Ivy DB

File and Data Reference Manual

Version 3.0

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Chapter 1. Introduction

Ivy DB is a comprehensive database of historical price, implied volatility, and sensitivity information for the entire US 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. Ivy DB includes historical data for all US listed equities and market indices and all US listed index and equity options from 1996 till present. Ivy DB 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 Ivy DB data from raw end-of-day pricing information provided by Spryware, LLC. 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 data within Ivy DB is organized in several files:

- Security file (IVYSECUR.yyyymmddD.txt)
- Security_Name file (IVYSECNM.yyyymmddD.txt)
- Exchange file (IVYEXCHG.yyyymmddD.txt)
- Distribution file (IVYDISTR.yyyymmddD.txt)
- Security_Price file (IVYSECPR.yyyymmddD.txt)
- Option_Info file (IVYOPINF.yyymmddD.txt)
- Option_Price file (IVYOPPRC.yyyymmddD.txt)
- Zero_Curve file (IVYZEROC.yyyymmddD.txt)
- Index_Dividend file (IVYIDXDV.yyyymmddD.txt)
- Std_Option_Price file (IVYSTDOP.yyyymmddD.txt)
- Option_Volume file (IVYOPVOL.yyyymmddD.txt)
- Volatility_Surface file (IVYVSURF.yyyymmddD.txt)
- Historical_Volatility file (IVYHVOL.yyyymmddD.txt)
- Open_Interest file (IVYOPTOI.txt)

Files are produced nightly in a tab-delimited format. Security, Security_Name, Exchange, Distribution and Option_Info files contain a full copy of the tables by the same name. Therefore these particular five tables are being truncated during the nightly data load processes.

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 Ivy DB.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
char	8	CUSIP
char	6	Ticker
char	4	SIC
char	1	Index Flag
integer	-	Exchange Designator
char	1	Class

char	1	Issue Type **
char	3	Industry Group **

** Columns added in Version 2.5

Field descriptions

Security ID

The Security ID is the unique identifier for this security. Unlike CUSIP numbers and ticker symbols, 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 Ivy DB.

CUSIP

The first 8 digits of the security's current CUSIP number

Ticker

The security's current ticker symbol. For stocks with multiple classes, this field contains only the base of the complete ticker. For example, NYSE tickers BKS.A and BKS.B would both contain BKS in the ticker field. Class indicators are stored in the Class field.

SIC

The security's SIC code

Index Flag

A flag indicating whether the security is an index. Equal to '0' if the security is an equity, and '1' if the security is an index.

Exchange Designator

A field indicating the current primary exchange for the security:

00000 – Currently delisted
00001 – NYSE/ARCA
00002 – AMEX
00004 – NASDAQ National Markets System
00008 – NASDAQ Small Cap
00016 – OTC Bulletin Board
32768 – The security is an index

Class

The class designator, if any, of the security on the effective date

Issue Type

The type of security:

0 – Common Stock
A – Market index
7 – Mutual or investment trust fund
F – ADR/ADS
% – Exchange-traded fund
(blank) – Unspecified

Industry Group

The Industry Group classification for this security from the North American Industry Groups database from MorningStar, LLC. The classification code is a 3-digit number: The first digit represents the security's macroeconomic sector classification; the second digit represents the security's business segment; and the third digit represents the security's industry group.

A complete listing of the MG Sector Classification Code is given in Appendix A.

Security_Name File

The Security_Name file contains a historical record of changes to the ticker, issuer and issue descriptions, and CUSIP's for a security.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Effective Date**
char	8	CUSIP
char	6	Ticker
char	1	Class
char	28	Issuer Description
char	20	Issue Description
char	4	SIC

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

Class

The class designator, if any, of the security on the effective date

Issuer Description

A description of the issuing company or entity

Issue Description

A description of the particular issue

SIC

The SIC code for the security

Notes

All securities have at least one Security Name record dating from the start of the historical record, containing the security's ticker, CUSIP, and descriptive information as of the starting date of Ivy DB.

Exchange File

The Exchange file contains a historical record of changes to the active exchange for a security, and new listing and delisting information.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Effective Date**
integer	1	**Sequence Number**
char	1	Status
char	1	Exchange
char	1	Add/Delete Indicator
integer	-	Exchange Flags

Field descriptions

Security ID

The Security ID for the security.

Effective Date

The effective date of the exchange change

Sequence Number

A unique integer, starting from 1, to distinguish between multiple exchange changes occurring on the same day.

Status

The change in the status of the security that generated the exchange record:

`$` – Initial entry (start of historical record)
`A` – The security is inactive (no longer being priced)
`C` – The security has been purged due to inactivity
`D` – The security has been delisted
`E` – The security's exchange has changed
`N` – The security has been newly listed (but not yet priced)
`S` – Trading in the security has been suspended
`X` – Security is inactive due to an acquisition or merger
`3` – The security has been reactivated, and this is the first day priced
`4` – The security is new, and this is the first day priced

Exchange

The exchange added or deleted
A – NYSE
B – AMEX
F – NASDAQ National Market System
G – Index
H – NASDAQ Small Cap
O – OTC Bulletin Board
% - Other OTC
? - Exchange not known
D - Chicago Stock Exchange
E - ARCA Stock Exchange
J - Toronto Stock Exchange
K - Montreal Stock Exchange
T - Boston Stock Exchange
U - Non-NASDAQ OTC
V - Canadian Venture Exchange (CDNX)
X - OTC Equipment Trust

Add/Delete Indicator

* – Exchange was added
(blank) – Exchange was deleted

ExchangeFlags

The primary exchange for the issue, after the change:
00000 – Currently delisted
00001 – NYSE/ARCA
00002 – AMEX
00004 – NASDAQ National Markets System
00008 – NASDAQ Small Cap
00016 – OTC Bulletin Board
32768 – The security is an index

Notes

All securities have at least one Exchange record dating from the start of the historical record, with status '$', containing the security's exchange listing information as of the starting date of Ivy DB.

Distribution File

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

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Record Date**
integer	-	**Sequence Number**
date	-	Ex Date
real	-	Amount
real	-	Adjustment Factor
date	8	Declare Date
date	8	Payment Date
integer	-	Link Security ID
char	1	Distribution Type
char	1	Frequency
char	3	Currency
char	1	Approximate flag
char	1	Cancel flag
char	1	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

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
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

Approximate flag

0 – Amount field is exact
1 – Amount field is approximate

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

Security_Price File

The Security_Price file contains the price history for the security.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
real	-	Bid/Low
real	-	Ask/High
real	-	Close Price
large integer	-	Volume
real	-	Total Return
real	-	Cumulative Adjustment Factor
real	-	Open Price
integer	-	Shares Outstanding **
real	-	Cumulative Total Return Factor **

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the security.

Date

The date for this price record

Bid/Low

If this field 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.

Ask/High

If this field 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.

Close Price

If this field is positive, then it is the closing price for the security on this date. If it is negative, then it is the average of the closing bid and ask prices for the security on this date. In case there are no valid bid or ask for the day, the record does not appear in the table at all.

Volume

The sum of volumes on all exchanges 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).

Cumulative 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. For example, if a security has a 2-for-1 split on day T1 and a 3-for-1 split on day T2, the initial adjustment factor of 1 would become 2 on T1, and 6 on T2. If there is a subsequent 3-for-2 split on day T3, the cumulative adjustment factor would become 9. To calculate an adjusted close price for a security on a given day, multiply the Close Price by the Cumulative Adjustment Factor on that day 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).

Open Price

The opening price for this security, if available (equal to 0 if there is no opening price).

Shares Outstanding

The total number of a company's publicly traded shares divided by 1000. For ADRs the number represents the total shares outstanding of the foreign security.

Cumulative Total Return Factor

Similar to the Cumulative Adjustment Factor, but includes the effect of dividends and spin-offs. 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 on a given day including dividends, multiply the Close Price by the Cumulative Total Return Factor on that day 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).

Option_Info File

The Option_Info file contains information about the options for an underlying security.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
char	1	Dividend Convention
char	1	Exercise Style
integer	-	AM Settlement Flag **

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Dividend Convention

The method of incorporating dividends into the option calculations:
`(blank)` – Discrete dividend payments, constant projected dividend yield
`I` – Continuous implied dividend yield

Exercise Style

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

AM Settlement Flag

`0` – the option expires at the market close of the last trading day
`1` – the option expires at the market open of the last trading day

If an option is AM settled, as most cash-settled index option classes are**,** we use one less day than we use for PM-settled options to count days to expiration.

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

Datatype	Length	Field Name
integer	-	Security ID
date	-	**Date**
char	21	**Symbol**
char	1	**SymbolFlag**
integer	-	Strike Price
date	-	Expiration Date
char	1	Call/Put Flag
real	-	Best Bid
real	-	Best Offer
date	-	Last Trade Date
integer	-	Volume
integer	-	Open Interest
char	1	Special Settlement Flag
real	-	Implied Volatility
real	-	Delta
real	-	Gamma
real	-	Vega/Kappa
real	-	Theta
integer	-	OptionID
integer	-	Adjustment Factor

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this price

Symbol

The option symbol.

SymbolFlag

The flag is set to 0 for the old option notation (i.e. root and suffix) and it is set to 1 if the symbol is the new OSI symbol.

Strike Price

The strike price of the option times 1000.

Expiration Date

The expiration date of the option

Call/Put Flag

C – Call

P – Put

Best Bid

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

Best Offer

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

Last Trade Date

The date on which the option last traded

Volume

The total volume of option contracts

Open Interest

The open interest for the option, in number contracts. This is lagged by one-day after November 28th, 2000. Previous to this date, the open interest is **not** lagged by one day. We publish an update Open Interest file on the following morning (see Open_Interest file)_

Special Settlement Flag

0 – The option has a standard settlement (100 shares of underlying security are to be delivered at exercise; the strike price and premium multipliers are $100 per tick).

1 – The option has a non-standard settlement. The number of shares to be delivered may be different from 100 (fractional shares); additional securities and/or cash may be required; and the strike price and premium multipliers may be different than $100 per tick.

E – The option has a non-standard expiration date. This is usually due to an error in the historical data which has not yet been researched and fixed.

Implied Volatility

The calculated implied volatility of the option. Implied volatilities are not calculated for options with non-standard settlement.

Delta

The delta of the option. Indicates the change in option premium for a $1.00 change in underlying price.

Gamma

The gamma of the option. Indicates the absolute change in Delta for a $1.00 change in underlying price.

Vega/Kappa

The vega/kappa of the option. Indicates the change in option premium, in cents, for one percentage point change in volatility.

Theta

The theta of the option. Indicates the change in option premium as time passes, in terms of dollars per year.

OptionID

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

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. 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.

Zero_Curve File

The Zero_Curve file contains the current zero-coupon interest rate curve used by Ivy DB.

File layout

Datatype	Length	Field Name
date	-	**Date**
integer	-	**Days**
real	-	Rate

Field descriptions

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.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
real	-	Rate

Field descriptions

Security ID

The Security ID of the underlying index.

Date

The date of this dividend yield.

Rate

The annualized dividend yield.

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, 182, 365, 547 and 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.

File layout

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

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. The forward security price is calculated from the last closing security price, plus interest, less projected dividends.

Strike Price

The strike price of the standardized option set to be 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, which is derived by linear interpolation from the Volatility_Surface file..

Delta

The delta of the option with the units $/$.

Gamma

The gamma of the option with the units $/($^2).

Theta

The theta of the option. Theta is annualized.

Vega/Kappa

The vega/kappa of the option with the units $/volatility which can also be read as cents/%.

Option_Volume file

The Option_Volume file contains daily total contract volume information for each underlying security. Volume is aggregated by calls, puts, and total.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
char	1	**Call/Put Flag**
integer	-	Volume
integer	-	Open Interest**

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option volume record

Call/Put Flag

`C` – Call
`P` – Put
`(blank)` – Total

Volume

The total contract volume for (call, put, all) options for the underlying security on the specified date.

Open Interest

The total contract open interest for (call, put, all) options for the underlying security on the specified date.

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.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
integer	-	**Delta**
char	1	Call/Put Flag
real	-	Implied Volatility
real	-	Implied Strike **
real	-	Implied Premium **
real	-	Dispersion **

** Column(s) added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option volume

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 option.

Implied Strike

The strike price corresponding to this delta.

Implied Premium

The 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. Dispersion is only calculated if there are at least two contracts with non-negative implied volatility in OPTION_PRICE for the day for the underlying security. Otherwise dispersion is set to -99.99.

$$\text{Dispersion} = \sqrt{\frac{\left[\sum_i V_i \sigma_i \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)\right]^2}{\sum_i V_i \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)} - \hat{\sigma}_j^{\,2}} \quad *$$

* Please refer to page 34.

** Historical_Volatility file

** Table added in Version 2.5

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, and 730 calendar days, using a simple standard deviation calculation on the logarithm of the close-to-close daily total return.

File layout

Datatype	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
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

Volatility

The calculated realized volatility

** Open_Interest file

** Table added in Version 2.5
** Data is not provided on the DVDs.

The Open_Interest file contains the previous day's open interest information for each option and updates the value in the Optione_Price file. This file is provided each morning by 9:00 a.m.

File layout

Datatype	Length	Field Name
integer	-	Security ID
date	-	**Date**
char	21	**Symbol**
char	1	**SymbolFlag**
integer	-	Open Interest

Field descriptions

Security ID
The Security ID for the underlying security

Date
The date for the morning it was created.

Symbol
The option symbol

SymbolFlag
The flag is set to 0 for the old option notation (i.e. root and suffix) and it is set to 1 if the symbol is the new OSI symbol.

Open Interest
The open interest for the option

Chapter 3. Calculations

The implied volatilities and option sensitivities contained in Ivy DB 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 Ivy DB 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 Ivy DB option models is derived from BBA LIBOR rates and settlement prices of CME Eurodollar futures.

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 Step 2.

Step 4. Each subsequent zero rate is computing by treating the Eurodollar strip implied future rate as a forward rate:

$$F_i = 100 - P_i$$

$$DF_i = DF_{i-1} / [\ 1 + (F_{i-1} / 100) \times (\ n / 360\ )\ ]$$

where P_i is the Eurodollar settlement price and F_i is the implied Eurodollar future rate for futures settlement date i, DF_i is the discount factor to futures date i, and n is the number of days between futures settlement date i–1 and futures settlement date i. This step is repeated to generate discount factors out to ten years.

Step 5. Each of the calculated discount factors is converted into a zero rate by using the formula from 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 Ivy DB for dividend payments depends on the type of the underlying security.

The Ivy DB 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, Ivy DB 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, Ivy DB 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.

For dividend-paying indices, Ivy DB 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: The AMEX Computer Technology Index; the Amex Oil Index; the CBOE Internet Index; the PHLX Semiconductor Index, the PHLX Gold Index; and the CBOE S&P 100 Index. For the S&P 100 index, we assume that the dividend yield is equal to that computed for the S&P 500 index. For the other American-exercise indices, we use the results of the dividend regression unmodified. While this may induce a slight bias into the calculations, we expect the overall effect on the computed implied volatilities to be minimal.

European Options

Most index options have a European-style exercise feature, and can be 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 annualized 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.

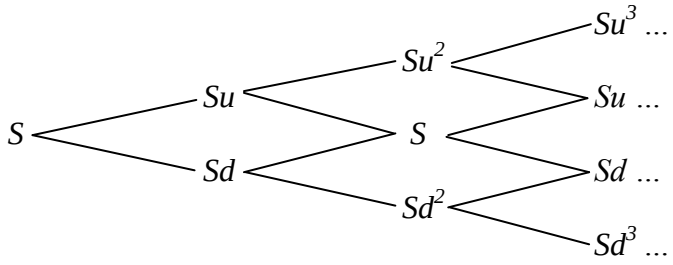
The price of a call option at the beginning of each sub-period is dependent on its price at the end of the sub-period, and is given by:

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

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

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:

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

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.

Missing Values

There are several situations where the implied volatilities cannot be calculated for the OPTION_PRICE, STD_OPTION_PRICE, and VOLATILITY_SURFACE tables. 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 option is a "special settlement" (Special Settlement Flag = 1)
2. The midpoint of the bid/ask price is below intrinsic value
3. The vega of the option is below 0.5
4. The implied volatility calculation fails to converge
5. The underlying price is not available

For the STD_OPTION_PRICE and VOLATILITY_SURFACE tables the implied volatility will be set to –99.99 if any of the follow conditions hold:

1. An insufficient number of option data points are available to perform the interpolation.

Chapter 4. Appendices

Appendix A: Industry Group Codes

Code	Description

1 Basic Materials
11 Chemicals
110 Chemicals - Major Diversified
111 Synthetics
112 Agricultural Chemicals
113 Specialty Chemicals
12 *Energy*
120 Major Integrated Oil & Gas
121 Independent Oil & Gas
122 Oil & Gas Refining & Marketing
123 Oil & Gas Drilling and Exploration
124
Oil & Gas Equipment & Services
125
Oil & Gas Pipelines
13
Metals & Mining
130
Steel & Iron
131
Copper
132
Aluminum
133
Industrial Metals & Minerals
134
Gold
135
Silver
136
Nonmetallic Mineral Mining
2
Conglomerates
21
Conglomerates
210
Conglomerates
3
Consumer Goods
31
Consumer Durables
310
Appliances
311
Home Furnishings & Fixtures
312
Housewares & Accessories
313
Business Equipment
314
Electronic Equipment
315
Toys & Games
316
Sporting Goods
317

Recreational Goods, Other
318
Photographic Equipment & Supplies
32
Consumer Non-Durables
320
Textile - Apparel Clothing
321
Textile - Apparel Footwear & Accessories
322
Rubber & Plastics
323
Personal Products
324
Paper & Paper Products
325
Packaging & Containers
326
Cleaning Products
327
Office Supplies
33
Automotive
330
Auto Manufacturers - Major
331
Trucks & Other Vehicles
332
Recreational Vehicles
333
Auto Parts
34
Food & Beverage
340
Food - Major Diversified
341
Farm Products
342
Processed & Packaged Goods
343
Meat Products
344
Dairy Products
345
Confectioners
346
Beverages - Brewers
347
Beverages - Wineries & Distillers
348
Beverages - Soft Drinks
35
Tobacco
350
Cigarettes
351

Tobacco Products, Other
4
Financial
41
Banking
410
Money Center Banks
411
Regional - Northeast Banks
412
Regional - Mid-Atlantic Banks
413
Regional - Southeast Banks
414
Regional - Midwest Banks
415
Regional - Southwest Banks
416
Regional - Pacific Banks
417
Foreign Money Center Banks
418
Foreign Regional Banks
419
Savings & Loans
42
Financial Services
420
Investment Brokerage - National
421
Investment Brokerage - Regional
422
Asset Management
423
Diversified Investments
424
Credit Services
425
Closed-End Fund - Debt
426
Closed-End Fund - Equity
427
Closed-End Fund - Foreign
43
Insurance
430
Life Insurance
431
Accident & Health Insurance
432
Property & Casualty Insurance
433
Surety & Title Insurance
434
Insurance Brokers
44

Real Estate
440
REIT - Diversified
441
REIT - Office
442
REIT - Healthcare Facilities
443
REIT - Hotel/Motel
444
REIT - Industrial
445
REIT - Residential
446
REIT - Retail
447
Mortgage Investment
448
Property Management
449
Real Estate Development
5
Healthcare
51
Drugs
510
Drug Manufacturers - Major
511
Drug Manufacturers - Other
512
Drugs - Generic
513
Drug Delivery
514
Drug Related Products
515
Biotechnology
516
Diagnostic Substances
52
Health Services
520
Medical Instruments & Supplies
521
Medical Appliances & Equipment
522
Health Care Plans
523
Long-Term Care Facilities
524
Hospitals
525
Medical Laboratories & Research
526
Home Health Care
527

Medical Practitioners
528
Specialized Health Services
6
Industrial Goods
61
Aerospace/Defense
610
Aerospace/Defense - Major Diversified
611
Aerospace/Defense - Products & Services
62
Industrial
620
Farm & Construction Machinery
621
Industrial Equipment & Components
622
Diversified Machinery
623
Pollution and Treatment Controls
624
Machine Tools & Accessories
625
Small Tools & Accessories
626
Metals Fabrication
627
Industrial Electrical Equipment
628
Textile Manufacturing
63
Materials & Construction
630
Residential Construction
631
Manufactured Housing
632
Lumber, Wood Production
633
Cement
634
General Building Materials
635
Heavy Construction
636
General Contractors
637
Waste Management
7
Services
71
Leisure
710
Lodging
711

Resorts & Casinos
712
Restaurants
713
Specialty Eateries
714
Gaming Activities
715
Sporting Activities
716
General Entertainment
72
Media
720
Advertising Agencies
721
Marketing Services
722
Entertainment - Diversified
723
Broadcasting - TV
724
Broadcasting - Radio
725
CATV Systems
726
Movie Production, Theaters
727
Publishing - Newspapers
728
Publishing - Periodicals
729
Publishing - Books
73
Retail
730
Apparel Stores
731
Department Stores
732
Discount, Variety Stores
733
Drug Stores
734
Grocery Stores
735
Electronics Stores
736
Home Improvement Stores
737
Home Furnishing Stores
738
Auto Parts Stores
739
Catalog & Mail Order Houses
74

Specialty Retail
740
Sporting Goods Stores
741
Toy & Hobby Stores
742
Jewelry Stores
743
Music & Video Stores
744
Auto Dealerships
745
Specialty Retail, Other
75
Wholesale
750
Auto Parts Wholesale
751
Building Materials Wholesale
752
Industrial Equipment Wholesale
753
Electronics Wholesale
754
Medical Equipment Wholesale
755
Computers Wholesale
756
Drugs Wholesale
757
Food Wholesale
758
Basic Materials Wholesale
759
Wholesale, Other
76
Diversified Services
760
Business Services
761
Rental & Leasing Services
762
Personal Services
763
Consumer Services
764
Staffing & Outsourcing Services
765
Security & Protection Services
766
Education & Training Services
767
Technical Services
768
Research Services
769

Management Services
77
Transportation
770
Major Airlines
771
Regional Airlines
772
Air Services, Other
773
Air Delivery & Freight Services
774
Trucking
775
Shipping
776
Railroads
8
Technology
81
Computer Hardware
810
Diversified Computer Systems
811
Personal Computers
812
Computer Based Systems
813
Data Storage Devices
814
Networking & Communication Devices
815
Computer Peripherals
82
Computer Software & Services
820
Multimedia & Graphics Software
821
Application Software
822
Technical & System Software
823
Security Software & Services
824
Information Technology Services
825
Healthcare Information Services
826
Business Software & Services
827
Information & Delivery Services
83
Electronics
830
Semiconductor - Broad Line
831

Semiconductor - Memory Chips
832
Semiconductor - Specialized
833
Semiconductor - Integrated Circuits
834
Semiconductor Equipment & Materials
835
Printed Circuit Boards
836
Diversified Electronics
837
Scientific & Technical Instruments
84
Telecommunications
840
Wireless Communications
841
Communication Equipment
842
Processing Systems & Products
843
Long Distance Carriers
844
Telecom Services - Domestic
845
Telecom Services - Foreign
846
Diversified Communication Services
85
Internet
850
Internet Service Providers
851
Internet Information Providers
852
Internet Software & Services
9
Utilities
91
Utilities
910
Foreign Utilities
911
Electric Utilities
912
Gas Utilities
913
Diversified Utilities
914
Water Utilities