IvyDB Europe
Reference Manual

Version 2.2
Rev. 9/29/2016

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Revision Summary

Date	Revision History	Revision Class	Comments

Chapter 1. Introduction

IvyDB Europe is a comprehensive database of historical price, implied volatility, and sensitivity information for the European listed index and equity options markets. 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 Europe data files are updated nightly to reflect new closing prices, dividend payments or other corporate actions, and option contract expirations, new listings, or other changes.

OptionMetrics compiles the IvyDB Europe data from raw end-of-day pricing information. This raw data is edited and organized to facilitate its use in options market research. Interest rate curves, dividend projections, and option implied volatilities and sensitivities are calculated by OptionMetrics using our proprietary algorithms, which are based on standard market conventions.

Chapter 2. File Formats

The daily data within IvyDB Europe is organized in several files:

- **Security** file (INTL.IVYSECUR.yyyymmddD.txt)
- **Security_Name** file (INTL.IVYSECNM.yyyymmddD.txt)
- **Distribution** file (INTL.IVYDISTR.yyyymmddD.txt)
- **Distribution_Projection** file (INTL.IVYDISTRPROJ.yyyymmddD.txt)
- **Security_Price** file (INTL.IVYSECPR.yyyymmddD.txt)
- **Option** file (INTL.IVYOPINF.yyymmddD.txt)
- **Option_History** file (INTL.IVYOPHST.yyyymmddD.txt)
- **Option_Price** file (INTL.IVYOPPRC.yyyymmddD.txt)
- **Zero_Curve** file (INTL.IVYZEROC.yyyymmddD.txt)
- **Index_Dividend** file (INTL.IVYIDXDV.yyyymmddD.txt)
- **Volatility_Surface** file (INTL.IVYVSURF.yyyymmddD.txt)
- **Std_Option_Price** file (INTL.IVYSTDOP.yyyymmddD.txt)
- **Historical_Volatility** file (INTL.IVYHISTVOL.yyyymmddD.txt)
- **Currency** file (INTL.IVYCURRENCY.yyyymmddD.txt)
- **Exchange** file (INTL.IVYEXCHNG.yyyymmddD.txt)
- **Country** file (INTL.IVYCOUNTRY.yyyymmddD.txt)
- **Ticker** file (INTL.IVYTICKER.yyyymmddD.txt)
- **Futures** file (INTL.IVYFUTURE.yyymmddD.txt)
- **Futures_Price** file (INTL.IVYFUTPRC.yyyymmddD.txt)

Files are produced nightly in a tab-delimited format. Line terminator used is CRLF. Text encoding is UTF8. 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 primary key (unique fields) for each file is shown in **bold**.

Security File

The Security file contains information on all equity and index securities known to IvyDB Europe.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
integer	-	VALOR
char	2	Country
integer	-	Optionable
integer	-	Issue type
char	1	Dividend convention

Field descriptions

Security ID

The Security ID is the unique identifier for this security issued by OptionMetrics. Security ID's are unique over the security's lifetime and are not recycled. The Security ID is the primary key for all data contained in IvyDB Europe.

VALOR

Swiss Security Number that is used for identifying securities and options

Country

The security's issuing country

Optionable

Indicates whether a security has options at a certain date

Issue type

The type of security:
1 – Shares
7 – Trust-Shares
12 – Trust cert. unit/fund invest, foundation units
34 – Indices
(blank) – Unspecified[1]

[1] See Appendix C for full list of issue types

Dividend convention

The method of incorporating dividends into the calculations:
`D` – Discrete dividend payments, constant projected dividend yield
`C` – Continuous dividend based on calculated dividend yield
`I` – Continuous implied dividend yield

Security_Name File

The Security_Name file contains a historical record of changes to the issuer, and VALOR for a security.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Effective date**
integer	-	VALOR
char	255	Issuer
char	9	SEDOL
char	12	ISIN

Field descriptions

Security ID

The Security ID for the security

Date

The effective date of the change

VALOR

Swiss Security Number that is used by SIX Telekurs for identifying securities and options

Issuer

A description of the issuing company or entity

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.

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-numerical code.

Distribution File

The Distribution file contains information on a security's distributions and splits.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Record date**
integer	-	**Sequence number**
date	-	Exdate
real	-	Amount
real	-	Adjustment factor
date	-	Declare date
date	-	Payment date
integer	-	Link Security ID
char	1	**Distribution Type**
char	1	Frequency
char	3	**Currency**

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 amount of the cash distribution

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

Link security ID

For mergers or acquisitions, the Security ID corresponding to the equity of the acquiring company. For spin-offs, the Security ID of the spun-off security.

Distribution type

The type of distribution:
`0` – Unknown or not yet classified
`1` – Regular dividend
`2` – Split
`R` – Reverse 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

Frequency

Payment frequency:
`0` – Dividend omitted
`1` – Annual
`2` – Semiannual
`3` – Quarterly
`4` – Monthly
`5` – Frequency varies
`7` – Interim
`8` – Final
`9` – Unknown
`blank` – Not available

Currency

The code for currency of the cash distribution, see Appendix B or Currency file

Distribution_Projection File

The Distribution_Projection file contains dividend projections based on distributions history. See description of dividends projection in Chapter 3.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Rundate**
date	-	**Exdate**
real	-	Yield

Field descriptions

Security ID

The Security ID for the security

Rundate

The date when projection was made

Exdate

The projected ex-distribution date

Yield

The projected dividend yield. Calculated as $\frac{lastKnownDividendAmount}{security\ Price(asOfRunDate)}$, where the security price is the closing price of the underlying security from there reference exchange.

Security_Price File

The Security_Price file contains the price history for the security.

File layout

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

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

Bid

If there was no trading at this date, the closing bid price for the security

Ask

If there was no trading at this date, the closing ask price for the security

High

The highest price for the date

Low

The lowest price for the date

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

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 caluclated as: $\frac{S_t * F_t + A_t}{S_{t-1}} - 1$, where

S – Security price
F – Adjustment factor from Distribution 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 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).

Currency code

The code for currency of the cash distribution, see Appendix B or Currency file

Cumulative total return factor

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).

Volume

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

Option File

The Option file contains information about the options for an underlying security. It is a current snapshot of the OPTION_HISTORY file with the most updated option IDs and their respective properties.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
integer	-	**Option ID**
integer	-	**Exchange**
char	255	Description
integer	-	Currency
bigint	-	Strike
date	-	Expiration
char	1	CallPut
integer	-	Underlying VALOR
integer	-	Contract size
integer	-	Option style
integer	-	Version
char	1	Exercise style

Field descriptions

Security ID

The Security ID for the underlying security

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

Description

Text description of the option contract

Currency

The currency code, see Appendix B or Currency file

Strike

The strike price of the option times 1000

Expiration

The expiration date of the option

CallPut

C – Call
P – Put

Underlying VALOR

VALOR of the underlying security

Contract size

The size of option contract expressed in number of shares

Option style

The supplemental code for different option types (weekly, daily, etc.)
`0` – Regular
`13` – Daily
`32` – Weekly

Version

Version of an option contract. If an option contract was modified from its original version the version is incremented. These options are marked in Option_Price file as Special Settlement.

Exercise style

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

Option_History File

The Option_History file tracks the change in option's properties over time. The change in option properties may result from corporate actions or vendor's/exchange's corrections. This file contains exactly the same fields as Option file and the entry date when a certain option entered into the database.

File layout

Data type	Length	Field Name
integer	-	Security ID
integer	-	Option ID
integer	-	Exchange
char	255	Description
integer	-	Currency
bigint	-	Strike
date	-	Expiration
char	1	CallPut
integer	-	Underlying VALOR
integer	-	Contract size
integer	-	Option style
integer	-	Version
char	1	Exercise style
date	-	Start 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	-	**Security ID**
date	-	**Date**
integer	-	**Option ID**
integer	-	**Exchange**
integer	-	Currency
real	-	Bid
date	-	Bid time
real	-	Underlying bid
real	-	Ask
date	-	Ask time
real	-	Underlying ask
real	-	Last
date	-	Last time
real	-	Underlying last
real	-	Implied volatility
real	-	Delta
real	-	Gamma
real	-	Vega
real	-	Theta
char	1	Calculation price
bigint	-	Volume
integer	-	Open interest
integer	-	Special Settlement
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 code for currency of option contract, see Appendix B or Currency file

Bid

The bid price for this option contract

Bid time

The trade time of bid price

Underlying bid

The bid price for underlying security synchronized with bid time

Ask

The ask price for this option contract

Ask time

The trade time of ask price

Underlying ask

The ask price for underlying security synchronized with ask time

Last

The last price for this option contract

Last time

The trade time of last price

Underlying last

The last price for underlying security synchronized with last time

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

Calculation price

Indicates the method for calculating security price used in option pricing model[2]
A – Ask

[2] See synchronized underlying price description in Chapter 3

B – Bid
L - Last
M – Medium (arithmetic average of bid and ask)
S – Settlement
~~G – Generated~~*

*Generated flags are no longer used in Version 2.2.

Volume

The volume on the exchange where the option is traded on this date.

Open Interest

The open interest for the option, in number of contracts. Open interest is lagged by one-day for contracts traded on Euronext exchanges and is delivered via Patching system.

Special Settlement

0 – The option has a standard settlement. (Number of shares of underlying security specified in contract size are to be delivered at 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.

Reference Exchange[3]

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

[3] As an example of the reference exchange definition, please visit Eurex Options Clearing Conditions.

Zero_Curve File

The Zero_Curve file contains the current zero-coupon interest rate curves used by IvyDB Europe. 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

Index_Dividend file

The Index_Dividend file contains the current dividend yield used for implied volatility calculations on index options. Index dividend yield is projected per options expiration, i.e. each option series with certain expiration date has corresponding dividend yield. Please refer to the Dividends section for more information about index dividend yield estimation.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
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

The option series expiration which

Rate

The dividend yield

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, one underlying security may be represented by several volatility surfaces, one for each currency.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
smallint	-	**Delta**
char	1	Call/Put Flag
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

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.

Currency

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

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, 365, 547, 730, 912, and 1095 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.

File layout

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

Vega/Kappa

The vega/kappa of the option

Theta

The theta of the option

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 1852 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

Datatype	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

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 exchange is located

Name
Exchange full name

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
Currency code

Symbol

Currency alphanumeric symbol

Name

Currency full name

Country File

The Country file contains the codes for each country provided in ISO 3166 standard.

File layout

Data type	Length	Field Name
char	2	**Country code**
char	255	Country name

Field descriptions

Country code

The two-symbol country code

Country name

The corresponding country name

Ticker File

The Ticker file contains ticker symbols of securities. Ticker symbol is a code used to uniquely identify shares of a security traded on a particular exchange.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
integer	-	**Exchange**
date	-	**Effective date**
char	20	Ticker

Field descriptions

Security ID

The Security ID for the underlying security

Exchange

The exchange where security is traded with particular symbol

Effective date

The effective date for particular symbol on the exchange

Ticker

The ticker symbol may consist of letters, numbers or a combination of both

Futures File

The Future file contains information about the future contracts for an underlying security.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
integer	-	**Future ID**
integer	-	**Exchange**
char	255	Description
integer	-	**Currency**
date	-	**Expiration**
integer	-	UnderlyingValor

Field descriptions

Security ID

The Security ID for the underlying security

Future ID

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

Exchange

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

Description

Text description of the future contract

Currency

The currency code, see Appendix B or Currency file

Expiration

The expiration date of the future

Underlying Valor

Valor number of the underlying security

Futures_Price File

The Future_Price file contains the historical prices for the future contracts on an underlying security. The future prices are used for index dividend calculation.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Future ID**
integer	-	**Exchange**
integer	-	**Currency**
real	-	ClosePrice
bigint	-	Volume

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of the future price record

Option ID

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

Exchange

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

Currency

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

ClosePrice

The close price for the future contract

Volume

The volume for the future contract

Chapter 3. Calculations

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

Interest Rates

Each of the option pricing models used by IvyDB Europe 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 Europe 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. Options with expiration greater than longest available maturity use the longest available maturity point.

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 Step 2.

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

Dividends

When the underlying equity or index pays dividends, each of the option pricing models requires an estimate of the dividends to be paid up until the option's expiration. The

methodology used by IvyDB Europe for dividend payments depends on the type of the underlying security.

The IvyDB Europe 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 Europe 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 Europe 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 projections file, and extend out to three 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. Since the currency of dividend amount used in yield calculation is consistent with security price, the yield field has no units, thereof it can be used by implied volatility model, even if the option quote has different currency.

European and Asian Indices

For dividend-paying indices, IvyDB Asia-Pacific assumes that the security pays dividends continuously, according to a continuously-compounded dividend yield. The dividend yield for European and Asian indices is calculated based on linearized put-call parity. The present value of the dividend payments is:

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

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

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

- ***Note:*** The underlying price S used in index dividend calculation is derived from the index spot price and dividend yield is calculated per each maturity.

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

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

$$d_2 = d_2 - \sigma\sqrt{T} / 2,$$

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.

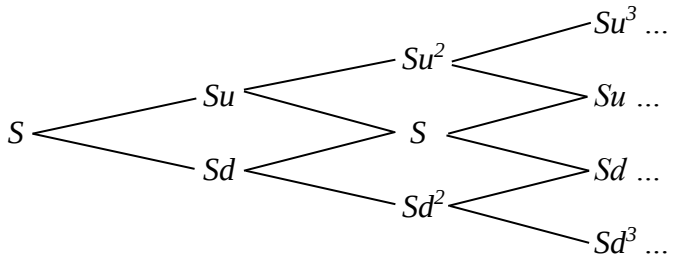
The price of a call option at the beginning of each sub-period is dependent on its price at the end of the sub-period, and is given by:

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

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 Europe proprietary pricing algorithm uses advanced techniques to achieve convergence in a fraction of the processing time required by the standard CRR model.

Option prices used in calculations

The implied volatility calculation uses option price according to following rules:

1. Settlement option price (if available.)
2. Last trade (if available.)
3. Midpoint: An average between bid and ask prices (if available.)
4. Bid (if available)
5. Ask

The Option_Price file contains the CalculationPrice field that indicates which price was used in the implied volatility calculation. See CalculationPrice description in Option_Price file.

Synchronizing underlying price with option price

The implied volatility calculation uses underlying prices that are time synchronized with option bid, ask or last quotes. The Option_Price record contains three fields for option bid, ask and last prices: quote, trade time and underlying security price which is closest to the trade time. For example, Bid field represents the quote, BidTime field represents the trade time and BidSync represents the underlying price synchronized with the BidTime.

The calculation selects underlying security price based on the following rules:

1. If the LastTime is later than BidTime and AskTime, then UnderlyingLast is used, else arithmetic average between UnderlyingBid and UnderlyingAsk is used.
2. If UnderlyingBid doesn't exist, use UnderlyingAsk (and vice versa).

Currencies

IvyDB Europe aggregates options and underlying securities data from several European exchanges. Those include Euronext, London Stock Exchange, EUREX and others. Often options and underlying instruments are traded on these exchanges in different currencies. IvyDB Europe takes such scenarios into account. The following rules apply in implied volatility calculations, volatility surface construction and standardized options calculations:

- Option's quote currency and underlying price currency are the same in all calculations.
- Volatility surface construction uses average value of the underlying price from different exchanges with the same currency. This implies construction of

volatility surface for each available currency per underlying security. The same principle applies to standardized option prices calculation.

- The underlying price in Option_Price file is always in the same currency as option quote.
- 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)

*Option price data for all values of vega added in Version 2.2.

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 $\hat{\sigma}_j$ 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:

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

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:

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

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.
Note: Weekly options for European indices (such as DJ Euro Stoxx, DAX, SMI, AEX, etc.) are excluded from the volatility surface.

Settlement Prices vs. Tick Prices

The European data set contains two sources of option prices:

1) Tick prices – contain bid, ask or trade quotes and are extracted from daily tick files.
2) Settlement prices – calculated and published by exchanges.

As a result, an option contract may have: (a) tick price only, (b) settlement price only or (c) both prices available.

IvyDB Europe organizes and combines the prices into two sets (and respective volatility surfaces):

1) Settlement price is a primary source (default) and tick price is a secondary source (in other words, for options with both prices available, settlement price is used). For options that don't have settlement prices tick prices are used.
2) Tick price is a primary source and settlement price is a secondary source. For options that don't have tick prices settlement prices are used.

Tick files are only available since 2006 as this is when we started receiving a daily feed from European markets. Data older than 2006 was backfilled from historical files and the historical option prices that were available to us were last trade prices. These appear in

the settlement file as it is the primary file for IvyDB Europe. See more details about switching between the two sets in IvyDB Europe Utilities Guide (TickInst Application).

Appendix A: Frequently used exchange codes

Exchange code	Symbol	Country	Exchange name
6	EBR	Belgium	Euronext Brussels
13	FRA	Germany	Frankfurter Wertpapierbörse
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
126	MRV	Spain	Mercado Espanol de Futuros
211	LIF	UK	Euronext Liffe, London
222	FTI	UK	FTSE Indices, London
353	STX	Germany	STOXX, Frankfurt
361	LSS	UK	London Stock Exchange SETS
380	VTX	UK	Virt-X, London

* Full exchanges list can be found in Exchange table in daily file.

Appendix B: Frequently used currency codes

Currency code	Symbol	Country	Currency name
1	SWF	Switzerland	Swiss frank
184	CAD	Canada	Canadian Dollar
333	USD	USA	US Dollar
402	GBP	UK	Pound sterling
534	JPY	Japan	Yen
814	EUR	EU	Euro

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

Appendix C: Issue Types

Code	Issue Type
0	Bond, compound instrument consisting of several bonds
1	Shares/Units with shares/Particip. Cert.
6	Hybrids, structured instruments
7	Trust-Shares
8	Interest Rate
12	Trust certificate unit/ fund, investment foundation units
13	Part in cooperative society
21	FRN/Variables/Grad., index-link interest
26	Money Market instr. (CD/CP)
27	Commodities
28	Other instruments with cash-flow
31	Convertibles
34	Index
36	Currency swap

Appendix D: Full List of Exchange Codes

Code	Exchange
4	Sixswiss Exchange
5	Bxberne Exchange
6	Nyseeuronext Brussels
12	Nasdaqomx Nordic Exchange, Copenhagen Equities
13	Frankfurterwertpapierboerse
14	Boerseduesseldorf Ag
15	Bayerischeboerse
16	Baden-Wuerttembergischewertpapierboerse
17	Hanseatischewertpapierboerse
18	Boerseberlin-Bremen
19	Niedersaechsischeboerse Zu Hannover
21	Eurex
25	Nyseeuronext Paris
26	Nyseeuronext Monep
36	Lselondon Stock Exchange
37	Nyseeuronext Amsterdam,Options
38	Nyseeuronext Amsterdam
39	Nyseeuronext Belfox
40	Nasdaqomx Nordic Exchange, Helsinki Equities
42	Mercatodei Derivati
44	Xetra
46	Mercatocontinuo Italiano
47	Boursede Luxembourg
51	Nyseeuronext Lisbon
53	Nasdaqomx Nordic Exchange, Stockholm Equities
54	Mercadocontinuo Espanol
126	Meffmercado Espanol Financiero De Futuros, Renta Variable
145	Irishstock Exchange
167	Nasdaqomx Nordic Exchange, Stockholm Derivatives
190	Ubsinvestment Bank
202	Claridenleu Ag
203	Zkbzuercher Kantonalbank, Kurse
211	Nyseeuronext Liffe
222	Ftseindices
233	Dowjones Index
310	Stoxxltd
353	Lselondon Stock Exchange, Sets
361	Swissblue Chip Segment
380	Nyseeuronext Cash Markets And Indices
399	Ioblondon International Order Book

507	Xetraus Stars
516	Xetraeuropean Stars
528	Borsaitaliana S.P.A., External Trades
773	Deutscheboersen-Indices & Xetra-Etf
830	Nyseeuronext European Eq Off-Exchange Traded Reports
873	Nyseeuronext European Eq Off-Exch Traded Reports In Fc
878	Sixswiss Exchange
999	Optionmetrics Artificial Exchange Code