
real	-	Rate

Field descriptions

Security ID

The Security ID of the underlying index

Date

The date of this dividend yield

Expiration

Expiration of the options series for given dividend yield. Dividend yield for European and Asian indices is calculated separately per each option expiration date. US dividend yield is calculated as single value for all options expirations, therefore for US indices the field contains ‘1/1/1900’ value.

Rate

The dividend yield

Distribution File

The Distribution file contains information on a security's distributions.* IvyDB GI handles ETFs dividends as a stream of discrete payments.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Record Date**
integer	-	**Sequence Number**
date	-	Ex Date
real	-	Amount
real	-	Adjustment Factor
date	-	Declare Date
date	-	Payment Date
char	1	**Distribution Type**
char	1	Frequency
integer	-	**Currency**
integer	-	Cancel flag
integer	-	Liquidation flag

* Do not use the Distribution File for Market Indices

Field descriptions

Security ID

The Security ID for the security

Record Date

The record date for the distribution

Sequence Number

A unique integer, starting from 1, to distinguish between multiple distributions with the same record date.

Ex Date

The ex-distribution or ex-dividend date

Amount

The dollar amount of the cash distribution if the distribution was announced; yield if the dividend is projected (the dividend is projected when the Distribution Type is %).

Adjustment Factor

The adjustment to the security's price that is required to compare pre-distribution to post-distribution prices.

Declare Date

The declaration date for the distribution (if available).

Payment Date

The payment date for the distribution

Distribution Type

The type of distribution:
`0` – Unknown or not yet classified
`1` – Regular dividend
`2` – Split
`3` – Stock dividend
`4` – Capital gain distribution
`5` – Special dividend
`6` – Spin-off
`7` – New equity issue (same company)
`8` – Rights offering
`9` – Warrants issue
`%` – Regular dividend projection

Frequency

Payment frequency:
`0` – Dividend omitted
`1` – Annual
`2` – Semiannual
`3` – Quarterly
`4` – Monthly
`5` – Frequency varies
`blank` – Not available

Currency

The ISO code for currency of the cash distribution

Cancel flag

`0` – The distribution was or will be made as scheduled
1 – The distribution was cancelled, or a regular payment was omitted

Liquidation Flag

`0` – The distribution is a non-liquidating distribution.
`1` – The distribution is either a partial or total liquidating distribution.

Volatility_Surface file

The Volatility_Surface file contains the interpolated volatility surface for each security on each day, using a methodology based on a kernel smoothing algorithm. This file contains information on standardized options, both calls and puts, with expirations of 30, 60, 91, 122, 152, 182, 273, 365, 547, and 730 calendar days, at deltas of 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, and 0.80 (negative deltas for puts). A standardized option is only included if there exists enough option price data on that date to accurately interpolate the required values.

Since an underlying security may be traded on different exchanges in different currencies, the volatility surface file also contains a currency code. Options that were used in the surface construction have the same currency across exchanges. Therefore, a single underlying security may be represented by several volatility surfaces, one for each currency.

Underlying instrument may be traded on several exchanges. The process of choosing an underlying price for implied volatility calculation and surface construction for particular instrument is described in Reference Exchange chapter.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Date**
integer	-	**Days**
smallint	-	**Delta**
char	1	Call/Put
real	-	Implied Volatility
real	-	Implied Strike
real	-	Implied Premium
real	-	Dispersion
integer	-	**Currency**

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this volatility surface

Days

The number of days to expiration

Delta

The delta of the option

Call/Put Flag

C – Call
P – Put

Implied Volatility

The calculated interpolated implied volatility of the standardized option

Implied Strike

The calculated strike price corresponding to this delta

Implied Premium

The calculated premium of a theoretical option with this delta and implied volatility

Dispersion[4]

A measure of the accuracy of the implied volatility calculation, roughly corresponding to a weighted standard deviation, a larger dispersion indicates a less accurate smoothed implied volatility. If the dispersion is close to zero, indicating that there is only one significant data point for the implied volatility calculation, the dispersion is set to –99.99.

$$Dispersion = \sqrt{\frac{\sum_i V_i \sigma_i^2 \Phi(x_{ij} y_{ij} z_{ij})}{\sum_i V_i \Phi(x_{ij} y_{ij} z_{ij})} - \hat{\sigma}_j^2}$$

Currency

Currency code of the options and underlying used in particular surface construction

[4] See more in Volatility Surface chapter.

Std_Option_Price file

The Std_Option_Price file contains information on “standardized” (interpolated) options. Currently, this file contains information on at-the-money-forward options with expirations of 30, 60, 91, 122, 152, 182, 273, 365, 547, 730 calendar days. A standardized option is only included if there exists enough option price data on that date to accurately interpolate the required values.

Since an underlying security and its options may be traded on different exchanges in different currencies, the standardized option prices also contain currency information. Thus, one underlying may be represented by a number of standardized option groups, one for each currency.

Underlying instrument may be traded on several exchanges. The process of choosing an underlying price for implied volatility calculation for particular instrument is described in Reference Exchange chapter.

File layout

Data type	Length	Field Name
integer	-	**SecurityID**
date	-	**Date**
integer	-	**Days**
float	-	Forward Price
real	-	Strike Price
char	1	**Call/Put**
real	-	Premium
real	-	Implied Volatility
real	-	Delta
real	-	Gamma
real	-	Theta
real	-	Vega
integer	-	**Currency**

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option price

Days

The number of days to expiration

Forward Price

The calculated forward price for the underlying security on the expiration date of the option.

Strike Price

The strike price of the option, currently always equal to the forward price

Call/Put Flag

C – Call
P – Put

Premium

The calculated interpolated premium for the option

Implied Volatility

The calculated implied volatility of the option

Delta

The delta of the option

Gamma

The gamma of the option

Theta

The theta of the option

Vega/Kappa

The vega/kappa of the option

Currency

Currency code of the standard option price record

Historical_Volatility file

The Historical_Volatility file contains the realized volatility for each optionable security on each day. Realized volatility is calculated over date ranges of 10, 14, 30, 60, 91, 122, 152, 182, 273, 365, 547, 730, and 1825 calendar days, using a simple standard deviation calculation on the logarithm of the close-to-close daily total return.
Since an instrument can be traded on different exchanges in different currencies, the realized volatility is calculated per currency.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
integer	-	**Currency**
float	-	Volatility

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this realized volatility calculation

Days

The number of days included in the calculation

Currency

The currency of the underlying security

Volatility

The calculated realized volatility

Zero_Curve File

The Zero_Curve file contains the current zero-coupon interest rate curves. The file also contains currency code corresponding to the given curve.

File layout

Data type	Length	Field Name
integer	-	**Currency code**
date	-	**Date**
integer	-	**Days**
real	-	Rate

Field descriptions

Currency code

The currency of this zero curve

Date

The date of this zero curve

Days

The number of days to maturity

Rate

The continuously-compounded zero-coupon interest rate

Exchange File

The Exchange file contains a list of exchanges and their codes.

File layout

Data type	Length	Field Name
integer	-	**Exchange code**
char	3	Symbol
char	30	Country
char	30	Name

Field descriptions

Exchange code

Exchange code

Symbol

Exchange alphanumeric symbol

Country

The country where the exchange is located

Name

Full name of the exchange

Currency File

The Currency file contains a list of global currencies and their codes which are compliant with ISO standards.

File layout

Data type	Length	Field Name
integer	4	**Currency code**
char	10	Symbol
char	30	Name

Field descriptions

Currency code (ID)

Currency code

Symbol

Currency alphanumeric symbol

Name

Currency full name

Calculations

The implied volatilities and option sensitivities contained in IvyDB GI are calculated in accordance with standard conventions used by participants in the index option markets.

Interest Rates

Each of the option pricing models used by IvyDB GI requires a continuously-compounded interest rate as input. This interest rate is calculated from a collection of continuously-compounded zero-coupon interest rates at various maturities, collectively referred to as the *zero curve.* The zero curve used by the IvyDB GI option models is derived from BBA LIBOR rates. A separate zero curve is calculated for each of major currencies: US Dollar, Euro, Japanese Yen, British Pound, Canadian Dollar and Swiss Franc.

For a given option, the appropriate interest rate input corresponds to the zero-coupon rate that has a maturity equal to the option's expiration, and is obtained by linearly interpolating between the two closest zero-coupon rates on the zero curve.

The zero curve is calculated as follows:

Step 1. The BBA LIBOR rates for maturities of 1 week and 1-12 months are converted to discount factors using the formula:

$$DF = (1 + r \times d / 360)^{-1}$$

where r is the BBA LIBOR rate and d is the actual number of days to maturity.

Step 2. The LIBOR discount factors are converted to continuous LIBOR zero rates using the Actual/365 day-count convention:

$$L = -365/d \times \ln(DF)$$

where L is the continuously-compounded LIBOR zero rate.

Step 3. The zero rate on the nearest futures contract date (greater than one week) is obtained by linear interpolation between the two closest LIBOR zero rates computed in.

There is currently no convexity adjustment applied to the computed zero-coupon rates.

Dividends

US Indices

For dividend-paying indices, IvyDB assumes that the security pays dividends continuously, according to a continuously-compounded dividend yield. A put-call parity relationship is assumed, and the implied index dividend is calculated from the following linear regression model:

$$C - P = b_0 + b_1 S + b_2 ST + b_3 K + b_4 KT + b_5 D_{BA}$$

In this model, C – P is difference between the price of a call option and the price of a put option with the same expiration and strike. When calculating this difference, the bid price of the call is used with the offer price of the put, and vice versa. D_{BA} is a dummy variable set equal to 1 if the call option's bid price is used. S is the underlying security's (index's) closing price, K is the strike price of the call and put options, and T is the time to expiration in years. The regression is calculated using three months of option data across all strikes and expirations with an exception of contracts expiring in less than 15 days, for a single underlying. According to the principle of put-call parity, the dividend yield on the underlying index will be approximately equal to the negative of the estimated parameter b_2.

This put-call parity relationship only holds exactly for European options. There are only a few index options which trade according to American exercise and the CBOE S&P 100 Index is one of them. For the S&P 100 index, we assume that the dividend yield is equal to that computed for the S&P 500 index. While this may induce a slight bias into the calculations, we expect the overall effect on the computed implied volatilities to be minimal.

European, Asian and Canadian Indices

The dividend yield for European and Asian indices[5] is calculated based on linearized put-call parity. The present value of the dividend payments:

$$PV(div) = P - C + (S - K) + K(e^{rT} - 1)$$

where *r* is interest rate to the option expiration and *T* is time to maturity in years. Then the implied dividend yield is:

$$d = \frac{PV(div)}{T \times S}$$

Volatility Indices

[5] With exception of several indices (Taiwan Stock Exchange Capitalization Index and IBEX35).

Dividend yield for volatility (VIX, VSTOXX) and few other indices (IBEX35, TAIEX) is set to zero, as the volatility is calculated off the futures contracts with corresponding maturity.

ETFs

The IvyDB option pricing methodology for equity options assumes that the security's current dividend yield (defined as the most recently announced dividend payment divided by the most recent closing price for the security) remains constant over the remaining term of the option. This "constant dividend yield" assumption is consistent with most dividend-based equity pricing models (such as the Gordon growth model) under the additional assumptions of constant average security return and a constant earnings growth rate.

Even though the dividend yield is constant, IvyDB assumes that the security pays dividends at specific pre-determined times, namely on the security's regularly scheduled ex-dividend date. In the case of dividends that have already been declared, the ex-dividend dates are known. For dividend payments that are as yet unannounced, IvyDB uses a proprietary extrapolation algorithm to create a set of projected ex-dividend dates according to the security's usual dividend payment frequency. These projections are listed in the distribution file as Distribution Type = '%', and extend out to five years. Because the actual cash dividend to be received on the ex-dividend date is a function of the security price on that date, and is computed internally by the option pricing models, the Amount field for the projected dates is set equal to dividend yield.

European Options

European-style options are priced according to the Black-Scholes model:

$$C = Se^{-qT} N(d_1) - Ke^{-rT} N(d_2)$$

$$P = Ke^{-rT} N(-d_2) - Se^{-qT} N(-d_1)$$

where

$$d_1 = [\,\ln(S/K) + (r - q + \tfrac{1}{2}\sigma^2)\,T\,] / \sigma\sqrt{T}\,,$$

$$d_2 = d_1 - \sigma\sqrt{T}\,,$$

C is the price of a call option, P is the price of a put option, S is the current underlying security price, K is the strike price of the option, T is the time in years remaining to option expiration, r is the continuously-compounded interest rate, q is the continuously-compounded dividend yield, and σ is the implied volatility.

For calculating implied volatilities and associated option sensitivities, the theoretical option price is set equal to the midpoint of the best closing bid price and best closing offer price for the option. The Black-Scholes formula is then inverted using a numerical search technique to calculate the implied volatility for the option.

American Options

Options that have an American-style exercise feature are priced using a proprietary pricing algorithm that is based on the industry-standard Cox-Ross-Rubinstein (CRR) binomial tree model. This model can accommodate underlying securities with either discrete dividend payments or a continuous dividend yield.

In the framework of the CRR model, the time between now and option expiration is divided into N sub-periods. Over the course of each sub-period, the security price is assumed to move either "up" or "down". The size of the security price move is determined by the implied volatility and the size of the sub-period. Specifically, the security price at the end of sub-period i is given by one of the following:

$$S_{i+1}^{up} = S_i u \equiv S_i \exp\left(\sigma\sqrt{h}\right)$$

$$S_{i+1}^{down} = S_i d \equiv S_i \exp\left(-\sigma\sqrt{h}\right)$$

where $h \equiv T/N$ is the size of the sub-period, and S_i is the security price at the beginning of the sub-period.

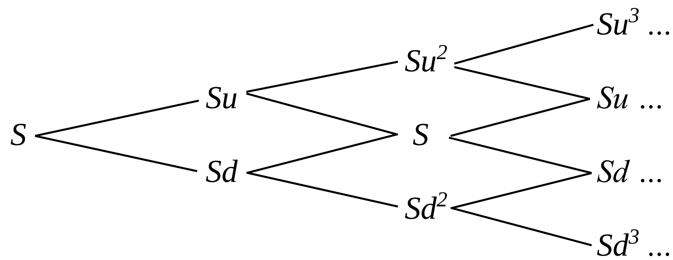
The price of a call option at the beginning of each sub-period is dependent on its price at the end of the sub-period, and is given by:

$$C_i = \max\left\{ \begin{array}{c} \left[pC_{i+1}^{up} + \left(1-p\right)C_{i+1}^{down} \right] \big/ R \\ S_i - K \end{array} \right\} \tag{1}$$

and likewise for a put option. Here, r is the interest rate, q is the continuous dividend yield (if the security is an index), $R \equiv exp([r\text{-}q]h)$, and C_{i+1}^{up} and C_{i+1}^{down} are the price of the option at the end of the sub-period, depending on whether the security price moves "up" or "down". The "risk-neutral" probability p is given by:

$$p = \frac{R-d}{u-d}$$

To use the CRR approach to value an option, we start at the current security price S and build a "tree" of all the possible security prices at the end of each sub-period, under the assumption that the security price can move only either up or down:



The tree is constructed out to time *T* (option expiration).

Next the option is priced at expiration by setting the option expiration value equal to the exercise value: C = max(S−K,0) and P = max(K−S,0). The option price at the beginning of each sub-period is determined by the option prices at the end of the sub-period, using the formula above. Working backwards, the calculated price of the option at time i=0 is the theoretical model price.

To compute the implied volatility of an option given its price, the model is run iteratively with new values of σ until the model price of the option converges to its market price, defined as the midpoint of the option's best closing bid and best closing offer prices. At this point, the final value of σ is the option's implied volatility.

The CRR model is adapted to securities that pay discrete dividends as follows: When calculating the price of the option from equation (1), the security price S_i used in the equation is set equal to the original tree price S_i^0 *minus* the sum of all dividend payments received between the start of the tree and time i. Under the constant dividend yield assumption, this means that the security price S_i used in equation (1) should be set equal to $S_i^0\,(1-n\delta)$, where S_i^0 is the original tree price, δ is the dividend yield, and n is the number of dividend payments received up to time i. All other calculations are the same.

The CRR model usually requires a very large number of sub-periods to achieve good results (typically, N > 1000), and this often results in a large computational requirement. The IvyDB GI proprietary pricing algorithm uses advanced techniques to achieve convergence in a fraction of the processing time required by the standard CRR model.

Currencies

IvyDB GI aggregates options and underlying securities data from exchanges worldwide. Often options and underlying instruments are traded in different currencies. IvyDB GI takes such scenarios into account. The following rules apply to implied volatility calculations, volatility surface construction and standardized options calculations:

- Option's quote currency and underlying price currency are the same in all calculations.
- Zero_Curve file contains zero-coupon interest rate for every currency used in calculations at certain date.

Missing Values

There are several situations where the implied volatilities cannot be calculated for the Option_Price table. These reasons change based on the method of calculation used and as a result differ by table. These reasons are detailed below and are organized by tables.

For the Option_Price table the implied volatility will be set to -99.99 if any of the following conditions holds:

1. The midpoint of the bid/ask price is below intrinsic value
2. The vega of the option is below 0.5
3. The implied volatility calculation fails to converge
4. The underlying price is not available
5. The option is a "special settlement" (Special Settlement = 1)

Reference Exchange

The underlying instrument is traded on multiple exchanges. An option contract or clearing conditions document provided by the exchange explicitly specifies the exchange with the spot price for given instrument.

IvyDB GI uses the following rules when determining the underlying price for implied volatility calculation and volatility surface construction:

1. If available, the price from reference exchange is taken.
2. If the price from reference exchange is not available, then the average underlying price across available exchanges is used.

Standardized Option Prices

The standardized option prices and implied volatilities in the Std_Option_Price file are calculated using linear interpolation from the Volatility_Surface file. First the forward price of the underlying security is calculated using the zero curve and the projected distributions. Next, the volatility surface points are linearly interpolated to the forward price and the target expiration, to generate an at-the-money-forward implied volatility.

Volatility Surface

The standardized option implied volatilities in the Volatility_Surface file are calculated using a kernel smoothing technique. The data is first organized by the log of days to expiration and by “call-equivalent delta” (delta for a call, one plus delta for a put). A kernel smoother is then used to generate a smoothed volatility value at each of the specified interpolation grid points.

At each grid point *j* on the volatility surface, the smoothed volatility $\hat{\sigma}_i$ is calculated as a weighted sum of option implied volatilities:

$$\hat{\sigma}_j = \frac{\sum_i V_i \sigma_i \, \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)}{\sum_i V_i \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)}$$

where i is indexed over all the options for that day, V_i is the vega of the option, σ_i is the implied volatility, and $\Phi(.)$ is the kernel function:

$$\Phi\left(x, y, z\right) = \frac{1}{\sqrt{2\pi}} e^{-\left[\left(x^2 / 2h_1\right) + \left(y^2 / 2h_2\right) + \left(z^2 / 2h_3\right)\right]}$$

The parameters to the kernel function, x_{ij}, y_{ij}, and z_{ij} are measures of the "distance" between the option and the target grid point:

$$\begin{aligned} x_{ij} &= \log\left(T_i / T_j\right) \\ y_{ij} &= \Delta_i - \Delta_j \\ z_{ij} &= I_{\left\{CP_i = CP_j\right\}} \end{aligned}$$

where T_i (T_j) is the number of days to expiration of the option (grid point); Δ_i (Δ_j) is the "call-equivalent delta" of the option (grid point); CP_i (CP_j) is the call/put identifier of the option (grid point); and I{.} is an indicator function (=0 if the call/put identifiers are equal, or 1 if they are different).

The kernel "bandwidth" parameters were chosen empirically, and are set as h_1=0.05, h_2=0.005, and h_3=0.001.

Options with less than 11 days to their maturity are excluded from volatility surface construction.

Appendices

Appendix A: Frequently used exchange codes

Exchange code	Symbol	Country	Exchange name
4	SWX	Switzerland	Elektronische Borse Schweiz
6	EBR	Belgium	Euronext Brussels
13	FRA	Germany	Frankfurter Wertpapierborse
21	EUX	Germany	EUREX, Frankfurt
25	EPA	France	Euronext Paris
26	EPD	France	Euronext Monep
36	LON	UK	London Stock Exchange
37	EAD	Netherlands	Euronext Amsterdam Options
38	EAM	Netherlands	Euronext Amsterdam
39	EBD	Belgium	Euronext BELFOX, Brussels
42	MDD	Italy	Mercato dei Derivati, Milano
44	ETR	Germany	XETRA
46	MCI	Italy	Mercato Continuo Italia
103	TPE	Taiwan	Taiwan Stock Exchange
107	OSA	Japan	Osaka Stock Exchange
113	HFE	Hong Kong	Hong Kong Futures Exchange
123	KRX	Korea	Korea Exchange
126	MRV	Spain	Mercado Espanol de Futuros
211	LIF	UK	Euronext Liffe, London
310	DJI	US	Dow Jones Index, NY
336	KFO	Korea	Korea Futures Market
353	STX	Germany	STOXX, Frankfurt
361	LSS	UK	London Stock Exchange SETS
380	VTX	UK	Virt-X, London
529	HSI	Hong Kong	Hang Seng Indices
7051	TFX	Taiwan	Taiwan Futures Exchange
855	AFO	Australia	Australia Futures and Options
999	NBO	US	National Best Bid/Offer

Appendix B: Frequently used currency codes

Currency code	Symbol	Country	Currency name
1	SWF	Switzerland	Swiss Franc
184	CAD	Canada	Canadian Dollar
248	KRW	Korea	Won
333	USD	USA	US Dollar
366	TWD	Taiwan	Taiwanese Dollar
402	GBP	UK	Pound Sterling
470	HKD	Hong Kong	Hong Kong Dollar
534	JPY	Japan	Yen
814	EUR	EU	Euro

* Full currencies list can be found in Currency table in the daily file.